Science Policy Study—Hearings Volume 7
INTERNATIONAL COOPERATION IN SCIENCE

HEARINGS

BEFORE THE

TASK FORCE ON SCIENCE POLICY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

FIRST SESSION

JUNE 18, 19, 20, 27, 1985

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WITNESSES

INTERNATIONAL COOPERATION IN SCIENCE

TUESDAY, JUNE 18, 1985

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to notice, at 10:04 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. The task force will be in order.

The task force has scheduled 4 days of hearings on international cooperation in science. These hearings will be both a continuation and an extension of the April 25 task force hearing on International Cooperation in Big Science: High Energy Physics.

The focus of these hearings will remain on international cooperation in big science because of the important policy issues facing the Federal Government in this area. However, other disciplines will be considered, as well as a number of additional issues concerning international cooperation in science in general.

The hearings on international cooperation in science will consider three sets of issues: One, international cooperation in big science; two, the impact of international cooperation on research priorities; and, three, coordination in management of international cooperative research.

We are privileged to have a number of distinguished Government and academic scientists and scientific administrators to appear as witnesses. Today's first witness is the distinguished physicist, Dr. Victor Weisskopf of Massachusetts Institute of Technology. His numerous awards and honors include membership in the National Academy of Sciences and recipient of the National Medal of Science.

Professor Weisskopf made pivotal contributions over 5 years to CERN, the European Laboratory for Particle Physics. He became Director-General of CERN in 1961, just after the first accelerators were being turned on, and served until 1965. Under his leadership, CERN developed into one of the world's most successful research institutions.

Dr. Weisskopf, we will be delighted to hear from you at this time.

[A biographical of Dr. Weisskopf follows:]

Dr. Victor Frederick Weisskopf

Dr. Victor F. Weisskopf, institute professor and former head of the Department of Physics at the Massachusetts Institute of Technology, is widely known for his theoretical work in quantum electrodynamics, the structure of the atomic nucleus, and elementary particle physics.

A naturalized United States citizen since 1943, Dr. Weisskopf was born in Vienna, Austria, in 1908. Receiving his Ph.D. from the University of Göttingen, Germany, in 1931, Dr. Weisskopf then went on to work as an associate to Schrödinger at the University of Berlin in 1932, as a research associate to Bohr at the University of Copenhagen in 1933 and 1935, and as research associate to Pauli at the Institute of Technology in Zurich (1934–36).

Dr. Weisskopf came to the United States in 1937 to join the faculty at the University of Rochester where he was instructor (1937–39) and assistant professor (1939–45). In 1943, he joined the Manhattan Project at Los Alamos, NM, where he worked as group leader and associate head of the theory division on the exploitation of nuclear energy. Subsequently, in 1944, he was one of many physicists who participated in the founding of the Federation of Atomic Scientists. The Federation's purpose was mainly twofold; to warn the public of the consequences of atomic war—thus hoping for the creation of an international agreement against the use of atomic weapons, and to support the peaceful use of atomic energy.

In 1945, he was appointed professor of physics at the Massachusetts Institute of Technology, and later given charge of the theory group in M.I.T.'s Laboratory of Nuclear Science. At that time, he and his group made important contributions to theories of nuclear reactions and quantum electrodynamics. In 1949 Dr. Weisskopf became a member of the emergency committee of scientists whose president was Albert Einstein. This committee fought for control of atomic weapons and for an understanding between the countries of the East and West concerning atomic armaments. He participated in a manifest against the hydrogen bomb (1950) and in a campaign for the exchange of scientists by the United States and the rest of the world (1950–53). Weisskopf was actively engaged in the rehabilitation of natural sciences after World War II and aided in the planning of the international laboratory CERN in Geneva, Switzerland.

In 1961, Dr. Weisskopf became Director-General of the European Center of Nuclear Research [CERN], in Geneva, therefore heading an international research establishment that operated the world's second most powerful large particle accelerator. He assumed this position when the construction of the accelerators was completed and research was about to begin. Under his leadership CERN developed into one of the most successful research institutions. He served as Director-General during a 5 year leave of absence from M.I.T., and when he returned to Cambridge in 1965 his colleagues in Switzerland published a volume of 39 original essays in his honor, the preface of which said, in part: "It is Weisskopf's unique achievement that he has carried over the devoted idealism and the enthusiasm of his early days into a new world of organized research and large-scale experimentation. Through the work he did at CERN, through the impact of his mature personality, he has had a profound influence on modern physics in Europe."

Upon his return to M.I.T. in 1966, he was given the rank of institute professor, an honor bestowed sparingly by M.I.T. in recognition of faculty members of great distinction. In 1967 Weisskopf was appointed head of the Department of Physics, a position he held until his retirement in 1973. In October 1973, 3 months after his official retirement at M.I.T., many of the world's leading scientists, including six Nobel Laureates, gathered at M.I.T. for a 2-day symposium in Dr. Wiesskopf's honor.

Professor Weisskopf is the author of more than 200 papers on nuclear physics, quantum theory, radiation theory, science policy and nuclear disarmament. A collection of his essays appears under the title *"Physics in the XX Century"*. He is a former member of the board of editors of Nuclear Physics and Annals of Physics. He wrote *Theoretical Nuclear Physics* together with John M. Blatt (1952) and his book, *Knowledge and Wonder: The Natural World as Man Knows It* (Doubleday & Co., 1962; 2nd edition, M.I.T. Press, 1979), written for the intelligent layman, was selected by the Thomas Alva Edison Foundation as the best science book for the year for youth. The first volume of *Concepts of Particle Physics* with K. Gottfried appeared in 1984 (Oxford University Press); the second volume will appear in 1986.

STATEMENT OF DR. VICTOR F. WEISSKOPF, INSTITUTE PROFESSOR, DEPARTMENT OF PHYSICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MA

Dr. **Weisskopf.** Thank you very much for asking me to testify before your committee.

As the chairman said, I was director-general of CERN in Geneva from 1961 to 1965. I am a U.S. citizen. I would like to say a few words about the development of CERN, since CERN is the first and probably most successful international scientific laboratory.

The idea of CERN actually was seeded by an American, Prof. I.I. Rabi, in 1950, but it was enthusiastically taken up by the European scientists, and in a very quick succession of events, in 1952, 12 Western European countries signed a convention to build a small accelerator and a big one.

The big one was a 30-GeV accelerator. It was at that time, when it was finished, the biggest in the world. However, the Brookhaven Laboratory had a similar one which was finished about 1 year later. This construction lasted until 1960, and in 1960, the research started. That was the time when I became director-general.

We had, of course, to face several problems. The Europeans had no experience in big science, nothing like the Brookhaven Lab or the war experience of the United States. There was a problem of international collaboration, and our relation to the universities.

The advantages we had at that time were an enormous enthusiasm in two directions: First, for the topic of going into the basic structure of matter; and, second, the idea of having a European laboratory. It was the United States of Europe in physics. Another advantage was that there were excellent engineers available.

Now, when research started, it was not only member state physicists who worked there. We had important guest groups from the United States, which was not a member; from Poland—indeed, Poles made important discoveries at that time—and also, a little later, from the Soviet Union.

Right at the beginning, it was clear that a laboratory can only live if it expands. That means that it plans for more machines than those two. One of the most important decisions at that time was to start—it was still the time I was there—the so-called ISR, Intersecting Storage Rings, which is a proton-proton collider, which at that time was a technical innovation. There was nothing like this even in the United States. This is now the tool for every new plan in the world of high energy physics.

At the same time, also, it was planned to have a very big machine soon after, namely the so-called SPS. That is a machine of 400 GeV which is of the same kind as the one in Fermilab. Let me say the storage rings, the collider, were finished in 1971, and the SPS was finished in 1975. Then CERN was again a much larger laboratory.

Now, CERN had the difficulty of establishing a tradition, and that took some years, some time. I would believe that now, after 20-odd years of CERN, CERN has acquired all the technical scientific tradition to be one of the first laboratories in the world.

Recently, they have used the SPS tunnel to do again a colliding experiment, and that was again a first, namely proton against antiproton of very high energy, and that led to those famous discoveries of the quantum of the weak interaction of the radioactivity force, which is one of the real great successes in high energy physics.

The plan for the future, just to be very short, is to build a very large 50- to 100-GeV electron-positron collider, again a collider which is now under construction and will be finished maybe at the end of the eighties.

Now, I should say that this is not all of the high energy physics in Europe. Most of the European countries, the Western countries, have concentrated their activities in CERN, but Germany, West Germany, has its own high energy establishment which is called DESY, which has a budget which is about a fifth of the CERN budget, and is now about to construct a very high-energy-proton-electron machine for about $400 million. So you see that Europe is in full swing.

Now, let me say a few words about why there is this enthusiasm for that kind of physics, not only in Europe but also in this country, and then I would like to speak about the plans in the country and the possible international collaboration.

The field is at present in a development which is quite unique. I would compare it with the 1930's. Before 1932, nobody knew what the nucleus, the atomic nucleus, was made of. In 1932, the neutron was discovered, and within 8 years nuclear structure developed to what it is now, and with all the physics and also the practical applications—nuclear power, nuclear explosives—all this within 8 years.

I would like to compare the present situation in high energy physics with this situation because in the last decade a number of new discoveries were made of the particles that make up the proton and the neutron and their properties, the so-called quarks—I don't like the name, but that is the way they were called—and here, also, a completely new physics was discovered, and we find ourselves in the same state of tremendous development as we found ourselves in the thirties with respect to nuclear science.

At that time, in the thirties, of course, America was the leading country, and the great development was due to E.O. Lawrence, the cyclotron development, which all was based in this country; not all, but most of it.

Now let me say a few words about international collaboration in the future. As you know, there is in this country a project which is the SSC, the Superconducting Super Collider, which is planned. It is the most expensive; it is several billions. That means it is about ten times more expensive than the previous machines. It is supposed to add and do what is necessary in order to go further in the development of this physics.

And now the question comes, of course, how can we get international support and not have duplication of efforts by other countries, but have collaboration of efforts?

Now, let me say the following words about international collaboration. I see five steps: First, international conferences; second, foreign people and foreign groups joining in experiments at the host laboratory and using the instrumentation of the host laboratories; for example, Americans coming to CERN or Europeans coming to Fermilab.

The third step is foreign groups not only coming and joining but bringing their major instrumentation along. I would like to call this international exploitation of the machine, and it happens quite often.

Today, for example, the United States is planning a tens of million dollar project to exploit LEP, the electron collider that will be finished at the end of the eighties at CERN; and, vice versa, Europeans come with their instruments to Fermilab. That is three.

The fourth step of international collaboration would be foreign support for the construction of a new project, for example, the SSC. It could be done by money, or perhaps more efficiently by delivering important parts of this, but the construction still on the national—or regional, in the case of Europe—administration.

The fifth step, before I go into the detail, would be a truly international laboratory, a completely world international, not like CERN, only Western Europe, but having, for example, the United States and Western Europe and Japan and perhaps the Soviet Union collaborate at a world accelerator.

Now, let me go through these steps with a few words. The first, the international conferences, is an old tradition. For 30 or 40 years we had yearly conferences either about the whole field or about specialized parts, which are very open, and the Soviet Union and other Communist countries participated, and there was never any indication that they held back any kind of information. After all, this is basic science.

The second step, namely, the foreign people and groups joining experiments in the host laboratory, is also an old tradition. Between Western Europe and the United States, right from the beginning, we had Americans at CERN when I was director, who joined experiments, and vice versa, and recently Japan has entered into this exchange, also.

The third step, that foreign groups bring major instrumentation, international exploitation of the machine, is more recent. But there is more and more of it. As I said before, the United States now is, for example, bringing very important instrumentation to CERN and also to DESY a few years ago and, vice versa, the Western Europeans, to Fermilab and to SLAC. Also, the Soviet Union is now contributing major instrumentation to some experiments at CERN.

The fourth point, foreign support in the construction of new projects, delivering important parts, is only in the very beginning stage. For example, it seems that HERA—the proton-electron accelerator, about $400 million worth, roughly, which is now under construction in Hamburg, Germany—there Germany is trying to get the Italians, and the French, and Canadians interested in delivering parts. So that is beginning.

The fifth step of a truly international laboratory is a very questionable affair, and I am not sure whether the time is right for it because it is a very complicated administrative task to have this worked out. We were interested in it for a long time. I was in committees, even chairman of committees, to promote this, but it was never very successful.

Let me now say a word about the influence of international cooperation on the new projects. Now, there are actually two new projects. There is the United States that wants to build the SSC. I would say a community of physicists wants to build the SSC for several billion dollars.

The motivations are clear. American high energy physics has not had recently the updraft corresponding to the interest of the field.

Europe has taken some of the important discoveries. We have only relatively few machines for the future, and there is a great danger that we lose the young generation, and that would be the death of the field.

Now, there is also a Western European project of a similar kind only on a smaller scale, the so-called LEP hadron collider. In the tunnel of the electrons, you could build a hadron collider, which is a lot cheaper but, of course, with much less energy—the tunnel and the infrastructure are already there.

Now, here is a kind of difficult competition. From the physics point of view, it probably would be good to have both machines, one after the other, but financially, I just don't believe it can happen, for the following reason—and this is why I am not very optimistic about number four; namely, a large participation of Europe in the building of SSC or the United States in the building of this European program.

Why? Because Western Europe is, in a way, overexpanded. It has a tremendous program for the near future, up into the 1990's; namely, the HERA in Germany and LEP, the electron-positron accelerator, which is an enormous affair of 27 kilometers' circumference. This will keep them busy, both the construction and the science, way into the 1990's, and they haven't got enough money even to run them. So that is why it is doubtful that they can invest in the SSC.

Now, of course, the same in a way is true here. United States' high energy physics is suffering from not fully being able to exploit what we have at the Fermilab, and we, of course, are all concentrated here for the SSC which would be the future of American high-energy physics and, therefore, do not want to support plans, intermediate plans, in Europe.

However—and this is the last thing I want to say—we should never forget that the construction of a machine is not the most expensive part. The exploitation of a machine, if we have the usual lifetime of 15 to 20 years, costs at least three, four, or five times as much as the construction. And here, I think, international collaboration is probably most hopeful.

Imagine, for example, that the SSC is constructed and finished in the 1990's. Then I am sure it is obvious that the Western Europeans and the Japanese would be interested in commonly exploiting it, and then one should have some kind of international exploitation organization. This is, I believe, the most hopeful international activity.

So I can only say, before I end, the field is in an enormous state of development with the most interesting things coming up; a new field of natural phenomena opening up like the nuclear phenomena in the thirties. There are plans to do this. The plans cost much money. Western Europe and America are in a very leading position, and we must do what we can so that this country does not lose this leading position.

This is why I think construction of the SSC is so important, even if it is done nationally, and I am quite sure that it will be exploited in an international way. Thank you.

[The prepared statement of Dr. Weisskopf follows:]

Testimony on CERN and International Collaboration in High Energy Physics

Victor F. Weisskopf

before the Task Force on Science Policy of the

Committee on Science and Technology

of the U.S.. House of Representatives

on June 18, 1985

Content:

I. *The early history of CERN*

Since the end of World War II proposals for international activities in modern physics and technology were made in the framework of the United Nations or as a European effort. One of the results of these initiatives was the foundation of EURATOM, a European organization for the study of nuclear structure and energy production.

In those years in many European countries, in particular in France, Italy, West Germany and Belgium, the idea of moving towards some form of economic and/or political unification was considered of primary importance by many authoritative politicians.

Another incentive was the scientific, technical and administrative experience gained in the U.S.A.during and immediately after the war, of wide and complex organizations operating in the field of the nuclear sciences and their applications. This experience had brought about the creation in United States of a few big research laboratories such as the Argonne National Laboratory and the Brookhaven National Laboratory. In particular the Brookhaven National Laboratory had been created and run very successfully by the Associated Universities,Inc. But nothing like it existed in Europe.

At the same time in many European and American circles, scientists were becoming aware of the continuously increasing gap between the means available in Europe for research in the field of nuclear physics and elementary particles, and the means available in the United States. It was becoming more and more evident that such a situation could be changed only by a considerable effort made in common by many Euopean nations.

To these one should add a further important element: immediately after the Second World War cosmic ray research had a very high level in Western Europe and was in part carried out through successful international collaborations. The discovery, in 1946, by Conversi, Pancini and Piccioni that the cosmic ray mesotron is a weak interacting particle and not a Yukawa particle, the discoveries in 1947 by Lattes, Occhialini and Powell of the π-meson and of its decay into the muon, and of the first two strange particles by Rochester and Butler, are the most brilliant results of an extensive and rich production obtained in Western Europe. The mountain laboratories in Switzerland, France and Italy and even more the nuclear emulsions laboratories of the Universities of Bristol and Bruxelles, led respectively by Powell and by Occhialini, had become points of encounter of young physicists originating from many different countries. The life in common in mountain huts and the coordination of the experiments planned by different groups paved the way to the idea of wider and more ambitious collaborations which were popping out in various places in Europe.

Cosmic ray physicists, of course, were interested in a European laboratory only if devoted to high-energy physics. In the years 1948-1950, the various aspects of the problem, including energy and cost of machines, were examined in frequent discussions among European scientists.

At the *European Cultural Conference* held in Lausanne in December 1949, the proposal was made to create in Europe an international research institution without mentioning, however, nuclear physics or fundamental particles.

In June 1950 the General Assembly of UNESCO was held in Florence and the American Nobel Laureate, Isidor I. Rabi, who was a member of the delegation from the United States, made a very important speech about "the urgency of creating regional centres and laboratories in order to increase and make more fruitful the international collaboration of scientists in fields where the effort of any one country in the region was insufficient for the task". In the official statement approved unanimously by the General Assembly along the same lines, neither Europe nor high-energy physics were mentioned. But this specific case was clearly intended by many people, in particular, by Rabi himself and by Pierre Auger, who was Director of the Department of Natural Sciences of UNESCO.

A further endorsement of this idea came from the *International Union of Pure and Applied Physics* at the beginning of the summer 1950. Rabi's proposal, with specific reference to Europe and high-energy physics was discussed at the meeting of the Executive Committee of IUPAP in September 1950 in Cambridge, Massachusetts. In December 1950, a commission for scientific cooperation met at Geneva for the planning of a European institution independent of UNESCO, which, after all, was a worldwide organization. As a result of the meeting,funds were made available, immediately by Italy, and soon afterward by France and Belgium. The total sum collected was very modest, about $10,000; it was, however, sufficient to initiate the first steps for arriving at the planning and construction of a large particle accelerator.

At the beginning of 1951 a small office at UNESCO was established to work out the constitution of a working group of European physicists interested in the problem. Two goals were immediately established: a long-range. very ambitious, project of an accelerator second to none in the world, and in addition the construction of a less powerful and more standard machine which could allow at an earlier date experimentation in high-energy physics by European teams. A council of the provisional organization was created whose task was the nomination of the officers responsible for the appointment of the remainder of the staff and for planning the laboratory.

In July of the same year, 1952, an international nuclear physics conference was held in Copenhagen; on that occasion the type of accelerators to be built as the main goal of the new European organization was amply discussed. The decision was taken to explore the possibility of constructing a $10 GeV$ proton-synchrotron which, at that time, represented the biggest machine in the world.

During the month of August, some European experts went to Brookhaven in order to study in detail the Cosmotron (with a maximum energy of about $3GeV$) that was very close to completion. During their two-week visit, and in some way in connection with the discussions going on in relation to the European project, the American scientists Courant, Livingston, and Snyder came out with the "strong-focusing principle".

This important discovery came soon enough to allow a change of the plans of the provisional organization: the group embarked on the study of a strong-focusing accelerator of $20-30GeV$ instead of the weak-focusing $10GeV$ machine considered until then. A much smaller synchrocyclotron of $0.6GeV$ was to be constructed in parallel.

During the summer of 1952 four sites were offered for the construction of the new laboratory: one near Copenhagen, one near Paris, one in Arnhem in the Netherlands and one in Geneva. After long and lively discussions the site in Meyrin near Geneva was unanimously selected.

All the European members of UNESCO had been invited to the Conferences in Paris and in Geneva 1951 and 1952 but no response came from the countries of Eastern Europe. A Convention establishing the permanent organization was signed on July 1st, 1953 by twelve countries: Austria, Belgium, Denmark, France, Greece, Norway, Sweden, Switzerland, United Kingdom, Yugoslavia. At the beginning, the United Kingdom was rather cautious in committing itself to take part in the new organization. The U.K. government preferred to remain in the formal position of an observer during the first two stages, while, by signing the Convention, it became a full-right member of the permanent organization. Yugoslavia was able to join as the only communist country because it broke with the Soviet Union a few years before. Unfortunately the membership lasted not long. The financial burden was too heavy and Yugoslavia quit CERN in 1962.

The decisive authority was to be the Council, composed of two representatives from each member state. The council determines the budget through its Finance Committee. The contributions of the member states are set proportional to their GNP but never more than 25%.

One of the great advantages of the budget process at CERN is the custom introduced in 1964 to determine every year the budget for two years with a tentative agreement about the subsequent two years. This makes planning much easier than with a yearly budget.

In October 1953 a design staff was assembled in Geneva, partly at the Institute of Physics of the University and partly in temporary huts built in its vicinity. At that time the transition took place from mainly theoretical work to experimentation and technical designing.

During 1953 an administrative nucleus began to function in a temporary Geneva office. A Director General was chosen: It was Felix Bloch (1905-1983), a Swiss born Nobel Laureate and American citizen, Professor at Stanford University. In the fall of 1954 the provisional Organization was replaced by a permanent one. The first Council Meeting officially establishing CERN was held in Geneva on October 7, 1954. It confirmed the plans of erecting a laboratory in Meyrin with a smaller synchrotron and a large proton-synchrotron. The total construction cost amounted at that time to 300 Mil francs, which roughly corresponds to 250 Mil. Dollars of today.

II. *Construction Period*

On August 13, 1954, major excavation work started at a site in Meyrin, a suburb of Geneva,on land donated by the Canton of Geneva to the organization, with full support of the Government of Switzerland. The site is adjacent to the French frontier north of Geneva. A whole laboratory with all buildings, equipment, workshops, restaurants, etc., had to be erected on that land.

The first Director-General, F. Bloch remained only one year. He was not enough interested in the problems of constructing large facilities. He was replaced by the Dutch physicist, C. Bakker, who, before, was in charge of constructing the smaller machine. The construction went on extremely well; a number of American physicists and engineers came to Geneva to help and participate, such as Drs. John and Hildred Blewett from Brookhaven.

One of the most fortunate circumstances was the eagerness with which many young physicists and engineers gave a positive answer to offers to join the recently born provisional organization for contributing to the construction of a laboratory of still rather indefinite future. I could give a list of names of people recruited in that period and that later contributed remarkably to the development of CERN. I will, however, mention a single case. The young man was John Adams, who joined CERN, and devoted his whole life to its development. He supervised the construction of the two major accelerators built at CERN in the last 30 years.

Most of the parts of the construction were ordered from the industries of the member states but some material had to be purchased in the United States, such as some computers and special electronics. The principles of the organization were to request bids from member state industries and to accept the best and lowest offer, without any effort to divide the contracts evenly among the member states. Only when the items were unavailable in Western Europe were purchases made in non-member countries.

During the construction period, a 13th state, Spain, joined the organization. Spain withdrew around 1970 because of financial difficulties and rejoined in 1984.

This is perhaps the place to mention another international laboratory organized by the Communist countries at about the same time. Perhaps it was an answer to the rejected offer extended to the East European countries – not the Soviet Union – to join CERN. It is located in Dubna north of Moscow and also contains a larger and a smaller accelerator. In contrast to CERN they did not switch to the new "strong focusing" method. This is why their major accelerator was not very successful. Dubna's member states included, of course, the Soviet Union, who played the dominant role, whereas in CERN no member state has a dominant position.

The small synchro-cyclotron was operated for the first time in 1958 and the large accelerator had its first circulating beam on November 29, 1959, a major triumph of European engineering. At that time it was the largest accelerator in the world, although the Brookhaven "Alternating Gradient Synchrotron" (AGS) of equal size was already under construction and was completed a year or two later.

Actual research started with the small machine in 1958. An important result was found right away: The decay process of the "pion" was cleared up and it was shown that the pion decays preponderately into "muons" and not electrons.

Unfortunately the construction period ended with the tragic death of the director, Professor C. Bakker, in an airplane accident.

III. *The Research and Expansion Period.*

I was asked to be the Director General of CERN in the fall of 1960. I accepted the job and stayed until the end of 1965. I was and am an American citizen. The choice fell on me probably because of my European origin, and my acquaintance both with the American and the European way to do scientific research. I was attracted not only by the subject of research, but also by the idea of an international scientific laboratory, the first of its kind, symbolizing a united Europe.

The organization faced several difficulties: The European physics community had no experience in running large enterprises. There was not much "Big Science" in Europe at that time. Too little preparation for experiment was made during the construction period. Somehow new forms of research organization had to be found, in order to coordinate work done by the different nations, and to foster active participation of the national university laboratories with CERN. How many scientists should be employees of the Lab and how many working as guests of the Lab for periods of time? Last but not least, the new fledgling institution needed a spirit of enthusiasm, not only for its scientific aims but also for its pioneering role as a symbol of European unity.

Obviously one could not have expected that CERN would immediately be at par or more productive than corresponding institutions in the U.S. with a much longer experience and tradition. The scientific results achieved at CERN in the first decade of research were of great importance, but some significant breakthroughs, such as the discovery of several neutrino-types and new kinds of so-called quark-particles could have been made at CERN but were made in the U.S.

Although the CERN facilities were primarily destined for member state scientists, groups of scientists from other countries, in particular Americans, participated by joining European teams or by performing their own experiments. This was an established custom in High Energy Laboratories. Many Europeans are working in American labs. Perhaps CERN was a little more reluctant to accept outsiders than the U.S. laboratories.

Scientists from communist countries were not excluded. Indeed a group of Polish scientists came to CERN in the sixties and made important discoveries in the field of hypernuclei. A treaty with the Soviet Union was worked out in the late sixties allowing access to the CERN facilities for Soviet scientists in exchange for access for European researchers to the newly built $80 GeV$ accelerator(3 times more than CERN and Brookhaven at that time). The collaboration with the Soviets was not as profitable as we hoped but did yield some valuable results.

The CERN council and leadership was aware of the fact that CERN cannot survive in the long term with the two accelerators constructed in the fifties. It must develop new facilities in order to stay at the forefront of research. Therefore, already in the first five years of research, when I was Director-General, ideas for new instruments were discussed and developed. In 1965 we presented to the Council three new steps: An improvement program for the existing accelerators, the construction of "Intersecting Storage Rings" (ISR), and the construction of a ten times more powerful accelerator reaching $300 - 400 GeV$. The Council approved the execution of the first, the construction of the second, and an increase of about 50% of the budget for the following four years in order to extend the research program and to devote some money to R&D of the third step. It was a memorable session, since it implied the appropriation of almost, one billion Swiss francs, a proof of the enthusiasm of the member states for the new laboratory, not only as an example of the rising scientific significance of Europe, but also as a symbol for Western European unity.

The Intersecting Storage Rings were a new device to get much more effective collisions between particles by having two opposite beams of $30 GeV$ protons collide with one another. It was the first of its kind for protons. No such device was planned in the U.S. at that time. CERN took an innovative step in accelerator construction. Technologically it was a great success; the intensity reached after completion in 1971 was much higher than expected. It changed the landscape of High Energy Physics. Today and in the future most facilities will be built on that principle at higher energies. The new installations at Fermilab and the SSC accelerator planned for the U.S. are larger versions of the ISR.

A number of interesting discoveries were made with the ISR, but some were missed. CERN had yet to develop its research tradition to the level of the one in the U.S. in order to exploit its facilities in the best possible way as is the case today.

In order to accommodate the new facilities the site had to be enlarged. This was done in 1964 by a gift of adjacent land on the French side of the frontier by the French government. CERN became truly international. The frontier runs right across the site but people, machinery and particle beams cross it all the time

The final approval of the construction of the large $300GeV$ accelerator at a cost of 1000 Mil francs (roughly 500 Mil dollars) at the end of 1971 and construction was finished in 1976. This facility is similar to the first accelerator at Fermilab which was ready for research one to two years earlier. The CERN machine was built more expensively, with more margin for additions. This is why it was possible to exploit it somewhat more efficiently. Toward the end of the seventies the European scientists and the CERN staff had reached the necessary maturity and experience to perform research on an equal level with the U.S. The relatively generous budget (reaching 700 Mill francs annually in the eighties, about 300 Mill $) gave them opportunities to do outstanding work, sometimes better and faster than the U.S. laboratories who suffered from decreasing support.

Examples of important CERN discoveries are the observation of so called "neutral currents" in radioactivity, that supported the new theories of these processes and, lately, the discovery of the "W- and Z- particles", the quanta of weak interactions. They are the carriers of the force that produces radioactivity. The latter discovery was made possible by transforming the large accelerator into an effective proton-antiproton beam collider. This technological feat was made by an ingenious device for producing an intense antiproton beam, invented by one of the leading engineers at CERN, Dr. Van der Meer. This accomplishment brought a Nobel award to Van der Meer and Carlo Rubbia, the leader of the team. These results, together with a long list of other achievements are the proof that today CERN is at the front line of research, equivalent and sometimes superior to the parallel U.S. institutions, both in respect to the scientific research and in respect to the technological inventiveness of its engineers and instrument builders.

A few years ago the Council approved an ambitious project of an electron-storage ring for colliding electron beams up to 100*GeV*. The length of the tunnel containing the beams is 27 kilometres and the cost is about 400 Mill $. The first phase will be ready in 1988. This facility did not get separate funding. It will be built within the present budget by cutting out other activities, such as the ISR. There is no doubt that CERN will remain at the forefront of particle physics for some time to come.

Not all European High Energy Physics is done at CERN. In the last decade the European countries have sharply reduced their facilities in order to fully support and work at CERN. They have kept running only some minor activities. There is one important exception: West Germany. They built a major national facility in Hamburg, called DESY (German electron synchrotron). This institution grew steadily by adding new facilities devoted to electron acceleration and colliding beams up to 40GeV. It is nationally administered but many European and American groups are using this facility with great success. It is generally considered as an excellent laboratory. Recently construction of a very large proton-electron colliding facility (HERA) was approved and is under construction at DESY. It will be the largest of its type in the world.

IV. *General Remarks about International Collaboration in High Energy Physics.*

The last 30 years have witnessed a thorough internationalization of High Energy Physics. Up to the '50's the USA had a kind of monopoly on the highest energy machines. That did not prevent a number of important discoveries to be made elsewhere with cosmic rays. But from the mid-fifties on, laboratories with accelerators at the energy frontier appeared in Western Europe, in the Soviet Union, and in Japan, so that High Energy Physics became indeed a truly international enterprise. A special significance must be attributed to CERN since it was the first great laboratory in this field that is internationally owned, run and paid for, albeit only by Western European nations. As such it represents an innovation in the sociology of science of which the Western Europeans are justifiably proud. It spawned other Inter-European activities in astronomy, space science and molecular biology.

In the following remarks we will use the term "international" in a sense in which the West-European nations (and also the Communist nations allied with the Soviet Union) are considered as one "nation". In this respect the term should have been "interregional", but it is common usage to use "international" for this purpose.

There are several degrees of international collaboration:

1. The organization of regular international conferences on the subject.

2. The participation of foreign researchers or teams in the work at a national (or regional) facility using the instrumentation of the host laboratory.

3. Research of foreign groups with major instrumentation brought along from home and installed in the host laboratory.

4. Financial support by foreign countries (regions) for the construction of a new facility. This can be done by contributing funds or by delivering important parts to the facility. The construction, however, would be under national or regional administration.

5. Establishment of a truly international Laboratory as a collaboration of several regions or on a world scale, with international funding and administration.

The first step has become an established tradition for 3 decades, in form of the so-called "Rochester Conferences" spanning the whole field of High Energy Physics. They were started in Rochester, New York. Dr. Robert Marshak deserves credit for initiating them. Today they are held every two years, alternating in USA, Western Europe and Soviet countries, and lately in Japan. Furthermore international conferences are held regularly about special topics such as accelerator technology, and other particular problems. These conferences are open to large numbers of invited scientists. The discussions are free of any restrictions. We have no evidence that the Soviet scientists have held back any information.

The international character of the field is most evident in steps 2 and 3. All major accelerators around the world are used and exploited by groups of nationals of other countries or regions than the one which owns the machine. This international exploitation has become more important in the past decades. It is no longer possible for one nation or region to have all types of machines necessary for the progress of the field. It is a financial necessity to have the different types of very high energy accelerators distributed over the regions of the globe. Duplications of facilities may be very useful for physics and convenient for the physicists, but we can afford them only for smaller scale machines. Work in other countries is necessary if research is supposed to cover the whole frontier as it should.

It is, therefore, of utmost importance that international exploitation is maintained and facilitated as much as possible. The situation is not too bad today, but could be better. The foreign groups are of necessity disfavored citizens in a certain sense. They work far away from their home bases, they are up against technical difficulties in a foreign laboratory where they have to rely on in-house help and support. There has been a reasonable reciprocity in the use of facilities although, in the opinion of some, CERN was not as generous to foreign groups as the U.S. laboratories. But problems do remain and may get more serious when there will be a scarcity of experimental areas, and the construction time of experiments becomes ever longer. This is to be expected with the new giant projects, where installations and instrumentations cost more than several accelerators of the old style.

Step 4 has not been implemented in the construction of existing facilities but is much discussed and encouraged for some presently planned projects. It will be realized in the case of the German HERA facility where Italy, Canada and Japan have made some proposals of participation. The participiction of a nation in the construction necessarily implies some special rights for their scientists in the use of the facility. Here a problem arises: so far the admission of a team to a facility was supposed to be based solely upon the scientific merit of its proposal, whether they are foreign or not. Obviously, that principle was not always adhered to. National teams had a somewhat better chance. But an explicit right for experimentation on the basis of having contributed to the construction, raises some serious problems.

International participation of some form is under discussion today for the construction of two large projects: The Supercollider (SSC) developed by the American community, and a proposed "Hadron collider" at CERN in the LEP tunnel. The first is a giant proton beam collider of $20,000 GeV$ at a cost of several billions of dollars to be ready in the mid nineties. The second one would be of lesser energy, 5000 to 9000 GeV and much cheaper (around one billion depending on the energy) since it is a smaller machine and the infrastructure and tunnel are already there. It could be ready in the nineties, if the construction does not interfere too much with the exploitation of LEP.

Clearly these projects would have a better chance of being approved if there were a sizable foreign contribution to their construction. In both projects, there is a danger that the high costs would either postpone or eliminate them.

Unfortunately the two projects are competitive. The approval of one would imply the rejection of the other if such approval would occur in the near future. Both sides feel strongly about their projects: the USA needs a vigorous project of assured technical feasibility so as to not suffer a decline in its activites; CERN would like to see a future in hadron collider physics which, after all, was pioneered by them.

These are the reasons that negotiations are difficult at this moment. Also, the European High Energy program is so extended with HERA and LEP under construction, that the European governments would not consider any further new projects or participation in new projects for some time to come. Japan or Canada may be more inclined to consider participation of the Step 4 type with either the US or the European Project.

The simultaneous construction of both projects, although unlikely, would not be unreasonable from the physics point of view, since they cover two different energy regions which the SSC would have difficulties to cover by itself. When the technical and financial possibilities will have become clearer, it is hoped that some plans of international collaboration will emerge. Obviously, an early completion of a powerful machine in the U.S.A., such as the SSC, would be in the interest of all High Energy physicists including the European community. It is reasonable to assume that the Europeans would participate in the exploitation by providing equipment and instrumentation according to step 3 if not some help in the construction according to step 4.

What about step 5, the truly international laboratory? It would avoid the "disfavored citizen" syndrome since the participating regions take part on equal terms. A world laboratory including even Soviet participation was proposed and discussed since the inception of CERN. I myself, among many others, was a promoter of this idea. Experience suggests, however, that the political, managerial and financial problems of a world machine may be cumbersome and risky. At this stage High Energy Physics is probably still better served by national or regional facilities, preferably constructed with active participation of other regions according to step 4. Still we should not abandon the thought of a world machine. Comes a time when the cost and effort of the next accelerator is so high that there may be no other way but world cooperation. Let us not forget the human significance of such a future venture. It may serve as a symbol of better relations between different parts of the world, in the sense that CERN was a symbol of Western European unity and cooperation. Indeed, this symbolic value was an important reason for its generous governmental support.

There is a possible variant of Step 5 which is not much discussed. The cost of operation and of equipment for an accelerator over the 15 to 20 years of useful life is considerably higher than the cost of construction. Therefore, it may be of advantage to have an installation constructed with national funding and then have the research, equipment and operation funded and administered internationally. This would avoid the bureaucratic difficulties of an international construction project and it would be a better guarantee that the foreign communities have the same rights and expenses as the home community. In this case all participating nations would pay the costs of running the facility, whereas, today, guest teams get most services free of charge.

Reliance on regional or national projects brings up the difficult question of "who should do what at the energy frontier", with all the awkward problems of world planning, of competition, duplication, location, distribution, and desire to be at the frontline. We are now in the midst of these problems. There are a few fundamental principles involved here.

Obviously, competition and desire to be at the frontline are good things. They are an essential part of the driving force of science. Pure love of knowledge, independent of who found it, is not the only driving force. But, if High Energy Physics as a supernational human endeavour is to survive, those drives must be channeled and not be allowed to obstruct the developments in other regions. A serious decline of High Energy activities in one region affects all other regions in due course.

It is, therefore, important that different types of those large accelerators are distributed over the world and that each region has its specific machine or machines. Hence, it may be tempting to think of an international body that coordinates construction projects and distributes "rights" to build this or that accelerator. Such a solution would perhaps avoid some of the troubles coming from duplication and harmful competition, but it would stifle the initiatives and the forward drive of regional and national groups and may end up in counterproductive squabbles.

But the world community of High Energy physicists should be strong enough to solve these problems without "regulative agencies". So far it has gone pretty well, simply by informal and semiformal discussions, by intelligent foresight, sympathy and actual help, technically and financially, for the endeavors of others. It has prevented some unnecessary duplications in the past, it has led to a reasonable development where each region contributed in its own way to the progress of the field and had open doors for foreign groups. The higher the cost of a single machine, the more essential it is to avoid duplication and maintain open doors.

But it is the duty of the community to come to a mutually acceptable solution. It is an issue of scientific responsibility versus scientific greed. But it is also an issue of wise policy towards the governments who pay the bills. We certainly will lose the support that we have received in the past if it appears that different parts of the world community are trying to outpace each other and are no longer cooperating in the planning and construction of the future accelerators with mutual help and assistance. Even under the best conditions, this support is not assured.

Science is a human effort and any human activity carries along human difficulties, stuff for frictions and tensions. High Energy Physics is no exception. Because of the great successes in the past, both in science and in world cooperation, the community has a special duty to maintain this spirit and to be sensitive to the effects on the other regions of its regional actions, projects and dreams. The world community must get together in one way or another, and reach a solution of the problem of what should be done where, with the financial, intellectual and technical resources that we expect to be available. It must find the solution that is best for the progress of science, best to maintain the enthusiasm of all participants, and best to attract many young people to the field. Only then will they be able to continue their great search of the innermost structure of matter.

DISCUSSION

Mr. **Fuqua**. Thank you very much, Dr. Weisskopf, for a very interesting and thought-provoking commentary about some of our involvement in international cooperation. I think we all recognize the importance, particularly in the basic research areas, that we can cooperate and still be competitive in the marketplace in goods and services that our various countries will produce.

I was intrigued by your comment that as we look, and I am not really speaking of SSC but other big science—it could be in fusion or the Space Station or some of those—that maybe the host country provides the facility and then have what is a break from norm, which is to have a user fee for those that use it. I think that is a novel idea. It seems to solve a lot of the problems.

We were visiting recently with one of the science ministers in Europe. He said one of the biggest problems with international cooperation in science is the location, and that cooperation in space did not provide that problem. But when you were talking about ground facilities, then certain countries would insist that it be in their continent or their country, and I guess our own national pride of the various countries is involved.

Do you think that would be—you mentioned this briefly, but the fact of having user fees?

Dr. **Weisskopf**. That is a very interesting question. So far, there is very little user fee. For example, if an American group comes to CERN, it gets service. Indeed, I should say the budgets are roughly equal in Europe and here, but Europe has only 1½ laboratories, namely CERN and Hamburg, whereas we have here more than three, and therefore they have more money available for services. But this is free, and all they do is pay for the small instrumentation.

In case, as I have sort of proposed once, for example, the SSC is built and then opened for international exploitation, I think perhaps new rules should be introduced, and it may even be, in a way, an international administration of the experiments where people pay for the beam in some way. It could be divided up according to whatever is necessary.

Now, I believe that may develop. At present it is not so. At present, people get it sort of free, except if they bring their instruments in.

Mr. **Fuqua**. Except there is reciprocity, though. We have Europeans that come to, say, Brookhaven.

Dr. **Weisskopf**. Yes, exactly.

Mr. **Fuqua**. We have American scientists who go to CERN, and there is an interchange between them.

Dr. **Weisskopf**. Absolutely. The Europeans mostly go to Fermilab or SLAC, but some are also in Brookhaven. Exactly, there is a reciprocity. But now, if there is, however, one especially expensive institution like the SSC, I think the reciprocity may no longer be——

Mr. **Fuqua**. Because the operating costs would be, as you pointed out, very expensive.

Dr. **Weisskopf**. Yes, that is right.

Mr. **Fuqua**. It would not be like operating on a much smaller machine.

Dr. **Weisskopf**. I would like to make one remark. In Europe, things went so easy and, I must say, astonishingly well because of two reasons. First, I think the idea of European unity which, especially at the beginning, was strong—now it is a little weaker—but because the largest distance between member states is 2 hours by airplane from Stockholm to Geneva. Mostly, it is only one hour.

Now, that, of course, is a big difference. If Americans have to work at CERN or CERN people have to work at wherever that is, in Texas or somewhere, this is 8 to 10 hours. So that makes this international exploitation a little more difficult, and that is why people often are very doubtful whether this is the right solution.

Mr. **Fuqua**. Let me ask you another question. Should the United States try to maintain superiority or be the leader in all disciplines of science? And then, what impact would that have on international cooperation, if we decided as part of our national policy that it was important to us to be the world leader?

Dr. **Weisskopf**. Let me perhaps first answer this in high energy physics. First, I am more competent there, and second, it is easier to answer.

I don't think it would even be possible to be the leader in the sense that every single approach and direction in high energy physics has the best and most active instruments in the United States. That is not so. It was not even so for the last decade.

Therefore, I think the right policy is to divide up. Still, I would hope that in the most important and highest energy frontier, we do have the leadership. This is why I think the SSC is so important.

But certainly, for example, in the electron-electron collision apparatus that is now built at CERN, I don't think America should compete; or HERA, where it is proton-electron. Let them do this, and, of course, with international exploitation.

So I do think leadership does not mean leadership in every field. But I do think that America owes itself, as the strongest industrial nation, to be at the frontier in the sense that the most important things, we are able to do. Now, in other fields, I am, of course, not so competent, and therefore perhaps I should not comment on it.

Mr. **Fuqua**. In other words, those areas that other countries have an apparent lead in or are very knowledgeable would lend itself, then, to cooperation in those fields rather than trying to excel in every field in the United States?

Dr. **Weisskopf**. Yes. But this is, of course, very difficult because of nationalistic or regionalistic tendencies, both in Western Europe and here and in Japan.

For example, of course, the Europeans would like to have also a proton-proton collider, in particular since the Europeans were the first to introduce that system. It is now all over. So these are difficulties.

As you can read in my written statement, I am against a regulatory agency that says, "You do this and you do that," because that dampens initiative. But a certain understanding should be reached, and I am very optimistic on this.

At present, you know, they both want, of course, the highest, but I do believe that in a few years they will see that both financial and scientific reasons will bring them to divide up the world in a reasonable way, and I do believe they will support SSC at the end, not necessarily financially but in the exploitation.

Mr. FUQUA. I appreciate your saying that we don't need a science policy management agency. It would probably be the worst thing that we could ever do, and I want the record to be clear that I am not advocating that. I was only propounding as the devil's advocate.

Dr. WEISSKOPF. May I say to this that in my experience over the last 50 years, I believe that scientists in this field have shown a great sense of collaboration, so that I am very optimistic that we will reach a reasonable solution among us, among the scientists. Whether we get the financial support from the Government, that is another question.

Mr. FUQUA. The scientists have been able to agree internationally much more conclusively than we politicians. [Laughter.]

Mr. Packard.

Mr. PACKARD. Thank you, Mr. Chairman.

I am certainly grateful to have you here, Dr. Weisskopf. Your experience and expertise in this field have certainly excelled, and you bring a great deal of dignity to this hearing.

You mentioned in your testimony—and I almost caught it as a passing thought rather than a part of your printed testimony—that you thought that to lose the young generation of physicists would be a death to the field, and I think you were referring primarily to the United States and its competitiveness in this field.

Dr. WEISSKOPF. Yes.

Mr. PACKARD. Beyond the SSC, what should the United States be doing to not only develop but to excite the young generation of physicists in the United States?

Dr. WEISSKOPF. Do you mean apart from the SSC?

Mr. PACKARD. Above and beyond the SSC. I can see where that, in and of itself, will excite young people, but what else can we be doing?

Dr. WEISSKOPF. Well, I think that is a very important problem. I do believe, for example, that we should support the present labs, like Fermilab, which has now enlarged its energy, and SLAC, which has a new way of colliding. This should be supported more generously than it is at present in order to have young people be given an opportunity to do experiments there.

The same is true about supporting universities in preparing, and sometimes even doing, such experiments. I personally believe that this field of physics is underfunded compared to the possibilities. I mean, if we had fewer labs, it would be not underfunded. But the trouble is that at present we just cannot do the experiments that, in principle, technically we could do, and that, of course, discourages the young people from getting into this field. They have to wait too long until the experiment is approved.

In other words, to answer your question, apart from supporting the SSC—which, of course, gives a future so people will enter the field, because they will think, "Aha, we will have opportunities; here is the future" at the same time, I think also we have to create more opportunities so that they can learn this field or work, because you can also make wonderful discoveries with the present machines, and I hope we will.

Does this answer your question?

Mr. PACKARD. That is very fine. Thank you.

On the SSC, we find Japan, and Canada and, of course, the European Community very interested on a cooperative international basis. Do you think that the international considerations for locating the plant or the test site should outweigh the local and national considerations for location of the SSC?

Dr. WEISSKOPF. I don't think it makes much difference whether this is now in—I don't know—on the east coast or in the Middle West or on the west coast, from the point of view of distance. Well, it is a few hours additional. I think the Europeans, of course, would prefer to have it nearer to the east coast. But I don't think this is a decisive point.

Mr. PACKARD. Thank you very much, Mr. Chairman.

Mr. LUJAN [as acting chairman]. Mr. Boehlert is next.

Mr. BOEHLERT. Dr. Weisskopf, will spending of national funds in international laboratories be to the detriment of our national laboratories? We only have so many dollars to go around.

Incidentally, you are preaching to the choir here because we are in agreement in terms of the underfunding problem.

Dr. WEISSKOPF. I see. That is a very interesting question. There were, of course, complaints about, for example, that we spent something like $30 million on—I wouldn't be sure of the figure, but roughly—in funding experiments at these new European machines, for example at LEP, and that we could use this $30 million here.

I still think that is a very good investment, because, as we discussed before, it is international science, and we cannot and should not have all possibilities here. LEP, for example, is a possibility we will never have here.

But we must give our scientists the opportunity to work on this, and therefore I think those $30-odd million are very well expended. I think, if this would not be done and we only have our own, it would narrow the field in the United States.

In addition, of course, it fosters the international spirit. If we do this to them, they will do this to us and will send instrumentation of equal or maybe more value to our places, which is already beginning. If the SSC is finished, it will be done, probably, to a much larger extent.

Mr. BOEHLERT. One other question, Doctor. How do you apportion a fair share of a country's contribution to an international effort?

Dr. WEISSKOPF. That really depends on the international effort. I mean, it is like in high energy physics, that if we have to divide up the frontier, I think a fair share would correspond to the size of this effort abroad compared to the effort we have, and we think we are interested in this because we cannot do it here, and therefore, a fair share would be that share that makes it possible to realize.

Mr. BOEHLERT. Thank you. No further questions, Mr. Chairman.

Mr. FUQUA [resuming as chairman]. Mr. Lujan.

Mr. LUJAN. Just one quick one. The chairman said that the scientists have been able to get together much more so than the politicians, and I rather suspect that that is because the politicians have to put up the money, and that always lends itself to a little bit of division.

We are looking at big-scale projects now at a minimum of $17 billion to $18 billion when you take the Space Station, the Super Collider, the engineering facility for fusion, and that is just talking about the construction cost, not talking about the operating cost. The Space Station is moving along pretty well in the sharing of costs.

But, in your testimony, you seem to be rather pessimistic about the SSC and even perhaps the fusion facility.

Dr. WEISSKOPF. I don't know much about the fusion facility, and I don't want to talk about it simply because I am ignorant.

As far as the SSC is concerned, it comes at an inopportune moment for the Western Europeans because they are, in a way, overextended. For example, I am spending a lot of time over there, and I am still sort of a kind of consultant.

I was not very much in favor of HERA. I thought they have already enough with the rest. But they did decide to build HERA, and this is why this is an inopportune moment for them to invest much money in the United States.

Mr. LUJAN. How long do you think before they could join in such an effort?

Dr. WEISSKOPF. I think that the situation, within a decade, will change. This is why I am emphasizing the international exploitation angle so much, because I believe, in a decade, sort of the middle nineties, LEP will have produced a lot of physics, HERA probably, too, and then the Europeans will much more seriously think of the next step.

It is an unfortunate point that just at that moment where we would like to have influx from Western Europe—financial and otherwise, construction—at this point, Europe is, to my estimate, somewhat overextended financially.

Mr. LUJAN. Thank you.

Mr. FUQUA. Mr. Brown.

Mr. BROWN. Dr. Weisskopf, from your experience, could you explain to me how the scientific and the political community interacted to develop the CERN organization? How did that come about? Was there a role for the national and international scientific organizations in physics in connection with that development?

Dr. WEISSKOPF. Very much so. I consider this development that I have sketched shortly in the printed version as a really most impressive international undertaking, because as I said, it was due to the fact at that time the enthusiasm for common European activities was very high, and strongly encouraged by the United States.

It was not only Rabi's intervention in the building of the big machine at CERN. We had the help of American engineers and physicists. They were all enthusiastic about this idea of an international lab on the European scale.

Your question relates to the governments. Well, again, I do not think that, on purely physics grounds, we would have gotten CERN. I would say that at least 50 percent of the reason that the European governments supported it quite generously was the fact that this is—maybe I exaggerate—but I believe it is the only real successful Western European activity. I mean, there are a lot of paper-shuffling agencies in Western Europe.

EURATOM was not a success, as you all know. The European Space Organization is rather limping ahead. CERN had these tremendous triumphs where it is now equal, some people say even better, than the institutions here. I have my doubts. It is perhaps better supported financially, but it is certainly equal.

So these were the reasons. It was loved by the governments as one of the few things that really succeeded.

Mr. BROWN. I am interested in exploring the ways in which the scientific community, through their organizations, can interact more strongly with the political community.

Dr. WEISSKOPF. With the government.

Mr. BROWN. CERN is obviously a successful model. I puzzle over the relationship here in the United States. I am not quite sure what role, say, the American Physical Society plays in this process of developing the SSC, and I would be interested in knowing if there can be a more active role, or if there needs to be, or if we are going to operate through the government bureaucracies as we seem to be doing, mainly.

Dr. WEISSKOPF. The physics community is, of course, much larger than the high energy physics community.

Mr. BROWN. Of course.

Dr. WEISSKOPF. The high energy physics community is, as you probably know, completely united in this aim. The physics community has helped. I have not heard, at least, any important criticism or even feelings that you are taking the money away from somebody else. Outside physics, the situation may be different.

Similar things happened, of course, also in Europe. In Europe, there was—again, the high energy physics community was extremely enthusiastic, and let me say one thing. They had very strong personalities. In my life in science, I can say one thing: Personalities are the really driving force, not only in science, as you probably know. We had Amaldi, we had Sir Ben Lockspeiser, we had Peyrou—people of very strong conviction and influence in their countries.

What you say here, I do believe that perhaps more concerted discussion here would be desirable. However, I am not too dissatisfied. I think the Physical Society has committees discussing it and came to a rather favorable appraisal. But, as in Europe, there are other scientists that complain.

There is now in Britain a movement for reducing the CERN contribution, which I fear may have some effect and would slow down the whole development and make it even more difficult for the Europeans to contribute to SSC. So there are other scientists who feel this science is oversupported.

Mr. BROWN. Thank you, Dr. Weisskopf.

Mr. FUQUA. Mr. Stallings.

Mr. STALLINGS. No questions.

Mr. FUQUA. Mr. Walgren.

Mr. WALGREN. You say in your testimony that there comes a time when the cost and effort of the next accelerator is so high there may be no other way to build it other than a world cooperative way. How will we know that? When will we recognize that as being the fact?

Dr. WEISSKOPF. That is a very difficult question to answer. I believe we will know this. There are two things there: first, the cost itself. It is always very difficult to say whether $4 billion is much or not much because it depends what you are comparing with. That is one thing.

The second thing, however, is the readiness of collaboration, and that, I think, is to some extent a political situation, whether Western Europe, Japan, or maybe even some Communist countries are ready to collaborate. That is more political. That depends on the political atmosphere. Even between Western Europe and the United States, as you know, not everything is so good as it could be.

So I believe the two conditions, that it is really beyond the possibility of one country—as it was in CERN. In 1950 it was clear that one country could not have built that machine, period, of course, it was that spirit of collaboration.

Now, I personally think the SSC, expensive as it is, is not beyond the means of this country in the same sense as in Europe at that time. So, these two conditions: First, it must be really beyond the means; and, second, there must be a spirit of collaboration, not only scientific but political, and so that would be the condition.

Mr. WALGREN. You indicated that much of what has happened in science has been driven by the personalities involved. How would you recommend us as a political organization trying to balance the high energy physics off against the other elements of science, when you say that so much of what happens is really determined by the personality?

It is very hard, as you know, to take account of all the needs in science, and when one area is substantially more expensive than others, that really sticks out like a sore thumb. And if it is driven by a personality, then don't we have the obligation to try to override those personalities and go back to some kind of more broad-based distribution?

Dr. WEISSKOPF. Well, we have to be careful there because, without personalities, any field of science is not going to produce much; it will just run along the accustomed lines instead of innovation.

I remember very well when Enrico Fermi, who was certainly one of the great personalities, in the fifties asked for a 400-MeV cyclotron in Chicago, which at that time was a very big thing. I remember, we didn't even ask, "What do you want to do?" If Fermi wants that machine, he is certainly going to produce great things, and he did.

So, you see, it is not so much—if I understand you right, you say that strong personalities have also a strong influence on you people and try to have a better chance of getting money out. That is true, but it is perhaps not so bad that it is so.

Of course, one has to analyze whether this is just strong personality to get the money or whether it is strong personality as leaders in their field of science, like Enrico Fermi and others today, like Leon Lederman. But I do believe that to give large amounts of money to fields where there are no obvious personalities is a dangerous thing.

Now, fortunately, we have in our scientific—now I am speaking quite generally, other sciences—we have a lot of very strong personalities in our country, perhaps even more than in other countries, and therefore I am not too afraid. But one must be careful.

Mr. **Brown**. Would the gentleman yield?

Mr. **Walgren**. I would be happy to yield.

Mr. **Brown**. Are your thoughts on this at all influenced by the success of people like Dr. Teller in getting funding for the space defense initiative and x-ray lasers?

Dr. **Weisskopf**. Look, I think that is a completely different field.

Mr. **Brown**. It is a different field, but it is a strong personality who is getting funding for projects that he is deeply interested in.

Dr. **Weisskopf**. I certainly cannot help thinking of it. [Laughter.]

Mr. **Walgren**. If I might ask just one maybe more clear way, how would you approach the distributive function that we obviously have as funders, as Mr. Lujan said? I understand that you are pleased with what has happened with physics, and in your testimony you indicate that, as a physicist, as a high energy physics physicist, you look with satisfaction on what has happened.

But what about stepping away from that or above that and looking at the various levels of decisionmaking which we have in our society? How would you approach the distributive obligation at that point?

Dr. **Weisskopf**. That is, of course, a tremendous problem, and I was faced with it just a few months ago when I was supposed to testify before the British commission that had to decide whether they should go ahead with CERN. There, of course, there were representatives of other sciences, but that was not the first time.

Your problem is a very difficult problem; namely, how can one evaluate one science against the other? Every science, of course, has not enough support, really, and so you have here a very hard problem.

Again, I would say there are two points of view. Let me mention that which is nearer to my heart first, namely the point of view of how much will it contribute to new ideas about the structure of nature. Now, here I think high energy physics would be high up; other science would be less; biology would be very high up, and brain science, for example. If I were young now, I would go into brain science. I think, there, there are new horizons coming in.

So that is the scientific point—well, almost, I would say, philosophic. What brings us nearer, fastest, and most importantly, to the secrets of nature?

The second point, of course, is a practical one; namely, application—commercial and, I am afraid, also military. Here, this is a different point of view, and the applied-science point of view. From this point of view, of course, high energy physics and astronomy, which now are the most exciting sciences—by the way, I have not mentioned astronomy; also not in the printed one. This unification of particle physics with astronomy and cosmology is one of the most exciting things that has happened in science, in my view.

Both astronomy and high energy physics may have applications, but they are far off. This is, then, of course, always a very difficult decision.

But I always like to make this parallel. If you look, for example, at the history of world development, you will always see that those countries that were ahead in the fundamental sciences were also ahead in industrial development, because that goes together. The spirit of invention, the spirit of we have to find out why goes together with applications.

First it was England, then it was France, and Germany, and then the United States. So basic science and practical applications go hand in hand, although there is not necessarily a direct causal relation.

Mr. WALGREN. Thank you, Mr. Chairman.

Mr. FUQUA. Mr. Reid.

Mr. REID. I have no questions, Mr. Chairman.

Mr. FUQUA. Mr. Lewis.

Mr. LEWIS. I have no questions.

Mr. FUQUA. Thank you very much, Dr. Weisskopf. We appreciate your being here with us today and sharing with us very important subject matter.

[Answers to questions asked of Dr. Weisskopf follow:]

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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RECEIVED
JUL [illegible] 1985
COMMITTEE ON SCIENCE
AND TECHNOLOGY

July 18, 1985

Honorable Don Fuqua
Chairman
Committee on Science and Technology
Suite 2321
Rayburn House Office Building
Washington, D.C. 20515

Dear Congressman Fuqua:

I thank you very much for your letter regarding my testimony before the Science Policy Task Force on June 18, 1985.

I will try to answer the questions that you have sent to me.

1. What are (a) the advantages and (b) the disadvantages of sharing the cost of big science facilities on an international basis?

I cannot answer this question in all generality. The advantages or disadvantages of international cost sharing depend very much on the nature of the projects and on the general situation in the field at the present and in the near future.

Let me, therefore, look at the projects planned by the High Energy communities for the near future. There are two large projects: One is the Superconducting Super Collider (SSC) in the United States and the other is the Lep Hadron Collider (LHC) in Western Europe. Ther first is planned to collide two proton beams up to 20 TeV, at a cost of several billion dollars; the second plans to collide protons up to 8 or 10 TeV in the available tunnel, in which an electron beam collider is inthe process of construction. Its cost is probably around one billion dollars. Both communities study these projects intensely. It is clear to most people in the field that a realization of both projects, roughly at the same time, would be a senseless waste of effort. It would make sense only if the European project were an intermediate stepping stone of say 5 to 6 TeV realizable at an early time and the U.S. project were to be postponed to a much later date at the highest possible energy, even higher than 20 TeV against 20 TeV. However such a policy is not in the interest of U.S. High Energy Physics, and probably also not in the interest of a healthy development of world High Energy Physics.

In order to understand this situation, it must be realized that, at this moment, Western Europe is overextended in respect to High Energy Physics facilities whereas United States has not enough facilities. In Europe, two relatively large facilities are under construction: "HERA" at Hamburg, an electron-proton collider at a cost of about 1/2 billion dollars, and LEP, at CERN, an electron collider at a cost of almost 1 billion dollars.

In the United States there is no major facility under construction. The Fermilab accelerator is converted to a proton collider of 1 TeV against 1 TeV, and SLAC constructs a single path collider for electrons. Both are relatively small projects; furthermore, a similar facility to the first one was constructed earlier - albeit at half the energy - at CERN and led to historic discoveries and two Nobel prizes.

This is why the United States community strongly urges the construction of the Superconducting Super Collider as soon as possible. The present dearth of new facilities is most harmful. There are much too few opportunities for younger people to work; we are about to lose many interested people because of the lack of instruments. Such loss of young people is most detrimental to the future of the field.

Coming back to the question of advantages of international cost sharing, I must divide the question into two parts. Cost sharing between Western Europe and United States and cost sharing between United States and regions that have no frontline High Energy Physics facilities such as Canada, or no larger facilities such as Japan and perhaps China. I omitted the Soviet Union since, at this point in time, a collaboration is not likely.

I do not see any realistic possibility of cost sharing with Western Europe within the next decade or two. They are overcommitted with their own facilities. Their budgets are already too restricted for the completion and exploitation of HERA and LEP. These two facilities will begin to operate in the late eighties, and will need much financial support to be adequately exploited and upgraded in the nineties. Therefore, it is highly improbable that Western Europe could afford to spend significant amounts to help the construction of the Superconducting Super Collider. The same is true in reverse. The United is in such dire need for a new frontier facility that a financial participation in the European LHC project seems rather improbable.

The situation is quite different, however, in respect to other nations. A participation of Canada or Japan in the construction of the Superconducting Super Collider is possible. It would be in the interest of these countries to do so since it would make it easier for their scientists to participate in research and it also may bring about orders to their industries. But the amounts may not be of great significance. Every dollar helps, however, and efforts should be made to obtain their participation. It would also be helpful to the idea of international collaboration. It should be added that the HERA project is actively negotiating such participation with Canada and other countries.

To summarize my answer: International sharing of the cost of big science facilities is a good thing. The only disadvantage I can see, in principle, is that it increases the bureaucratic efforts, it may slow down the construction to some extent. Unfortunately, at the present moment, such cost sharing between the most active regions in High Energy Physics -- Western Europe and United States -- does not seem very probable. However, cost sharing with Canada or Japan should be actively explored.

2. What would be the best worldwide configuration of high energy physics facilities from the point of view of science? How might this best be determined?

From the point of view of science, the best configuration would be to have different frontier facilities in the two main regions: United States and Western Europe. The contacts between High Energy Physicists all over the world are excellent. Therefore the determination of what should go where is not a major problem. It will depend upon the enthusiasm of the groups for different facilities. At present, for example, it seems clear, that Europe will have the largest electron colliding facilities in LEP and HERA. The U.S. should not try to construct similar machines, except if some completely new technology comes up. This may come with the new innovative SLC (single beam collider) at SLAC which is in a development stage.

Therefore it is logical to have the SSC constructed in the U.S. I am convinced that the Europeans will give up their LHC (Proton collider in the LEP tunnel) if the United States decides to begin soon the construction of the more powerful Superconducting Super Collider, which would also benefit the Europeans.

3. Should some or all future "big science" facilities be developed on the basis of international cooperation?

This question is answered by my comments to questions 1 and 2. I certainly recommend detailed international discussions on these subjects. One should also distinguish between international construction and international exploitation. So far only the first item was discussed. International exploitation is going on all the time and will be also going on when new facilities are available. We will come back to this in question 4.

4. What is the trend of international collaboration in high energy physics? Is it increasing, decreasing or remaining relatively constant?

The answer is quite clear: It is increasing. There are more foreign teams working at United States facilities, and more United States teams working at CERN and other European laboratories. The reason is clear: Since different regions now have different facilities, there are always groups that want to make use of facilities not available at home. This is a most desirable development. It would be a waste if all kinds of facilities had to be duplicated in each region.

Most of these foreign teams construct their instrumentation largely at home and install them in the respective laboratories. As an example, a large team of mostly (but not exclusively) United States scientists are preparing an experiment at LEP, costing more than 20 Million Dollars.

At present these arrangements are such that the foreign team does not pay any "rent" or beam time. The local services are essentially free. Of course, it pays for its own instruments. Many of these guest teams are collaborations of groups from different nations who all contribute to the cost and fabrication of the instrumentation. The aforementioned team at LEP is a collaboration, not only with some European nations, but also with Soviet and Chinese groups. The free use of the beam and the local services reduces the bureaucratic work. In the long run the costs are equalized by the reciprocal uses of facilities.

There may be problems in the future, when a particularly expensive facility will be exploited, such as the SSC. It may be necessary then to contemplate the possibility of sharing operational expenses with the visitors, in some form of international administration of the facility.

So far the increasing use of foreign teams has not brought about serious difficulties. On the contrary, the international spirit of the field was emphasized; guests and hosts are profiting from the exchanges of experience, ideas and inventions.

5. What attributes of high energy physics make international cooperation easy to achieve?

Does the field have attributes that make international cooperation difficult?

6. What factors either (a)facilitate or (b) inhibit international cooperation in high energy physics?

High Energy Physics is particularly apt for international collaboration because of two reasons:

1. It studies the basic nature of matter at its most fundamental level. This is far removed of any commercial or military use. The only driving force is the human urge to know what makes nature tick. This urge is common to all humans, independent of nationality, religion, race or political system.

2. In spite of the enormous complication and sophistication of the ideas, instruments and tools, the fundamental aim is simple: The study of the interaction of elementary particles by investigating collisions of particles and the resulting radiations. Thus the methods used in the different laboratories are similar. Any innovation spreads rapidly, often by telephone to other labs. This makes for strong links between high energy physicists of the world and facilitates collaboration.

There is little that would inhibit such cooperation. Sometimes overambitious teams do not want to tell all their findings, fearing that others would overtake them. But such incidents are rare, perhaps rarer than in other fields of science.

7. What does "world leadership" in high energy physics mean? What particular benefits accrue to the "world leader" versus "number two"? Why should national policy makers care whether or not the nation is first, second or third in high energy physics research?

It is not the question of being first or second, a designation which would be hard to define. The important thing is to be actively and successfully involved in this science. In order to reach this, it is necessary to have first rate facilities able to work at the frontier of science. The United States does not need to own facilities at all frontiers but must have them at some frontiers. With the lively exchange of teams, American scientists can work on those frontiers not covered at home, by being guest teams abroad. But if there are no frontier facilities at home, the supply of competent scientists is going to dry out. This is also the reason why the pace of innovation is important. The U.S. already lacks enough frontier facilities. If we wait too long with the next step, we will lose the manpower necessary to continue. A younger student would not enter the field if he has no chance for more than a decade to perform experiments.

The question may be asked, why the United States need to be actively engaged in this field. Couldn't we profit from the discoveries made abroad without contributing to it? There are reasons why this would be disastrous. If we give up, or seriously slow down our high energy physics activities, the other nations will follow suit and the field as such will wither away, since the United States is considered as the leading nation in science.

Why would it be disastrous if high energy physics would wither away? After all, it deals with phenomena far away in time and space. The relevant phenomena have taken place, outside our laboratories, only shortly after the big bang or in cosmic cataclysms, such as far away neutron stars or black holes. They have no practical applications in the foreseeable future. This is a fallacious conclusion. The tree of knowledge has many branches; basic research into the innermost structure of matter is on the top, as it were. It uses the most advanced technical means, it presents the strongest challenges to physicists and engineers. It is one of the manifestations of the most daring and progressive spirit in science. The frontier fields of science represent the driving edge of the human spirit. They infiltrate the spirit of inventiveness and innovation into all other basic or applied branches. If you cut the top of the tree, the tree will wither away.

We have seen in the history of the modern world that the leading nations in industry and in political power were also the leading nations in basic science: France in the 18th century, England in the 19th century, Germany at the beginning of the 20th century and the United States later on. This is no coincidence. It is the spirit of daring and innovation in the basic sciences that sets the style of a community. This is why we need to maintain our proficiency and ability (if not leadership) in high energy physics as well as in other basic fields, such as astronomy, cosmology, even if direct practical applications seem to be far removed.

8. Are the experiences of international cooperation in high energy physics directly applicable to other fields of science? What lessons may be learned?

I believe that the answer to the first question is yes. In particular, to those fields where the necessary facilities are large and expensive. A typical example is modern Astronomy where international cooperation is already quite active. I remind you of the large base line arrays of radio antennas. Here the different stations must be so far away that they necessarily are located in different countries. Space science is another example where international collaboration is useful because of similar facilities of different character which could be constructed by different regions and exploited internationally. The recent European "Giotto" rocket dedicated to the exploration of Halley's comet is a good example. The United States has not constructed a rocket for that purpose but makes use (perhaps not enough) of the European venture. It is hoped that the lesson of high energy physics--construction of different facilities by different regions and common exploitation--will be applied in greater measure in space research, earth sciences and other fields. Science, especially basic science, is one of the best means to bring nations together.

Sincerely yours,

Victor F. Weisskopf

Victor F. Weisskopf

Mr. FUQUA. Our next witness is Sandra Toye, head of the Oceanographic Centers and Facilities Section of the National Science Foundation. She will discuss the international experience of scientific ocean drilling programs of both the current Ocean Drilling Program and its predecessor, the Deep Sea Drilling Project.

Ms. Toye, we are pleased to have you with us. You may proceed.

STATEMENT OF SANDRA D. TOYE, HEAD OF THE OCEANOGRAPHIC CENTERS AND FACILITIES SECTION, NATIONAL SCIENCE FOUNDATION, WASHINGTON, DC

Ms. TOYE. Thank you, Mr. Chairman. It is a privilege to accept the invitation to address the task force on the international experience of scientific ocean drilling.

For nearly two decades, these programs have been at the forefront of international collaboration in basic research and therefore may provide some models.

In the interest of your time—and I think you are a bit behind schedule—I will skip over all of the historical and descriptive materials and proceed directly to some of the conclusions, which I think may be more at the heart of your interest.

Mr. FUQUA. We will make your entire statement part of the record.

Ms. TOYE. Very good. Thank you.

Scientific ocean drilling became international and has stayed international, I think, for five reasons. The first is that it is forefront science; the second, that it demands state-of-the-art technology; third, it operates worldwide; the fourth, it is expensive—although, I feel, rather modest after the preceding speaker—and, fifth, that it requires large amounts, in fact enormous amounts, of scientific manpower.

The first condition of scientific excellence, I think, cannot be overemphasized. The drilling program has been engaged from the beginning in excellent and exciting science. It has been associated closely with the entire plate tectonics revolution, which is itself one of those occasional scientific events that provides an entirely new and different way of looking at the secrets of nature.

There is very little difference in the degree of excitement that exists today in the current Ocean Drilling Program and that which existed in the very new period of discovery at the very beginnings of ocean drilling 15 years ago. Plate tectonics is still an infant science, and it still commands the interest of the very best earth scientists all over the world.

The second condition, I think, is technological complexity. The technological difficulty of finding and reentering a drill hole on the ocean floor through 20,000 feet of water has been likened to threading a weighted string from the top of the Empire State Building into the neck of a soda bottle sitting on the sidewalk below.

Now, you add to that that you are doing this from a platform that is heaving and being pushed by wind and waves, that you have to get enough torque at the end of this long string to penetrate not only sediments but hard rock, the salts in the ocean basement, and you have to do it gently enough to recover the samples that are your reason for going there. I think that gives you some concept of the extreme high tech aspect.

When the Deep Sea Drilling Project was started in 1968, their drill ship, the *Glomar Challenger,* was the most advanced drilling vessel in the world at the time. Our new ship, which just set sail in January this year, which we have named *Joides Resolution,* is the SEDCO 471, one of the class offshore drilling vessels.

We have fitted it with shipboard laboratories that allow one to do at sea virtually anything that can be done on land and the very finest geophysical labs, and through engineering development, we will soon be able to add to scientists the capabilities to get into areas we simply could not get with *Challenger.* This includes the high latitude polar seas, the hydrothermally active regions, the midocean ridge crests, and into back arc basins.

A third aspect which I will mention very briefly, but it is terribly important, and that is, this is inherently a global program. We operate worldwide on the high seas so that ocean drilling has always been an internationally visible and very obvious presence in the world of geosciences.

The fourth factor is cost, although again I feel quite modest about this. Nonetheless, in terms of basic research, drilling is expensive. To build a new drill ship today from the keel up would cost something in excess of $100 million.

Our operating costs for the program are about $35 million a year. About one-third of that cost is provided by international contributions. These costs made collaboration interesting, in the first place, and they also then limit the possibility that competitive programs would suddenly mushroom in other places.

I think the most significant factor for ocean drilling, for international collaboration, is its absolutely enormous demand for human talent. About 1,100 top scientists and technical experts in a typical year devote a major segment of their productive time to the Ocean Drilling Program. There just are not enough people in this field to carry out this kind of program year after year without international collaboration. It has an extremely demanding manpower profile.

The lessons and examples from this experience to me are a few, again, to reiterate: that there must be a strong scientific rationale as a precondition. Cost alone I don't think is enough. There are inconveniences, delays, disadvantages in international cooperation. I think, for those to be worthwhile, there must be the sense of scientific excitement and capability.

In the case of the scientific drilling programs—I have said it before; I will say it in a different way—a joint international program of ocean drilling is vastly better than anything that any one nation by itself could put in the field.

I have already mentioned the fact that international collaboration demands costs. There are expenses, of course, for travel, for communications. But I think the far more important costs are measured in time, and that is that international cooperation requires that scientists be willing to spend their most limited resource, which is their time, on items that are often nonscientific in the way of the consensus building that is essential to run successfully an international program.

The third point has already been mentioned, and that is that international programs demand long-term commitments. This is to some extent a fallout from the preceding point. International decisionmaking tends to be slow. It is also inherent in the nature of science. As we meet here, there are planning committees that are looking at proposals for drilling in the Pacific Ocean in 1989 and 1990, and I think that kind of planning cycle is not atypical of other large science enterprises.

It is easy in this situation to get into a chicken-and-egg syndrome, and we have had a bit of this problem in drilling. The partner governments do not want to commit until they are sure that the major partner, which is the United States, is committed to a given course of action. On the other hand, U.S. policymakers want to have reasonable assurance of international participation before they commit.

I think the benefit we have had has been in the attitude of our congressional committees and of the Federal policy agencies, who have simply recognized the essential nature of a U.S. commitment in starting the new program and have been prepared to accept risks, carefully defined and limited, but nonetheless to accept an element of risk and step out forward. The foreign governments, I think, have complied beautifully in that we have asked for and received a commitment in principle to the entire 10-year planned life of the program.

I have made, finally, the rather obvious point, but it is sometimes difficult to do in practice, and that is that you must consider the interests of all the partners in the management and governing, in the administrative side of an international program.

In ocean drilling, the first foreign involvement was with an ongoing U.S. program, and the partners did not really expect to be significantly involved with the management. When we planned the Ocean Drilling Program, their attitude was quite different. They expected, and we were able to negotiate, I think, very suitable administrative involvement.

The larger question is, of course, for you to judge, and that is to what extent this experience is in fact a model for others. I find my own feelings a bit mixed in this regard.

In ocean drilling, the United States is clearly the leader. We are the majority player. If, indeed, the United States is going to participate in scientific activities where we are in the minority or in a secondary position, I think perhaps the particular skills we need for membership are different than the ones we need for leadership in a project.

The very nature of our program has resolved one problem which Dr. Weisskopf alluded to. That is, ocean scientists have never had the luxury of staying at home. They have always had to go to some far-flung place to do their work. So we simply have not had the issue, and we also do not have a large ground-based, highly visible and very expensive fixed facility.

I think the most important, though—and many people don't realize this—ocean drilling is not a time-sharing proposition. This is not the existence of a facility on which people take turns. Every program is planned by the entire international group participating. Every time the ship goes to sea, it is staffed by a totally integrated scientific and technical party from all of the participating countries. That, I think, is unique.

So, in summary, I am not sure the extent to which our experience is useful. I think, indeed, that is a judgment that groups like this can make.

I say again, to echo Dr. Weisskopf, that we are fortunate in that the pursuit of scientific knowledge is not a zero sum game. There are plenty of mysteries there for everyone.

[The prepared statement of Ms. Toye follows:]

National
Science
Foundation

STATEMENT OF

SANDRA D. TOYE

HEAD OF THE OCEANOGRAPHIC CENTERS AND FACILITIES SECTION

BEFORE THE

SCIENCE POLICY TASK FORCE

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

JUNE 18, 1985

Mr. Chairman:

It is a privilege to accept the invitation of the Task Force on Science Policy to discuss the international experience of scientific ocean drilling programs -- both the current Ocean Drilling Program (ODP) and its predecessor, the Deep Sea Drilling Project (DSDP).

For nearly two decades, these programs have been at the forefront of international collaboration in basic research. It is especially worth noting that they have operated by the good will and voluntary adherence of the partners involved: ocean drilling is independent of any umbrella international organization.

In view of the limited time available for today's discussion, I would like to submit the full text of my remarks for the record, skipping over most of the historical and descriptive materials to concentrate on two questions which seem to be at the heart of the Task Force inquiry:

- What are the criteria or characteristics that make a program a candidate for international cooperation?

- What are the special procedural, administrative or functional requirements of an international program?

BACKGROUND: THE DEEP SEA DRILLING PROJECT, 1968-83.

At the end of the Versailles Summit of June 1982, the Heads of State appointed a working group to assess areas in which cooperative international action could enhance the application of science and technology to social and economic objectives.

The working group report strongly endorsed international exchange and dissemination of scientific knowledge as beneficial in its own right, and accordingly encouraged informal collaboration in all areas of research and technology. The report went on to recognize a smaller number of activities for which more formal arrangements would be desirable, urging its governments:

> "... to seek cooperation in, and in certain cases joint operation of large scientific research installations, the cost of which is prohibitive for a single government but which are nonetheless indispensable for the advancement of science."1

The working group pointed to 4 ongoing international projects which they felt exemplified this category. Scientific ocean drilling was among them.

When the Summit Working Group issued its report, the Deep Sea Drilling Project (DSDP) drillship GLOMAR CHALLENGER had just embarked on the final months of its spectacular 15-year-long journey of discovery.

DSDP originated in the mid-1960's as a modest at-sea portion of Project Mohole. When Mohole succumbed to budget and technical problems, the ocean component survived. It was intended to be an 18-month project carried out by four U.S. oceanographic institutions. Operations began in 1968 with the newly-built GLOMAR CHALLENGER, and the program immediately found itself at the heart of the plate tectonics revolution. DSDP was quickly renewed for five years, and several other U.S. institutions joined the program. Scientific planning for the program was carried out by Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), an association of the participating institutions.

In 1974, already extensive international participation was formalized by establishment of IPOD -- the International Phase of Ocean Drilling. Five countries joined the program: Federal Republic of Germany, France, Japan, the USSR, and the United Kingdom. The USSR was active until 1979; the other 4 countries remained as members throughout the remaining decade of the DSDP. The conspicuous success of IPOD, both scientifically and politically, made it an obvious model for future international cooperative programs.

THE TRANSITION TO THE OCEAN DRILLING PROGRAM

During the final years of DSDP, several plans for a follow-on program were considered. There was some sentiment for simply extending DSDP for an additional 5 to 10 years, particularly because of the advent of a tool called the Hydraulic-Piston Corer (HPC). The HPC enabled recovery of virtually-undisturbed sediment cores, thus giving the infant science of paleooceanography an enormous burst of productive data.

However, the weight of opinion, especially in the international community, was that the built-in technical limits of GLOMAR CHALLENGER were barriers to much of the most exciting research being contemplated in the next decade. When CHALLENGER left the ways in 1968, she was a revolutionary vessel, but a decade later, she had been surpassed by several generations of bigger, more capable ships. The equipment could no longer meet the demands of the science.

The last four years of DSDP operations resulted from a pair of two-year "final" extensions. These short extensions were exceedingly difficult to manage, especially in the international arena. Scientific planning became an increasingly contentious matter, as proponents of current and proposed new technology squared off. It became clear that DSDP/IPOD was nearing its conclusion.

Ocean Margin Drilling Program (OMDP), 1980-81. OMDP would have been a U.S. effort funded jointly by NSF and a consortium of U.S. oil companies. Using the Government-owned GLOMAR EXPLORER converted for drilling with marine riser and blowout preventers,2 effort would have been concentrated on a few relatively deep holes in passive margins. The passive margins are of great interest to scientists because they hold information about early rifting of the plates; they are of special interest to oil companies because of possible concentrations of oil and gas. The program was abandoned primarily because the oil companies lost interest as petroleum prices dropped.

The OMDP concept was deeply disturbing to the international community. They resented the exclusionary nature of the program, and felt that their loyal support of IPOD had been brushed aside in favor of narrow national interests in the planning for a follow-on program. It has taken years of patient work to rebuild their confidence.

Advanced Ocean Drilling Program (AODP), 1982-83. AODP, like the DSDP, was to be an internationally-supported, world-wide drilling program addressing a broad range of scientific questions. Scientific objectives and the associated technical requirements were spelled out at the international Conference on Scientific Ocean Drilling (COSOD) in November 1981, immediately after collapse of the OMDP. COSOD strongly endorsed the need for a more capable ship. Borrowing the engineering development work done for OMDP, COSOD proposed conversion of GLOMAR EXPLORER, without riser, as a platform for AODP. Uncertainty about conversion and operational costs of the enormous ship eventually led to abandonment of this plan. The search for an alternative platform capable of meeting COSOD scientific objectives went on.

Ocean Drilling Program (ODP), 1983-1993+. Intellectually, ODP is a direct descendant of IPOD and AODP. With the demise of the EXPLORER plan, the scientific community turned to the state-of-the-art ships operating in the commercial offshore drilling fleet. Because of the long depression in oil prices, lease costs for these ships were at an all-time low. A Request for Proposals issued in September 1983 elicited several highly-competitive bids at prices within the program's budget estimates. The final contract for the drillship SEDCO/BP 471 provided for a five year initial charter and options to extend for as many as ten additional years under the same basic terms.

With the ship issue resolved, the community moved into high gear on other preparations for the program. An entirely new management scheme was developed and set in place; the drillship was converted for scientific service; and the scientifically sophisticated and technically advanced program has now begun. Just a few months ago, in January 1985, the ship, informally renamed JOIDES RESOLUTION, set sail on the first expedition of what is expected to be at least a decade-long program. In the new ODP, international collaboration remains central-- scientifically, managerially, technically -- to the governance and conduct of the program.

THE MANAGEMENT STRUCTURE OF THE OCEAN DRILLING PROGRAM

The U.S. National Science Foundation manages ODP on behalf of the participating international community. Contributions of foreign members are deposited in a Trust Fund in the U.S. Treasury, and are drawn upon, along with N.S.F. appropriated funds, to pay for the joint operational costs of the program. These include drillship operations and logistics, downhole logging, engineering development, management, archiving and publications.

Four membership agreements have been signed so far: Canada, France, West Germany, and Japan. Negotiations are still in process with the United Kingdom and a consortium of smaller countries organized by the European Science Foundation. A more extensive discussion of international arrangements will be presented later in these remarks.

Joint Oceanographic Institutions Incorporated (JOI), a not-for-profit corporation of ten major U.S. oceanographic institutions, is the prime contractor for the program. It subcontracts with member institutions for the various services required. Texas A&M University (TAMU) is the science operator; their responsibilities include the operation of the drillship, engineering development, and data management and archives. The Lamont-Doherty Geological Observatory (LDGO) of Columbia University is home for the Borehole Research Group, whose task is to adapt commercial downhole logging techniques to scientific operations and to develop new measurement tools. TAMU and LDGO, in turn, have subcontracts with commercial firms for the drillship charter and the logging operations.

Scientific planning is the province of JOIDES, the namesake for the ship. I shall discuss the structure and function of JOIDES in somewhat more detail in a few moments. For now, I simply wish to emphasize that this unique organization is the driving scientific force for ocean drilling, and is the primary arena for international interaction.

THE INTERNATIONAL STRUCTURE OF ODP: THE PRIVILEGES AND COSTS OF MEMBERSHIP

Although ODP operates as a multi-lateral program, the formal international structure consists of a series of bilateral agreements between the National Science Foundation and its counterpart agency in each participating country. To reinforce the multilateral character of the program, the Memoranda of Understanding (MOU's) are identical in all matters of substance, varying only to accommodate such administrative particulars as the different fiscal years of each country.

Each member agrees in principle to support the program throughout its planned 10-year span; the body of the MOU will remain in force through 1993. The contribution baseline is $2.5 million per member, per year. This sum can be changed in response to changes in the cost of the drillship lease, which are in turn tied to one of the specialized Producer Price Indices. The detailed financial arrangements with each partner are embodied in a short annex to the MOU which is renegotiated annually.

In return for its contribution, each member is guaranteed certain minimum levels of participation:

- a seat on each committee, panel, or other instrumentality of JOIDES;
- 2 representatives on the scientific roster for each cruise leg;
- 1 co-chief scientist per year;
- full access to all data and samples and to technical plans and specifications for equipment or techniques developed by the Program; and
- 100 copies of all publications.

The MOU's cover only the jointly supported operational aspects of the project. In addition, each country separately provides salaries, travel costs, and research support for its own scientific participants, and for geophysical field studies necessary to select and site drill holes. The wide variations in national approaches to science support makes it difficult to tabulate these additional costs, but the range appears to be from about 50 to 100% of the cost of the operational contribution. Thus, the current full cost for a single country to take part in ODP is about $4 to 5 million per year.

In the case of the United States, NSF provides the U.S. contribution to the joint program -- currently about $22 million per year -- and also funds the separate U.S. science program for ODP. The latter is handled through peer-reviewed research proposals and a service contract with an academic consortium which is the coordinating center for the U.S. community.

The only formal international coordinating mechanism established under the MOU's is the ODP Council. No counterpart for the ODP Council existed during the DSDP era. The foreign partners felt this to be a serious omission. They argued that there should be a governmental consultative body which would periodically review the general progress of the program and discuss financial plans and other management issues.

The Council is the only body in ODP which recognizes nations *per se*: countries which participate in ODP as members of a consortium may elect to attend Council in their own right or be represented by someone acting for the consortium. Since the Council is strictly a consultative body, there are no provisions for voting. The Council held its second annual meeting here in Washington just a few days ago, June 5-6. So far, it has proven to be a valuable means of communication and a useful forum for an early airing of concerns and problems before they become critical.

JOIDES: THE DRIVING SCIENTIFIC FORCE

Membership in ODP is a dual process: in addition to signing an MOU with the NSF, participants must be members of JOIDES. JOIDES is the international association which has provided scientific direction and planning to both the DSDP and the ODP. The Terms of Reference of JOIDES define members as:

> "...representatives of oceanographic and marine research institutions or other organizations which have a major interest in the study of the sea floor and an adequate capability in terms of scientific manpower and facilities to carry out such studies."

This admittedly subjective criterion has nonetheless worked well as a filter.

JOIDES has only a single class of membership. Periodic recommendations for "Associate" or other secondary membership arrangements have been rejected. The members feel that scientific authority and responsibility are absolute, and that equality is an essential and indivisible manifestation of that condition. In 1982, for the first time, JOIDES agreed to consider a consortium as a member, thus providing a way for smaller countries to take part. But any consortium must present itself to JOIDES as a single entity and act with one voice in the organization. Current JOIDES membership consists of ten U.S. oceanographic institutions and the lead agency or designated institution for each of the four international members.3

In the case of the U.S., there is a distinct separation between the funding source (NSF) and the participating institutions. NSF is not a voting member of JOIDES, although it holds a liaison seat on each of its constituent bodies because of the NSF role as overall manager of the program.

Practices in this regard vary among the international members. In some cases, the Government agency which signs the MOU is also the JOIDES member; in others, another institution will be designated to represent the national scientific community. For West Germany, for example, the cognizant Government agency is the Deutsche Forschungsgemeinschaft, which is similar to the NSF; but the JOIDES member is the national geological survey, the Bundesanstalt fur Geowissenschaften und Rohstoffe. For France, in contrast, a single agency, the Institut Francais de Recherche pour l'Exploitation de la Mer (IFREMER), carries out both functions.

In our view, both models work equally well. They simply reflect differences in national approaches to the support of basic research and the internal organization of their marine geology and geophysics communities.

The principal instrumentalities of JOIDES are an Executive Committee (EXCOM) and a Planning Committee (PCOM). EXCOM, which provides overall management and policy guidance, is comprised of senior managers of the member institutions -- deans, department chairmen, or their bureaucratic equivalents. PCOM members are senior working scientists, named to represent their national or institutional research community. The member institutions are careful to maintain scientific balance in PCOM, with appropriate representation of disciplinary and regional specialties.

PCOM is the focal point for all scientific planning for ODP. It has a network of panels and working groups which screen drilling proposals, evaluate instrumentation and measurement techniques, and assess geophysical survey data and other safety and siting information. PCOM screens the recommendations of these panels and committees to select drilling targets, specify the major scientific objectives of each leg, and provide the operators with nominations for co-chief scientists. The operators and their subcontractors are responsible for producing detailed ship's tracks, actual drilling schedules, and final scientific rosters, but these are developed with close interaction with PCOM and the cognizant panels or working groups.

In the view of the international scientific community, membership in JOIDES, and in particular, the right to seats on PCOM and the planning panels, is the single most important and most jealously guarded attribute of membership in ODP. JOIDES decisions on scientific priorities are at the heart of the entire program. The PCOM is a constant source of quality control and performance evaluation for the operators and contractors. Although the ODP has provisions for management oversight, audits, and formal reviews of contractor performance, praise and criticism from PCOM are the feedback which have the greatest influence on program management decisions.

Voting procedures for EXCOM and PCOM have been carefully crafted to deal with the built-in U.S. majority (10 U.S. vs. 4 current or 6 anticipated international votes). For any resolution to be enacted, the specified 2/3 affirmative majority must include at least one non-U.S. member. In practice, the groups rarely vote, most decisions being taken by consensus or acclamation. When formal votes are taken, it is often for the purpose of publicly affirming the existence of consensus, and the announced vote is thus usually unanimous.

Hotly-contested issues do arise, primarily in the panels and working groups, which operate on a simple one-person, one-vote basis. These votes rarely, if ever, split on national lines. The divisions are scientific: proponents of competing hypotheses, enthusiasts for particular drill sites, or practitioners of different disciplines often disagree, but national origins seem not to have much to do with it.

This is not to say that the voting rules are meaningless. The "qualified majority" rule stands as a constant reminder that concerns of member countries must be reasonably dealt with. In JOIDES management issues, a slightly less-than-perfect decision that enjoys the support of all of the participating countries is usually preferable to an "ideal solution" which seriously offends the needs or sensibilities of one of them.

THE RATIONALE FOR COLLABORATION

Scientific ocean drilling is an international program for five reasons:

- It is forefront science;
- It demands state-of-the art technology;
- It operates worldwide;
- It is expensive;
- It requires large amounts of scientific manpower.

It is worth spending a few minutes looking at these forces in some detail, because they may point to criteria applicable to other programs.

1. Scientific Excellence

The first condition can not be over-emphasized: the program is engaged in excellent and exciting research. DSDP came along just at the time that the theories which we now subsume under the rubric of plate tectonics had begun to gain intellectual respectability. It is hard to realize that only 20 years ago, the prevailing theory held that the continents and ocean basins had been permanent features of the earth from the beginning of geologic time. By the 1960's these assumptions were being challenged. But it was not until the voyages of GLOMAR CHALLENGER that there was direct proof of the validity of the new ideas. DSDP samples have proved that the ocean basins are young; that the six continents were once a single land mass; and that the creation and destruction of crustal materials are ongoing processes. The history of ocean drilling is thus inextricably linked with the plate tectonics revolution -- one of those rare scientific events that provides an entirely new and different approach to understanding the universe.

The difference between the excitement in ODP planning today and in the period of new discovery which characterized the first years of DSDP is slight. Plate tectonic theory is still young, with much that is unknown. Its practitioners are developing process-oriented studies and models which will not only describe but quantify and eventually predict the dynamics of the earth. By any measure, is still forefront science, followed closely by all earth scientists everywhere.

2. Technological Complexity

For the marine geologist, the drill is the counterpart of the land geologist's sampling hammer. Sophisticated remote sensing techniques such as multi-channel seismics, acoustic tomography and geopotential satellite missions are still remote: the drill is the only tool which can recover large-volume samples from the deep ocean floor. Data retrieved by drilling provides context for these other data sets and direct proofs for hypothesis testing. To put it another way, drilling results often correct, refine or challenge models established by remote sensing.

The technological challenge of finding a drill site in 20,000 feet of water has been likened to hitting the mouth of a soda bottle on the sidewalk with a weighted string suspended from the top of the Empire State Building. Add to that the problem of applying enough torque for the drill to penetrate the sediments or hard crustal materials, and to do so gently enough to recover the samples with as little disturbance to the material as possible; then calculate how to do all of this from a platform which is responding to wind, current, and waves, and one begins to understand the technological and engineering component of this program.

JOIDES RESOLUTION is a state-of-the art commercial vessel. The shipboard laboratories provide capabilities at sea which exceed all but the very finest laboratories ashore. Drill string design and other rig improvements may soon enable scientists to probe critical areas which were out of reach of CHALLENGER: hydrothermally-active regions, mid-ocean ridge crests, back arc basins, and the high latitude polar seas.

3. Global Operation

The intellectual scope of ocean drilling is inherently global, seeking nothing less than the origins and processes that shape the earth itself. Operationally, too, ocean drilling takes place on the high seas, all over the world. Originally, these were places claimed by no one and presumed to be without economic significance. Today, with Exclusive Economic Zones extending 200 miles seaward, heightened public environmental concerns, and economic interest in offshore petroleum and seabed mineral deposits, ocean drilling operations have come to have economic and political implications; implications which are sometimes at cross purposes with scientific objectives.

In particular, as we contemplate the possible future addition of a deep riser capability and blowout preventers to the scientific inventory of the ODP, drilling targets will move nearer to shore, especially into passive margins. There are many compelling scientific questions to be addressed in these regions. But in the margins, economic interests, and thus national and commercial proprietary concerns, must also be considered. The unsuccessful attempt in 1980-81 to establish the Ocean Margin Drilling Program illustrates the dilemma. For industrial interests to be sufficiently motivated to support this costly activity, payoff had to be visible; this tended to translate to proprietary rights: geographic exclusivity and limited access to tools and results. Caught between mutually exclusive national and international objectives, the OMDP could not be sustained.

ODP has returned to the world oceans as its operating area. After the OMDP experience, we have worked hard to restore the trust of the international community in the open, non-proprietary nature of the research, and to demonstrate the willingness of the U.S. to keep it that way. Any future plan for riser operations must deal forthrightly with this inherent conflict between national and international interests, and find a formula which balances them to mutual benefit.

4. Cost

Drilling is expensive. The costs of building, outfitting and operating a drillship and supplying the necessary scientific and logistical services are beyond the means of all but a few countries. In today's market, the cost of building a state-of-the-art ship approach $100 million. It cost over $10 million to convert JOIDES RESOLUTION by installing laboratories and scientific drilling and coring capabilities. Joint ODP operations and services cost about $35 million per year, and additional support for the individual research efforts provided separately by each nation to its own research community probably adds $20 million or so to that amount.

While these costs do not approach the expense of, say, a big accelerator or a space telescope, they are nevertheless a substantial demand on any single nation's science budget. This makes collaboration financially desirable, and limits the likelihood that a competing program may suddenly develop.

5. Personnel Requirements

Perhaps the most important motive for international collaboration in ocean drilling is its enormous demand for scientific, engineering, and technical talent. One of the senior U.S. founders and supporters of ocean drilling, Prof. Charles Drake of Dartmouth, often refers to the program as a "people-eater". This causes consternation and merriment at international conferences when translators not familiar with American slang render this as, "ODP is a cannibal."

But consider these facts:

- About 280 scientists, engineers, technicians, seamen, drillers, curators, and administrative and support personnel are full-time employees under ODP contracts.

- Another 250 are unpaid members of planning groups and advisory panels, most of which meet several times annually.

- One hundred fifty (150) individuals go to sea each year to take part in scientific cruise legs averaging about 2 months each in duration; they also formally commit themselves to 2 to 6 months of work in the following year to process, analyze and edit the data collected by the group, postponing individual research until they have fulfilled this collective responsibility.

- Although not sailing on the drillship, another 150 scientists will collect or analyze geophysical data, survey potential sites, or perform shore-side analysis of cruise results.

The bottom line is that in a typical year, more than 1100 highly trained specialists will devote a major segment of their productive time to the ODP, and many hundreds more will use DSDP or ODP cores, rocks, or other samples and data in ongoing individual research projects.

This factor, beyond all others, has dictated that the program be international. There are simply not enough people to carry out the program without worldwide participation.

SUMMING UP: LESSONS AND EXAMPLES

What lessons might be drawn from the ODP experience?

1) The existence of a strong scientific rationale is an essential pre-condition for international collaboration. Cost alone is not sufficient reason for scientists or governments to accept the inconveniences, delays, and other disadvantages of international cooperation. For these to be acceptable, the program must be at the forefront of the scientific enterprise. If an instrument or facility is in question, it must be uniquely capable of tackling the most compelling or difficult problems of the field.

Occasionally it is suggested that we should "stimulate some international support" as a way of easing funding burdens for such costly but standard facilities as research ships and observatories. Standard facilities are not good candidates for formal cooperative programs. This does not rule out *ad hoc* arrangements for shared use at a scientist-to-scientist level or even on a bilateral basis.

In the case of ODP and DSDP, as I have indicated, the needs of the program for both scientific talent and forefront technology have combined to make collaboration not just acceptable, but highly desirable. A joint international program of deep ocean drilling is vastly better in terms of scientific quality than any single nation could produce alone.

2) International collaboration exacts costs. Monetary costs for international travel, communications, meetings and representation are substantial. Wise managers should build them into their budgets. For an international program, a meeting in Paris or Tokyo is no more exceptional than one in Chicago or Omaha. And communication -- frequent and repeated -- is absolutely indispensable. In ODP, a small part of the Trust Fund is earmarked for the additional program management costs NSF incurs because of the international nature of the program.

But the far more important costs are measured in days, months and years. International cooperation requires that scientists be willing to spend their most limited resource -- their productive time -- in non-scientific but essential consensus-building.

This means meetings that must be twice as long or twice as frequent as the agenda suggests in order to allow for translation, jet lag, or consultation with a home office that is several thousand miles and 10 time zones away. It means allowing 3 months for joint scientific decisions that a national committee might reach in an afternoon. At the policy level, it means that no major change can be accomplished in less than 3 years -- and a more realistic timeframe is probably 5 years.

3) International programs demand long term commitments. This requirement derives in some measure from the preceding point -- that is, that international decision-making is inherently slow. For instance, I have not yet found a country which uses the same fiscal year as we do. Thus any proposal that is timely for the U.S. appropriation and planning cycle has just missed the deadlines of half of the partners, and is six months too early for the other half!

The timing problem is also inherent in the nature of basic research, and particularly in the "big science" that is in the candidate category for internationalization. This month, JOIDES panels will meet to evaluate proposals for drilling in the Pacific in 1989 or 1990. The planning cycle for many large scale cooperative research efforts is similarly long.

A classic chicken-and-egg syndrome can easily develop. Before the partner governments are willing to commit to a significant change, they want some assurance that the majority partner, the U.S., will do the same. And U.S. decision makers, on the other hand, want reasonable assurance of international support before they give the go-ahead. Indecision or precipitous change anywhere in the system reverberates for a long, long time.

In ODP, we have benefited greatly from the attitude of our Congressional oversight committees and the Executive Branch policy agencies, OSTP and OMB. They have recognized the need for U.S. commitment and they have been willing to accept a degree of risk, carefully limited and defined, to get the program moving. The international partners have also found ways to make commitments-in-principle for the planned 10-year duration of the ODP. Their decisions, like ours, will be reviewed in the course of annual budget cycles; but any unilateral negative decision on renewal will be seen as the very serious matter that it is.

4) Governance and management of international programs must provide for significant involvement of partners. When countries joined the DSDP in 1974, they were joining a U.S. program in mid-stream. The new partners received equity in scientific activities but they did not participate significantly -- nor did they expect to -- in the management and administration of an ongoing program. When planning for ODP began, however, the partners made it clear that they would not accept similar exclusion in a new program designed from the start as a cooperative venture. We have opened significant areas of ODP staffing and procurement to the participating international community; strengthened and formalized government-to-government consultation by setting up the ODP Council; and brought the international partners systematically into budget review, audit, and other control functions for the program.

THE LARGER QUESTION: IS ODP A MODEL FOR OTHER PROGRAMS?

ODP is a program in which the U.S. is the acknowledged leader and majority participant. If the U.S. is to take part in a wide range of international programs, we will almost surely be a minority shareholder in some, and a visitor on other nations' home turf in others. We need to give some thought to the rights and responsibilities of effective membership, and well as of effective leadership, in international science.

In ODP, the very nature of the program has removed some of the issues which perplex other candidate programs. We hear the concern, for example, that U.S. scientists may find it an unacceptable inconvenience to travel to Tokyo or Geneva to use an instrument or facility. Since ocean scientists have never had the option of staying home, that has never been a problem for us. Perhaps more important, ODP is not a "time-sharing" arrangement where queuing problems can take on a national aspect. Every mission is staffed by an integrated scientific party drawn from all of the membership.

The management diagrams for ODP, viewed from outside, are complex. But having developed organically with the program, they have one undeniable virtue -- they work, and quite efficiently at that. Yet I could not recommend them as an organizational starting point to planners of other efforts.

In sum, then, while there are undoubtedly useful lessons to be learned from the international experience in scientific ocean drilling, there is also much that is not necessarily applicable to other candidate programs. It will require considerable discrimination among policy-makers, derived in part from careful studies such as this one, as well as the good will and enthusiasm of each involved scientific community, to develop mechanisms and arrangements that meet their particular needs.

Fortunately, the pursuit of knowledge is not a zero - sum game. One nation's discoveries do not diminish the residue available for discovery by others. There are mysteries enough to go around.

FOOTNOTES

1) "Technology, Growth, Employment," a report of the Working Group on Technology, Growth and Employment established by the Heads of State and Government at the Versailles Summit; Paris, January 1983, page 77.

2) A riser is a large-diameter pipe which surrounds the drillpipe in exploratory or production drilling. It is a conduit for circulating drilling fluids called "muds" to control overpressures, and is thus an essential part of controlling seepage or blowout. Up to now, scientific drilling has taken place in sites with virtually no possibility of hydrocarbon accumulation, and is done without a riser.

3) JOIDES members are Department of Energy, Mines and Resources (Canada); Bundesanstalt fur Geowissenschaften und Rohstoffe (Federal Republic of Germany); Institut Francais de Recherche pour l'Exploitation de la Mer (France); Ocean Research Institute of the University of Tokyo (Japan); University of California at San Diego, Scripps Institution of Oceanography; Columbia University, Lamont-Doherty Geological Observatory; University of Hawaii Institute of Geophysics; University of Miami, Rosenstiel School of Marine and Atmospehric Science; Oregon State University, School of Oceanography, University of Rhode Island, Graduate School of Oceanography; Texas A&M University, Department of Oceanography; University of Texas, Institute of Geophysics; University of Washington, College of Ocean and Fishery Sciences; and Woods Hole Oceanographic Institution.

DISCUSSION

Mr. FUQUA. Thank you very much, Ms. Toye.

When you speak of "big science"—and you mentioned ocean drilling—I think about a third of the costs, support costs, really, don't get you any science. We have other programs like the Antarctica Program with tremendous support costs involved, and that has been an international program.

Ms. TOYE. Yes.

Mr. FUQUA. In these programs, is the science we get—and when we are talking about SSC, we are talking about a big expense just to operate compared to the science that we may get back, and when you talk to a meteorologist or an astrophysicist, they have different opinions about what you get back from that kind of money. They say, "You give me that money and I'll bring you all kinds of information."

I am not trying to play one discipline off against the other, but how do you equate where you allocate your resources, particularly in these projects that have a very high support cost?

Ms. TOYE. In ocean drilling, first of all, let me make clear there is a whole component of scientific cost which I have not alluded to here because each country funds its own scientific activity. The only joint part is the operation, and those run perhaps of the order of $20 million a year that is invested in the research costs as such.

Again, the question of balance. One of the virtues of ocean drilling is this is a leased vessel. On the day that the scientific community concerned does not feel it is worth the money, we will, with a certain amount of pain, be able to end the contracts and fold it down. So in our case——

Mr. FUQUA. Yes, but you are not helping us now. We don't want to have to make that choice.

Ms. TOYE. Well, I think, in this case, the point is that the relevant scientific communities have made that decision over and over again within a set of sciences which are not enormously well funded. The earth sciences and ocean sciences are relatively modest, and I think that decision has been made repeatedly by advisory groups that have looked at this, and most recently since we have just renewed the program at a rather higher operating cost, and they have overwhelmingly said that this is forefront work and this should be done.

Mr. FUQUA. One of the criticisms of U.S. joint international cooperation has been that the United States is not a good partner, not a solid partner. We would be in this year and cut back next year and back in, and we are not a reliable partner, as evidenced in this program where the Soviet Union was to participate, and as a result of a political and diplomatic decision, we disinvited them to join.

Do you have memoranda of understanding, or are there long-term contractual agreements, or how do we do that and make our own selves be perceived as a reliable partner?

Ms. TOYE. We have memoranda of understanding for this program for the entire 10-year planned life of the program. In the Deep Sea Drilling Project, this was a much shorter renewal, and in fact the political issue came to bear more and more frequently in the later years.

Nonetheless, it is a fact for us, as for the other members, that these are agreements in principle, and the validity of the program is examined every year in the budget and appropriations process. The most significant loss was the one you mentioned, when the Soviet Union was disinvited or simply removed itself from the program, and we handled that by reprogramming within NSF funds.

Mr. FUQUA. Did the United States pick up the portion that the Soviets would have had, or was it distributed proportionately?

Ms. TOYE. No; NSF did, because we are on an advance payment situation with the partners, which is helpful in terms of U.S. cash flow, but it does not lend itself easily to ex post facto adjustments.

Mr. FUQUA. One of the points that Dr. Weisskopf mentioned about CERN is that they had 2-year plan, and they were already working on the following; each year they were working a 2-year plan. Would that be more helpful in international programs?

Ms. TOYE. Again, I am not sure. The scientific planning, we are working on about a 5-year time frame.

Mr. FUQUA. No; I am really talking about more funding.

Ms. TOYE. We have a 5-year plan. I am just not certain that the U.S. constitutional process allows that. But I think, sir, that in our case, the acknowledgment that we have enjoyed, again both from the Hill and from OSTP and from OMB, that this is significant, has made that a potential problem but not really a very real one for us.

Mr. FUQUA. Mr. Brown.

Mr. BROWN. I have no questions.

Mr. FUQUA. Mr. Stallings.

Mr. STALLINGS. No questions.

Mr. FUQUA. Mr. Reid.

Mr. REID. No questions.

Mr. FUQUA. Mr. Lewis.

Mr. LEWIS. No questions, Mr. Chairman.

Mr. FUQUA. Thank you very much, Ms. Toye. We appreciate your sharing your thoughts with us this morning.

[Answers to questions asked of Ms. Toye follow:]

QUESTIONS FOR THE RECORD

Ms. Toye

1. The Deep Sea Drilling Project started as a joint project carried out by four U.S. oceanographic institutions. When did the project first have foreign participation? Why was it felt necessary to formalize this participation with the establishment of the International Phase of Ocean Drilling (IPOD)?

   Ocean Science is inherently international, and foreign scientists and engineers participated in DSDP from the beginning. The original JOIDES scientific panels included British and Mexican scientists and technical specialists from British Petroleum and Royal Dutch Shell. The first foreign scientist to sail on CHALLENGER was Professor Maria Bianca Cita of the University of Milan, on Leg 2, October-November 1968.

   Pressure to formalize international participation came from both sides. Foreign scientists wanted to be part of the mainstream of the program, participating regularly by right, not as invited guests. On the U.S. side, there was a need to broaden the financial support base for the program and to augment U.S. scientific and technical personnel. (see pp. 9 and 10 of original testimony).

2. You note on page 3 of your testimony that "[t]he Ocean Margin Drilling Program concept was deeply disturbing to the international community." Given the previous successes of the international drilling program, why did the U.S. decide to go it alone? Was it because it was felt that the international arrangements were too cumbersome?

   The U.S. "backed into" the decision to drop international participation. It was essentially a managerial and political choice never widely supported by the U.S. scientific community. It was not a decision based on a conscious evaluation of the scientific or administrative strengths or weaknesses of IPOD/DSDP.

   The original concept of the OMDP called for both international and industrial (petroleum industry) participation. These proved to be mutually exclusive. Oil industry interest centered on the assessment of exploitable resources in passive margin regions and on the development of new analytical techniques for discovery and technologies for extraction of relatively deep deposits. These proprietary interests called for restrictions and preferences in the use of data which were incompatible with an international program. Indeed, they also proved to be incompatible with the basic research tradition of publication in open literature, a problem which contributed to the eventual abandonment of the program.

3. You note that "[a]lthough ODP operates as a multi-lateral program, the formal international structure consists of a series of bilateral agreements between the National Science Foundation and its counterpart agency in each participating country." What are the relative advantages and disadvantages of bilateral and multilateral cooperative arrangements?

   Because the U.S. is the predominant scientific and financial partner and the sole manager of the ODP, bilateral agreements seem most appropriate. This mechanism maintains a very clear line of contracting responsibility: NSF authority is not diluted or attenuated by any multilateral management body. It also makes NSF clearly responsible for program performance to each partner country, which they view as highly beneficial.

   In a program in which participant "shares" are more nearly equal in size, a multilateral structure would be preferable.

4. What alternative arrangements might be considered to increase international collaboration in the Ocean Drilling Program?

   As I mentioned in my testimony, there have been periodic attempts to establish some sort of associate membership in JOIDES. This has not been favorably received by the members. The recently adopted JOIDES policy of admitting a consortium to membership is an attempt to make participation accessible to smaller countries without diluting the egalitarian membership principles of the organization.

   JOIDES is exploring several possibilities for systematically involving scientists from developing countries in ODP. Such involvement occurs now, but on an *ad hoc* basis.

5. To what extent is NSF's job made more difficult by not having identical bilateral agreements? What are the advantages and disadvantages of having different Memoranda of Understanding?

   On the contrary, the ability to make different arrangements with each partner greatly *eases* our job. We can accommodate the budget cycles and other administrative requirements of each partner. If we did not have that latitude, management would be much more difficult.

   The ODP agreements are identical in all *matters of substance* (see testimony, page 4.) This is essential to maintain equity among members and to establish consistent and fully-understood statements of privileges and responsibilities.

6. On page 7 of your testimony you state that "[i]n JOIDES management issues, a slightly less-than-perfect decision that enjoys the support of all of the participating countries is usually preferable to an 'ideal solution' which seriously offends the needs or sensibilities of one of them." To what extent might this arrangement tend to stifle individual scientific creativity or initiative?

   Not at all. All *scientific* planning entities of JOIDES operate on a straight majority, one person-one vote, procedure. (See page 7 of testimony). Their deliberations focus entirely on scientific and technical issues. Debate is intense; decisions are often close; and scientifically creative and risky enterprises fare very well. The qualified majority system exists only in the management entities of JOIDES, which do not have authority to alter the scientific decisions of the panels.

On policy and budget issues, as I have indicated, compromises are sometimes necessary. For example, a few years ago it was proposed to use microfiche rather than hard copy printing for certain DSDP publications. This would have resulted in considerable savings, and a clear majority of both U.S. and foreign members were prepared to vote for the change. However, two of the international members do not have microfiche readers available in their research centers and universities, and therefore depend entirely on the availability of hard copy. In light of this problem, the proposal was dropped, despite the existence of a majority in support of it.

7. Should some or all future "big science" facilities be developed on the basis of international cooperation?

Certainly not all. There are many instances in which a national community can fully utilize a big facility, and if costs represent an acceptable fraction of the funds available for the particular category of research, then a national facility may be preferable. If a research activity is closely tied to national security or industrial competitiveness, international cooperation may be totally inappropriate.

But these leave many other cases in which international collaboration may greatly enhance the capabilities which can be afforded and the quality of the science that can be performed.

8. What does "world leadership" in oceanography mean? Is there a "world leader" in oceanography? Has the Ocean Drilling Program made it possible for the U.S. to be the world leader in oceanography?

The last part of the question is easier to answer than the first. The U.S. is pre-eminent in marine geology and geophysics. The enormous success and influence of ocean drilling in the evolution of plate tectonic theory has been a major contributing factor to U.S. leadership in all of the geosciences, and certainly in marine geology and geophysics.

The larger question is difficult to answer in any field of science. It is particularly so for oceanography, which includes basic research in a number of quite diverse fields -- marine biology, physical oceanography, acoustics, marine geology and geophysics, marine chemistry -- and such applied activities as environmental monitoring, mapping and charting, and fisheries research.

The United States community is widely regarded as the world leader in basic ocean research. This is measured by the dominance of U.S. trained scientists in forefront research worldwide, the leadership of U.S. institutions in international undertakings in virtually all of the ocean science disciplines, and the degree to which U.S. research sets the standards of excellence and relevance everywhere.

This does not mean that U.S. predominance is uniform across all aspects of all of the disciplines. There are some decided soft spots in the U.S. achievement: in high latitude ocean research, for example, U.S. efforts are hampered by the lack of ice-strengthened research ships and other specialized equipment and technology required for polar operations. There are also general and growing concerns that the equipment and instrumentation available to U.S. oceanographers is obsolete, and that the recruitment of young scientists and engineers into the field is inadequate.

9. What particular benefits accrue to the "world leader" versus "number two" in a particular area of science? Why should national policy makers care whether or not the nation is first, second or third in a given area of science?

Again, this is a difficult question to answer. In areas essential to national defense or industrial competitiveness, being number one may be not only desirable, but essential. But most research is not a zero-sum, win-lose proposition. If a breakthrough in cell biology in China or France enables U.S. researchers to unravel a major problem in cancer research or plant genetics, everyone wins.

The more important question is whether we sustain a level of excellence as a nation which keeps us in a position both to contribute to and to benefit from forefront activities across a broad spectrum of scientific and engineering research, and to produce a sufficient stream of well-trained young scientists and engineers.

10. Should federal science funding include the aim of keeping the U.S. first in every field of science, and if so, will international cooperation be either beneficial or detrimental to achieving this aim?

Being "first" across the board is probably impossible; it is also not clear that it is either necessary or desirable. International cooperation can improve our own science performance not only by sharing costs, but also by sharing knowledge and expertise. That has been the case in ocean drilling: the international program is scientifically better than an exclusively national program could be.

Mr. FUQUA. Our next witness is Dr. Walter A. McDougall, associate professor of history at the University of California at Berkeley.

Professor McDougall is the author of a highly acclaimed political history of the space age called *The Heavens and the Earth: A Political History of the Space Age.* is the July selection of the History Book Club, and it was the subject of a cover article in the June 3 issue of the *New Republic.*

Dr. McDougall, we will be pleased to hear from you at this time.

[A biographical sketch of Dr. McDougall follows:]

DR. WALTER A. McDOUGALL

Walter A. McDougall, 38, was born in Washington, DC, and raised in Wilmette, IL. He graduated from new Trier Township High School in 1964 and Amherst College, Amherst, MA, in 1968. He then served 2 years as an artilleryman in the U.S. Army, including a year in Vietnam, 1969–70. He then entered graduate study in history at the University of Chicago, including a year's research in Europe. He took his PhD in 1974 and the following year began teaching at the University of California, Berkeley, where he is now associate professor of history.

Dr. McDougall has authored two major books and co-edited a third. He has been a fellow of the Woodrow Wilson International Center for Scholars at the Smithsonian and was named one of the "The Best of the New Generation: Men and Women Under Forty Who Are Changing America" by Esquire magazine. His current books are *The Grenada Papers* (with Paul Seabury) and *The Heavens and the Earth: A Political History of the Space Age.*

STATEMENT OF DR. WALTER A. McDOUGALL, ASSOCIATE PROFESSOR OF HISTORY, UNIVERSITY OF CALIFORNIA AT BERKELEY, BERKELEY, CA

Dr. McDOUGALL. Thank you, Mr. Chairman.

I deeply appreciate your invitation to serve as a kind of wild card and share my historical perspective.

My father is a patent attorney, and I have always marvelled at his combination of legal and technical knowledge. Yet this committee delves into everything from ocean drilling to DNA research, high energy physics and space stations, from the point of view of science, law, and the national interest. May I say I believe the committee has earned more thanks and sympathy from the public than it probably gets.

Your agenda rightly notes that changes in science policy usually occur only in times of crisis. At the very least, however, this task force can do a great service by revealing the barriers to change that operate in normal times.

In 1828, 21 years after Robert Fulton's steamboat plied the Hudson, the British First Lord of the Admiralty reported:

> Their lordships felt it their bounden duty to discourage to the utmost of their ability the use of steam vessels, as they considered that the introduction of steam was calculated to strike a fatal blow at the naval supremacy of the Empire.

This executive blindness afflicted Britain until 1848, when the British Parliament studied French naval plans and decided momentously to rely on private industry to perform naval research, since the British private sector was technically superior and more efficient.

But the legislators wisely continued some funding for state arsenals to monitor the performance of contracts. When the French approved construction of ironclad steamships in 1857, the British, thanks to the Parliament, responded with vigor and preserved naval leadership.

Now, this anecdote illustrates four points pertinent to the task force inquiry. First, even the mightiest industrial power cannot ensure its future without foresight and leadership. Second, the bureaucracy cannot always be counted on to provide that leadership.

Third, the Parliament was wise to depend on the dynamic private sector that had made Britain the world leader in the first place, while the French Government, like the Soviet today, lacked that private dynamism and had to crack the whip itself. And even though France inaugurated the age of ironclads, as the U.S.S.R. did the space age, she was unable to keep up with Britain. Fourth, all this testifies to the wisdom of the committee's survey of U.S. science policy.

Now, it is often said that science is by nature an international and cooperative enterprise, and that only suspicious governments prevent it from being so. This I believe to be false.

Throughout history, scientists have often been jealous of their discoveries, resentful of competitors, prudent to serve their royal patrons, or simply patriotic. Whether it be Leonardo in the court of the Medicis, or the British and Prussian science academies arguing whether Newton or Leibniz first discovered the calculus, or Vannevar Bush and Sir Henry Tizard swearing fealty to Roosevelt and Churchill, scientists have usually placed civic duty before devotion to a universal ethos.

Even the Piltdown Man hoax of 1912 was sustained in part by hopes that this resounding discovery might restore the prestige of British science.

To be sure, governments contributed heavily to international competition in science. From the Royal Academies of the European monarchs to the massive United States and Soviet research complexes of today, governments displayed a growing appreciation of the importance of science for military and economic security.

Nevertheless, beginning in the mid-19th century, governments also came to see, in limited cooperation in science, either common gains to be made or national advantage for themselves. Over the past century, three kinds of international cooperation have emerged:

First, what I call housekeeping cooperation, in which governments jointly support activities of an intrinsically global nature, like the 19th century coastal and continental surveys, meteorological or oceanographic services, or the sharing of the electromagnetic spectrum by the ITU. Such cooperation is perceived by all parties as necessary, whatever disputes may arise over policy.

Second, there is ground-breaking cooperation in which governments jointly support basic research for the discovery of new knowledge, like the International Polar Years of 1882 and 1932, the IGY of 1957 to 1959, or United Nations' studies of drought, erosion, endangered species, or bilateral experiments and conferences. Such cooperation is perceived as discretionary but mutually beneficial, whatever reservations may arise over cost.

Third, there is what I call competitive cooperation, in which governments each perceive benefit in collaborative research, but not the same benefit. This is most problematical to policymakers, for such projects require tradeoffs between costs and benefits to oneself and between benefits to oneself and benefits to others.

Big ticket items in nuclear, space, or seabed research—indeed, all sharing or transfer of technology, equipment, capital, ideas, or management skills—fall into this category. Such competitive cooperation is perceived both as discretionary and as a potential giveaway.

The pros and cons of such big-ticket cooperation are well treated in the OTA studies on "Civilian Space Stations" and "Competition and Cooperation in Civilian Space Activities," for which I was happy to serve as an advisor.

We tend to take for granted the diplomatic, scientific, and fiscal value of cooperation in big science. President Kennedy said, "Let us do the big things together," and proponents have touted international cooperation in space, for example, as a cement for alliances or detente, or a moral substitute for arms races, or a force for global integration.

Yet such hopes have often proven unrealistic, both in domestic and foreign policy. When the Communications Satellite Act of 1962 was debated, Senators protested the giveaway to private industry of technology developed at taxpayer expense. How much more would taxpayers of any country protest the transfer of critical technology to a foreign nation? When JFK made that appeal to the Soviets for a joint moon landing, Congress amended the NASA appropriations bill in such a way as to prevent it.

Similarly, big-ticket scientific cooperation meets roadblocks in foreign policy. It is justified as a diplomatic tool and a means of sharing the heavy financial burden involved. But that first justification rests on the alarmist assumption that our allies might weaken Western unity if we did not cooperate, implying an allied policy of spite, if not blackmail.

The second justification, sharing of costs, assumes that 5 percent or so in cost savings to the United States is not outweighed by the 5 percent of contracts lost to American industry, the 5 percent of lab time surrendered to foreign experimenters, and the incalculable price of technology transfer. It is not clear that cooperation is politically or financially worth the trouble.

My article on the European Space Program, which I deposited with the staff, describes the strategies of competitive cooperation adopted by France and Europe after Sputnik and the vigorous American response.

President de Gaulle initiated a crash program to break the U.S. monopoly in nuclear, space, and computer technology, and prevent Europe from becoming a technological backwater. To this end, he restructured the French economy, quintupled spending on R&D, and sought cooperation with other European countries and with NASA.

But French cooperative programs were shrewdly designed to channel foreign funds, ideas, and markets into a technology flow irrigating France's own garden. The French took whatever the United States would give them in satellite design, solar cells, telemetry, systems integration, and so forth, giving them a leg up on their European competitors. They also promoted European research for space boosters and satellites, but always spent many times more on their national programs than on their cooperative efforts.

In European agreements, the French insisted on clauses allowing them to apply jointly discovered know-how to their national effort without being enjoined to share nationally derived know-how with the others.

What de Gaulle intuited was that our age of continuous technological revolution would not be an age of global integration, nor of the triumph of communism, as Khrushchev boasted, but rather an age of heightened self-sufficiency and competition, even neomercantilism.

For de Gaulle embraced the capitalist assumption that competition was the engine of progress, but also the Communist assumption that competition was the solvent of community. A smaller country like France could not afford chaotic competition within but had to unite at home in order to compete with rival states abroad.

In the 1960's, NASA offered scientific cooperation and perhaps a subcontracting role to the Europeans. But their industrial lobby, Eurospace, made explicit that the European goal was to acquire prime contractor status for all space applications systems and not to play little brother to the United States.

Building on what they could derive from cooperation with NASA, assimilate from American literature, or purchase from American firms, the Europeans practiced a kind of Euro-Gaullism, borne of resentment of U.S. dominance and a desire to play an independent role on the frontiers of science.

The White House and Congress both endorsed space cooperation as a matter of principle and good will, but U.S. policy in the early space age was not naive. NASA's approach could be summed us as "cooperation in science; competition in engineering." In other words, NASA would launch foreign experiments and even foreign satellites but not transfer technology that could feed into foreign military programs or competitive economic systems.

This was prudent, but as others have testified here, science and technology can rarely be separated. Beginning with space science, then moving to applications, the Europeans, Japanese, and Canadians caught up with the United States in one after another targeted field and now compete for world markets in Government-subsidized, neomercantilist fashion.

Let us face the fact the U.S. power has been in relative decline since the late 1940's and again since the mid-1960's. Our situation is not unlike that of Britain in the years been 1900 and 1914. For a century, Britain had enjoyed naval, financial, and technological leadership. She was the keeper of the balance of power and defender of human rights.

But the industrial revolution inevitably spread to Europe, North America, Japan, and finally Russia. By 1902, when Britain emerged from the Boer War, a costly guerilla war not unlike Vietnam in its effects, she was still the world leader, but her relative power had shrunk markedly.

New industrial, naval, and colonial powers chipped away at British leadership in this market or that region of the globe. Foreign technology surpassed the British in many fields, and all the other powers raised protective tariffs, smashing the free trade system led by Britain.

Like America after Sputnik, Edwardian Britain echoed with cries to get the country moving again: for science and engineering in the schools instead of the classics; emphasis on foreign languages; merger of British firms to compete with foreign trusts; more aggressive exporting; funding of R&D; and protective tariffs.

But whatever hopes Britain had of rebounding were crushed by World War I, and the years around 1900 proved to have been her climacteric. Is the United States today facing its moment of decline? I suspect that this question, perhaps subconsciously, is in our minds as we discuss science policy.

But the causes of Britain's decline—hence, the lessons to be learned—are not clear. Britain, for instance, did not lack for R&D. It led the world in research until the 1930's and was still a healthy third into the 1960's.

Nor was British science inferior. The trouble was that many British inventions were exploited abroad and not by British business. Indeed, Britain helped to create her own competition by exporting capital and technology to industrializing countries like Germany and the United States.

But she cannot be blamed for that. Britain needed the foreign markets and was contributing to world economic growth. In the same fashion, the United States helped to create its competition through the Marshall plan.

In short, counting dollars spent on R&D or patents and Nobel Prizes won, in a kind of intellectual Olympic Games, are not useful measures of where one stands. Nor is protectionism a solution to foreign competition. For such a reversal of policy by the leading free trade and financial power would not only betray our principles but reduce the volume of trade for all countries and erode the unity of the West far more than any failure to cooperate in science. This is the lesson of the 1930's.

A crackdown on technology transfer through secrecy and refusal to cooperate might also be counterproductive. As angry as we are when we read of high-technology leaks, sales, and espionage, I don't believe the American people would want a commercial police capable of shutting off nonstrategic leaks.

What is more, secrets are hard to keep even with restrictions. We all remember the rapid Soviet development of the A-bomb. And the value of a given secret is always debatable.

Rather than be moved to imitate Soviet secrecy or Gaullist neomercantilism, the United States should accept its relative decline as inevitable and even a measure of the success of our postwar policies toward Europe and East Asia, and take steps instead to ensure that we remain leaders in those fields of science and technology that we deem critical. And even in those fields, the best way to stay ahead in the race, perhaps, is not to hurl obstacles at our rivals but simply to run faster. After all, we all play our best tennis against a tough opponent.

Having said that, however, we need not approach scientific cooperation with gratuitous generosity. This may or may not apply to the Third World. Perhaps we can discuss that later. Rather, we should approach big ticket cooperation with the knowledge that our prospective partners are asking themselves how such cooperation will help them leverage us in the future; and we ought to demand real concessions for making our facilities available.

As for which fields of science are critical, I understand how difficult it must be to choose. When his colleagues were agonizing over the complexities of space policy after Sputnik, the late Senator Clinton Anderson told Senators not to despair. His experience on the Joint Atomic Energy Committee had taught him that "committee members cannot compete with scientists on their own ground. So we stay in our field—the objective."

Congressmen are, by definition, more qualified than any expert to weigh the national interest, and I, for one, gratefully defer to your judgment. I can only suggest that in science, as in all else, the first duty of government is to ensure the life, liberty, and property of the people. I personally am not comfortable with government responsible for the pursuit of happiness, so I harken back to John Locke's original words.

Life, liberty, and property translates into research for health, environmental sciences, defense, and seed money for new commercial fields. That is not meant to be an exclusive list. But let us remember that government cannot do for universities or the Pentagon or for American business what they are no longer willing to do for themselves. That, perhaps, was the crux of Britain's later problems.

I do not think that American business suffers yet from the British disease. Rather, I believe that if we make the same decision as the Parliament did in 1849, to encourage and to rely on the dynamism of the private sector, universities and business, that this country need only be excited about the prospects for American science.

Thank you, Mr. Chairman.

[The prepared statement of Dr. McDougall follows:]

Science Policy Task Force Hearings
International Cooperation in Science
June 18, 1985

Dr. Walter A. McDougall
Associate Professor of History
University of California, Berkeley

In 1828, 21 years after Robert Fulton's steamboat plied the Hudson, the British First Lord of the Admiralty reported: "Their Lordships felt it their bounden duty to discourage to the utmost of their ability the use of steam vessels, as they considered that the introduction of steam was calculated to strike a fatal blow at the naval supremacy of the Empire." The same executive blindness afflicted other governments, until a series of French parliamentary commissions first debated appropriations for research and testing for a steam-powered navy. After 1848, when Louis Napoleon came to power, the British Parliament responded with inquiries on the new technology and the French threat, and decided, momentously, to rely on private industry to perform research, since the British private sector was technically superior and more efficient. But the legislators wisely continued some funding for state arsenals to monitor the performance of contracts. When the French approved construction of ironclad steamships in 1857, Great Britain, thanks to her Parliament, responded with vigor and preserved naval leadership.

This anecdote illustrates four points pertinent to the Task Force inquiry. First: even the clear industrial leader cannot ensure its future without foresight and leadership. Second: the bureaucracy cannot always be counted on to provide that leadership. Third: the Parliament was wise to depend on the dynamic private sector that had made Britain the world leader in the first place—while the French government, like the Soviet today, lacked that private dynamism and had to crack the whip itself. And even though France inaugurated the age of ironclads, as the USSR did the Space Age, she was unable to keep up with Britain.

Fourth: all this testifies to the wisdom and boldness of this survey of U.S. science policy. My father is a patent attorney, and I marvel at his combination of legal and technical knowledge. Yet this committee delves into everything from DNA research to high-energy physics to space stations, from the points of view of science, law, and policy. I believe the committee has earned more thanks—and sympathy—from the public than it probably gets. Your agenda notes that changes in science policy usually occur only in times of crisis. I hope you are able to change that tendency, although perhaps it is only in crises that political and public support for extensive change can be marshalled. This is surely the lesson of history.

I deeply appreciate your invitation to share my historical perspective on international cooperation in science. I have little to contribute to specific policy debates, but I shall try to help frame the "big picture."

It is often said that science is by nature an international and cooperative enterprise, and that only suspicious governments prevent it from being so. This is false. Throughout history scientists have often been jealous of their discoveries, resentful of competitors, prudent to serve their royal patrons, or simply patriotic. Whether it be Leonardo da Vinci in the court of the Medicis, English and Germans arguing over whether Newton or Leibniz first discovered the calculus, or Vannevar Bush and Sir Henry Tizard swearing fealty to Roosevelt and Churchill, scientists have usually placed civic duty before devotion to an abstract ethos of universality. If we have an opposite notion today, it is because of the many European scientists who fled Nazism for America and then, after 1945, rebelled against the atomic bomb and promoted open, international management of science. But even these scientists, by and large, left Europe only because they were driven out—and those who were not driven out, like von Braun or Sakharov, served even Hitler and Stalin faithfully for years. Even the Piltdown Man hoax of 1912 was sustained in part by hopes that this resounding discovery might restore the prestige of British science.

To be sure, governments contribute heavily to international competition in science. From the Royal Societies and Academies of the European monarchs to the massive U.S. and Soviet research complexes of today, governments displayed a growing appreciation of the importance of science for miiltary and economic security.

Nevertheless, beginning in the mid-19th century, governments also came to see value in limited international cooperation in science, simply because they saw either common gains to be made or national advantage for themselves. Over the past century, three kinds of international cooperation in science have emerged:

(1) "Housekeeping cooperation" in which governments support joint study or management of activities of an intrinsically global nature, like the 19th century coastal and continental surveys, meteorological or oceanographic services, or the sharing of the electromagnetic spectrum by the I.T.U. Such cooperation is perceived by all parties as necessary, whatever disputes may arise over policy.

(2) "Ground-breaking cooperation" in which governments jointly fund and perform basic research for the discovery of new knowledge, like the International Polar Years of 1882 and 1932, the I.G.Y. of 1957-59, UN studies on drought, erosion, or endangered species, or the many bilateral experiments in space science sponsored by NASA. Such cooperation is perceived as discretionary, but mutually beneficial, whatever reservations may arise over cost.

(3) "Competitive cooperation" in which governments each perceive benefit in collaborative research, but not the same benefit. This is most problematical to policy-makers, for such projects require trade-offs between costs and benefits to oneself and between benefits to oneself and benefits to others. "Big-ticket" items, indeed all sharing or transfer of technology, equipment, capital, ideas, or management skills (such as joint development of a nuclear or laser facility, deep sea laboratory, or space station) fall into this category. Such "competitive cooperation" is perceived both as discretionary and as a possible

"give-away." The pros and cons of such "big-ticket" cooperation are well treated in the O.T.A. studies on "Civilian Space Stations" and "Competition and Cooperation In Civilian Space Activities," for which I was proud to serve as an advisor.

We tend to take for granted the diplomatic, scientific, and fiscal value of cooperation in "Big Science"—President Kennedy said, "Let us do the big things together"—and proponents have touted international cooperation in space, for example, as a cement for alliances or détente, a moral substitute for arms racing, and a force for global integration. Yet such hopes have often proven unrealistic both in domestic and foreign policy. When the Communications Satellite Act of 1962 was debated, Senators protested the giveaway to private industry of technology developed at taxpayer expense. How much more would taxpayers of any country, protest the giveaway of critical technology to a foreign nation? When JFK made that appeal to the Soviets for a joint moon landing, Congress amended the NASA Appropriations Bill in such a way as to prevent it.

Similarly, "Big Ticket" scientific cooperation meets roadblocks in foreign policy. It is justified as a diplomatic means of strengthening the Western alliance and of sharing the heavy financial burden involved in space or nuclear research. But that first justification rests on the assumption that our allies might weaken Western unity if we did not cooperate, implying a policy of spite at best and blackmail at worst, which I consider alarmist. The second justification—sharing of costs—assumes that 5 percent (or so) in cost savings to the U.S. is not outweighed by the 5 percent of contracts lost to American industry, and the 5 percent of "lab time" surrendered to foreign experimenters, and the incalculable price of technology transfer. It is not at all clear that cooperation is politically or financially worth the trouble.

My article on the European space program, which I deposited with the staff, describes the strategies of "competitive cooperation" adopted by France and Europe after the Soviet Sputnik and the vigorous American response. President deGaulle initiated a crash program to break the U.S. monopoly in nuclear, space, and computer technology, and forestall the decline of Europe into a technological backwater. To this end, he restructured the entire French economy, quintupled spending on R&D, and sought cooperation with other European countries and with NASA. But French cooperative programs were themselves shrewdly designed so as to channel foreign funds, ideas, and markets into a technology flow irrigating France's own garden. The French took whatever the U.S. would give them in satellite design, solar cells, telemetry, systems integration, and so forth, thus getting a leg up on their European competitors. They also promoted European development of space boosters and satellites, but always spent many times more on their own national program than on their cooperative efforts. In European agreements the French insisted on clauses allowing them to apply jointly discovered know-how to their national effort, without being enjoined to share nationally derived know-how with the others. What deGaulle intuited—and every French government since has followed his intuition—was that our age of continuous technological revolution would not be an age of global integration, as the Americans liked to believe, nor of the triumph of Communism, as Khrushchev boasted, but rather an age of heightened self-sufficiency and competition, even neo-mercantilism. For deGaulle embraced the capitalist assumption that competition was the engine of progess, but also the communist assumption that competition was the solvent of community. A smaller country like France especially could not afford chaotic competition within, but had to mobilize and unite at home in order to compete with rival states abroad.

In the 1960s, European industry formed an international lobby called EUROSPACE to promote the drive for "state-of-the-art" technology. NASA offered scientific cooperation and perhaps a sub-contracting role to the Europeans, but EUROSPACE made explicit that its goal was not to play little brother to the US: "The target for European industry is clearly to acquire prime contractor status for all space applications systems." Building on what they could derive from cooperation with NASA, assimilate from American literature, or purchase from American firms, the Europeans in turn practiced a kind of "Euro-Gaullism," borne of resentment of U.S. leadership and a desire to play an independent role on the new frontiers of science.

The White House and Congress both endorsed space cooperation as a matter of principle and good will, but U.S. policy in the early Space Age was not naive. NASA's approach could be summed up as "cooperation in science; competition in engineering." In other words, the U.S. would place foreign experiments on U.S. satellites, or even launch foreign satellites, but not transfer technology that could feed into foreign military programs or competitive economic systems. This was prudent, but as others have testified here, science and technology can rarely be neatly separated. Beginning with space science, then moving to applications, the Europeans, Japanese, and Canadians have caught up with the U.S. in one after another targeted field, and now compete for markets with government-subsidized, fixed-price, neo-mercantilist "chartered companies" like ARIANESPACE.

Hence the dilemma faced by the U.S. Let us face the fact: the U.S. has been in relative decline in the world since the late 1940s and again since the mid-1960s. Our situation is not unlike of Britain in the years between 1900 and World War I. For a century Britain had enjoyed naval, financial, and technological leadership. She was the keeper of the balance of power and the leading force in the world for human rights. But the industrial revolution inevitably spread to Europe, North America, Japan, and finally Russia. By 1902, when Britain emerged from the Boer War, a costly guerilla war not unlike Vietnam in its effects, she was still the world leader, but her relative power had shrunk markedly. New industrial, naval, and colonial powers chipped away at British leadership in this market or that region of the globe. German or American technology surpassed the British in some fields, and all the other powers raised protective tariffs, smashing the Free Trade system led by Britain. Like America after Sputnik, Edwardian Britain echoed with cries to get the country moving again: for science and engineering in the schools instead of the Classics, emphasis on foreign languages, merger of British firms to compete with foreign trusts, more aggressive exporting, funding of R&D, and protective tariffs. In the end Britain relied on diplomatic alliances to safeguard her Empire and remained Free Trade until the Great Depression.

Still, Britain declined: the years around 1900 proved to be her climacteric. Is the U.S. today facing its moment of decline? I suspect that this question, perhaps subconsciously, is in our minds as we discuss science policy. But the causes of Britain's decline, hence the lessons to be learned, are not clear. Britain, for instance, did not lack for R&D: it led the world in research until the 1930s, and was still a healthy third in R&D into the 1960s. Nor were British scientists inferior: the trouble was that their inventions were exploited abroad and not by British business. Indeed, Britain helped to create her own competition by exporting capital and technology to industrializing countries like Germany and the U.S. But she cannot be blamed for that: Britain needed the foreign markets, and was contributing to world economic growth. In the same fashion the U.S. helped to create its competition through the Marshall Plan.

In short, counting dollars spent on R&D or patents and Nobel prizes won (in a kind of intellectual Olympic Games) are not useful measures of where one stands. Nor is protectionism a solution to foreign competition. For such a reversal of policy by the leading Free Trade and financial power would not only betray our principles, but reduce the volume of trade for all countries and erode the unity of the West far more than any failure to cooperate in science. This is the lesson of the 1930s. A crack-down on tech transfer through refusal to cooperate and an imposition of secrecy might also be counter-productive. As angry as we are when we read of high tech leaks, sales, and espionage, I don't believe the American people would want a commercial police capable of shutting off such leaks. What is more, secrets are hard to keep even with restrictions (witness the rapid Soviet development of an atomic bomb), and the value of secrets is dubious. (Edward Teller, I believe, has stated that there is no secret worth keeping classified for more than one year.)

Rather than be moved to imitate Soviet-style secrecy or Gaullist-style neo-mercantilism, the U.S. should recognize that its relative decline is inevitable—even a measure of the success of our postwar policies toward Europe and East Asia—and take steps to ensure that we remain leaders only in those fields of science and technology that we deem critical. And even in those fields, the best way to stay ahead in the race is not to hurl obstacles at our rivals, but simply to run faster. And if the Europeans and Japanese are in a position to challenge us, so much the better: we all play our best tennis against a tough opponent.

Having said that, however, we need not approach scientific cooperation with a gratituitous generosity. (This may or may not apply to the Third World—perhaps we can discuss that in the question period). Rather, we should approach "Big Ticket" cooperation with the knowledge that our prospective partners are keenly measuring how such cooperation will help them leverage us in the future, and we, too, ought to demand real concessions for making our facilities available.

As for which fields of science and technology are critical, I understand how difficult it must be to choose. The late Senator Clinton

Anderson, who was agonizing over what to do about space in the wake of Sputnik, wrote this to the President of DuPont:

> "I had a professor in math—calculus I think—who said that I could solve most problems in math if I could state them correctly. If I could state my problem to you, I would probably have it half-solved. My trouble is that I can't.... I went to see LBJ and pointed out that this problem was likely to be tossed into the lap of Congress....I want the military to have every opportunity to push satellites into outer space, but if that is the only thing we do then the Russians, who are very adept at propaganda, will say that the president's program for peaceful uses of space is hypocrisy....Perhaps the conquest of outer space ought to be left to a completely separate civilian agency.... It may be NACA or NSF should take charge. In my bill I assigned it to the AEC.... Now you can see what considerations of this kind do to an individual whose business life has been devoted to running a little insurance company in a small Western city."

Later, however, Anderson told Senators not to despair. His experience on the Joint Atomic Energy Committee had taught him that "committee members cannot compete with scientists on their own ground. So we stay in our field—the objective."

Congressmen are, by definition, more qualified than any expert to weigh the national interest, and I am grateful we have you gentlemen to do it. I can only suggest that in science, as in all else, the first duty of government is to ensure the life and liberty of the people, which translates into research for health, environmental sciences, and defense. I personally do not like the notion of government responsibility for "the pursuit of happiness." As for economic growth the government has evolved a role in planting seed money for new fields, but ultimately it cannot do for business what business is unwilling to do for itself. That, perhaps, was the crux of Britain's later problems. I do not think American business suffers from the British disease. Rather I believe that if we make the same decision as the Parliament in 1849 to encourage but to rely on the dynamism of the private sector, that this country need only be excited about the prospects for American science and technology.

DISCUSSION

Mr. FUQUA. Thank you very much, Dr. McDougall. It was a very interesting historical perspective of where we have come from and possibly need to go.

You mention in the latter part of your discussion about taking steps to ensure that we remain leaders only in those fields of science and technology that we deem critical. Will international cooperation be detrimental or beneficial to achieving those goals?

Dr. McDOUGALL. Well, sir, I expect that it would depend on the field. I know that your task force is not primarily interested in defense fields. That clearly, though, would be one area in which we would have to be very careful about international cooperation.

In civilian fields, I think that international cooperation could certainly play a role in helping us remain a leader.

Mr. FUQUA. We are talking, really, in the basic research area, not in the applied.

Dr. McDOUGALL. Right.

Mr. FUQUA. It could be applied in a lot of different fashions.

Dr. McDOUGALL. I understand. This notion of competitive cooperation, of course, is a two-way street. Countries that perceive themselves as being behind—the Japanese or the Europeans, for instance, in the 1960's and 1970's—could use cooperative programs with the United States to give themselves a running start in trying to catch up with American research in certain fields that they deemed critical to their economic future.

And, of course, we can do the same thing in areas in which other countries have facilities that perhaps we either do not have or do not particularly want to spend the money to build; then we could use international cooperation as a way of keeping us up with them.

Everyone, I think, recognizes that there is a quid pro quo. Scientists wear several hats, as we all do. I like to think of scientists as just regular human beings. They are interested in their own work and their own careers in their own universities.

At Berkeley recently, President Mitterrand visited and signed with the president of the University of California a big plan for exchange programs between French universities, and Berkeley, and the other campuses of University of California. Clearly, one has one's own university situation in mind, and one's own personal career, in addition to one's national standing. Scientists exist in all these worlds simultaneously.

But looking at it from the policy point of view, governments who fund these programs are clearly going to be asking for a quid pro quo for any act of cooperation. What I am merely suggesting is that when we negotiate such agreements for international cooperation in big science, that those of you who are particularly interested in the standing of American science make sure that the effect of a given program on American science and American science vis-à-vis foreign efforts is kept in the forefront of the negotiation, so that we do not, in a sense, bargain away a scientific program in return for a diplomatic gain that the State Department might be pushing for, or that—I am speculating—the position of American science not be bargained away in exchange for a given agency simply wanting to get international cooperation in, in order to improve their budget situation in the Congress. Those would be examples of tradeoffs that we would want to look very carefully at.

Mr. FUQUA. Your historical perspective suggests something about our prospects of controlling the pace of technological change. Could government do that? Can we as policymakers do that? Or should we be involved in that? Or is that a thing that is going to happen on its own in a free society?

Dr. MCDOUGALL. Yes; Mr. Chairman, I understand. I have been called a pessimist by some people. Some people have disagreed with me; others have merely called me a pessimist without necessarily disagreeing with me. But it is my conclusion from looking, particularly, at the 20th century that controlling the pace of change is very difficult for any given country to do, even for the leader.

Since the industrial revolution and the growing interplay between science and technology, and, of course, the growing application of science and technology to military systems, international competition has probably played the greatest role in stimulating, or in setting the pace, as you suggest, of scientific and technological change, so that a given country is not really able to control the pace because, if a given country chooses to slow down, some other country is going to push ahead.

In military systems, this is obvious, but I think it is probably true even in basic science. I think that we would all be nervous if the Soviets, for instance, achieved a clear leadership in one or another area of basic science, even if there were no particular military applications or commercial applications to that scientific field at the moment. The very fact that they were gathering this scientific capital and we were not, I think, would disturb us.

So the fact that there are a number of highly industrialized countries promoting scientific and technological progress means that the only way that one could control the pace of science would be through international agreements somehow to prevent any country from pushing ahead in a new field of research, and I think that would be very, very hard to negotiate and probably even harder to enforce.

Mr. FUQUA. Let me rephrase it just a little bit. Suppose you have something like Sputnik, which this country did react to. That was perceived as a military threat to the United States. That is very clear to understand, that you would respond in fashions of that type, and the United States did respond.

But suppose you are talking about bioengineering or you are talking about fusion energy, the more basic types. How would you respond to that? In other words, if it is not a military threat but maybe it is a technological threat or something that this country feels, for economic reasons—it may lead to military reasons, but it may be economic reasons that we feel that it is in the national interest to move forward so that we do not lose jobs or maybe lose technological advantage that we may have.

Dr. MCDOUGALL. Well, your question is a good one in terms of probing toward a definition of the word "critical," or one could also say——

Mr. FUQUA. Or world leader.

Dr. McDougall. Or leader or national interest, and perhaps putting some flesh on the skeleton of that vocabulary is what your task force inquiry can do for us all.

Yes, an example of that would be, say, the 30–20 gigahertz technology that the Japanese and others have developed.

Now, one thing I want to clarify—my remarks may have given a false impression—first of all, I am not a scientist, so I cannot judge these matters, but it is my impression that the United States is not behind in any strategic, military, or economic technology that I am aware of.

So, in using the British analogy, I don't want to give the impression that I think the United States is falling behind. But in areas like the 30–20 Comsat technology, we are failing to market technologies which we have developed, which other countries have also developed, but they are able to market them, and they have institutional structures for getting the stuff out and competing with us in given markets in ways that we so far have not.

If we do deem a given technology as commercially important, as important for the economic health of this country in the near or median future, then yes, indeed, we have to move ahead, and I think that that would be—see, in putting together my remarks on which fields are critical, I used the gimmick of life, liberty, and property. Originally, of course, property would not have been included in that.

The Government of the United States moved into the field of science very slowly, gradually, over the course of its first 150 or so years. Interestingly enough, I believe the first area, aside from defense, but even then there was not much done in the way of R&D on defense until perhaps the Civil War—the National Academy of Sciences was formed—but particularly World War I, when the NACA was formed—the first area in which the Government got interested in science was in the environmental aspect, wit large; that is to say, not pollution control, to be sure, in the 19th century, but control of rivers, study of the Lewis and Clark expedition, exploration, surveying, building the railroads, doing the various kinds of geological work needed to build the railroads and so forth. That was the first area, and then later on, medicine, life.

Only since World War II—indeed, I think it is safe to say, really, only after Sputnik did the U.S. Government decide that it has an important role to play in property; that is to say, in funding research deemed to have an economic benefit in the future.

Perhaps Comsat technology—well, nuclear technology would come first, and then Comsat technology perhaps was the next large commercial area in which the Federal Government got involved, and that, of course, is why the Comsat Act was so important, because the Government then had to decide what to do with this technology that the taxpayers had paid for. How are we going to market this? How are we going to fold that into our system of free enterprise? And whether the Comsat Act will prove to be a model for future systems like a commercial Landsat system or other things on the horizon that we cannot now see, I don't know. It is something that Congress will have to decide.

But, yes, that is a long way of saying that I would certainly include economic and commercial technologies or basic research pointing toward a commercial goal as being included in the Government's responsibility.

Mr. Fuqua. You mentioned the 25 to 30 GHz, and of course, this committee had funded that for a number of years, and we didn't get much support from the administration, previous administrations, for that, and it was phased down, and we reinitiated that in the last couple of years to resume that because of an economic interest that we felt was vital to the country.

Dr. McDougall. I congratulate the committee on that move. We would all like to see private industry carry the ball in these matters to the greatest degree possible. This administration, I think, wants to do that, and I applaud that decision as well, because as I said in my remarks, the Government ultimately cannot do for other sectors of American society what those sectors are not willing to do for themselves.

This is the burden of my brief allusion to France and the Soviet Union. If government is in the position of having to goad its citizens and its institutions into doing something deemed important for the national interest and continually crack the whip on them, then that country is sick. Now, the implication of that is that a Socialist country is sick from the word "go," and I would agree with that. [Laughter.]

What Government, I think, wants to do in the United States—I think most people in Government would agree—is not to supplant private efforts but to stimulate them and encourage them, and that means helping universities in basic research too expensive for the universities to fund on their own, and provide seed money for corporations to get involved in new technologies which they, by themselves, cannot profitably perform.

But the danger in that—I am not criticizing such activities. I just complimented the committee on supporting the 30–20 business. But the danger of that, of course, is that we create a dependence in private institutions on the Government. They have their own budgets just as the Congress does, and if they can get the Government to pay for something instead of they, themselves, paying for it, that is great from their point of view.

If the Government is going to decide what the next big technology is and let them know and then pay for it, then their own initiative is going to suffer. We can say, "Well, we think this is going to be the next big technology; it might have commercial ramifications, say, material processing in space; but if the Government money is going to go somewhere else, then to heck with it; we will go the way the Government wants us to go rather than pursue this on our own."

How one prevents that kind of behavior—I don't think you can prevent it entirely, but how one can mitigate the consequences of such behavior is, of course, a decision for lawmakers. Certainly, though, we would want to reward somehow universities and corporations that were willing to come up front and invest on their own in new fields.

I believe Grumman, for instance, has been spending a lot of money on their own in the last 10 years investigating ways to build large structures in space. I don't know whether anything is going to come of it. I am not carrying a brief for Grumman. But I remember, at various aerospace exhibits back in the 1970's, being amazed that Grumman was up front on this.

Hughes Aircraft did the same thing in Comsat technology. NASA engaged in joint ventures with a couple of firms, but Hughes went ahead on its own in developing a geosynchronous satellite technology and made a tremendous contribution.

I would hope there would be some mechanism for the Government to encourage such initiative in private institutions, even as it engaged in public spending to stimulate new fields.

Mr. FUQUA. Mr. Reid.

Mr. REID. Thank you, Mr. Chairman.

I would like to compliment you and thank you for having Dr. McDougall. You know, this is the second time that I have had the opportunity to listen where you have brought in a historian to review a particular area of science. You will recall we had the professor from Duke who had a Ph.D. in military history, and it was interesting.

I think that we do not often enough look at what we are doing here from a historical perspective, and I have certainly appreciated your testimony here today. I think it has been excellent.

As I hear a condensation of your testimony, it is to the effect that we need a mix between the private and public sector to develop scientific research. Isn't that right?

Dr. McDOUGALL. Yes, sir.

Mr. REID. And one passing comment—because my beeper went off—I see that for a young man you have written a spate of material, and some of the subjects are extremely interesting to me.

I wonder if you have come across anyone that has written anything looking at the progress of science as developed in the military and science as developed in the private sector, and where the contributions have been made. Has anyone done that?

Dr. McDOUGALL. Not to my knowledge, although I expect there is probably some report sitting in some DOD file somewhere that was funded on the inside, where that may have been done. But I am afraid, off the top of my head, I have to say the answer is "No." And I will tell you that in preparing these remarks, I, myself, went back to the library and tried to find something of that sort and came up empty. Now, that is not to say that there isn't anything.

Mr. REID. Mr. Chairman, I think that would be an interesting thing for us to look into, because I, during the past few years, have developed a real curiosity as to what the contributions on the long term from a scientific standpoint really are, not only in the United States but worldwide. As you know, in the Soviet Union, the best and the brightest and the most money goes into the military, but I wonder what really long-term contributions are made in that society, and in ours, with the military scientific advancements.

Dr. McDOUGALL. Well, sir, I can say a few words about that which I hope are pertinent.

There was tremendous debate in this country—I am poaching here a bit on Dr. Roland's turf—but there was tremendous debate in this country just after World War II about what to do with science. The military effort had been so successful during the war that there was a consensus that the Government continue support for basic research. The question was how to do it.

The great fear at that time was that not only nuclear research but also other areas of basic research would fall into the hands of the military. No one wanted that; in fact, the military did not want that, either. And so these various formulas were kicked around.

Senator Kilgore had a plan for a kind of National Science Foundation which would be politically controlled, a kind of political committee for the planning of the future, which frightened a lot of people, and other plans. Vannevar Bush's plan, of course, was for a civilian-controlled National Science Foundation which would, nevertheless, have liaison to the military so that military work could get done.

These things were kicked back and forth, and the Government found itself in a horrible bind, because if the taxpayers were going to pay for it, then Government, Congress, had to have oversight. But if politicians were going to decide what the research was, then we were going to have a kind of Soviet system.

In fact, when the AEC was first debated in Congress, Representative Claire Booth Luce and some others decried this as a commissariat. One scientist said that you can call this a Nazi bill or a Communist bill, whichever you think is worse. [Laughter.]

The idea of Government control of the creation of new knowledge was very frightening to many people. And if you take it to its extreme, of course, it is. This is obviously what this committee wants to prevent, and the chairman has spoken eloquently on that already.

Then there was the question of the military versus civilian. Well, the Budget Bureau got into this, too, by the way, and managed to mess up Congress' plans on more than one occasion, which I guess it does with regularity.

What finally happened, as you know, is that the vast majority of basic scientific research in the United States that was funded by Government did end up being funded by the Department of Defense by accident, because at least the Department of Defense was an existing institution, and there were congressional committees to oversee its activities, and the military made direct contracts with universities to fund their research, and so the DOD ended up having this responsibility even though it had never sought it.

The National Science Foundation that did come into existence was at first a very small, and weak, and underfunded organization.

Well, in the 1950's, during the Eisenhower years, as we know, concern grew that we weren't doing enough in basic sciences and that the Soviets were catching up to us in a number of critical fields, in nuclear research and in rocketry in particular.

By 1955, I discovered in my research that you had scientists, committees of scientists, some of whom were the same ones who, in 1946, had protested the military's involvement in science, now demanding in the White House that the DOD take a more active role in promoting basic research, because the DOD, needless to say, did most of its work in applied research. They wanted to develop weapons systems, and since they had the big bucks, the scientists were now saying: "Well, the DOD has to get more and more into basic research, not only because they have the money but also because the military competition is moving ahead so quickly that the DOD cannot wait for new science to be created and then try to apply it to the military; rather, they have to engage in basic science itself."

So you had a striking turnaround in the space of 10 years from everyone being afraid of military control of basic science to scientists actually advocating military funding of basic science.

But the dilemma has always been one of Government supporting scientific research with somehow not controlling the activities of the scientists. We have to leave them free to do their own thing; they are the best judges of what to do, and so forth. And, of course, that is a dilemma we have never solved.

Now we find the same phenomenon occurring, of course, in the labs that the University of California manages, Los Alamos, and Livermore, and also in the JPL, which is run by NASA, a controversy over the mix of how much of the research done there is civilian, how much of it is military, and is it healthy to have too much military, and so forth and so on. I don't think we are ever going to get away from that problem as long as we in the United States maintain a separation of the civilian and the military.

Some people would say that is really a sentimental hypocrisy, that there really isn't any separation any more between the civilian and the military areas; we have a war economy or a military industrial complex or whatever.

Well, it is true, certainly, that we have many links between universities and the Defense Department, corporations and the Defense Department, and so forth and so on. That is all true. That is inevitable and necessary in an age of continuous technological revolution.

However much we may muddy the waters, I do not think we should give up that distinction we have between the civilian and the military in American society. It is what sets us apart from the Soviet Union and, to a lesser degree, from countries like France, where they have a space program. They have one space program. It is run at the top level in part by military men. Everything they do, they think in terms not only of basic research and applied science for civilian goals but also for their military goals.

And so you have, ultimately, in the case of the Soviet Union, a totalitarian system, and we don't believe in that, and so, even though we introduce inefficiencies into our system and muddy the waters, nevertheless, if we do away with or if we try to streamline the operation, say, of the space program by combining military and civilian space activities, we are sacrificing the values that this country stands for.

So, as awkward as it is to have two space programs, I am in favor of preserving that. Just one example. The Soviet Union simply lies about what it does and gets away with it. They say, "Oh, our space program is civilian. We are interested in the peaceful conquest of the cosmos." Well, who knows how much of it is military? Fifty, sixty, ninety percent? And they simply lie about that and say their program is all civilian.

We admit the fact that we have a military space program, separate it off from our civilian program, and get all kinds of propaganda and flak thrown at us from not only the East bloc but also the Third World countries, because we are honest about what we do and the Soviets lie.

Well, I don't know about you gentlemen, but that angers me. But I would rather be honest and take the heat than sacrifice the values of the country.

I think I wandered a little bit afield.

Mr. REID. If you in fact do, professor, come across some work that has been done on that subject, or you decide to get interested in it, I would appreciate hearing from you about that.

Dr. McDOUGALL. Thank you for bringing me back to your question.

The answer to your question is—I expect you already know the answer—that basic research in the military has been extraordinarily important in every country, including our own. It is my understanding that computer technology came out of the Department of the Army during World War II. Obviously, space technology came out of the military departments. Nuclear technology came out of the Department of the Army, and the list could go on and on.

Mr. REID. Anyway, I think you have made the point, and I appreciate it very much. Your testimony has been very enlightening.

Thank you, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Reid.

I might point out that we have commissioned the Congressional Research Service to do a study for us in conjunction with our task force work on Defense Department-supported basic research and the impact of the Mansfield amendment during the time of its existence.

Mr. Lewis.

Mr. LEWIS. No questions.

Mr. FUQUA. Thank you very much, Dr. McDougall, for being here this morning. It has been very interesting and enlightening, and I think you have given us a very good historical perspective.

Dr. McDOUGALL. Thank you, Mr. Chairman.

[Answers to questions asked of Dr. McDougall follow:]

SCIENCE POLICY TASK FORCE—QUESTIONS FOR THE RECORD

Walter A. McDougall

1. Do you agree with the Science Policy Task Force Agenda when it claims that changes in science policy usually occur only in times of crisis? What are the major exceptions to this assertion?

I agree that major changes in science policy occur usually in times of crisis. Of course, this statement is open to disputation about what constitutes a "major" change or a "crisis". But the historical evolution of U.S. science policy is certainly bound up with war. The National Academy and Morrill Act date from the Civil War, the National Advisory Committee for Aeronautics from World War I, the Office of Scientific Research and Development and the Manhattan Project from World War II, and the National Science Foundation from the Cold War. Sharp increases in funding of R&D occurred during the Korean War and again after Sputnik, when NASA and the current structure for defense-related R&D also emerged. The two most fundamental changes in the scientific posture of the federal government were when applied science for military purposes came to be viewed as vital to national defense, and then during the 1950s when basic and civilian science came also to be viewed as vital to national defense, both because of the accelerating pace of scientific advance, and because of the overall competition with the U.S.S.R. for prestige (especially in the Third World) in which science, racial harmony, national health and welfare were as much tools of foreign policy as missiles or spies.

Of course, it could be said that sharp changes in any arena of public policy tend to occur during perceived crises, be it anti-trust laws during the "robber baron" era, social security during the Depression, the CIA and military unification during the Cold War, or farm policy today. In a pluralistic democracy it is difficult to mobilize support for a new governmental posture in normal times. This is a useful check against the over-zealous, especially in the executive branch: "if it ain't broke, don't fix it." But it can also tempt factions anxious for change into provoking a crisis mentality where none need exist. The ups and downs of the space program are an obvious example: when there is no perceived threat from the Soviet Union, space budgets dwindle, no matter how important continued progress may be in the long run.

When policy changes are perceived as necessary in the absence of a crisis, consummate political skill is called for. Change in organization and procedure is more easily done than change involving significant new public expense, and such "non-crisis" change is more easily led by the White House than from below.

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2. What have been the historical barriers to international cooperation in science? Can you discern a current trend?

The very realization of the importance of science to national economic and military security, which got governments into supporting science in a big way, also militated against international cooperation. If scientific research were deemed innocuous and discretionary, cooperation would be easy, but at the same time governments would have little incentive to spend large sums on it at all. Given the role played by modern warfare in the growth of state-sponsored science, this conundrum is quite understandable. Ever since the first flush of detente, we have been looking for ways to cooperate with the Soviets which do not involve important "give-aways." It cannot be done. If it's important, it involves potential "give-aways"; if it's not important, why do it? In the last ten years the problem of gratuitous transfer of science and technology unfortunately applies also to U.S. relations with its allies. The French, Japanese, and others view international cooperation quite self-consciously as a path toward eventual competiveness. Joint European space and atomic programs have been plagued from the start by such a double agenda, with each nation seeking advantage vis-a-vis its partners, even as Europe as a whole seeks to become competitive with the U.S. No responsible government would act differently.

If the competitive imperative were the only one, however, we would not expect to see any scientific cooperation at all. Countervailing trends also exist, derived from the immense cost of such scientific tools as particle accelerators and space stations. As a result, institutionalized cooperation has been expanding in the last two decades, at least among the non-communist industrialized nations.

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3. Based on the historical record, how has the United States benefitted politically, financially, militarily, and scientifically, from international cooperation in science? What types of cooperation produced the best results?

Following on the previous answer, cooperation has been expanding in recent decades for financial and diplomatic considerations. But given the competitive impulse for each government, every incidence involves arduous negotiations to balance national costs and benefits, with great potential for ill will and misunderstanding. "Cooperation" per se, therefore, is not even an automatic diplomatic plus, whatever effect it has on national standing in science. We should not shy away from cooperation, but neither should we expect too much from it. At present the U.S. is the only free world country capable of engaging in "big science" by itself. For us, cooperation is a luxury. And yet as leader of the free world and leading advocate for free enterprise and open societies, the U.S. has chosen not to use our advantage in scale against other countries, and has even helped them to become competitive in certain fields of commercial importance. This is the glory and the tragedy of the American position.

I am not able to evaluate the scientific benefits of cooperation, but I am somewhat skeptical concerning non-scientific benefits. The U.S. has always tended to aim its sights too high. The Atoms for Peace program promised a global developmental boom based on cheap energy. Instead, it only revealed the barriers and drawbacks to transferring high technology to backward nations, as well as increasing potential for nuclear weapons proliferation. In the 1960s Kennedy promised world understanding and integration through a global Comsat system. Instead, we learned that governments in other developed nations resent our leadership, while those in under-developed ones are more interested in dictatorial control of information than in free and open communication. In short, the U.S. has meant well, but has tended to take for granted that other governments share our liberal goals, or that liberal governments will follow from the spread of our technology.

In sum, our cooperative efforts have failed to "buy" the friendship of any nation* (the U.S.S.R. has also failed: we feared that Third World countries would be attracted to Communism because of Soviet space triumphs after Sputnik—none were except those who were inclined toward Communism anyway). To be sure, certain forms of cooperation are in everyone's interest or are simply necessary, whether we (or others) like it or not. I discussed such "housekeeping" cooperation in my prepared remarks. These types of cooperation produce the best results. In strategic arenas of science, we have had some successes, but only in the realm of negative, prohibitive cooperation: e.g., the Antarctic treaty and Non-Proliferation Treaty, in which the U.S., the Soviets, and others combine to prevent the spread of national claims or expertise that could prove dangerous.

*A footnote: The Space Treaty, for instance, was an offspring of two abiding American mentalities. The first might be termed the Wilsonian, stressing liberalism and the rule of law. Moral metaphors dominated the Wilsonian vision. The international order was a post-lapsarian jungle teeming with suspicion and fear, which in turn bred militarism, imperialism, and tyranny. The United States should promote the rule of law, whereupon cooperation, trust, and disarmament might remind man of the harmonious aspirations for which he was made. In such a world science and material progress would abound. The second strain might be termed the Hooverian, stressing engineering and material prosperity. Here managerial and medical metaphors dominated. Poverty and ignorance weakened bodies politic and made them susceptible to tyranny, communism, and war. Unbridled growth, fashioned by financial and technical engineers through trade, investment, and technology, could eliminate the conditions that bred political disease. In the first vision, law and democracy fosters science and development; in the second, science and development fosters law and democracy. American leaders since Roosevelt, and especially since Kennedy, have embodied both strains—after all, at least they promise that there is something we can DO about global problems. But they contradict each other to a degree, and in any case have shown meagre results at tremendous cost (consider Third World debt).

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4. Can you draw any conclusions from the historical record regarding the relationship between government funding of science and a nation's economic and military strength? What effect, if any, has international cooperation had on this relationship?

Economists have been trying for decades to produce a model that quantifies the relationship between R&D spending and growth. To my knowledge, they have succeeded only in discovering the myriad influences and conditions other than R&D that influence the productivity of an economy, which is to say, the productivity of people. There is an intuitive link between R&D and growth which none would deny, but R&D spending is only a necessary, not a sufficient condition. Consider the Soviet Union, which spends upward of 4 percent of its GNP on R&D, yet cannot disseminate the most ordinary new technology through its civilian sectors. A free economy and political stability seem to be the greatest prerequisites for growth. In this regard, we must be careful that governmental efforts to stimulate growth do not weaken entrepreneurial behavior! That would be the most perverse of results. But as we know, whenever government starts giving away millions or billions of dollars, individuals and firms and universities will adjust their behavior in order to cash in, and soon become wards of the state, doing only what is necessary to receive grants and subsidies, and avoiding the risks of innovative undertakings. The defense and electronics industries are obvious examples, but the "knowledge" and "welfare" industries may be just as afflicted. Government funding of "big science" is mandatory in the present age, and has obvious short-run or middle-run advantages in stimulating technological progress relevant to items on the political agenda, but if increasing bureaucratic funding (hence direction and regulation) of industrial R&D saps the creativity of the private sector, the long-run effect would be to kill the golden goose. This was the real thrust of Eisenhower's farewell address: it was not just a smear of the defense industry.

The effect of international cooperation on the government-science relationship is even more difficult to weigh. A smaller country like France has clearly acquired state-of-the-art technology more quickly than she would otherwise because of cooperative science in space, nuclear power, and electronics. But the neo-mercantilist policies of such a country do not ensure that the expense was "worth it." Even if Ariane does capture a large chunk of the launch-vehicle market, was it a worthwhile investment? By free market standards, probably not. The best way to ensure that cooperation does not violate basic economic principles is probably to encourage joint ventures by private firms, but even there U.S. firms may choose to throw in their lot with foreign systems, to the detriment of U.S. government or ivate enterprise.

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5. What has been the relationship between development (especially during the 20th century with regard to Third World countries) and R&D? What do you see as the policy implications of this for the United States?

This question tempts an historian to recount the whole debate over the origins of the Industrial Revolution in England and its spread around the world. One of the crucial issues is the role of government: did England industrialize first because her liberal government got out of the way of private entrepreneurs, or was the British government a vital support for the spread of the factory system and new technology? Conservatives stress individual creativity and capital formation, a supply-side argument; Marxists stress the role of the state in conquering world markets, and of West Indian slavery in producing vast profits that financed industrialization, a demand-side argument; while modernizationists like Walt Rostow stressed the role of political infrastructure—a unified home market freed from mercantilist constraints, a free market in land and labor, triumph of middle class values, contract law, etc.—and then a rising rate of national investment. Historians of technology include individual craftsmanship and raw materials, while diplomatic historians point to the impetus given Britain by the contract system of military procurement during the Napoleonic Wars, as opposed to the French arsenal or tribute system of war finance.

However, British industrialization is not a model for other nations for the very reason that it was first. More useful analogies are drawn from the later industrialization of other countries playing "catch-up". And what we find is that Germans, Americans, Japanese, and others benefitted from Britain's free trade policy and from large influxes of British capital. As economic historian Alexander Gershenkron theorized, the more backward a country, the more the state played a role in forcing industrialization. Tsarist and Communist Russia are the best examples. But industrialization proceeded quickly, and at the lowest cost in human misery, in liberal and relatively free market societies like the United States. These were the very nations in which government investment in R&D and plant were lowest! The same is certainly true for Asian countries since World War II. Free enterprise and receptivity to private foreign capital have prospered Taiwan, South Korea, Singapore, etc., while planned economies such as China and India have lurched back and forth, at great human cost, despite large government R&D efforts. Of course, in those countries much R&D spending has gone for the military. The desire to play Great Power politics seems to be the greatest barrier to the wise use of R&D funds, but that desire also seems to be an inevitable by-product of post-colonial self-assertion.

American policies to replicate our own development by transferring capital and technology to the Third World have largely failed. This has been due in part to perverse policies, waste, and corruption in the target countries, in part to tragic fluctuations in commodity prices, especially oil, and in part to the misapplied generosity of the U.S. itself. Government-to-government loans were not the model for our own industrialization (although they were in the Tsarist Russian case), and they have not worked in the Third World. Similiarly, transfer of high technology in hopes of helping Third World countries "leapfrog" the early stages of industrialization is inappropriate in most cases, socially destabilizing, and politically counter-productive (if the locals grow bitter at what they perceive as "unfulfilled American promises." Pron准onents of LANDSAT (a winderful tool), for instance, promised tremendous benefits in such areas as malaria control, fishing, erosion control, or scientific agriculture. But in many countries the entire social structure and cultural patterns would have to be uprooted in order to implement reforms based on LANDSAT-derived data. The very technology that helps us to "view" the earth without national boundaries also blinds us to stubborn local conditions. We are reaping a bitter fruit of Third World acrimony in such forums as UNISPACE in part because of our over-promising in the 1960s.

Past disappointments should not prevent us from doing what we can to meet local needs with R&D and tech transfer, but once again we should not expect too much from such cooperation. Making private international loans and encouraging free enterprise is the best approach, but political conditions often make that impossible. In sum, we cannot do for others what they will not or cannot do for themselves. We are not THAT powerful—and Third World peoples would resent us even more if we were.

6. Based on your extensive research of the United States and international space programs, what conclusion do you draw about the effect of international cooperation in the area of space programs and space science? What changes in our current space policy, if any, would you recommend?

Now that most developed countries have assimilated the basics of launch and satellite technology, we have little to lose commercially from cooperating widely in space science. The wonderful thing about a space telescope, a reconnaissance of Mars, or a mission to Halley's Comet, is that they are relatively free of commercial applications. Robotics and software, e.g., pose certain problems, but can be isolated up to a point. Joint endeavors in space science, therefore, are an exciting, high-profile opportunity for cooperation. Their political effect, however, should not be overestimated. Good-will missions such as the Apollo-Soyuz Test Project are the result, not the cause, of detente. Furthermore, sharing of infrastructure, such as the space station, raises far thornier problems due to the potential for military and commercial applications. We should not let ourselves be talked into sharing the station on the premise that it would prevent the Europeans from building their own station or from going over to cooperate with the Soviets. The Europeans will be participating in our station in large part IN ORDER TO prepare themselves for their own station and shuttle system. They will make their own policy according to their own lights; we cannot make their policy for them.

As for our own space policy, it appears that the Congress will soon have to update existing arrangements on the division between military vs. civilian spaceflight, on military service rivalry in space, and on public vs. private enterprise in space. The National Commission on Space will be a useful planning and study tool, as is the Office of Technology Assessment. But there seems to be a growing consensus that a revision of the 1958 structure is now needed. It seems to me, however, that a first step might be precisely to RESTORE the structure originally provided for in 1958: a National Aeronautics and Space Council to coordinate departments and advise the President, and standing Space Committees in Congress to oversee the expanding role of spaceflight in coming decades. Such a structure might suffice to force the release of technology with commercial applications from the Department of Defense, coordinate policies among NASA, Commerce, and NOAA on applications satellites and commercialization of launch vehicles, and divide responsibilities for R&D and operation. If Star Wars should ever reach the deployment stage (and/or long-range bombers be phased out), a major reform of the Pentagon will also appear necessary.

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7. What does "world leadership" mean in a field of science mean? What particular benefits accrue to the "world leader" versus "number two"? Why should national policy makers care whether or not the nation is first, second, or third in a given area of science?

"World leadership" in science is a state of mind based loosely on quantifiable measurements of achievement, Nobel prizes, and budgets, and on expectation of future progress. In short, it's an ego-trip at best and a trap at worst. When we let the half-informed impressions of others (Third World elites, e.g.) define our own mood and policy, we have fallen into a trap. Librarian of Congress Daniel Boorstin wrote that when the gods wish to punish us, they make us believe our own advertising. "We suffer abroad," he wrote, "simply because people know America through images, while our enemies profit from the fact that they are known only, or primarily, through their ideals." The real strength of America is its liberty. If we believe that progress in science and technology stems from liberty, then we, too, should be content with our ideals and confident that others will adopt them. But trying to "prove" that our system is better through scientific and technical exhibitionism only invites doubt and contempt (if they're trying so hard to prove they're better, maybe they in fact are not!). In some fields, we may need to ensure that we remain the leader, as in fields of science critical for defense. In other important fields—environmental and medical welfare, e.g.—we shall want to push ahead, but would be delighted if another nation made breakthroughs before us (who cares where a cure for cancer comes from?). In lower-priority fields we can only be pleased that another country is taking the lead (and spending the money), especially since it may contribute to their national pride in a harmless way. To insist on leading everywhere would be to spite our friends. In sum, we should not worry overmuch if some other nation "beats us" to something. Let us allocate our budget according to our own criteria, and not in hopes of manipulating the sensibilities of foreigners.

Mr. **Fuqua**. Our fourth and final witness is Dr. Harold Jaffe, the Acting Director of the Department of Energy's Office of International Research and Development Policy. He will provide an overview of the international cooperation activities of the Department of Energy.

Dr. Jaffe, we are very glad to have you with us today.

[A biographical sketch of Dr. Jaffe follows:]

Dr. Harold Jaffee

Harold Jaffe is responsible for developing, coordinating and monitoring all DOE bilateral and multilateral R&D agreements, coordinating DOE's activities in the R&D program of the International Energy Agency and all U.S. Government activities in the Nuclear Energy Agency, and developing and coordinating associated Departmental policies. Dr. Jaffe joined the Atomic Energy Commission in 1970 and served in a number of technical management positions until 1976 when he joined the International Affairs organization. Prior to his current assignment, Dr. Jaffe served as the Deputy Office Director of the Office of Technical Programs under the International Affairs Office of the Energy Research and Development Administration [ERDA] and the Department of Energy.

Immediately prior to his Government service, Dr. Jaffe was the General Manager of the Aerojet General Corp. plant at San Ramon, CA, and a member of the board of directors of the Idaho Nuclear Corp. His primary responsibility was in research and development. He also worked in petroleum research for the Union Oil Co. of California. He has had 16 years of industrial experience.

Dr. Jaffe received his B.S. in chemistry from the University of Illinois and his Ph.D. in Nuclear Chemistry from the University of California, Berkeley. He is the recipient of the NASA Exceptional Service Medal, and various group achievement awards.

STATEMENT OF DR. HAROLD JAFFE, ACTING DIRECTOR, OFFICE OF INTERNATIONAL RESEARCH AND DEVELOPMENT POLICY, OFFICE OF INTERNATIONAL AFFAIRS AND ENERGY EMERGENCIES, U.S. DEPARTMENT OF ENERGY, WASHINGTON, DC

Dr. **Jaffe**. Thank you, Mr. Chairman. It is a pleasure to be here today.

I would like to present an abbreviated statement this morning because of the time.

Mr. **Fuqua**. Yes. We will make your prepared statement in its entirety part of the record.

Dr. **Jaffe**. Thank you very much.

For those that try to follow me, I will be walking through the statement, so it will be difficult to follow.

Currently, the DOE participates in over 140 bilateral and multilateral agreements and annexes concerned with energy research and development, and they involve about 25 countries. These activities span the basic sciences such as high energy physics that we heard about this morning and fusion, to the more applied technologies such as enhanced oil recovery and end-use conservation technology.

Of this number of over 140 bilaterals, approximately 30 are of an umbrella type which cover cooperation in a particular broad area or programmatic area, and it defines general terms and conditions for activities in such a broad area. We have such agreements in the broad area of fusion, and then under these umbrella agreements, we have subagreements that deal with specific topics.

We are also involved in about four dozen bilateral project agreements which deal with specific topical areas such as, again in the area of environment-related activities, programs in CO_2 and climate research; in fusion, a Doublet-III project; and I can also give examples of other areas.

With my statement, I have appended a table that summarizes these bilateral agreements by country and by topical area.

The Department also participates in approximately 28 multilateral research and development agreements, primarily under the International Energy Agency based in Paris. We also have agreements with the Nuclear Energy Agency based in Paris. Both of these organizations are part of the Organization for Economic Cooperation and Development, the OECD.

With the growth in international cooperative activities and their positive record of achievement within the Department of Energy, at least in our perspective, the DOE R&D programs are presently adjusting their plans to take advantage of increased opportunities for mutually beneficial international joint activities. You have heard a little of that this morning in connection with Professor Weisskopf's discussions.

There are several reasons that are driving the Department and the Government, as well as Western Europe and Japan, to closer cooperation:

First, the countries of Western Europe and Japan, like ourselves, all face significant budget constraints. They all recognize that energy security still remains a problem in the longer term, in spite of what is happening in the energy markets today, and that ways must be found by the scientific and technological communities to further stretch the limited financial resources and apply them to the most appropriate activities. First, then, is money.

Second, progress in some areas of energy science demands large facilities and program continuity. It is becoming increasingly difficult for any one country to build and operate major facilities needed for progress, for example, in magnetic fusion or high energy physics, nuclear physics, even in facilities related to the phenomena of combustion, which is so basic in our energy field.

By pooling resources and talent—and here let me emphasize talent, because we don't have the world market cornered on scientific talent—by pooling both financial resources and talent more effectively, we are in a better position to maintain scientific momentum, both we and our friends.

Third, the time is right now for closer working relationships with other countries in the energy fields. Our economies have become increasingly interconnected and interdependent over the past 10 to 15 years. The level of scientific and technical activities in Western Europe and Japan has come closer to ours; in other words, there is more opportunity for getting real quid pro quo.

Program directions complement ours, and technological interchange has become commonplace and really, truly, much more mutually beneficial. Also, international cooperation is considerably easier to conduct these days because of rapid advances in telecommunications and satellite data links.

An international political consensus seems to be emerging, supporting greater international cooperation in energy science. The

Department's most recent energy policy plan, the National Energy Policy Plan, points out that it is incumbent upon the United States as the world's largest producer and consumer of energy resources to play a leading role in promoting cooperative approaches in mutual energy concerns of the free world.

At the initiative of the Department of Energy, it is expected that Secretary Herrington, along with other energy ministers of the International Energy Agency member countries, will endorse the concept of increased international collaboration at an IEA ministerial meeting next month, in the month of July. We anticipate that this will facilitate further efforts to increase international collaboration, including sharing of program plans with other countries, coordinating where possible, jointly designing our programs to take greater advantage of the ongoing and planned work in various participating countries.

We are putting a particular emphasis on coordinating plans. It has been our experience that where we have had the opportunity to get together at an early stage in the development of a program, there is much greater potential for real cooperation. Where we have a project in mind, have designed it, and then are ready to go out to ask people to help us build it, we have run into much more static. So our approach now is to try to bring the potential cooperative partners together at an early stage in the planning of major activities.

Significant obstacles still exist which must be overcome. I would like to mention a few. We do have, and we have felt them in the Department, a problem in connection with long-term commitments. This contrasts somewhat with some of the testimony you heard earlier.

As a result of some major past programmatic exchanges in areas involving international cooperation that DOE was involved in, we have become, indeed, perceived among some of our international friends as an unpredictable and unreliable partner. There are a few very notable examples of this, and they came about as a result of major budget perturbations in the past.

Unlike many other countries, we do operate on an annual budget cycle which can, on occasion, result in unexpected and sudden changes. Some of our partners tend to feel a much stronger commitment to international activities and hence a commitment to proceed even though there are some internal changes.

Next we must recognize, and hopefully adjust, some of our policies and procedures regarding international R&D cooperation to minimize administrative impediments, and there are a number of real ones. National laws, regulations, and policies were not made with extensive international collaboration in mind.

For example, cross participation in projects through the provision of scientific equipment and components for major facilities is in some cases hampered by tariffs and taxes. Exchange of scientific staffs for periods of several years would be facilitated by changes in the visa and work permit regulations, by issues such as insurance and other items of that type. We are trying to examine these sorts of administrative issues and address them in a number of international bodies.

Finally—and this is one of my personal concerns—although English is the international language of science, the necessity for foreign language skills is increasing. As many of you may know, in recent years there has been sort of a downplay of this on the university level.

Foreign language skills are important, particularly if we are to make optimum use of U.S. scientists assigned overseas. There are nuances in the language that we miss, and there is an awful lot of information that we miss because we tend to lack the breadth of language skill that so many of our allies abroad have.

I would now like to briefly discuss the coordination and management of international cooperative research as far as the Department of Energy is concerned.

Coordination, of course, is handled both unofficially, informally, as well as on a government-to-government level. The unofficial type of coordination goes on through meetings, the conferences that were alluded to earlier, workshops, scientist-to-scientist interaction, which are vital to the progress of science.

From the more formal standpoint, within the Department of Energy, the management of activities in scientific areas resides with the technical program areas in which the scientific activity is housed.

Beyond just the Department's standpoint, from an international standpoint, there have been a number of efforts to try to coordinate international scientific activities. I guess one of the most significant recent ones is exemplified by the Working Group on Technology, Growth, and Employment established following the 1982 Versailles Economic Summit. This is a process that was put into being in 1982 and has continued now with a report going to each of the annual Summit meetings.

Within the energy framework, there are four topics that are dealt with in the Summit context. There is a High Energy Physics Summit Working Group which is discussing long-term plans of the Summit countries in the field of high energy physics and is attempting to promote greater cooperation in the technology necessary to conduct high energy physics research. Dr. Trivelpiece, the Director of the Department of Energy's Office of Energy Research, has been our representative in that organization.

There is also a Summit Working Group on Magnetic Fusion which similarly is investigating the needs for future large facilities, and there are Summit Working Groups in two other energy technologies: breeder technology and photovoltaics, solar.

For multilateral scientific and technological activities, DOE works through the International Energy Agency, as I mentioned, and the Nuclear Energy Agency. The International Energy Agency has a Committee on Research and Development which is really the organizing group for this large number of multilateral activities that we have under that organization.

They serve to pull together projects; they don't run projects. The countries that participate in projects are the management structure. The international body, the International Energy Agency, serves as a facilitator in pulling together international cooperative activities.

Within the Department, as I mentioned, the program office has the budget authority and the responsibility for implementing the international research and development activities. These cooperative projects must compete with purely domestic activities for support and must be justified on the basis of their contribution to domestic program objectives.

The Office I represent serves as the central coordinating point for the Department in its international activities to ensure that all of DOE's concerns, as well as foreign policy considerations, are incorporated in the early stages of formulating an international activity.

Our Office is responsible for the policy guidance and the preparation and conclusion of agreements, and of course, we work very closely with the Department of State and the foreign policy community, as well as with the Department's senior policy and program management.

I would like to close by observing that Secretary Herrington, in his recent speeches, has indicated that DOE has been able to forge a strong partnership with the research community in the field of energy science and technology, a partnership that is complementing the private initiatives rather than competing with them. The Department is now actively beginning to move that partnership beyond the U.S. border to establish international collaboration for energy research and development projects.

I think with that, Mr. Chairman, I would be happy to take any questions. Thank you.

[The prepared statement of Dr. Jaffe follows:]

TESTIMONY OF

HAROLD JAFFE

ACTING DIRECTOR

OFFICE OF INTERNATIONAL RESEARCH AND DEVELOPMENT POLICY

OFFICE OF INTERNATIONAL AFFAIRS AND ENERGY EMERGENCIES

BEFORE THE

HOUSE SCIENCE & TECHNOLOGY TASK FORCE

ON SCIENCE POLICY

JUNE 18, 1985

ON

INTERNATIONAL COOPERATION IN SCIENCE

Thank you for the opportunity to contribute to the important work of the Task Force on Science Policy. It is indeed a pleasure and honor to be here. I hope that my presentation will give an overview of the international cooperative activities of the Department of Energy that will be useful in your deliberations on the direction of U.S. science policy in the years to come. My statement is divided into two parts: the first, on International Cooperation in Energy Science; and the second, on Coordination and Management of International Cooperative Research within the Department of Energy.

International Cooperation in Energy Science

Currently, the Department participates in over 140 bilateral and multilateral agreements concerned with energy research and development involving more than 25 countries. The most active cooperative programs are in the areas that are most concerned with scientific pursuits rather than the development of technology. Of this number, close to 30 are umbrella-type bilateral government-to-government agreements. These umbrella agreements lay out broad directions and the general terms and conditions under which cooperative activities may be undertaken, either in a generic program area, such as energy R&D or science and technology, or in specific programmatic areas, such as fast breeder reactors or nuclear waste management. DOE is involved in approximately four dozen bilateral project agreements which commit the Department to a specific activity or program of activities. For example, Japan is participating in, and learning from, the DOE R&D activities being conducted at Three Mile Island. Incidentally, Japan is one of DOE's most active and important energy R&D partners, and contributes around $25 million per year to conduct joint experiments using unique DOE experimental facilities. A table is appended summarizing the bilateral agreements by country and topic.

DOE also participates in 28 multilateral research and development agreements under the auspices of the International Energy Agency; each of these agreements has specific project annexes with a range of activities from exchanging information to the testing of large, expensive equipment in multi-million dollar test facilities. DOE supports three project agreements under the auspices of the Nuclear Energy Agency and works with the International Atomic Energy Agency by contributing to its technical assistance activities, its non-proliferation programs, and its international technical and scientific conferences and symposia.

With the growth in international cooperative activities and their positive record of achievement, the DOE R&D programs are adjusting their plans to take advantage of increased opportunities for mutually beneficial joint activities. While the magnetic fusion program has benefited from more than 25 years of international cooperation, the strategic Magnetic Fusion Program Plan of February 1985 now emphasizes international involvement at an early stage of planning for major new activities to minimize unnecessary duplication and accelerate achievement of common goals.

There are several reasons driving the United States as well as Western Europe and Japan to closer cooperation in energy R&D activities.

-- The countries of Western Europe and Japan, like the United States, all have budget constraints. In addition, the governments increasingly recognize the importance of an appropriate division of labor between the private and the public sector. The private sector is better equipped to pursue commercial and nearer-term opportunities. The government can contribute by undertaking longer-term basic research. Western Europe, Japan and the United States all recognize that energy security still remains a problem in the longer term, and that energy technology can make an important contribution in achieving diversity and security of energy supplies and usage. Ways must be found by the scientific community to further stretch limited resources and apply them in appropriate activities.

-- Progress in some areas of energy science demands large facilities and program continuity. Today, large teams of scientists with highly specialized skills design, construct and operate large, expensive experimental facilities. Years are required to exploit the investment in human and technical resources. It is becoming increasingly difficult for any one country to build and operate major facilities needed for progress in magnetic fusion, high energy physics, nuclear physics, the research necessary to understand the phenomena of combustion, development of new materials, etc. By pooling resources and talent more effectively, scientific momentum may be maintained in the face of static or declining R&D budgets.

-- The time may be right for closer working relations with other countries. Western Europe and Japan share the same energy objectives as we do. Our economies have become increasingly interconnected and interdependent over the past ten to fifteen years. As the level of scientific and technical activities of Western Europe and Japan have become closer to ours, and program directions complement ours, technological interchange has become more commonplace and mutually beneficial. We have become accustomed to working with each other on a daily basis, and we are gradually developing the mutual understanding and trust that are indispensable to even greater collaboration and scientific interdependence. International cooperation is being made considerably easier to conduct by the rapid advances in telecommunications and satellite data links.

An international political consensus seems to be emerging supporting greater international cooperation in energy science. The Department's most recent National Energy Policy Plan points out that it is incumbent upon the United States, as the world's largest producer and consumer of energy resources, to play a leading role in promoting cooperative approaches to the mutual energy concerns of the free world.

The International Energy Agency (IEA) has just published an Energy Technology Policy Study which supports international collaboration 1) as a means of reducing risks; 2) to allow next steps to be taken in the design, development, construction and operation of very costly experimental facilities which may be difficult or impossible for a single country to support; 3) to increase the efficiency or pace of R&D; and 4) when the R&D has unique transboundary implications.

The leaders of the Economic Summit process approve annual reports from the Working Group on Technology, Growth and Employment which is exploring the prospects for greater international collaboration in 18 areas including four of primary interest to DOE, namely, high energy physics, magnetic fusion, photovoltaics, and fast breeder reactors.

Finally, it is expected that Secretary Herrington, along with other Energy Ministers of the IEA Member Countries, will endorse the concept of increased international collaboration at the IEA Ministerial meeting this July. We anticipate that this will facilitate further efforts to increase international collaboration, including sharing program plans with other countries, coordinating, and where possible, jointly designing our programs to take greater advantage of the ongoing and planned work in the various participating countries.

Significant obstacles still exist which must be overcome if the full benefits of international cooperation are to be realized. Among the obstacles are:

-- A significant problem we have is the difficulty of making long-term commitments. As a result of some significant past programmatic changes in areas involving international cooperation, the Department is perceived overseas as somewhat unpredictable and unreliable. Unlike most other countries, we operate on an annual budget, which on occasion can result in unexpected, sudden and major changes in direction.

-- We are exploring new ground. We are moving beyond the past practice of responding to opportunities and requests for cooperation. As we seek out and take advantage of the capabilities overseas by planning collaborative programs on an international basis, we must recognize, and hopefully adjust, some of our policies and procedures regarding international R&D cooperation to minimize administrative impediments. National laws, regulations and policies were not made with extensive international collaboration in mind. For example, cross participation in projects through the provision of scientific equipment and components for major facilities is currently hampered in some instances by tariffs and taxes which are not compatible with the time frame of the collaboration. Exchange of scientific staff for periods of several years will benefit by changes in visa and work permit regulations, insurance coverage, etc. Cross-participation in facilities which are widely separated geographically rely heavily on inexpensive and efficient data transmission. However, some countries charge for the transmission of scientific data across their borders. Also, effective data communication standards need to be established to ensure compatibility.

-- Although English is the international language of science, the necessity for foreign language skills is increasing, particularly if we are to make optimum use of U.S. scientists assigned overseas, and are to minimize misunderstandings not uncommon in policy-level negotiations among program managers.

Coordination and Management of International Cooperative Research

Coordination and management of research takes place in many different fora and with different degrees of official government involvement.

Scientist-to-scientist contacts, either over the telephone, at international workshops, meetings, conferences, etc., or through formal exchange programs, constitute the bulk of DOE's international activities. These contacts provide the seminal information and personal rapport necessary to coordinate research activities and to establish joint research programs.

On a government-to-government level, an example of coordination is through the Working Group on Technology, Growth and Employment, established following the 1982 Versailles Economic Summit, which reports to the annual Economic Summit the progress of the Summit Working Group on High Energy Physics. This Summit Working Group is discussing the long-term plans of the Summit countries so that they can be implemented in an orderly and cost effective way, is promoting greater cooperation in the technology necessary to conduct high energy physics research, and is exploring ways to mitigate the administrative obstacles to international cooperation. Activities in high energy physics are coordinated rather informally through the International Committee for Future Accelerators of the International Union of Pure and Applied Physics.

There is also a Summit Working Group on Magnetic Fusion which is similarly investigating the need for future large facilities, technology requirements, and ways to minimize administrative barriers. As previously noted, there are also Summit Working Groups dealing with other energy technology areas.

For multilateral scientific and technological activities, DOE works through the International Energy Agency (IEA) and the Nuclear Energy Agency, both autonomous bodies within the Organization for Economic Cooperation and Development. The IEA Committee on Research and Development conducts state-of-the-art reviews of technology; reviews the R&D plans, policies and budgets of the IEA Member Countries; conducts special reviews of international projects upon request; provides expert technical advice to the IEA Governing Board and Energy Ministers; sponsors international conferences, and facilitates the collaborative research efforts in the areas of End-Use Conservation Technology, Renewable Energy, Fossil Energy, and Fusion Energy. The Nuclear Energy Agency performs similar functions for nuclear fission activities.

DOE also participates in numerous cooperative activities and various international conferences and meetings of the International Atomic Energy Agency.

Internally, the DOE program offices have the budget authority and are responsible for the implementation of international activities. Cooperative projects must compete with purely domestic activities for support and must be justified on the basis of domestic program objectives. The Office I represent serves as the central coordination point for DOE's international activities to ensure that all of DOE's concerns as well as foreign policy considerations are incorporated in the early stages of the formulation of an international activity. We ensure that the DOE speaks with one consistent voice to its international partners, and that the experiences of the Department in international affairs are brought to bear to avoid repeating past mistakes. The office is responsible for the overall policy guidance, preparation and conclusions of agreements and DOE representation at policy related multilateral meetings. We work closely with the Department of State and the foreign policy community, and with the Department's senior policy and program management.

I would like to close by observing that Secretary Herrington in his speeches has noted that DOE has been able to forge a strong partnership with the research community in the field of energy science and technology, a partnership that is complementing private initiatives rather than competing against them. The Department has now begun to move that partnership beyond the U.S. borders to establish international collaboration for energy research and development projects. Under Secretary's Herrington's leadership, we will be working with our programs to bring about such a partnership. We hope, then, within the next several years, to be able to point with pride, along with our collaborative partners, to ongoing international collaboration. Our focus will be in such areas as the major fusion facilities and devices and the Superconducting Super Collider. We are currently assessing the areas where international collaboration can be most effective. Promising candidates for international collaboration are DOE's nuclear program, coal, nuclear waste management, renewable energy, and conservation R&D.

Bilateral energy research and development agreements of the US Department of Energy

Country	Science and technology or research and development in general	Technical information	Nuclear fission	Fusion and high energy physics	Fossil energy	Renewables, end use and other
Australia		x				
Belgium			x			
Brazil					x	
Canada			x		x	
China				x	x	
Denmark		x				
European Communities			x			x
Finland	x	x				
France		x	x			
Gabon						x
Federal Republic of Germany		x	x		x	
Israel	x					x
Italy						x
Japan	x		x	x		x
Mexico	x				x	
Netherlands		x				
Norway		x				
Saudi Arabia						x
South Korea			x		x	x
Spain	x					
Sweden		x	x			
Switzerland			x			
United Kingdom	x		x	x	x	
USSR				x		
Venezuela	x				x	
Yugoslavia	x					

DISCUSSION

Mr. **Fuqua**. Thank you very much, Dr. Jaffe.

You just alluded to the fact that your office coordinates the programs, but they are funded out of the various divisions, I guess, of the Department of Energy. Are any funds specifically set aside for international participation?

Dr. **Jaffe**. No, not really. I mean, there are a few exceptions for particular studies, but in terms of real collaborative scientific research, that all comes out of the program budgets, and they are not specifically excluded.

Mr. **Fuqua**. And they compete with other projects that may be pending before that particular part of DOE?

Dr. **Jaffe**. That is correct.

Mr. **Fuqua**. How do you take into account the technology transfer considerations in the implementation of joint projects so that we don't jeopardize national security interests or, for that matter, the competitive position of the United States?

Dr. **Jaffe**. Well, let me divide those two issues, or treat them separately. The national security concern is taken into account through internal reviews by parts of the Department that have a concern for technology transfer issues relating to national security.

In general, all of our activities in the international field are unclassified. All of our research activities in the international field are unclassified and do not involve what we would consider sensitive technology, militarily sensitive technology.

Now, that issue is looked at in each specific case. It was a point of concern a number of years ago in some activities related to MHD, and it was specifically looked at at that time, and it was decided that what we are doing, through both internal reviews, including our Defense Programs organization and our own staff, that there was no problem, that the benefit was appropriate.

In the area of technology transfer from the standpoint of the economic issues, here my response is a little more difficult. We have a practice of publishing most of the work that is done, unclassified work that is done within the Department, and hence most of what we do is made freely available in terms of research to the outside world.

What we are trying to do is to get something in return for making that freely available, and indeed, that is one of the motivations behind an international cooperative activity.

We have, within the Department, sensed the importance, for example, in the solar area, of developing an industry behind the technology that was supported by the Department, and consequently, the program officials would at times, in consultation with some of their contractors, steer clear of cooperation in certain areas which they felt were approaching some potential commercial benefit. It is on an ad hoc basis. There is no set formula to cover this area.

Mr. **Fuqua**. Are there any administrative obstacles such as tariffs and visas and national security considerations that stand in the way of international cooperation? I am not just speaking of DOE but for international cooperation in general.

Dr. **Jaffe**. Yes. There are issues that come up. They come up on a case-by-case basis. Just very recently, there was an issue of the formalism of extension of a visa beyond 3 years that turns out to be fairly complicated. Up to 3 years is fairly straightforward, and beyond that is more complicated.

We had a foreign visitor, a very highly regarded scientist, who happened to be from an Eastern Bloc country. His hosts were very anxious to extend the visa, and it is actually an activity that is underway right now. We are trying to work through a complicated series of actions there.

We are trying, incidentally, as part of the activities in the International Energy Agency, to pull together a compilation of administrative obstacles that we face and other countries face, and this issue is also being addressed in the Summit process. I think that there may one day be some recommendations for significant changes in a couple of areas where we do have problems.

Mr. **FUQUA**. From an administrative standpoint or a policy standpoint, what would be the advantages or disadvantages of having, say, one single U.S. agency to provide the management and oversight and the funding of international science activities? Or should it continue on a—I am not sure if piecemeal is the best term—but agency by agency, I guess, is a better phrase? Most of the agencies, from NASA, NSF, DOE, just to name a few, are involved in international programs. Should there be a coordination from, say, OSTP or some other agency?

Dr. **JAFFE**. Well, let me try to answer pieces of this. I think there are certainly elements which would benefit from coordination, more so than others.

Mr. **FUQUA**. I don't want to get your blood pressure up, but maybe even the State Department.

Dr. **JAFFE**. No, no. Let me give you an example of one that turned out to be a recent problem. It involved dealing with the People's Republic of China, and it turned out that the People's Republic of China had just recently instituted or brought into being patent policies, and they were dealing with the Department of Energy; they were dealing with NASA; they were dealing with NSF. It does, indeed, turn out that these three organizations, and some of the others that they dealt with, have slightly different patent provisions.

They had agreed on a set of terms with one of these agencies which were not acceptable to us, because we have different perspectives. We ended up discussing this matter for about a year, and I think, to the credit of the State Department—and I don't often compliment them this way—but to the credit of the State Department, they insisted on holding out for the most stringent set of conditions, which were akin to ours—we were ready to give in because we were anxious to proceed—and we eventually got an agreement and a consistent approach.

Now, there is nothing in our Agency's procedures that says that our patent provisions, intellectual property provisions, should be the same as those of NSF or NASA; yet there is some virtue, I think, in an area like this, from the standpoint of the other party, to try to present the United States in a consistent framework.

Now, I will give you a picture on the other side. We have internally from time to time said, "Gee, wouldn't it be nice if we could structure our cooperation so that we can trade technology in one area where we know they want it for technology in another area that we know we want?"

Within just the Department of Energy, to do this is exceedingly difficult, because not the rest of the world is organized the way we are. Parts of what we want may be in their equivalent of NASA, or their equivalent of the Commerce Department, and what they want may be in our organization or may be in NSF.

If one tries to do this across the Government, with the hope of if you do something for me in the Space Station, I will do something for you with the Superconducting Super Collider, it sounds wonderful, but I really think, in practice, it is next to impossible, because you are dealing with different departments, different ministries, and you essentially have to go up to the head of government to find people who have that common perspective. We were unable to do it very effectively just dealing with energy issues within the Department of Energy.

Mr. FUQUA. I might say that we have, as a committee, been trying to streamline the patent policy so that there is somewhat uniformity in that, and we have not succeeded, either. But we are still working on it.

Thank you very much, Dr. Jaffe, for being with us this morning.

Mr. JAFFE. My pleasure, sir.

Mr. FUQUA. It has been very helpful to us, and we thank you very much for taking your time. We apologize for keeping you so late.

[Answers to questions asked of Dr. Jaffe follow:]

POST-HEARING QUESTIONS AND ANSWERS

Relating to the

JUNE 18, 1985 HEARING

Before the

TASK FORCE ON SCIENCE POLICY
of the
COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

WITNESS: HAROLD JAFFE

1. What sort of multilateral entities might be established to deal with the contemporary and future requirements of international science cooperation? Are new mechanisms needed?

Sufficient organizational arrangements exist to meet anticipated needs for present and future requirements of international science cooperation.

The Committee on Energy Research and Development of the International Energy Agency, an autonomous body within the Organization for Economic Cooperation and Development (OECD) in Paris, promotes and coordinates international collaboration on a multilateral basis in such energy technology areas as fusion, renewable energy technologies, conservation technologies, and fossil fuels.

Multilateral collaboration in fission energy is conducted through the Nuclear Energy Agency of the OECD in Paris. The International Atomic Energy Agency in Vienna sponsors some conferences and studies in both fission and fusion energy.

These organizations, besides providing an institutional home for international undertakings, also sponsor useful workshops, seminars and conferences publish technical journals, technology reviews, etc.; provide a forum for discussion of directions of R&D programs; and convene task forces and panels of experts as necessary.

Research in high energy physics is coordinated through the International Committee for Future Accelerators of the International Union of Pure and

Applied Physics. Informal, yet effective, communications has been the hallmark of international collaboration in high energy physics.

It should also be noted that in the deliberations of the various energy-related Summit Working Groups for Technology, Growth and Employment the participants have agreed that implementation should and can be effectively done through existing mechanisms and that no new international organizations are to emerge from their efforts.

2. What are the relative advantages and disadvantages of bilateral and multilateral cooperative arrangements?

Bilateral agreements are generally:

a) easier to negotiate;

b) easier to implement;

c) easier to approach equity in the activity;

d) easier to control;

e) well suited for activities with strong foreign policy considerations;

Multilateral activities, on the other hand,

a) may be the most efficient and economical approach when several countries have reasonably similar goals and programs and are interested in collaborating;

b) can attract more political support and international prestige; and

c) provide an efficient means of assisting a number of smaller countries.

In summary, when considering programmatic benefits, including complexity, cost, control, balance and other related issues, bilateral relations are generally, but not always, favored. DOE has several times as many bilateral R&D agreements as multilateral. However, there are specific instances where multilateral approaches are favored.

Some projects naturally require a multilateral arrangement. An example is the IEA Large Coil Project in which three US made large superconducting magnets and three foreign-produced superconducting coils (from the EC/FRG, Japan and Switzerland) are all being tested at Oak Ridge National Laboratory at a unique test facility, thereby advancing the state of the art and performing tests and exchanging design and performance information which would not otherwise have been possible for the amount of funds expended.

Some multilateral arrangements also serve foreign policy purposes. For example, many R&D activities under the IEA assist smaller countries who cannot afford to do all the R&D required to reduce their dependency on imported energy sources. By working through the IEA, they are in a much better position to be able to select technology which will reduce their energy dependency, and thereby contribute to the common energy security objectives of the IEA Member Countries. In such cases, DOE helps other countries while helping itself.

Multilateral organizations are used in arranging international conferences when representation from many countries is desired. Also, when a comprehensive review of the state-of-the-art of a technical area is desired, arranging such a review through an international organization lends some prestige to the review as well as signaling that the review has importance greater than purely national concerns. In this way, a multilateral arrangement helps to gain access to the world's best experts.

Although bilateral agreements in general are easier to negotiate than multilateral agreements, this is not always the case. The pace of some bilateral negotiations depends upon the individual country involved rather than the number of countries. For example, if three countries are seeking a common project and have clearly defined a equitable sharing of work and responsibilities, it is a relatively straightforward process to draft and negotiate an agreement. If a country is unfamiliar with international activities, such as the Peoples' Republic of China was as it emerged from the Cultural Revolution, conclusion of an agreement can take several years. If a country requires broad internal consensus, bilateral negotiations can proceed quite slowly.

In general, DOE, when considering an international activity, weighs programmatic and policy considerations on a case-by-case basis each time in deciding whether to pursue a collaborative program on a bilateral or multilateral arrangement.

Mr. FUQUA. The task force will stand in recess until tomorrow morning at 10 o'clock.

[Whereupon, at 12:31 p.m., the task force recessed, to reconvene at 10 a.m., the following day, Wednesday, June 19, 1985.]

INTERNATIONAL COOPERATION IN SCIENCE

WEDNESDAY, JUNE 19, 1985

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to recess, at 10:08 a.m., in room 2325, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. Today's hearing is the second in a series of 4 days of hearings on international cooperation in science. These hearings on international cooperation in science are to consider three sets of issues: one, international cooperation in big science; two, the impact of international cooperation on research priorities; and three, the coordination and management of international cooperative research.

Our first witness today is Dr. Herbert Friedman, chairman of the Commission on Physical Sciences, Mathematics, and Resources, the National Academy of Sciences. Dr. Friedman is a distinguished astronomer who pioneered the development of rocket and satellite astronomy, and he has been awarded the National Medal of Science and is a member of the National Academy of Sciences.

Dr. Friedman, we are very delighted to have you share your time with us this morning.

[A biographical sketch of Dr. Friedman follows:]

Dr. Herbert Friedman

Herbert Friedman serves as chairman of the Commission on Physical Sciences, Mathematics and Resources in the National Research Council, and is a member of the National Academy of Sciences. His experience in space research has been continuous since the arrival of V-2 rockets in the United States in 1946. Among his awards are the National Medal of Science and the Presidential Medal for Distinguished Federal Service. In advisory roles, he has served as a member of the President's Science Advisory Committee, the General Advisory Committee for Atomic Energy, and various academic committees. He has been connected with international space programs in the roles of vice president of COSPAR and president of the Interunion Commission on Solar Terrestrial Relations and the Special Committee on Solar Terrestrial Physics of the International Council of Scientific Unions.

STATEMENT OF DR. HERBERT FRIEDMAN, CHAIRMAN, COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND RESOURCES, NATIONAL ACADEMY OF SCIENCES, WASHINGTON, DC

Dr. Friedman. Mr. Chairman, I am very pleased to be here. I have been asked to testify on aspects of international cooperation in space science and geophysics. My written testimony traces the development of astronomy from the classical era of small science to its emergence as big science in the past two decades. The Hubble Space Telescope now exceeds $1 billion in cost, and concepts for the next generation at the turn of the century will be even more expensive. Such world-class instruments are certainly candidates for development and operation by international consortia.

The pattern of cooperation in geophysics was set by the International Geophysical Year a little more than 25 years ago. It was a remarkably successful demonstration of international cooperation. Since the IGY there have been a number of international programs on a scale of hundreds of millions of dollars that were smoothly managed, evenly balanced in national contributions, and far more scientifically productive than would have been possible without joint planning and cooperation.

International cooperation in big science can take a variety of styles. In space and geophysics, it has most frequently taken the form of individually mounted national efforts coordinated in a unified observing program. The international magnetospheric study, for example, drew on an investment of hundreds of millions of dollars already committed to national programs, and brought them into a coordinated plan of operation that greatly multiplied the scientific returns for all participants.

As the IMS ran through its paces, the United States and European Community began to plan the International Solar Polar Mission, called ISPM, and the International Solar Terrestrial Physics Program, ISTP. Planning proceeded smoothly toward the dual spacecraft concept of the ISPM when the United States withdrew from completing its spacecraft. Europe had already spent about $100 million and protested vigorously. The United States retained its launch commitment, but our image as a reliable space partner suffered great damage.

After the shocking experience of the ISTM had calmed down, the Europeans, Japanese, and American communities were able to tackle the design of the ISTP Program. The principal plan components of the program include three NASA, one Japanese, two ESA, and possibly nine Soviet spacecraft. On April 1, 1985, the Japanese Government committed to a $70 million budget for the start of its satellite for the ISTP Program. ESA is ready to proceed with two missions, at a budget of $400 million for spacecraft and launch, plus $150 million for instrumentation.

The estimated cost of the three NASA missions is now $639 million. Details of the Soviet plan are not firm, but they have identified five high-altitude polar-orbiting missions and two satellites in highly elliptical orbit.

Because of the logjam of new starts in NASA, the ISTP Program is still not a new start. Suspicion is growing abroad that we will again default on our promises. Our credibility as international partners will diminish seriously if we do not show more positive evidence of commitment.

Last year, in testimony before the House Committee on Science and Technology, the theme of a long-range geosphere-biosphere program was put forward. An important element of the rationale was the need to recognize the long-term monitoring requirements for understanding of geosphere-biosphere phenomena.

To distinguish anthropogenic influences from natural climate processes and to understand the mechanisms involved in global change will require at least a decade, and probably much more, of accurate global monitoring of atmospheric and sea temperature, the concentration and distribution of radiatively active gases, volcanism, and aerosols, solar, and terrestrial radiation fluxes, ice masses, and sea level.

Existing global observing and monitoring programs must be sustained and new commitments made. The Volkmer committee expressed strong support for the study of Sun-Earth interactions, and recommended to NASA, DOD, NSF, and the USGS that they sponsor study within the National Research Council of the full scope of science and solar-terrestrial relationships.

I am pleased to report that the science agencies have responded positively to the congressional recommendation and that progress has been made both on the national scene and abroad during the past year toward definition of a broad plan of study of the Sun-Earth system.

Finally, I wish to offer some remarks about one specific thrust in astronomy. This is a trend toward interferometry to achieve the ultimate in high resolution. In radio interferometry, the state-of-the-art is represented by the very long baseline array, an approved program which calls for an array of 10 25-meter telescopes across the continent and to Hawaii and Puerto Rico. It will have a resolving power of a single telescope 8,000 kilometers in diameter. The cost of construction will be $75 million, and the annual operating budget, about $5 million.

An equivalent array is planned by the Canadians, and their design will digitize data in the same format as the VLBA so that the power of both arrays can be combined. In Europe, a VLBA network will link telescopes in all of Western Europe. Again, the format will permit joint operation, and the combined United States-Canadian-European array will be a truly giant instrument of remarkable image-forming speed and fineness of detail.

The next extension will carry such interferometry into space and will undoubtedly require the staging capability of the Space Station. With Japan and ESA assuming partnership in the Space Station development, they will very likely seek partnership in the astronomy goals as well.

Lastly, I would like to take this occasion to inform the task force that the National Research Council will examine a broad perspective on international cooperation in big science in September of this year. A special committee on large international science and technology facilities will convene under the cochairmanship of Frederick Seitz, the former president of the Academy of Sciences, and Ralph Gomory, vice president of IBM, to discuss the issues and recommend the form of further study.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Friedman follows:]

Hearings of the Task Force on Science Policy of the
Committee on Science and Technology
of the U.S. House of Representatives
June 19, 1985
Testimony by Herbert Friedman,
National Research Council

Mr. Chairman and members of the Task Force on Science Policy:

I have been invited to discuss aspects of international cooperation in various geophysics and space science programs. My statement is confined to two scientific disciplines, astronomy and global geophysics, which serve well to judge the value of international cooperation both past and future.

Astronomy

Astronomy has always had a strong international character. Major observatories have been located in many countries and traditionally been available to visiting scientists with recognized scientific qualifications regardless of where they came from. Because the community was small and private benefactors were generous, governmental funds were rarely necessary. Men like Andrew Carnegie, James Lick and Percival Lowell established many of the great observatories which served American astronomy so well for the past 100 years.

But astronomical research has been undergoing a social revolution over the past two or three decades. Rapid and global air travel has permitted the establishment of new observatories at remote sites with astronomical seeing being the prime factor.

The search for dark and unpolluted skies moved optical observatory sites away from cities to the tops of high mountains or to desert locations and radio telescopes as far as possible from man-made radio noise background. With these moves the logistical costs of observatory operations has risen sharply.

Astronomers no longer settle in to live comparatively normal family lives in municipal communities near their observatories and to conduct a relatively leisurely program of observations. Instead, they compete fiercely for a few nights a year at these remote sites. Hardly anyone any longer puts eyeball to eyepiece. Electronic imagers, trackers, and digitized spectrometers record the data and astronomers return quickly to their own institutions to digest their results. The volume of activity has thus expanded enormously and the cost of supporting the larger community and analyzing the flood of data has grown commensurately. As astronomy and astrophysics have moved to the forefront of physical science in this generation, the great surge of scientific accomplishment has given even ground based astronomy a "big science" image, but the image grows far bigger in space based astronomy.

Until the past decade, the U.S. investment in space astronomy far outstripped the commitment of the rest of the world. Foreign astronomers have participated in all U.S. space astronomy missions but as junior partners in the investment.

The Hubble Space Telescope mission, at 1.3 billion dollars, receives about 15 percent of its costs from the European community. More nearly balanced cost sharing has characterized the infra-red astronomy satellite (IRAS). For the turn of the century, a study now being conducted by the Space Science Board (SSB) of the National Research Council (NRC) foresees a magnificent agenda of future high technology missions, many coupled to the space station. The projected scientific performance is so advanced that accomplishment of these missions will certainly revolutionize our concepts of the universe. Cost will, however, exceed the most expensive present generation missions. Certainly, civilized societies will support the achievement of such goals but the costs entailed almost demand international cost sharing and cooperative scientific participation. These 21st century observatories should truly be world class facilities built and operated by international consortiums.

Closer at hand are concepts for new technology ground-based telescopes now under serious study, that average around a typical cost of about 100 million dollars. Most of these are U.S. concepts, some with expectations of primary funding by private sources and matching funds from federal agencies. The Very Long Base Line Array (VLBA) which received the highest priority for ground based astronomy in the recent NRC survey of

"Astronomy and Astrophysics for the 1980's," is an approved program which deserves special mention. It calls for ten 25 meter telescopes spanning the continent from the U.S.-Canadian border to Puerto Rico and from Hawaii to the Atlantic coast. The entire array will have the resolving power of a single telescope 8000 kilometers in diameter. With a resolution of about 3 x 10^{-4} arc seconds, it will probe the hearts of quasars, the most incredibly powerful energy machines in the universe. The VLBA is expected to cost about 70 million dollars with an annual operating budget of about 5 million dollars.

In past developments of long base line radio interferometry, international cooperation has played an important role. Links have been set up between U.S. telescopes and instruments in the U.S.S.R., Scandinavia, West Germany, and Australia. While the VLBA is planned to operate as a U.S. instrument, foreign astronomers will be welcome users. More important in the context of international cooperation is the prospect of similar instruments being built in other countries. Canadians are planning an array of eight 32 meter telescopes across the southern part of the country and possibly a ninth at Yellow Knife in the northwest territories. The digitized data will be recorded in the same format as that of the VLBA which will permit special coordinated observations combining the power of both arrays.

In Europe a network (EVN) has been organized linking existing telescopes in The Netherlands, West Germany, Great Britain, Italy and Sweden. A joint operation of the American-Canadian and European arrays could produce a truly giant instrument of remarkable image forming speed and fineness of detail.

The VLBA on the ground is a prelude to radio interferometry in space that could begin sometime before the end of the century with an orbiting dish (Quasat) linked to an international net on the ground. It can be expected to improve the resolution to about 60 microarc seconds. Where the natural limits on the sizes of energetic sources in the galaxy will be found is not yet known. With a resolution of a millionth of an arc second, astronomers will be able to look at the sources of tightly beamed relativistic jets of plasma, millions of light years long generated in the immediate vicinity of what are believed to be massive rotating black holes. We still do not understand the generation, collimation and interaction of these jets with the surrounding medium. And we cannot hope to understand such remarkable phenomena any better without being able to probe with very much higher resolution.

The second step in the Quasat concept will project radio telescopes into far more distant orbits and they will have to work interferometrically with each other as well as with the ground based arrays. The telescopes will be larger, but with the expected assembly capability available on the space station, diameters of the order of 100 meters should be technically feasible at working wavelengths down to 7 millimeters and perhaps even as short as 3 millimeters. The present planners are considering various configurations of 3 to 10 telescopes in orbits extending to millions of kilometers. The technologies required seem to be reasonable extensions of present day capabilities. With the Japanese and Europeans joining in the space station effort, it is not unreasonable to look for their cooperation in the conduct of these futuristic, scientific missions which require the support capabilities of the space station for assembling, servicing, refurbishment, etc.

Geophysics

Turning now to the broad discipline of geophysics, let me recall some of the background of the International Geophysical Year (IGY) which was the forerunner of all internationally cooperative geophysics in the past quarter century and still is the best model for future global programs.

With the end of World War II, American, British, French and Soviet scientists undertook high altitude research with rockets. The prospects of achieving earth orbiting satellites, combined with a grand campaign of rocket and balloon experiments and supporting ground base studies sparked the enthusiasm of geophysicists around the world. With American leadership, the idea of the IGY was brought before the International Council of

Scientific Unions (ICSU). An ICSU Special Committee for the IGY was established in 1954 and planning was initiated for a start in 1957-58. The Special Committee adopted as its major goals for the IGY the exploration of two great regions that modern technology had brought within human reach; the Antarctic continent and outer space.

With regard to the continent at the bottom of the world, the committee stated: the Antarctic represents... "a region of almost unparalleled interest to the fields of geophysics and geography alike. In geophysics, Antarctica has many significant unexplored aspects: for example, the influence of this huge ice mass on global weather; the influence of ice mass on atmospheric and oceanographic dynamics; ... the possibility of conducting original ionospheric experiments northward from the south polar plateau during the long total night season to determine the physical characteristics of the ionosphere during prolonged absence of sunlight...," etc.

From mid-1957 to the end of 1958, forty thousand scientists and technicians from 67 nations manned some 4,000 observing stations spread over the earth from pole to pole. The crowning achievements in space were the launching of the Soviet Sputnik in 1957 followed in 1958 by the U.S. Explorer I, which discovered the Van Allen radiation belts.

Total U.S. funding in scientific grants for the IGY program was $42M via the National Science Foundation (NSF). Logistical support for the Antarctic and operational support for rockets and satellites reached roughly $500 M. No published figures were available for the Soviet program, but the investment must have been comparable to that of the U.S.

The Antarctic program involved 12 nations: Australia, Argentina, Belgium, Chile, France, Japan, New Zealand, Norway, South Africa, the United Kingdom, the United States and the Soviet Union. Forty-eight new stations were established on the margins and interior of Antarctica. Ratification of the Antarctic Treaty was one of the great political successes attributable to the IGY. The Treaty set aside an entire continent for scientific and peaceful purposes. Its text states, "Freedom of scientific investigation in Antarctica and cooperation toward that end as applied during the international geophysical year shall continue subject to the provisions of the present treaty". The treaty was signed in 1959 and came into force in 1961.

Today, 18 countries conduct research in and around Antarctica. Over 40 permanent over-wintering stations are maintained, which during the austral summer are supplemented by many temporary field stations, over 35 dedicated Antarctic-research and resupply vessels, and over 50 aircraft.

Through the Antarctic Treaty System and the ICSU Scientific Committee on Antarctic Research (SCAR) a mutually beneficial relationship has developed which blends the research programs of individual nations into a coordinated effort of circumpolar scope and significance.

The establishment of a program under the aegis of SCAR to gain insight into the structure and function of the Southern Ocean ecosystem -- a prerequisite to wise management of its living resources -- is an example of how an initiative involving multi-national participation can be launched successfully. Recently, 18 ships from 14 nations participated in this largest ever biological oceanographic research effort in the oceans surrounding Antarctica. The data from this effort is shared freely, and under SCAR a series of data interpretation workshops and international symposia have been held to present these findings to the world scientific community.

The IGY has been hailed as the finest and greatest demonstration of unselfish international scientific cooperation. For the great scientific powers, it almost tore down the Iron Curtain and for the Third World, it offered dignified acceptance in the world of first class science at whatever level of participation was possible within their resources. Since the IGY, there have been several international programs such as the Global Atmospheric Research Program (GARP) and the International Magnetospheric Study (IMS) that included coordinated satellite observations and meshed global networks of ground level instrumentation with space based measurements.

The IMS is an example of successful global scientific cooperation in an enterprise that drew on an investment of hundreds and millions of dollars, without political interference in the scientific plan and without disputes over the individual national investments. It was charged as an international effort only for the small portion of administrative costs of scientific reporting and data management. This unusual set of conditions was possible because each major participant was already engaged in its own parochial program with its own resources when the value of international cooperation was recognized and the opportunity grasped.

At the time of conceptualization of the IMS, research in space physics was reported and discussed on the international scene under the aegis of the Interunion Commission on Solar Terrestrial Physics, later to become the ICSU special committee for Solar Terrestrial Physics (SCOSTEP). About 1969, it was apparent that NASA, the European Space Research Organization (ESRO), and the USSR were independently programming multi-satellite missions to study the earth's outer space. At the heart of the problem of understanding this dynamic environment was the need for simultaneous measurements across the many boundaries and regimes of magnetospheric space and to trace the connections between effects at ground level and the physical sources in space on the magnetic field lines linking them to ground points.

A satellite situation center at Goddard Space Flight Center provided real time positions of spacecraft of all nations so that scientists could relate the measurements at critical times in the crossings of magnetospheric boundaries. Out of the random sampling of previously uncoordinated space probing emerged a clear pattern of signals sharply delineated in space and time. By grasping the obvious opportunities for cooperation, the value of the scientific product was multiplied enormously.

The roster of spacecraft that contributed to the IMS included three prime U.S./E.S.A missions, International Sun Earth Explorers (ISEE), I, II, and III. Other contributing spacecraft were IMP-7 and 8, Atmospheric Explorer E, NOAA GOES, DoD's SOLRAD 11-A, and 11-B, Japan's ISS and EXOS-B. The U.S.S.R. brought in four of their Space Institutes, as well as their counterparts in Czechoslovakia, Bulgaria, the German Democratic Republic and Hungary. Their missions included a low-altitude circular orbit satellite, a high altitude elliptical orbit satellite and various interplanetary explorer satellites. A rough estimate puts the U.S. investment at about 20-25 percent of the total. In addition to providing the EXOS satellites, Japan spent about $22 M on peripheral ground based components. Altogether, scientists in about 50 countries were active in the program.

Office expenses of the Steering Committee that supervised the IMS ran to about $40,000 for the entire ten year period 1969-1979. The total cost of IMS-related missions in the 26 participating countries is far more difficult to determine, but most certainly was of the order of several hundred million dollars.

As the IMS ran through its paces, the United States and European communities began to plan the International Solar Polar Mission (ISPM) and the International Solar Terrestrial Physics Program (ISTP). The ISPM was to involve two spacecraft, one built by the European Space Agency, the other by the United States. They were to be launched in trajectories that would swing them around Jupiter in opposite senses and return them over the two poles of the sun high above the ecliptic plane at the same time. Planning proceeded smoothly to spacecraft construction when the United States withdrew from completing its spacecraft. Europe had already spent about 100 million dollars and cries of anguish could be heard across the ocean. The United States retained its launch commitment but our image as a reliable space partner suffered great damage.

After the shocking experience of the ISPM had calmed down, the European, Japanese and Americans were able to tackle the design of the ISTP program. The principal planned components of the program include 3 NASA, one Japanese, 2 ESA and possibly 9 Soviet spacecraft. Plans for the NASA/ESA and Japanese collaboration have been specific and detailed. On April 1, 1985, the Japanese government committed to a $70 M budget for the start of their "Geotail" satellite. ESA is ready to proceed with two missions, SOHO and Cluster, at a budget of $400 M for spacecraft and launch plus $150 M for instrumentation. The estimated cost of the 3 NASA missions is now $639M. Details of the Soviet plan are not firm but they have identified five high altitude ($2R_E$) polar orbiting missions, and 2 satellites in highly elliptical orbits (25 R_E).

This magnificant array of spaceships would tour the earth's outer space environment in a highly coordinated way to answer the most fundamental problems of sun-earth interactions. Unfortunately, the United States is already well behind the agreed upon schedule and a suspicion is growing abroad that, just as in the ISPM, we will default on our promises for the ISTP. In the event that we fail to bring in ISTP as a new start in 1987, it is hard to believe that our foreign colleagues in science will consider us credible partners. The interest in solar-terrestrial physics in Japan, Europe and the Soviet Union is very high. The U.S. may find itself on the sidelines when the rest of the world is strongly united in a great cooperative effort, if we do not show more definite commitment.

The 25th anniversary of the IGY in 1983 was the occasion for a retrospective examination of its accomplishments in many scientific forums. It occurred to me and other scientists that the time was ripe for organizing a new international program to study global change, employing all the knowledge and resources developed since the IGY in an integrated study of the entire sun-earth system. Preliminary discussions in the world scientific community have led to substantial enthusiasm for such a program with a long range format and proper integration of both biological and geophysical components. In the U.S., the name International Geosphere-Biosphere Program was adopted; geosphere to represent all of the disciplinary areas of the earth sciences -- lithosphere, hydrosphere, atmosphere, ionosphere, magnetosphere, etc. -- and biosphere describing the thin film of living environment that envelopes the surface of the earth.

In recent years, questions related to acid rain, greenhouse gases, ozone and atmospheric pollutants and all of the elements that control climate have received intensive scientific and political consideration. The contemporary concern for the environment has focused new attention on biogeochemical cycles and the various links between geophysical and biospheric processes. To understand changing conditions for life on earth and the role of human activities calls for urgent attention to developing the basic scientific knowledge of the geosphere and biosphere. A sound knowledge base must include a comprehensive understanding of the historical evolution of the earth and the dynamics of global change as they are written in the geological record.

Today, we find a large agenda of current and planned programs of interdisciplinary breadth. These programs are vital to the development of a more broadly based geosphere-biosphere program in the 1990s. Among the examples worth special note are the study of biogeochemical cycles undertaken by SCOPE, the ICSU Special Committee on Problems of the Environment, which has been concerned with the global cycles of carbon, sulfur, nitrogen and phosphorous. This theme of biogeochemistry is being examined from the standpoint of space observations in NASA's "Global Habitability Program". Other international programs close to the concept of IGBP are the International Lithosphere Program (ILP), the World Climate Research Program (WCRP) and the International Solar-Terrestrial Physics Program (ISTP) to which I have already referred. The WCRP embraces the World Ocean Circulation Experiment (WOCE) designed to achieve quantitative measures of the large scale circulation of the oceans and their interactions with the atmosphere. WOCE is dependent upon major satellite missions such as the Topography of the Ocean Experiment (TOPEX) and the Geopotential Research Mission (GRM) of the United States and the Earth Resources Satellite (ERS-1) of ESA, as well as surface and subsurface observing platforms.

It is important to recognize the long term monitoring requirements for understanding of geosphere-biosphere phenomena. To distinguish anthropogenic influences from natural climate processes and to understand the mechanism involved in global change will require at least a decade and probably more of accurate global monitoring of atmospheric and sea temperature, the concentration and distributions of radiatively active gases, vulcanism and aerosols, solar and terrestrial radiation fluxes, ice masses and sea level. Existing global observing and monitoring programs must be sustained and new commitments made.

In 1983, the NRC conducted a workshop and published its report entitled, "Toward an International Geosphere-Biosphere Program, A Study of Global Change." It examined all the elements of the sun-earth system as an interactive complex and the participants endorsed the concept of an interdisciplinary program to be conducted on a global scale under international auspices. In the same year, the ICSU Executive Board authorized a one day symposium on the subject of "Global Change" to be held in conjunction with the 20th ICSU General Assembly, September 24, 1984, in Ottawa.

The design of that Symposium followed the 1983 NRC study report. Enthusiastic support on the occasion led the ICSU assembly to establish an ad hoc planning committee that was charged with encouraging the full panoply of ICSU unions and special committees to study their proper roles in an IGBP and with assessing the feasibility of launching a program.

An NRC committee for the International Geosphere-Biosphere Program was established with support from NASA, NOAA, USGS, NSF and DOD in the spring of 1984 to design specific thrusts appropriate to the early phases of an IGBP. The report of that committee, "Global Change in the Geosphere-Biosphere", is in the final process of review and should be published very soon.

In its initial draft document outlining the main features of an international program, the ICSU Planning Committee has endorsed the prescription of the NRC IGBP Committee for a strongly focused interdisciplinary scientific approach to studies of the connections between the biological, chemical and physical processes that lead to changes in the global environment with primary emphasis on biospheric interactions. Workshops are planned including one sponsored by SCOPE and INTECOL (International Association for Ecology) in the U.S. this fall. In the discipline of solar-terrestrial physics SCOSTEP has already strongly endorsed the ISTP program and views it as a major component of an IGBP. In the community of earth scientists, there also is a sense of how to fit those activities into an IGBP. An expression of their thinking is emerging from a Space Science Board study named "Scientific Research Mission to Planet Earth."

Although the philosophy of an IGBP has received warm support, an observational program has not yet been initiated and is not likely to be realized until near the end of this decade. A great deal of planning must be accomplished in the next few years to move it ahead.

Criteria for International Programs

In all cooperative international scientific endeavors there are certain fundamental criteria that should be satisfied:

- The scientific goals must be highly important to all partners in the enterprise.
- The partners should have comparable scientific competence and matching resources.
- The context should reflect universal intellectual values or global societal concerns.
- There should be an international institutional framework into which the program can be fit so as to assure effective planning, execution and management of data.
- The political context must be peaceful.

All of the various programs discussed above meet these criteria.

I greatly appreciate the opportunity to offer these views to the Science Policy Task Force.

DISCUSSION

Mr. Fuqua. Thank you very much, Dr. Friedman.

Should all or some of big science—and you mention in the field you are very familiar with, astronomy, where you have—they probably don't cost the money that SSC's cost, but in big science, should all big science automatically look toward an international cooperative partnership, or should that be determined on a case-by-case basis, or should we even bother with trying to involve international cooperation?

Dr. Friedman. There are very positive benefits from involving scientists from all over the world. The intellectual contributions are multiplied in proportion to the degree of participation. We are now also in an era where the technological capabilities and the resources abroad are comparable to ours.

In the past couple of decades where we conducted missions in space astronomy, we have paid by far the larger portion of the bill. In the Hubble Space Telescope Program, Europe contributes about 15 percent. But in the recent IRAS, Infrared Astronomy Satellite, the relative contributions were almost equal. The Dutch and the British almost matched the United States contributions to that mission.

So you have the advantage of making the scientific competition much broader than it would be on a strictly national scale, which means that you flush out the best ideas and the technological capabilities which are sufficient amongst the other nations of the world to make them full contributors to the effort.

I think where it is important to preserve a national effort is in the smaller science missions where we are looking for real innovation, exploration of brand-new ideas which need to be sampled in a preliminary way. It is easier to do that on a national scale. Where goals have been essentially identified as international goals, it is much easier to carry out an international cooperative program.

If we keep the small science active, we will give the brightest young people in our country a chance to show their originality and creativity much more easily than if they are coupled into big science on an international scale.

Mr. Fuqua. Do you think that the United States should have a policy of trying to be first in every field of science? If so, what does that do if we are involved in international cooperation? Aren't we helping other countries to obtain a level that maybe we have?

Dr. Friedman. I think it's important in all of science to seek to be first. There is no real payoff, comparatively speaking, for second-class science. Whether you can go it alone or have to do it in an international consortium, I think will depend very, very much on the total cost. I refer to the future missions as world-class missions. I don't see how that can be avoided if we go over $1 billion a mission and there is a large agenda of very exciting science to be done. Then we have to look for worldwide participation, and we should strive to be on the first team of whatever effort is generated.

Mr. Fuqua. How would you describe a field like astronomy? Do you see that field as one that lends itself to international cooperation? Do you see that as increasing or staying about the same or diminishing in the future? Is there going to be more international cooperation or less, or about the same?

Dr. **Friedman**. I think there must be more international cooperation. I mentioned one example, in interferometry. It is typical of interferometry that you have the multiplicity of telescopes. That makes it possible for various participants each to take the responsibility for one of those elements, and then it is all put together as a cooperative project.

The Hubble Space Telescope now is a single telescope mission, and it will produce images 10 times the detail we have ever had before. But the prospects for the turn of the century by going into interferometry are to improve that resolution a factor of another thousand, and the challenge to astronomy is just extremely exciting.

I think all of the missions in that category do lend themselves to international cooperation in a way in which the management is not excessively complicated and in which the science ultimately is done in a truly cooperative way with all of the benefits.

Mr. **Fuqua**. You said you thought it would be good to do that.

Dr. **Friedman**. Yes.

Mr. **Fuqua**. Will that happen?

Dr. **Friedman**. There are already serious discussions in international forums of taking these next steps. There is a mission defined internationally, ESA and the United States, for example, to produce a mission called Quasat, which will put a large radio telescope in orbit and use it in an interparametric mode with the arrays of telescopes on the ground.

Then one can foresee the next step where several of these telescopes will be assembled on the space station and put into near-Earth orbit and eventually very distant positions in space and carry the resolution to its ultimate limit. There you can see responsibility being divided in a very natural way amongst various nations that really want to pursue those ultimate scientific goals.

Mr. **Fuqua**. Mr. Brown.

Mr. **Brown**. Dr. Friedman, continuing with astronomy for a moment, and interferometry, the process can apply at any portion of the spectrum, I presume; that is, you can improve the resolution through interferometry processes in radio telescopes, optical telescopes, and other telescopes as well?

Dr. **Friedman**. Yes.

Mr. **Brown**. Generally speaking, does that require multiple instruments?

Dr. **Friedman**. Yes, it does. The essence of an interferometer is that you have two or more telescopes which give you the separation that makes it comparable to the resolution of a dish of that size, and the more telescopes you use to fill in the aperture, the closer you come to getting a complete image in a short time.

Mr. **Brown**. So that that would hold out the desirability of having additional Hubble-type instruments in space as well as radio astronomy instruments in space and other kinds of instruments as well?

Dr. **Friedman**. Yes. There are already well-advanced design efforts to demonstrate that the next generation of telescopes, even in the optical range that a Hubble telescope operates can be made very much larger—for instance, 8 meters instead of 2.4 meters—without increasing the cost. Accordingly, it will be possible to make arrays of such telescopes to achieve the high resolution of interferometry.

Mr. Brown. Would those be using new lightweight segmented mirror technologies, computer-controlled?

Dr. Friedman. Yes.

Mr. Brown. I am always fascinated by the speed with which developments take place in the tools of science, but the problems that we have here are less of that nature than they are of a different nature.

I am interested in trying to understand a little bit better the way in which the scientific community relates both within itself, for example, from the Academy, the NRC, the disciplinary societies, the ICSU. And I assume that through long and troubled experience you have developed ways of reaching policy decisions and so on. I would like to understand that better, but I won't bother you to describe that now.

I am more interested in how the scientific community, speaking as one voice, relates to the political community both in the executive branch and in the legislative branch, because here we seem to find some real problems. I think in this committee we are interested in doing something about the backlog of new starts in the space program, for example, but we are constrained by the degree to which the administration supports these in the current budgetary climate.

I am interested to know how you interact with the executive branch in trying to establish priorities for major scientific initiatives and if there is anything that can be done to improve that process.

Dr. Friedman. We do have welcome access to the OSTP, and generally the desires of the scientific community are in tune with the priorities that are expressed by Jay Keyworth, for example.

Mr. Brown. Your priorities are established by Jay Keyworth, or the other way around?

Dr. Friedman. We establish our priorities, usually early on. By the time a mission gets exposure in the agencies, in the public arena, it becomes a matter of importance, of course, to the administration to express its views. And if I take specific examples, OSTP, which represents the administration's attitude, has been strongly supportive of the Hubble Telescope and strongly supportive of the VLBA.

I would say certainly in astronomy there have been strong expressions of support for every priority developed by the Academy studies, both the Field committee report on the 10-year goals in astronomy and the strategies which are produced by the Space Science Board.

In the process of producing those strategies, the agencies which would assume the mission roles are very much involved at all steps. NASA views the Space Science Board as an invaluable advisory asset, and if one looks at the 25-year record, NASA has followed the recommendations of the Space Science Board in a vast majority of cases and has been able to achieve a surprisingly large portion of the recommended goals of the scientific community.

The situation we are in now, where the backlog has grown and the new starts have been reduced to one or two a year, has gotten to be very painful. The future, I think, demands that there be a greater level of support if we are to do what we are capable of doing. It also demands that more attention be paid to the younger generations of scientists who need a mode of operation to develop their talents and express their ideas. There are things in that category, too, that could be done now which I wish were being pushed more aggressively.

On a mission which is in space right now, the present Shuttle, there is a payload called Spartan. The scientific community has asked for that for 10 years now. Spartan was to be a way of very easy access to space at a level comparable to what used to be the old rocket program, where people in the academic arena could get a simple rocket like an ARABB, put a $50,000 payload on it, and achieve some very first-rate science. That permitted universities to be involved in space and to bring their graduate students along.

Spartan is a very simple concept. You take a rocket-class payload and put it on a carrier which can be put out of the Shuttle, and instead of getting 4 minutes of a rocket flight, it gets 2 days. And then you bring it back in. It has no interfaces with the Shuttle.

It's the simplest possible mode of operation. The scientists can work independently of a lot of the interference—if I want to use it that way—that comes from the usual big-science missions. And it should be a very easy way for inexpensive university-type science to function.

Now, we hope this demonstration will be very persuasive, but then it will be important to schedule such missions much more frequently. Already there is a queue, I believe, of at least a dozen payloads that would quickly move into the use of the Spartan technique and suddenly bring back a large community of young people to the science program.

Mr. Brown. Well, Dr. Friedman, we had some discussion of that in the committee, recognizing the need, as you have expressed it, discussing the range of payloads that could be put on the Shuttle to accommodate the scientific community of the kinds you are describing through the Spacelab itself and intermediate loads that might have to have some kind of support connections.

We thought there was inadequate funding for that, which is not particularly important, but we were giving that problem real consideration here in this committee, and sympathetic consideration.

The question I have is, is there a similar opportunity for that to be expressed to the executive branch so we are not fighting with them over these important scientific opportunities or priorities all the time? I think we share Keyworth's concern, which we know is real, for the interests of great concern, but we get hung up over little questions of a few million dollars here and there about what is important. And we don't know whether Keyworth or anybody in OSTP or OMB gives the attention to these items that we think they are entitled to.

Dr. Friedman. Well, the bottom line, I suppose, is what does eventually happen. I will tell you that up to now we have gotten encouragement, sympathy, and we have gotten, I am sure, very substantial support in keeping the Space Telescope alive and coming, we all hope, to a successful conclusion.

But the energy of the OSTP community, I suppose, is also limited, and can be exhausted in struggling with a mission like the Space Telescope and other things of that size.

Mr. BROWN. Well, it is very important to remember that none of these important projects are conceived and developed in one administration. Going back to IGY, it was conceived, developed, and planned and implemented over a period of years which spans several administrations. And in order to ensure that it continues over several administrations, it requires that there be a broader base than just the individual occupancy of a particular position in any administration. Am I communicating to you?

Dr. FRIEDMAN. Yes. Certainly.

Mr. BROWN. That is why I am focusing on this linkage, which has to be ongoing and which has to have some political basis somewhere.

Dr. FRIEDMAN. We have been talking primarily about astronomy. For reasons that I think are entirely admirable, the country at large supports our astronomy efforts, which far exceed those of the rest of the world. If we try to put it in a political context, we usually come down to talking about spinoffs. What are the broad values in a very practical technological way of doing missions of this type? I think there are very good reasons in the spinoff category for doing them, but we are not usually forced to push those reasons in order to get political support.

Mr. BROWN. Well, I don't think you should. Your strength is that in basic science you are funded not because of the spinoffs but, in this administration, and I think in the Congress, because of a recognition of the importance of basic science per se. You get into the spinoff problem when you get into technology and the applications of technology.

I apologize for taking so much time, Mr. Chairman.

Mr. FUQUA. Mr. Packard.

Mr. PACKARD. Thank you, Mr. Chairman.

Mr. Brown asked a question that I was particularly interested in also, and that is, how we prioritize, and so forth. Let me carry that just a little bit further. You have talked about how we do it here nationally, but I am interested also in terms of international prioritization and how that fits in, as well as the private sector here in this country, and how they are involved in that prioritizing of our dollars.

Frankly, we are reaching the point where I think a lot of our policy is driven by economic concerns and considerations. How do we determine how much of our budget is going to go toward astronomical research, and how much is going to go toward high-energy physics, and how much is going to go toward biomedical and a multitude of other scientific research programs?

I would be interested in your evaluation of how that can be carried out now in the international community and the dollars that are available from the various international participants, as well as plugging in the private sector and whether they have any influence in that prioritization.

Dr. **Friedman**. The situation differs rather strongly in different scientific disciplines. I take pride in being an astronomer, and I admire my colleagues all over the world, and I think they come up with brilliant concepts of what the future holds for astronomy. They are all in tune with each other's thinking.

To a large extent, just as this country supports astronomy for its intellectual goals, the same situation holds abroad. When we get to areas of geophysics, then the situation becomes much less clear. Political elements become important. Questions of societal benefits in a very practical and early-return category become the first questions in deciding how to go ahead.

When we talk about the greenhouse gases, what they do to climate, and we talk about acid rain, we are dealing with a subject that is very fractionated, which the science, for all the effort that has gone into it, is still kind of fuzzy, and in which political and private sector considerations are as important as the goals of understanding the science.

So what we do, and what we don't do, and how long we take to do things is a mix of what scientists think they can accomplish, what the political system wants to support, what the societal benefits arena urges on governments to do, and so on.

So these two areas, astronomy and global problems in geophysics, with great societal impact, are very different. And how you get support for them is a very different matter.

Mr. **Fuqua**. Dr. Friedman, we are going to have to take a short break. We have a vote on the floor, and we will be right back. I think Mr. Walgren and Mr. Lujan may have questions to ask of you. So if you will tolerate us for a bit.

[Recess.]

Mr. **Fuqua**. The task force will resume.

Mr. Lujan.

Mr. **Lujan**. Thank you, Mr. Chairman.

I went out to vote a little earlier than the rest of them did, and I guess the discussion had moved into science for the sake of science, whether it is a noble goal to achieve a whole bunch of Nobel Prizes or whether out the other end has got to come out something in the area of spinoffs. I would like to pursue that a little bit because I think that is central to the point of science policy, whether we do it for one reason or the other or a combination of both, whether it is worth knowing where a star is only for the sake of knowing it or whether it is because it is going to give us some benefit that we can guide ourselves in a particular direction, whether it is like the three Magi to find Christ, or to find a pot of gold at the end of the rainbow, or whatever.

Would you expand on that some, the two purposes and how they fit?

Dr. **Friedman**. The easy way to answer your question, Congressman Lujan, is to take a retrospective look at what has happened in the past. If we take the Sun, for example, at the turn of this century, scientists had no idea what makes the Sun or any other star shine. They talked about chemical burning. You take a pile of coal as big as the Sun and light it up, well, it will burn up in 2,000 years. So that certainly could not be the source. And yet that is where they were hung up.

Then Einstein came along with $E=Mc^2$, and scientists like Eddington and Bethe got into nuclear physics. Those new concepts were put together, and we came up with the thermonuclear fusion model of energy generation in a star.

All of what we do on the ground we can attribute to the concepts that developed from trying to understand what makes a star like the Sun shine. If we try to carry that to the present and say what are we going to learn by trying to understand what makes a quasar put out its enormous energy, a quasar generates as much power as 1,000 or 10,000 entire galaxies of stars, and yet the core of this tremendous energy machine can be compared best with the dimensions of a solar system.

We don't know how that happens. We talk about black holes. We are driven to something which is so fantastic that you still have to keep prodding yourself to say, "Yes, it's reasonable," because we don't know any way out of it.

Where that will lead to I can't predict. In these objects we see phenomena that must tell us a great deal about physics. Some of these quasars are projecting electron energetic particle beams which reach a million light-years and still remain focused as a beam. We talk a great deal about particle beams nowadays in a defense concept. And before we can understand how to hold those beams together, perhaps we better look harder at the natural phenomena that do it in so many cases now.

I am sure you have heard about the connections between fundamental particle physics and cosmology. We are talking about generating energies up into the trillion-electron-volt range. Now we look at the sky and we find that there are stars that are producing beams of high-energy gamma rays up to energies of 10^{16} eV, 10,000 times higher than anything we conceive of in a man-made machine.

We are just discovering them. A year ago there was one. Now there are two. And now there are suspicions that these stellar machines which are producing these enormously high-energy beams of gamma rays are also projecting particle beams.

There have been a number of preliminary claims that one of these sources, Cygnus X–3, is actually projecting a beam of muons which are detected here at Earth.

These new discoveries shake up the scientific world, and they sure draw the attention of technologists as well, because there are things going on in the universe that we never anticipated, beyond anything we conceive of on Earth.

Mr. **LUJAN**. Well, the bottom line is, I guess, there is enough for both, for those that think of science for science's sake, and also for those that would like some technologies out of whatever research dollars we put in. The bottom line is that something is going to come out, but we don't know at the present time what it's going to be.

Dr. **FRIEDMAN**. Yes. I have been talking about the scientific breakthroughs. I haven't tried to get into the spinoffs. We mentioned them earlier. And then you can get into debates about whether investing in the defense program produces technological progress and spinoffs faster than investing in pure science does. I don't know that anybody can answer that.

Mr. **Fuqua**. Thank you very much, Dr. Friedman. We appreciate the contribution that you have enlightened us with this morning.

Dr. **Friedman**. Thank you for inviting me, Mr. Chairman.

[Answers to questions asked of Dr. Friedman follow:]

QUESTIONS FOR THE RECORD
(Science Policy Task Force)
Herbert Friedman

1. What are (a) the advantages and (b) the disadvantages of sharing the cost of big science facilities on an international basis?

(a) Advantages

Economies of cost sharing to achieve mutually agreed upon goals.

Stimulation of joint scientific planning, operations and analysis.

General improvement in sharing of high technology.

(b) Disadvantages

Democratic management may encourage waste, bureaucratic impediments and other sources of delay.

The economic winner is the country in which the facility is built. A facility built in Europe with U. S. funds brings prosperity to the local area and vice versa.

Travel dislocations are a burden on scientists who come from abroad.

2. What would be the best worldwide configuration of (a) astronomy or (b) geophysics facilities from the point of view of science? How might this best be determined?

(a) -Ground based astronomy is best configured with national facilities. The scientific agenda is so well agreed upon internationally that duplication is not an issue. Cost sharing for the total progress of astronomy is essentially achieved by the sum of individual national investments in each country's telescopes.

- Very Long Baseline radio astronomy is a special case of similar major facilities in different countries which can be operated individually or in combination. The newly initiated VLBA in the U. S. will have counterparts across Canada and across Europe. Each array is self sufficient for the performance of major research but each array is designed to permit joint operation with its counterparts.
- Space Based Astronomy

  Cooperation has been very effective in many past missions, but the foreign share of cost has been relatively small compared to the U. S. investment. European and Japanese capabilities and budgets have reached a level more commensurate with the U. S. input and future joint missions should reflect more equal partnerships. Many high priority future missions will be "World Class" facilities and so expensive that cooperative approaches will be essential.

(b) -The ISTP program is the largest concept in the geophysics discipline and the one most generally international in cost sharing and scientific cooperation. Individual satellites would be built by NASA, ESA, the Japanese Space Agency and the USSR, but all would be placed in complementary orbits and designed to provide unified sets of data. ISTP has been jointly planned in great detail. It remains for the various nations to meet their commitments in the same time frame so that the coordinated observations can be achieved.

- Observations of the oceans require several missions to provide the variety of sensors and geographical perspectives essential to global models. The U. S. is moving ahead on TOPEX, which will observe circulation in the great ocean basins but primarily in mid-latitudes. NROSS will complement TOPEX from a higher inclination orbit, giving more coverage of arctic oceans. The European Earth Resource Satellite (ERS) mission, a Canadian SAR mission and a Japanese SAR are in the future picture. If all these missions are coordinated for international cooperation, the total returns will be much greater than the sum of the individual missions done in isolation.

3. What attributes of (a) astronomy and (b) geophysics make international cooperation easy to achieve?

(a) -The world community of astronomers is comparatively small and scientific consensus is the norm rather than sharp controversy.

- Exchanges of astronomers between observatories in different countries has been traditional.
- Scientific publication in astronomy is fast, international symposia are frequent and the International Astronomical Union is a very effective forum for regular synthesis of progress in every aspect of astronomy.
- Mission sharing in space projects at prorated costs has been achieved since early in the space program. As foreign countries have developed their space capabilities, their relative financial contributions have increased. Europe pays about 15 percent of the Hubble Space Telescope (HST) cost. The costs of the Infrared Astronomy Observatory (IRAS) were shared more nearly equally between the U. S. and the combination of The Netherlands and Great Britain. Distributing costs according to mission responsibilities which separate out easily is achievable in space observatories -- the scientific focal plane instrument, the telescope structure, power supplies, attitude controls, and data retrieval, can each be assigned to an individual partner.

(b) - Much of geophysics is global in nature and requires global international cooperation. Costs of deep sea drilling activities have been shared by many nations. Drilling on land is carried out in national programs, but the results are exchanged to understand the earth's crust as a whole. Seismic arrays are operated in several countries and scientific data are shared. Magnetic observatories have been undergoing standardization in digital formats to make uniform international data sets. Antarctic research is a joint effort of 18 nations. The problems of ozone, greenhouse gases and acid rain are global.

Past international programs in geophysics, beginning with the International Geophysical Year (IGY), have been notably successful, guided almost entirely by scientific requirements with minimal political interference. On a similar scale was the Global Atmospheric Research Program (GARP) involving ships, planes, satellites, balloons of many nations and the management capabilities of the World Meterorological Organization (WMO).

The above list can be made much longer, but the essential point is that global science requires global cooperation.

4. What factors either facilitate or inhibit international cooperation in (a) astronomy or (b) geophysics?

- The basic research nature of most scientific effort in astronomy and geophysics and the minimal influence of security considerations facilitates cooperation.

- Technology transfer questions of recent years are becoming more serious impediments to freedom of communication. Many technological aspects of astronomical imaging, mirror fabrication, sensor development and platform stabilization are of direct value to military technology.

- In geophysics, it is important to carry transects across national boundaries and to overfly with balloons and satellites. Exclusive Economic Zones off the continental shelves are important to protect resources but interfere with the freedom of research.

- Economic and political considerations restrict the feedom of scientific exchange.

5. Will spending of national funds on international facilities be to the detriment of national efforts? What is the appropriate level of funding on national research efforts versus international efforts and how should these levels be determined?

- Astronomy and geopohysics are already characterized by strong cooperative efforts.

- In the era of the Space Station, astronomy missions will reach "World Class" status. With the HST already over the one billion dollar mark, the next generation must be even more expensive. There may be no alternatives to international cost sharing if the major future goals of astronomy are to be achieved.

- In geology, international cooperation doesn't necessarily require major international facilities. Freedom to work in foreign lands permits the individual geologist to extend his research with relatively modest portable equipment.

- Major national facilities in geology, such as seismic arrays and radio interferometers for earthquake research, frequently run to $10M and higher. There are few alternatives to exclusively national support for such facilities.

- Space geophysics is already highly organized on an international basis. Scientific progress will be achieved primarily through missions such as the ISTP program already mentioned in connection with question 2. The largest segment of the national scientific community of space plasma physicists is committed to support joint multi-spacecraft missions.

6. What does "world leadership" in either astronomy or geophysics mean? What particular benefits accrue to the "world leader" versus "number two"? Why should national policy makers care whether or not the nation is first, second or third in either astronomy or geophysics?

- "World leadership" means that American scientists are working at the frontiers of important science and contributing a major share of the new discoveries.

- Science is intrinsically highly competitive. Every scientist must strive to be a leader in his field. To be "number two" is hardly worth the effort and doesn't rate a high level of support. We should beware of supporting cooperative science primarily for the sake of cooperation. If the area of cooperation covers second class science, we should not associate with it.

- Since applied science and technological developments follow from research, being the leader in research is essential to guarantee leadership in technological developments.

- From the standpoint of national pride and prestige, leadership in research as measured by Nobel Prizes, for example, is a statement of the success of American democracy and personal freedom of choice that all the world must admire and envy. Given the increasing costs of major facilities, it becomes less and less possible to support leading scientific thrusts in all disciplines on a national basis. Where a major international facility has the world leadership role, it is important for American scientists to be part of that team and to achieve leadership roles within the team.

7. Are the experiences of international cooperation in either astronomy or geophysics directly applicable to other fields of science? What lessons may be learned?

- The experiences of international cooperation in astronomy and geophysics are not intrinsically different for other sciences. However, as the answers given above make clear, the formats for cooperation in astronomy and geophysics are especially conducive to cooperation. The national investments are spent at home as each partner prepares his special contribution to a complex mission.

- In the case of a large accelerator, such as the SSC, most of the expenditure feeds the economy of the area in which construction takes place. If the U. S. builds the accelerator, we can at most expect other countries to support the construction of beam port instruments at home and finance their use at the accelerator. The experimental equipment would not likely exceed 20 percent of the cost of the accelerator itself.

Mr. Fuqua. Our second witness is Joe Gavin, the chairman of the executive committee of the Grumman Corp., and most recently its president. Mr. Gavin has recently served as the chairman of the National Research Council's Committee on International Cooperation in Magnetic Fusion Energy, and will present the results of that committee's study.

Thank you for being back once again, Joe, before at least some parts of the Committee on Science and Technology.

STATEMENT OF JOSEPH G. GAVIN, JR., CHAIRMAN OF THE EXECUTIVE COMMITTEE, GRUMMAN CORP., BETHPAGE, NY

Mr. Gavin. Thank you, Mr. Chairman. It is my distinct pleasure and an honor to be here today.

I am just going to hit the high points of the conclusions made by our committee.

Mr. Fuqua. We will make your prepared statement in its entirety part of the record.

Mr. Gavin. Yes. I understand.

The timing, I think, is important. This study occurred between September 1983 and September 1984. In reviewing it here recently, I think that the principal conclusions remain substantially sound. I see no reason to change them.

For the benefit of the listeners here today, I would say that the committee consisted of a number of people of quite varied backgrounds, and that a great deal of homework was done before visiting abroad. We talked to quite a number of people who are involved in both commercial and governmental international collaborative efforts before we went to visit in Japan, and in Germany, and in Europe. We visited in Europe, not only Germany, but France, and England, and also in Brussels, the European Community.

Now, it was a good time to have done this because at that time, and at present, I would say that the general goals of these major islands of effort were quite similar. The attitudes, however, were quite different. And I must say that our report did not attempt to rate various technical progress or machines. We were principally interested in attitudes, predictions for the future as to how things would go, and therefore this is not a report which gives you numbers for answers. It presents a number of views and where we encountered perceptions, we tried to report them as faithfully as we could, even though in some cases we weren't sure we agreed with those perceptions.

Let me just run through some of our conclusions.

We discovered that in the past the cooperation at the scientific level certainly had been very good, and there was a sufficient community of interest so that you could say it was a sound basis for anything that we try to put together for the future. We also concluded that while this country perhaps had three options: go it alone—spend the money to be the leader; collaborate in what might be the most effective global effort; or withdraw and face the fact that at some future date the technology would be licensed for some consideration in the future.

We felt that in the balance there was an advantage for joining on an international basis and that these benefits were not only domestic but would perhaps provide a sounder long-term development—not that the total involvement would cost less, but the cost per partner could be less than should any partner go it alone.

We also concluded that there seemed to be a window for trying to establish large-scale collaboration. The reason for that is if you consider the status of the Joint European Torus, the Tokamak at Princeton, and the JT–60 in Japan, it is quite apparent that there is work to be done with these large machines, and there is going to be several years of planning very likely before the next major experimental effort reaches the point where actual construction would begin.

So it seems as though that we have 2 or 3 years here where the essential planning could be carried out before major commitments were made for what various people have called The Next Step—The Fusion Engineering Reactor and so on.

The conclusion that goes with that, however, is that we came to the understanding that it isn't going to happen overnight. Large-scale international collaboration will not come about quickly.

There are a variety of reasons for that. In the first place, the attitudes of the three areas that we considered are quite different. The motivation in Japan is driven by the lack of energy resources and the fact that fusion development has an approved status which is a little bit different from that in either the United States or in Europe. In fact, the Japanese attitude is very straightforward, that, yes, some level of collaboration might make sense as long as it didn't interfere with their approved program. That is, their approved program had priority and it was very clear that that decision had been taken, and it represented their first consideration.

In Europe, we encountered what I considered a very interesting demonstration of international collaboration already. The European Community had raised the money and established the team and provided the infrastructure for building the Joint European Torus, which seems to have been not only a technical success but certainly an administrative and diplomatic success.

I think in Europe it is fair to say that the attitudes vary from country to country. I think that the British attitude, you might say, was softened somewhat by the fact that the North Sea oil appears to be of some duration, perhaps 10 years, perhaps 15.

I think in Germany there was more of a scientific curiosity, a desire to regain a position of leadership in this science and technology.

In France, I think the attitude again was slightly different, in that with the armlock which they seem to have on the breeder reactor, it wasn't clear that fusion had quite the priority, but still there was a feeling of wanting to be in the lead in this development.

So it is going to require a reconciliation of some of these attitudes as well as the detailed programmatic plans in order to determine what is real collaboration. I think it is one thing to arrive at an understanding at, say, the highest political level that collaboration is desirable. I think it is quite another thing to arrive at a roadmap which has been put together by people who understand in great detail what has to be done from an engineering or technical or scientific point of view to produce an approved program.

The next conclusion that we came to was that international collaboration will require stable international commitments. This is something that we as a group of Americans on this committee found very interesting to listen to, but it was told to us politely, bluntly, and on the side, so to speak, that America was not regarded as a very reliable partner.

Now, I realize that the narrow difference between agility on the one hand and reliability and consistency on the other is sometimes debatable. But there have been other areas of endeavor where we apparently have unilaterally changed course without adequate consultation and these scars persist.

So I think that there is going to be quite some discussion as to just how much of an international commitment, how firm a commitment can be made.

I might point out in this connection that in contrast to our annual budgeting tradition, that the European Community, in the case of the Joint European Torus, set up a 5-year plan. It is reviewed annually, but the major revision of the budget occurs at the 3-year point. So in this sense, there is more of a stability in what the plan is and what the funds are to support it compared to what we are accustomed to. This, I believe, is the type of difference that exists that we would have to find a way to satisfy potential partners or to live with ourselves.

Then beyond that there are a host of other considerations that have to be resolved, and I don't think we have found any that were completely unworkable. But, for example, there is the matter of everything from the ownership of intellectual property, licensing provisions, and so on. And these things differ to such a degree that it is going to take a fair amount of effort by joint planning teams to see what is the best solution.

I think that one of the reasons we felt—or the principal reason that we felt—that large-scale international collaboration was preferable—and now I am speaking for the committee as accurately as I can, is the fact that for a program that has potential results so far in the future, it did appear that it was to the advantage of these United States to be involved with an international program which would have the best potential for, first of all, doing a decent job but also being stable over the period of time that this research was being carried on.

So out of these conclusions, we have developed two recommendations. The first was—and I will read it—"The first priority should be the establishment of a clear set of policies and objectives and a considered program plan for future U.S. fusion activities."

Now, that sounds very straightforward, but I must say that the current Department of Energy plan is not sufficiently detailed to be understood by potential European or Japanese collaborators, and that a fleshed-out version is an absolute necessity before any joint detailed planning could proceed profitably.

I think there is still a concern abroad that we really have not pinned down what it is we want to do. I might say that it was during the course that we were overseas having some of these discussions that the projected core burning experiment disappeared from the scene, and I think confirmed in the minds of some of the people that we talked to that we had not really pinned down a program.

I am not debating the wisdom of that move. I am just telling you what the perception was. It was clear evidence that we did not have as firm a plan from which to speak as existed abroad.

The second recommendation is that, having carried out the development of a more detailed and considered program plan, the United States should take the lead in consulting with prospective partners to initiate the joint planning effort that is the first step toward collaboration.

I think that, in looking back at it, we would not today probably change those recommendations one iota. There has been progress made, of course, both abroad and here since that report was written. The JT–60 is up and running in Japan. Progress has been made at Princeton, and the European programs have proceeded.

Those, Mr. Chairman, are the highlights of our report.

[The prepared statement of Mr. Gavin follows:]

TESTIMONY BY JOSEPH G. GAVIN, JR.

BEFORE

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

Science Policy Task Force

INTRODUCTION

Mr. Chairman and Members of the Committee, I am Joseph Gavin, Chairman of the Executive Committee, Grumman Corporation. I am pleased to testify before you today on international cooperation of magnetic fusion energy.

Because the magnetic fusion process holds unique promise as a long-term energy source, efforts have persisted for many years to solve its challenging scientific and engineering problems. Major programs have been undertaken by the United States, Europe, Japan and the Soviet Union. As the size and complexity of the experimental devices have grown, international cooperation has occurred in order to produce earlier results, to share risk, to minimize investment or to acquire skills. Faced with even more demanding future program requirements, officials of the U.S. Department of Energy are considering whether greater levels of international cooperation in magnetic fusion is desirable.

In September 1983, I was asked by the National Research Council to Chair the Committee on International Cooperation in Magnetic Fusion Energy. The Committee consisted of ten members with broad backgrounds in electrical engineering, plasma physics, fusion technology, fusion reactor design, industrial participation in high technology projects, energy supply, technology transfer, and the legal, diplomatic and political aspects of international governmental ventures.

The purpose of the committee was to study and recommend a worthwhile course of action in international cooperation as measured by the criteria of acceptable policy, technical merit, and practical workability.

To accomplish this, the committee:

A. Identified and addressed the most important issues in international cooperation in magnetic fusion energy.

B. Reviewed and discussed alternative avenues of cooperation in view of scientific, technological, and engineering needs of fusion power.

C. Reviewed U.S. goals and objectives for the development of magnetic fusion as they may be phased over time and as they relate to technological progress, industrial involvement and selected socio-economic factors.

D. Identified and characterized long-term implications of various avenues of international cooperation with respect to U.S. goals.

E. Obtained the views of leaders of the U.S. and foreign fusion communities on the matter of benefits already realized from international cooperation in magnetic fusion energy and benefits expected from enlarged cooperation.

F. Recommended, with limitations, avenues of future international cooperation.

The committee also relied upon information obtained through various meetings with selected members of the Department of Defense, the National Aeronautics & Space Administration, and other Government agencies with experience in international cooperation.

DISCUSSION

The four major magnetic fusion programs of the world, the U.S., EC, Japan and USSR, are of comparable magnitude and are at a comparable stage of development. In each of these programs is a "Scientific Feasibility" experiment based on the most advanced magnetic confinement concept, the TOKAMAK. The U.S. and European Community (E.C.) programs recently started operating; within the next year or two, programs will begin operation in Japan and USSR respectively.

Broadly speaking, the near-term technical objectives of program planners in the four programs are similar:

1) To maintain a vigorous scientific base program

2) To initiate a major "next-step" TOKAMAK experiment

3) To continue to develop the less mature alternative magnetic confinement concepts

4) To expand the fusion technology development program

Pursuit of these objectives is financially constrained, in various degrees, in each of the four programs.

The physics of laboratory plasmas at near fusion conditions is essentially an experimental science today. World leadership in fusion generally resides in that country possessing the experimental facilities with the greatest capability to explore the frontiers of plasma physics.

Although you are well acquainted with the U.S. fusion energy program, I will comment on it to establish consistency in presentation. The U.S. has a strong experimental TOKAMAK program that has established many of the world record plasma physics parameters. Two of these experiments, TOKAMAK Fusion Test Reactor (TFTR) and Doublet III, should continue to extend the knowledge of plasma physics for the next five years or so. The U.S. also has the leading experimental program in the tandem mirror confinement concept which is the most advanced alternative concept. Smaller programs are going forward in other less advanced alternative magnetic confinement concepts.

The EC program is perceived by its participants to be on the threshold of assuming world leadership in fusion. This is based on a new generation of TOKAMAK experiments commonly known as JET, TORE SUPRA, ASDEX-4 and FTU that will be operating over the next decade. This view is shared by many in the U.S. The EC program managers believe that they should maintain their progress toward leadership by constructing a major new TOKAMAK experiment, Next European TORUS (NET), to operate in the mid to late 1990's. NET has the physics objectives of achieving an ignited plasma and a long-burn pulse and other ambitious technological objectives. Planning and conceptual design work on NET has been authorized by the Council of Ministers of the European Community and initiated at the technical level. The decisions whether or not to proceed to engineering design and to construction will be made in 1988 and 1992 respectively.

The Japanese fusion program is relatively newer than the other three major programs, but is moving rapidly toward full parity. The program of the Japanese Atomic Energy Research Institute (JAERI), under the Science and Technology Agency, is concentrating on the TOKAMAK and on fusion technology. The JT-60 TOKAMAK, which will begin operation within one year, will have confinement capabilities comparable to those of TFTR although JT-60 is not designed for deuterium-tritium operation. Conceptual design studies are in progress for a new major TOKAMAK experiment, the Fusion Experimental Reactor (FER), to operate in the mid to late 1990's. FER would have objectives similar to those of NET. The Fusion Technology Program is comparable to the U.S. program although not as broad.

The committee did not look into the fusion program of the Soviet Union. However, it is known that the USSR program is advanced to a level comparable with that of the other three major programs. The USSR program has historically been characterized by strong scientific insight. Past cooperation with the USSR has been technically fruitful and could beneficially be expanded from the rather modest current levels if U.S. policy constraints change. Policy issues could change sufficiently in the future to make renewed scientific cooperation with the USSR desirable; in that event, fusion would be a suitable vehicle.

CONCLUSIONS

A formal bilateral agreement with Japan has covered many cooperative activities over the past few years. There exist formal, multilateral agreements among the U.S., Japan and the EC for several cooperative activities under the aegis of the IEA. The U.S., Japan, EC, and USSR under the IAEA are cooperating in the International TOKAMAK Reactor (INTOR). Previous cooperative undertakings in fusion have been substantial and generally successful. With this background, the committee concluded:

PAST COOPERATION PROVIDES A SOUND BASIS FOR FUTURE EFFORTS

The extent to which any national or multinational fusion program will be willing to rely on international cooperation rather than its own strength and direction is a policy issue; the resolution of which may place constraints upon such cooperation. The main incentives for increased international cooperation are the expectation of enhanced technical results, probably cumulative savings -- through sharing of cost and risk -- in human and financial resources compared to those required by a separate program and long-run merit as seen at the heads-of-state level. For those and other reasons the committee concluded:

ON BALANCE, THERE ARE SUBSTANTIAL, POTENTIAL BENEFITS OF LARGE-SCALE INTERNATIONAL COLLABORATION IN THE DEVELOPMENT OF FUSION ENERGY

The points made previously concerning the approximate parity in the status of the world programs, their similarity in objectives, the gathering momentum of the EC and Japanese programs, the existence of technical needs and opportunities, political and administrative receptivity, and the absence of near-term competition in the commercialization of fusion support the following conclusion:

A WINDOW IN TIME FOR LARGE-SCALE COLLABORATION IS NOW OPEN

The EC and Japanese Fusion Program Plans have been developed in detail for the next few years and resource commitments have been made accordingly. Any major collaboration must meet the requirements of the separate national programs and therefore must be preceded by joint planning. Broader U.S. policy considerations may be at odds with technical opportunities for cooperation. The USSR has proposed joint international construction of the next step TOKAMAK experiment, yet it is unlikely that U.S. - USSR collaboration is possible in the current circumstances. Japan is willing to discuss further major collaboration, but in the U.S. there exists a political sensitivity to Japan on economic grounds. On the other hand, the EC, with whom collaboration would be the least controversial, shows little interest. These points are realized to the following conclusion:

LARGE-SCALE INTERNATIONAL COLLABORATION CAN BE ACHIEVED BUT NOT QUICKLY

The U.S. Government is perceived by some as lacking a firm commitment and a realistic plan to develop fusion. A clear policy statement on the goals of the U.S. fusion program and a corresponding plan to meet these goals not only would be helpful for evaluating proposed major international cooperative projects but would also improve perceptions of the U.S. commitment. The U.S. is also perceived by some as an "unreliable partner." The annual funding appropriation process makes it difficult for the U.S. to commit to multiyear projects without the possibility of facing a choice later of either going back on the commitment or sacrificing other elements of the fusion program. Requesting explicit budget items for international projects, after clear identification of the obligations implied for subsequent years, may ease the problem. The above factors result in the following conclusion:

INTERNATIONAL COLLABORATION WILL REQUIRE STABLE INTERNATIONAL COMMITMENTS

Technology transfer arises as an issue and a possible constraint in three areas: national security, protection of U.S. industry, and loss of advantage to foreign participants from technology developed by them because of provisions of the U.S. Freedom of Information Act. However, technology transfer does not seem to be a major concern at this time because of the remoteness of significant military or commercial applications of magnetic fusion.

There are numerous institutional choices for implementation of international cooperative agreements. Treaties constitute the most binding commitments to the U.S. Government but are the most difficult agreements to conclude. Existing international organizations such as IEA and IAEA offer auspices under which more extensive international cooperation could be carried out without the necessity of new implementing agreements. However, neither of these agencies or other existing international organizations would be suitable as sponsors for a major international project because they function primarily as coordinators and administrators and not as managers since they have their own priorities. Generally, a joint international project is complicated, but it can work if it is carefully planned and executed. The committee therefore concluded:

THERE ARE A HOST OF CONSIDERATIONS THAT MUST BE RESOLVED IN IMPLEMENTATION, BUT THESE APPEAR WORKABLE

In the course of its domestic workshops and its two overseas trips, the committee covered a wide range of topics concerned with international cooperation in the development of controlled magnetically confined fusion. The study considered "cooperation" in the general sense of acting with others for mutual benefit on either a small or a large scale and "collaboration" in a somewhat more specific sense of working actively together as approximately equal partners in sizeable enterprises.

The various meetings identified three qualitatively different paths to fusion energy that are open to the United States,

1) To make the commitment to become the all-out competitive leader in all its aspects

2) To engage in large-scale international collaboration

3) To withdraw with the intent of purchasing the developed technology from others in the future.

Reviewing the above and the individual conclusions stated earlier, the overall conclusion derived by the committee was:

> For the U.S. at this time, large-scale international collaboration is preferable to a mainly domestic program which would have to command substantial additional resources for the competitive pursuit of fusion energy development or run the risk of forfeiture of equality with other world programs.

RECOMMENDATIONS

Given this overall conclusion, two major recommendations follow:

The first priority should be the establishment of a clear set of policies and objectives and a considered program plan for future U.S. fusion activities.

The above is a necessary prerequisite for discussion with potential partners and for any long-range commitments that ensue.

Having carried out the preceding recommendation, the U.S. should take the lead in consulting with prospective partners to initiate a joint planning effort aimed at large-scale collaboration.

This joint planning activity would have to involve groups at the program leadership level and at the technical leadership level in appropriate roles and would have to be a continuing focused activity over many years.

DISCUSSION

Mr. **Fuqua**. Thank you very much, Joe.

You and I discussed this, I guess, prior to its release several months ago.

Mr. **Gavin**. Yes.

Mr. **Fuqua**. You mentioned the lack of commitment or appearance of lack of commitment on the part of the United States and that we were not a reliable partner.

Now, are we not putting the horse before the cart if we come up with a comprehensive plan and go to our potential collaborators and say, "Here is our plan. Do you want to join in," and then they say, "Well, you never asked us to participate in drawing up a comprehensive plan, and we think we know something about fusion energy," as has been evidenced by what has happened in Europe and also in Japan, who are probably our two most likely collaborators?

Mr. **Gavin**. I think the answer is very straightforward, and that is that until we have demonstrated that we can put together and have approved at the highest levels of the administration a plan, we are not going to be in a position to discuss collaboration.

I am extrapolating from the committee's work in saying that, so I suppose this represents a more personal opinion. But from conversations we had, I believe that it is absolutely essential that there be a plan that is underwritten both by the Congress and the administration where we can say, when we meet with potential partners: "This is what we have in mind to do. Now let's get together and see wherein we can find economies between us or better ways of doing things or some division of the work so that everybody doesn't have to do everything individually."

The Europeans, I think, have done this to a certain extent, but if you look at the national programs that are going on in the various countries, you will find that there has been a reduction in the amount of duplication. And certainly, the support of the Joint European Torus has been, I think, a remarkable demonstration of what can be done by collaborating, because certainly no one country could have comfortably supported that effort.

Mr. **Fuqua**. I know you were primarily involved in fusion. But would you say that would apply to other big science projects?

Mr. **Gavin**. I think they have to be looked at individually. There seems to be a very large difference in where the potential partners stand at the beginning of any collaboration. For example, I am familiar with NASA and the Space Station, and it seems to me that there this country has quite a different position with respect to its potential partners as compared to where we stand in the fusion research. We have made tremendous investments. We have done a lot of work which has not been duplicated elsewhere. And it seems to me we are in a position to be a stronger leader. I think in the case of fusion as it stands today, we seem to be losing any edge that we have, so that we are forced really to be a leader amongst equals more than perhaps is necessary in dealing with the Space Station.

I think that in the case of almost any other international collaboration, one has to look very carefully at the background that each partner brings, to decide what is a reasonable approach.

Mr. **Fuqua**. Mr. Packard.

Mr. **Packard**. Thank you, Mr. Chairman.

Let me carry this world leadership question a little bit further. Our national labs have an inherent interest in these kinds of research projects. I am wondering if world collaboration tends to detract or enhance our own national lab efforts in terms of world leadership?

Mr. Gavin. I think the only answer that can be given to that is to look at Europe, where international collaboration has occurred, to see what has been the outgrowth of that. I would say that there is some indication that the program, the science program in fusion in Great Britain has been inhibited a bit by the fact that that is the site of the Joint European Torus.

On the other hand, it appears that in France, Germany, and Italy, that the national programs are vigorous and alive. And I really don't have a basis for saying that the siting of the Joint European Torus is the entire reason why that difference seems to exist.

I think that obviously in any collaborative venture, we would have to look very carefully to see what elements of research should be retained in our national laboratories. I think that this is not only a matter of how you divide up the money, I think it is also a matter of trying to make sure that the various apparent directions of effort are adequately covered.

I think that certainly fusion is at the point in development that it would be a mistake to put all of the eggs in one basket at this point. There are still some alternative devices and approaches which need to be better understood.

Mr. Packard. If we are considered to be poor partners in a collaborative effort or a cooperative effort internationally, what specific things do you think we ought to do to change that image or that perception? If, in fact, your recommendations are carried out, and we do move forward on an international basis and a cooperative basis, then what should we do to change that perception?

Mr. Gavin. Well, I think that obviously any agreement should be approved at the highest level. I don't think it has to have, perhaps, the full force of a treaty, but it ought to be the next level down from a treaty.

I would suggest that since we have introduced the innovation already of buying certain items on a multiple-year basis in the military budget, that perhaps in some of these research budgets, that 2-year budgets would not be unreasonable to provide an additional stability to the program.

I think also that in any international undertaking like this there has to be two different kinds of committees involved to advise the governments. I think there has to be a technical committee and I think there has to be a committee that, in my jargon, would be a group of businessmen, people who understand the financial impact of these things and who perhaps are in a position to look forward.

The fusion program is certainly one where it takes a lot of long-range looking forward to see what the potential industrial impact is. This is something that, as long as you are operating in pure science, say, in the supercolliders, it is not clear that there is any industrial fallout to come. But if you look at the fusion program today, one would have to say that Japanese industry has been more involved and more directly involved than industry has been in this country, and I think perhaps more so than in Europe also.

But that is still a long way off, that potential industrial impact, but there should be somebody involved in this international collaboration to think about that. That is why I say I think you need a technical committee and, for want of a better term, a businessmen's committee to advise the Congress and the administration as to the progress of whatever program is undertaken.

Mr. PACKARD. Do you believe that the industrial and business community in the United States is largely neglected in terms of policy setting, and are we neglecting to some degree an involvement financially and otherwise with the private sector in our national science policy?

Mr. GAVIN. Well, it's hard to generalize there, because industry in this country varies so widely. Some have future horizons that are very close, and others that are really quite distant. In our particular business, new programs appear to be taking 10 to 12 years to reach fruition. That is a lot further than the next quarter. I think that there are many other industries in this country perhaps that involve less complex products where the future is much closer, and I think that it is very hard to generalize about policy planning for American industry. I am not an expert in it, but I think it is a big, very complex problem.

Mr. PACKARD. I don't wish to take longer than my 5 minutes, Mr. Chairman, but in the past we have discussed concerns about the fact that we have been outpaced by other countries—Japan is a significant example—in terms of applying much of the technology that comes out of our pure science programs. It may be that we are not doing or not involving the private sector in the scientific research areas as much as we could and should, and therefore we are not picking up the application of a lot of the information that we gather to where it becomes a marketable product. We are being, I guess, outmarketed by other countries in these applied areas.

Mr. GAVIN. Well, there is no question but that we are in a global economy. I would not want to be thought to be passing the buck. Frankly, I think that American industry can look to itself first with regard to being competitive. I think that there is a lot to be done right at home in a lot of companies to be more competitive. I may not make too many friends amongst my contemporaries by saying that, but the fact is that it can be done.

Mr. PACKARD. Thank you, Mr. Chairman.

Mr. FUQUA. Mr. Lujan.

Mr. LUJAN. Thank you, Mr. Chairman.

You know, I am not sure what international cooperation means, other than keep going in the direction of big machines. The Committee on International Cooperation in Magnetic Fusion Energy, it seems like all of the discussion is weighted towards Tokamak, and although the contention is that we don't really have a fusion program in this country, the fact of the matter is that we do. And that is a concentration on big machines. Putting aside the alternative concepts, I had occasion on two or three times, I guess, to try to take a shot of the dice, I guess, on some alternative concept and see if it works.

But the fact of the matter is that there is a stranglehold by the Tokamak community on the whole fusion program, and whenever you suggest something like that, it's going to take some of the money from the Tokamak, so that we are not really aggressive at doing alternative concepts.

Do you see that our participation in international efforts should be in those big expensive projects, and not address the alternative concepts in this area of international cooperation? You have mentioned it only once in your testimony, and only kind of as one of the things that we should do amongst the four things that you recommended, and didn't show up at all in the rest of the testimony.

Mr. GAVIN. Well, I think I touched on it very lightly earlier this morning, in putting out that one aspect of collaboration is to avoid duplicating efforts in some of these alternative approaches. It certainly seemed to me that the major forcing function for our international collaboration is the fact that these big machines are terribly costly and require a fairly long period to conceive, design, build, and put into operation.

I think that in all the places that we visited, there was a healthy activity with regard to certain alternatives—the reversed field pinch, for example—and then the question is, "Well, how many of those do you need?" And it would seem to me that international collaboration would tend to reduce the duplication amongst the alternatives and, in fact, it might produce more rapid progress with some of the alternatives.

I am not in a position to recommend which alternative or to debate that point, but I do think that certainly the consensus we ran into is that we should not abandon the more promising alternatives prematurely even though there was a consensus—and I think I can report that consensus accurately—that the magnetic fusion, basically the Tokamak or something like a Tokamak seemed to be the dominant mode and the one from which the next step should proceed. There is a lot of debate as to just what that next step should be and how big a step it should be.

Mr. LUJAN. Do you think we have abandoned some of those alternative concepts prematurely?

Mr. GAVIN. I am not sure that I am qualified to comment in detail other than that I suspect that some of the alternatives might move faster if there were a joint program.

Mr. LUJAN. NET, according to your testimony, has the objective of achieving an ignited plasma in a long-burning mode. That's the objective of NET. That is the same objective that we have in proposing this fusion engineering facility. We both have the same objective, is that so?

Mr. GAVIN. The basic objectives of all communities are roughly the same, I think. I think it's true that the studies done at Oak Ridge in the past few years have been aimed at about the same direction as the NET in Europe or the FER in Japan. I think some of the details are different, but the general size of the step seems to be similar.

Mr. LUJAN. Would it then make sense that we participate with the Europeans in NET instead of going it alone?

Mr. GAVIN. It's possible, but I will go back to what I said earlier. I think that until we have worked over some rather detailed plans to see how to do it and what to do, it's not clear that you can jump to that kind of conclusion. I wouldn't jump to that conclusion.

Mr. LUJAN. Weren't we ready to do that here about 4 or 5 years ago? I thought we, if my memory serves me correctly, we were looking at a facility of that kind, authorizing one and moving on ahead with it. So I just was under the impression that the fusion community was in agreement that the next step should be, and rather quickly, to authorize and establish a facility where we could achieve ignition.

Mr. GAVIN. Well, yes, I would have to say that if there had been no concern about the amount of funding required, that possibly that step could have been started. Whether in hindsight today it would have been the wise thing to do, I can't say.

Mr. LUJAN. We have some other things to do before?

Mr. GAVIN. Well, most recently, of course, there has been, if you go back a year, there was the consideration of the core burning experiment, which was sort of a halfway step to whatever the Oak Ridge study was finally called. And more recently there is talk about a much more limited ignition experiment, which would be essentially a scientific experiment as opposed to an experiment designed to develop engineering data, which would be useful in a progression of further development.

So at this point it's not clear to me what the best next step for this country would be. I am going to be confusing you with "next steps" here in a minute, but it's not clear to me what precise direction of the present plan is, because there are discussions going on about a minimum ignition experiment which can be argued to have some merit in that it would be relatively inexpensive and it could be accomplished perhaps in time so that whatever large more engineering oriented machine is considered for the future could benefit from that background.

Mr. LUJAN. Is NET that larger, more sophisticated engineering machine, or is it intended to be the limited experiment that we talk about here, because that is what I understand. We used to be talking about a $20 billion machine; now we are talking about a $3 billion machine. So I assume for $3 billion you don't get quite as much as you do for $20 billion. Is it a 3 or a 20?

Mr. GAVIN. NET, it's my understanding, is a very large machine.

Mr. LUJAN. Is it the equivalent of our 20?

Mr. GAVIN. Well, I am not going to confirm your 20 because that is a number that I am not familiar with.

Mr. LUJAN. Yes.

Mr. GAVIN. But it is a large undertaking.

Mr. LUJAN. Larger than this limited experiment?

Mr. GAVIN. Certainly, much larger than a limited ignition experiment.

Mr. LUJAN. You don't think we are ready to go into that, so you think we should not participate with it? We should continue with—for lack of a better description—the $3 billion? I am trying to find out—I really do not understand, because we keep pouring all this money, $300–$400 million a year, and I don't see anything happening.

Mr. GAVIN. Well, I believe that you should get a report as to the most recent progress at Princeton. I think progress has been made. I think there is a better understanding of what is going on in that machine, and I think that compared to, say, 3 years ago, between the Joint European Torus and the Princeton machine, a great deal is understood which wasn't previously understood.

Now, I believe that—well, first of all, I am not going to make a statement as to whether we are ready to do something or not, because I am an engineer, not a scientist, and we are still in the science part of this program.

I think it perhaps becomes very complex as to how science and engineering do become related because I think in this particular endeavor the two are very tightly related because some of the things that are postulated by the scientists just aren't going to happen unless some awfully good engineering is accomplished.

The real question then is how big a step to take beyond what we have currently in hand. This is something I think should be debated by people that are better qualified than I am in considerable depth. One of the reasons why we have to have a better understood and approved program is so that we can enter those discussions on an equal basis, and I think that if we can do that, there is some chance that an international collaboration will be of advantage to all of us.

Mr. LUJAN. Thank you, Mr. Chairman.

Mr. FUQUA. Joe, thank you very much.

Mr. GAVIN. Thank you, Mr. Chairman.

Mr. FUQUA. We hope we didn't keep you over your time.

[Answers to questions asked of Mr. Gavin follow:]

QUESTIONS AND ANSWERS FOR THE RECORD

Mr. Joseph G. Gavin

1. **What are (a) the advantages and (b) the disadvantages of sharing the cost of big science facilities on an international basis?**

There are usually many advantages and disadvantages associated with cost sharing international projects. The urgency and nature of the project and the prior relationship of the countries involved will affect the advantage/disadvantage ratio. Generally speaking the following advantages can be stated.

a. if properly managed, should save money for each participant, e.g., two countries cooperating on a large project may typically result in total cost about 1.5 x that of doing it alone - producing savings for each of about 25%.

b. Combined brain power may produce a more effective product.

c. Existence of international agreements may stabilize national programs.

d. Existence of international programs may improve international political climate.

The types of disadvantages to be expected are:

a. Difficult to agree on what, when, how, and where.

b. More difficult to manage.

c. Will take more time.

d. As a result of above could actually cost each country more than doing it alone.

e. Requires multi-year commitment.

f. In some cases makes countries interdependent.

g. Several facilities result in more variety -- one group may pick up vital information missed by the other -- perhaps due to differences in design.

2. **What would be the best worldwide configuration of magnetic fusion energy facilities from the point of view of developing its potential? How might this best be determined?**

This question is being addressed in two parts. First:

<u>Plasma Confinement Experiments</u> - Not only are there many different magnetic confinement geometries, but even within one there are many different possible choices of parameters, for example, in the case of the Tokamak, some of these are:

a. Scale size

b. Strength of magnetic field

c. Aspect ratio (long skinny to short fat)

d. Shape of cross section -- round, elliptical, bean and others

e. Method(s) of heating

f. Wall material

g. Diverters or limiters (many different varieties)

Modest size experiments are essential in filtering out the various possibilities. It is completely impractical to design all these variations into one - or even a few - experimental devices. Thus the dozens of modest size experiments around the world have combined to form a data base that was utilized to make parameter choices for the next phase of larger and better machines. This has, in turn, provided a way to check the earlier data as to its relevance. So to answer the question:

In the early phases of modest, exploratory devices, it is important to have many different exploratory experiments. The normal scientific competitive urge will ensure that these experiments are not really duplicates. These small machines can be modified fairly rapidly and at a relatively low cost. Thus dozens of small Tokamaks have been well utilized around the world.

With increased knowledge it has been possible to design and build a smaller number of larger devices with plasma parameters closer to reactor requirements. Here again they effectively supplement one another in building an international data base.

The main point of all this is that Tokamaks would not have occupied their present dominant position (and conceivably could have been cast aside completely) had it not been for the strong interaction between competing groups.

So much for the Tokamaks--but the variety of parameter choices involved in the Tokamaks is substantially exceeded by those in stellarators and other confinement geometries. Thus it would not make sense, in the exploratory phases in particular, to subdivide the work with each nation taking on the task of developing one approach.

Second, <u>Materials</u> - Here the situation is different. The problems are to a greater extent separable. For example, the task of development and characterization of new alloys for fusion application can be (and are to some extent) organized and subdivided between the international participants. Some larger test facilities will be needed. At present, Japan and the EC are following a somewhat different approach that the U.S. The EC and Japan are focusing their development activities on those required to build next generation Tokamak devices leading to a demonstration reactor, casting aside for now the question as to whether the results would be applicable to an operating reactor. In the U.S., with no present plans for an integrated "proto reactor", the modest development program is aimed at reactor relevant issues.

3. **Should federal science funding include the aim of keeping the U.S. first in every field of science, and if so, will international cooperation be either beneficial or detrimental to achieving this aim?**

   Federal science funding cannot aspire to keep the United States first in every field of science. The U.S. is not currently the leader in every field and it would be impractical to target more than a reasonable number of scientific fields for U.S. leadership. I believe that it is important that certain fields be targeted and that these fields be pursued consistently and vigorously.

   Whether international cooperation is beneficial or detrimental in the case of those fields of science targeted for leadership depends on a number of factors. These range from national aspirations to cultural perceptions. In this connection it appears quite clear that a leader in a particular field of science can attract international cooperation. A follower may have to pay some form of entry fee in order to gain access. In summary, I believe it is important to focus our attention on those fields that we have the motivation to pursue consistently and vigorously; spending our resources across <u>every</u> field can only work against aspirations for leadership.

4. **What is the trend of international collaboration in magnetic fusion energy? Is it increasing, decreasing or remaining relatively constant?**

   Indications are that the trend of international collaboration in magnetic fusion energy is increasing in value received but not necessarily in the overall dollar expenditure. Efforts are being made to increase hardware participation in exchange for scientific and technical data.

5. **What attributes of magnetic fusion energy make international cooperation easy to achieve?**

   Does the field have attributes that make international cooperation difficult?

   <u>Easy to Achieve</u>

   1. Attractiveness of goal
   2. Fundamental physics involved
   3. Commercialization many decades off
   4. Everyone wants high technology know-how
   5. Mostly positive past experiences with international cooperation

More Difficult

1. Eventual commercialization
2. Differing objectives of national programs
3. Fluctuations in national policies
4. Some examples of unsuccessful cooperation
5. National pride
6. "Needs" of established national institutions

6. **What factors either (a) facilitate or (b) inhibit international cooperation in magnetic fusion energy?**

Factors which facilitate international cooperation include promise of enhancement of needed technical progress, potential expansion of long-term economic benefits for each participant, possibility of saving cumulative development cost over the long term, achievement of worthwhile political objectives, and broadening of fusion constituencies.

Factors which inhibit international cooperation are imposed by policies to preserve the strengths of the various national programs and to seek national prestige through technical leadership in fusion. Taking into account the views of the groups who would be affected by expanded cooperation, the weight of the "pros" prevails over the "cons". Thus, on balance, there are substantial potential benefits of large-scale international collaboration in the development of fusion.

7. **What does "world leadership" in magnetic fusion energy mean? What particular benefits accrue to the "world leader" versus "number two"? Why should national policy makers care whether or not the nation is first, second or third in magnetic fusion energy research?**

"World Leadership" in magnetic fusion energy implies the potential for developing an export market; or as a minimum, the avoidance of dependence on importing the technology. Two examples come to mind:

First, the U.S. has enjoyed a leadership in commercial air transport in design and development since the 1950's. While we tend to take it for granted, this leadership has provided a very substantial, favorable increment to our balance of payments. The fact that the world's airports are populated by aircraft designed and built in the U.S. is a matter of very considerable prestige.

The second example is the development of the breeder reactor. In this instance, the U.S. has failed to maintain leadership and is now in an inferior competitive position. The net result is that France has established leadership and has attracted commitments from a number of other nations.

It seems to be fundamentally necessary for the U.S., which is now competing with a number of planned and managed economies, to decide where to focus its resources in order to enhance the possibility for attaining world leadership.

8. **Are the experiences of international cooperation in magnetic fusion energy directly applicable to other fields of science? What lessons may be learned?**

There are other fields of science that could benefit from the experiences of international cooperation in fusion energy. However, fields of science that are expected to go through a period of manufacturing complex systems are more applicable. Space science, fission energy and jet aircraft engines are examples of mature programs.

Mr. FUQUA. Our third witness is no stranger to members of this committee, Dr. Guyford Stever. He is president of Universities Research Association. Dr. Stever served as the chief scientist of the Air Force, president of Carnegie-Mellon University, director of the National Science Foundation, and director of the Office of Science and Technology Policy under President Ford.

He is a member of both the National Academy of Sciences and the National Academy of Engineering. He is currently the Foreign Secretary of the National Academy of Engineering.

Guy, you have appeared before this committee in many capacities over the years, and we are delighted to have you back again.

STATEMENT OF DR. H. GUYFORD STEVER, PRESIDENT, UNIVERSITIES RESEARCH ASSOCIATION, WASHINGTON, DC

Dr. STEVER. Mr. Chairman, members of the committee, I like this kind of hearing because you are down at my level. [Laughter.]

I appreciate your invitation. I want to congratulate you on doing something about international cooperation in science because there are really some new features overlaying that field that we have to look at very carefully. In the old days we have always kind of felt that there were several very positive reasons for being involved in international cooperation.

First of all, basic research, really basic research, basic science, which is primarily supported by governments throughout the world, is shared completely throughout the world.

Second, science and technology have a much more widely recognized role than in the past in both international trade and national security in a broader sense, and our realization of that has become sharpened over these past two decades.

There is consequently a very strong movement for building new international science and engineering relationships and increasing the effectiveness of existing relationships to yield mutual benefits to this country and foreign partners.

There is another reason. The nations of the world share many problems such as environment, natural resources, natural hazards, health and climate, and support for the underprivileged, all of which could be addressed jointly by scientific and engineering knowledge and practice.

Furthermore, it is becoming increasingly important to study some scientific problems in several fields on a regional or a global scale. That happens, as several governments are exhibiting increasing suspicion about activities of foreign scientists within their national boundaries.

Finally, there is no question that emerging nations which in the past have occasionally had a scientist or an engineer in the top ranks are becoming more and more developed in their capability and they want to participate on the world scene.

But there are three societal pressures which are currently—three strong societal pressures—which are currently working on international cooperation. The first, of course, is heavily accented because of the current budget crises, not only in the United States but throughout the world.

The second one is the concern, in this country particularly, that our relative industrial competitiveness is somehow decreased by the free outflow of our basic science.

Then the final one is the worry that our military secrets are leaking out through international scientific exchange.

Well, with those three very strong societal pressures on the several good reasons for carrying this, we have to look pretty carefully at the policies and the procedures and the practices and the projects and the programs that we have. Therefore, I congratulate you all for doing something about it, and I look forward to a good report from this operation sometime that puts this all in context.

I am not so sure that you aren't becoming the best putter-together in total of science and technology there is. Administrations come and go and they fail a little bit in the big picture, and some of your reports are very important in that respect.

You asked me particularly to speak about two things, one, the SSC in high-energy physics, and the second was the National Science Foundation and its role in international science and technology. Let me make a brief statement on each of those, and then I would be glad to answer any questions on them.

On the first, the SSC, unfortunately for high-energy phsyics, this arrived on the scene at a very hard, rough time. It's a big-ticket item. There used to be a song by the British great music hall singer that always ended up, "It's the biggest Aspidistra in the world." You may remember that old song. And SCC is the biggest Aspidistra in the world.

Mr. Fuqua. I missed that. [Laughter.]

Dr. Stever. And yet it comes when there is a tight budget, and so the pressure for internationalization of it is very strong.

Now, high-energy physics has an excellent record of international cooperation in science. It is exchanged at an individual level. It is exchanged in small projects. Visitors come, visitors go. When a foreign country has a facility which is more suited for a particular experiment devised here, or vice versa in countries, there is that visitation. But we have never succeeded in the total management and financing from capital and operations.

CERN is a big exception there, and we should study how well they have done. But now we are proposing that the world get together on an SSC, and as my predecessor in this seat, Mr. Gavin, said, people are suspicious of the fact that we are coming forward with our program and asking complete internationalization of it when they could have participated in the planning and so on.

Second, the high-energy physics budgets are really committed overseas pretty heavily, and it's going to be very difficult for them to get involved. I think there is no question—oh, there is one other reason: we haven't got the mechanism together, and I think it will take a prodigious effort of both government top people—and some of them have worked on this but still haven't made a great deal of progress—and the high-energy physics community itself.

So I think that it's going to be difficult to bring that off in a timely fashion in an international way, in spite of all the advantages for funding that international cooperation would have in that sense.

Let me speak very briefly to the NSF. I think that NSF's international cooperation in science role should be much stronger. It has all the necessary authorization in the acts from the Congress, but it would need budget strengthening to do it. I don't think we have done a very good job in the overall coordination and management of international cooperation in science. It's not to say that there aren't very well handled individual programs and projects. But the agencies involved are under strength.

OSTP. If there is an item that is very important to this current administration or previous administrations and previous OSTP's, they can move in and do a good job in coordinating getting together. But they don't have a long-term staying power in the business, and anything connected to basic science and long-range engineering needs some staying power.

The State Department has never had the total strength. They obviously have the approval power and act as much as they can and take on special projects. But they have never really had the total strength really to take a leadership role in thinking out the future of this thing. They do mind the traffic to make sure that the laws are kept and our friends are kept and so on.

But even there there is failure because again, as Mr. Gavin pointed out, we don't have a good reputation overseas with respect to our continuity in these things. We are very rough on our friends, and all you have to do is travel the world these days on anything related to science and engineering, and you will get that message constantly and everywhere.

NSF has been examining its international cooperation role, and it is very clear that there are lots of jobs that it could do to help out. We tried a decade ago to get NSF in a stronger total coordinating role, as you know, and there was some resistance.

But NSF could supply better analysis, data gathering on the effectiveness of all of our international science, data gathering as to what is happening, and analysis of what is happening, and in fact some kind of an evaluation capability. They haven't carried out that role too well, and to do that, they would have to strengthen—the current minions of OSTP would have to strengthen—their own capability, organizationally, I think, and also with respect to budget and also with respect to budget and assignment of people.

But I do think that the three agencies of OSTP and State and NSF working together could put together a better picture of what is happening and what is needed and so on. And clearly, the agencies that are interested in this, Defense and so on, can carry out and do carry out major important things. NASA, all of the agencies have important programs. But no one seems to put it all together.

[The prepared statement of Dr. Stever follows:]

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International Cooperation in Science

Testimony of H. Guyford Stever to the
Task Force on Science Policy of the
Committee on Science and Technology
June 19, 1985

Mr. Chairman and Members of the Task Force:

Thank you for inviting me to speak on international cooperation in science, a feature of science which has always been an important positive force in securing the health and progress of science both in the United States and throughout the world. Your review of science policy relating to international cooperation is important and timely.

International cooperation is currently subjected to three strong societal pressures: the desire to share the ever-increasing costs of scientific research which has resulted from the cornucopial growth of science and the need for ever more sophisticated and expensive instruments and facilities; the concern that our relative industrial competitiveness is decreased by the free outflow of our basic science results on which so much of the development of new products and processes and manufacturing technologies are based; and the worry that international scientific exchange is a source of leakage of our military secrets, so many of which depend on our latest scientific research. The interplay of these societal pressures, which vary markedly from field of science to field of science, constitute a complex science policy issue.

High energy physics has provided over the last half century an interesting example of this interplay. In the thirties and forties, high energy physicists laid the scientific groundwork and led in the development of commercial nuclear power and military nuclear bombs. The second and third societal pressures were heavily felt in those years. But then the work of high energy physicists, concentrating on the fundamental forces and the particle structure of the nucleus, departed from immediate relevancy to commercial and military affairs. The social pressure exerted on international cooperation in high energy physics has been almost completely related to sharing costs, and has reached a high point as the proposal to construct a superconducting supercollider has emerged. At this time, there is only a faint hint that the principal instrument used by high energy physicists, the particle accelerator, may have military application in beam weapons.

During these recent decades, high energy physics has produced an enviable record in international cooperation, using publications, meetings, personal contacts, and even widespread use of other countries' accelerators if such use was optimum for the performance of an experiment. Now there are some who suggest an international facility with capital funding, operational funding and management handled on a cooperative basis. The establishment of such an operation would take a prodigious effort by the high energy physics community and governments worldwide to arrange. It is difficult to imagine establishing such an operation in a reasonable time, and, if it is made a requirement for the SSC, it will surely delay it substantially. Perhaps more threatening to the scientists involved is the belief that the countries which did not have the facility would suffer in the progress of their high energy physics as both university professors and their graduate students would be handicapped by the difficulties of working so far from their home bases.

International cooperation in science goes far beyond high energy physics, and it takes many forms ranging from person to person associations on small scale research programs, to groupings of research exchanges, for example, in a government country to country bilateral exchange, to broadly organized multinational efforts. But there is another dimension, for each of the fields of science has its own characteristic interchanges -- atmospheric scientists share the global weather and climate data base; oceanographers rally around research ships exploring the many features of the oceans; geneticists share their plant and animal strains; and all share information characteristic of cutting edge research in their field. There is still another dimension of international cooperation -- governmental agencies share science related to their missions through many international agreements. All of these dimensions of international cooperation make the coordination and management of governments a difficult job. Even getting the full information about the extent of funding of international cooperation in science is difficult, for in many cases, especially on smaller projects, the funds are just not clearly earmarked in the overall grant or contract.

The overall coordination and management of international cooperation in science is not particularly well done. That is not to say that individual projects and programs are not handled well. The OSTP can do well on a program of great importance and visibility to a current administration but it lacks long term continuity and is always short of manpower to do the data gathering, analysis, and evaluation of the totality. Likewise, the State Department with approval responsibility for all international government-funded science programs, lacks the strength to lead, and finds itself in a follower role, making sure certain rules are followed and pitfalls are avoided. Defense, Commerce, NASA, Agriculture, and a large number of agencies perform in their mission area. But a long term, stable program of clear purpose is not seen. It is fragmented and it varies up and down too much with funding squeezes, often resulting in accusations of bad faith being exchanged country to country.

NSF has been examining its international cooperative role, starting two or three years ago in a favorable budget climate to strengthen itself, programatically and organizationally. It now finds itself in a weak budget climate for international cooperation, but it would still like to improve its performance anyway. NSF has the necessary authorization to play a stronger role, aiding OSTP and State by handling data gathering and analysis and helping in an evaluative role. It also wants to improve these functions for the programs which the NSF itself carries out. It has studied organizational strengthening to do that and is in the process of deciding what it can do organizationally at this time.

Personally, I think the voice of international cooperation in science should be stronger in NSF. Also, I believe that OSTP and State, with help from NSF, should be more tightly-knit in coordinating the many program operations and should do a better analysis and evaluation of individual programs and the totality of international cooperation in science.

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DISCUSSION

Mr. FUQUA. Thank you. Do you think there should be a coordinating agency, maybe a separate agency, or should it be in OSTP? You know, that stands for Science and Technology Policy.

Dr. STEVER. I think, if we ever got a Department of Science, this should be a very important part of it, and it might be done better with a Department of Science.

OSTP has its ups and downs on this capability. In fact, anecdotically, when I suddenly had science advising thrust on me, there was an organization called FCCSET, which was the Federal Coordinating Council for Science, Engineering, and Technology, and it had, I think, 16 coordinating subcommittees. There was great pressure at the time to reduce them, and so we put the pressure on everybody and we asked for volunteers to go out of business. We got one volunteer.

The State Department said they would handle international cooperation in science, and we all volunteered the weakest member of our group, which was tunneling technology, and we ejected it from the club. But it didn't go out of existence, it just stayed under different auspices. I don't think State Department did a very good job of handling this new responsibility.

So OSTP, I still think of it as it has its ups and downs because of changing administrations. An agency would be better.

Mr. FUQUA. Well, it's not intended to be a line operating agency.

Dr. STEVER. Well, or an organization assigned the responsibility to coordinate it, although big agencies like NASA, Department of Defense, and so on, don't take coordination very kindly, as you know. They take the heavy hand of Congress or the White House to make them act. So I think it's an organizational problem, which is difficult.

Therefore, I would back off to try to get OSTP and NASA and NSF and State Department into a stronger partnership on this.

Mr. FUQUA. We discussed this yesterday and whether it would be better to leave it somewhat like it is rather than to have an international cooperation czar trying to dictate and coordinate the policy. And I am sure it probably wouldn't take too long before that agency would get the title of "dictator."

Dr. STEVER. This is one area where we agree with the Soviets: Neither of us likes czars. [Laughter.]

Mr. FUQUA. And of course, DOE, particularly in their basic energy sciences, nuclear physics programs.

Dr. STEVER. Very strong player. They have got some of the biggest and most important programs.

Mr. FUQUA. In spending national funds on international facilities, would that be a detriment to our national laboratories as we see them today?

Dr. STEVER. Well, I think there is no question that all of the pressures of the past have been when each field of science has tried to be in first place in the world and assuring that first place by having all of the things readily available at home. If we have to back off of that position, you know, then there are some candidates, and the SSC is one.

It is going to be rough, though, if we were to yield to an international organization and to an international location that laboratory. You know, we all think that this internationalization of the SSC means that it will end up in Texas, or Colorado, or Florida, or Rhode Island, or New York City, or wherever, and our friends will come here. When we put the shoe on the other foot, it's kind of hard to conceive of how that field will stay first-class in this country. A lot of people won't want to make most of their scientific life abroad. Some will. Some do. But it will be a very rough decision.

Mr. FUQUA. Well, we and several members were visiting in Europe recently with one of the science ministers. That is the very point that he made from the European standpoint, that it made it much easier to cooperate in the Space Station because it was not site-specific.

Dr. STEVER. Exactly.

Mr. FUQUA. When you started locating something, a facility, in some country, then you created all the worst of everybody and brought the worst out in everybody.

Dr. STEVER. Yes; I think this is right. No, that is a very wise statement he made. We could put the SSC in orbit. Maybe that is your suggestion. [Laughter.]

Mr. FUQUA. That would be one way.

What roles do you think non-governmental agencies such as the Academies of Science and Engineering and maybe some of the professional societies should play in the implementing and the funding of international cooperation?

Dr. STEVER. Funding is a difficult question to answer, because the ones you mentioned don't really have much funding of their own.

Mr. FUQUA. No; but I mean involving them.

Dr. STEVER. Oh, yes; I think that the relationships which have been built up with all of those organizations and which are growing stronger are very important to continue to strengthen and fall back on because they all have something to contribute.

Mr. FUQUA. What I was really asking is should they be more involved than they are today?

Dr. STEVER. Well, I think it wouldn't hurt because a great deal of our strength in science is outside of the government, and so I would say, yes, I think this is correct. We get around some of that problem by having the people from outside government circulate into government, and this is, by the way, a strength that we have which lots of other nations don't have, of course. The centralized governments, everybody is in government there. But lots of the free world do not have the strength that we have of circulating our top scientists in and out of government.

But, no, I would get them more involved because so much of the strength is outside.

Mr. FUQUA. Mr. Packard.

Mr. PACKARD. Thank you, Mr. Chairman.

I see this internationalism as a real dilemma for us. It is certainly a very popular and appealing and altruistic idea. But it really never has taken hold and become a predominant effort in terms of scientific research. Nationalism is extremely important when it comes to advances in technology and advances in science. It has always been that way, and it is very difficult to break out of that mold.

Historically, countries have always felt that to discover something is of great national pride, and that still carries through with our science awards and so forth, the Nobel Prize, you know, where countries take a great deal of pride in having Nobel Prize winners in their own country. We certainly do in our country. And I don't know that we can break that down enough to really accomplish an international effort in terms of science.

Then, of course, you have all of the military and the application of the scientific research that is done that becomes very competitive, and I see this as a real dilemma.

Dr. STEVER. Yes.

Mr. PACKARD. Let me take the devil's advocate for a moment. Would it not be wise for us to recognize those significant problems dealing with internationalism and recognize that perhaps the reason that the United States is interested in internationalism is to get some financial help in developing good science and other countries, Third World powers and so forth, might find that it's a benefit to them because they can share in the technology that comes from a big brother with a lot of money involved. Are we actually looking up an avenue that is a blind alley and that, in fact, internationalism is just a hope and a dream but not possible in today's society, and therefore should we not consider maybe putting our efforts and our energies instead of into international efforts into moving forward on a national level?

Dr. STEVER. Well, I think you have certainly hit the dilemma, and that dilemma, which has been around for a very long time, is very acute. It has been highlighted recently.

I think there are some fields, however, where an international approach may still go. One of them certainly is in the basic, truly basic research, and SSC fits in that group. SSC and a number of basic research facilities are not going to impinge too much on the nationalism with respect to industrial competitiveness and military strength. But lots of applied science certainly gets into that category. But that now is also being interchanged internationally a lot more than you think, a lot more than the Federal Government controls, through truly the multinational companies. It is very difficult to keep secrets very long and to hold things tight, it's true.

In other areas where clearly there is an international base, data base—weather, climate, oceanography—in those certainly we ought to be international. There are others. I think certainly we should be international in helping the lower emerging countries in their science. There is no reason why we can't do that, because I don't think we're giving away the competitive or military store there.

I think that you can't go to one extreme or the other. You have still got to live with the dilemma that we are living with, which is more acute at the present time.

Mr. PACKARD. Do you not believe that the driving force behind that international approach is cost-sharing, that that really is what is making it difficult for countries like ourselves, who have given a significant contribution to science development and are finding now that, as a good illustration, the SSC, a $10 billion item, that we are finding difficult to justify that kind of a cost under the pressures that we have now and so we are looking outside of ourselves for assistance in financing?

Dr. STEVER. Exactly. No, I agree that that is a major driving force. It comes about because of the tremendous success of science. All the fields of science have just had unbelievable cornucopia-like existence in the last 20 or 30 years. The progress in all of them has been immense, and one of the reasons they are progressing is that new scientific equipment and laboratories, more and more expensive as the years go by, have come along to help them go on and make this progress.

So science, the inflation in science just doesn't come because salaries go up or there are more people hired or something. It comes because everything about it is more expensive in order to make the next forward step. The SSC is the perfect example of that—not a perfect example, but a good example.

Sure, as the whole world has gotten that pressure suddenly, you could say science shouldn't progress so rapidly or you can try to find out ways such as international cooperation and use it as much as you can even though you recognize it can't go to the extreme that you were talking about.

I would say that you are going to end up on this in-between position, do as much as you can but don't expect to do everything that way.

Mr. PACKARD. Thank you, Mr. Chairman.

Mr. FUQUA. Dr. Stever, thank you very much.

Dr. STEVER. Thank you.

Mr. FUQUA. Thank you for being with us today. We are sorry for running so far behind.

[Answers to questions asked of Dr. Stever follow:]

H. GUYFORD STEVER
1528 33RD STREET N. W.
WASHINGTON, D. C. 20007

July 21, 1985

RECEIVED
JUL 29 1985
COMMITTEE ON SCIENCE
AND TECHNOLOGY.

The Honorable Don Fuqua
Chairman, Committee on Science and Technology
U.S. House of Representatives
2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Fuqua:

Here are my responses to the questions posed by the members of the Science Policy Task Force to supplement my testimony before the Task Force on June 19, 1985.

Question 1. Is the NSF considering increased funding of international activities, and if so, would these funds be specifically earmarked for international programs, or be derived from individual programs?

Though I am no longer privy to all of the considerations by the National Science Board, the Director of the Foundation and his staff, my activities as Chairman of the Ad Hoc Committee on International Activities, appointed by the Director, show me that the International Programs, their funding, and other international activities of the Foundation are under serious examination at present. The leaders of the NSF are responding this year to the budget tightening thrusts of the Administration and the Congress, resulting in cuts, which many including me believe too serious, in the budgets for the NSF international programs. These cuts have triggered a complete examination of the efficacy and importance of the programs as well as the organizational framework required for the conduct of the activities. Some reorganization will help, though the complete potential of the NSF in doing its share of the international science and engineering activities needed by the country cannot be realized unless the funding is increased.

With regard to the choice of international programs per se versus a distribution of support for international activities throughout the normal research granting elements of the Foundation, a mixed strategy seems best. Bilateral science and technology agreements, with their specific requirements of program concentrations and cooperative relationships country to country are usually best supported by a separately funded NSF organizational element. International activity aimed purely at increasing the strength of U.S. sciences is best supported by the disciplinary elements of the NSF.

Question 2. Should some or all future "big science" facilities be developed on the basis of international cooperation?

In my view, there are far too many "big science" facilities in our future to justify the added burden of making them completely international. Perhaps we should start with one, or a few, to get experience. Clearly the Superconducting Super Collider and the large ~~Cyclo~~tron Radiation sources for materials research with their exceptionally large budgets are prime candidates. However, a large number of our future "big science" facilities, those which are not burdened with defense or "key competitive technology" constraints, can and should have open exchanges of research workers, instrumentation information, etc. Most fields of science have good records in providing such exchanges.

Many Americans are concerned that we support and conduct more than our fair share of basic research, while others concentrate their efforts on the utilization of ensuing technologies. I share that concern though I believe that the problem is much more complicated that that simply stated concern. However, it would be much to our advantage if some government agency, perhaps the NSF, were to monitor the quid pro quo of the basic science exchange. At least we could then deal with the concern in an informed way.

Question 3. Should federal science funding include the aim of keeping the U.S. first in every field of science, and if so, will international cooperation be either beneficial or detrimental to achieving this aim?

I think it is reasonable to have federal science funding include the aim of keeping U.S. first in every major field of science, though we should recognize that attaining that goal in some fields will result in just keeping us on a par with other leading countries which have similar aims. We should certainly never fall out of "world class" status in any major science field. International cooperation will help us, in my view, in attaining leadership and will certainly be an insurance that we do not fall out of "world class" status.

Comfortable as we have been with world leadership in science for several decades, we must now realize that other leading, fully developed and some largely developed nations now recognize the importance of the basic sciences --applied science--technology trilogy to their economic future. The competition in all three elements will be keener in the future, and we should welcome it.

Question 4. What is the trend of international collaboration in science? Is it increasing, decreasing or remaining relatively constant?

Until the early or mid-seventies international collaboration in science grew reasonably steadily, and by means of several modes -- government supported exchange, industrial company to industrial company exchange, as supported by international governmental units and by international-minded foundations. Funding limitations, especially those brought on by recessions, first served to curb the growth; these limitations were augmented by the depressing effect of the concern about the leak of critical technologies for defense and industrial competition. On the other hand, newly developing or changing political alliances, such as that with the Peoples Republic of China, have certainly caused an acceleration of international collaboration. All of this probably adds up to a plateau in the activities of international collaboration in science, though it would be a difficult point to prove.

Question 5. What factors either (a) facilitate or (b) inhibit international cooperation in a given field of science?

Because all nations believe in strengthening their own scientific and technological capabilities, peaceful and healthy economic relationships overlay facile international collaboration in science. Still, occasionally scientific collaboration has been used as a remaining link between nations even when other relationships were strained. That use of scientific collaboration was the basis for the establishment of the International Institute for Scientific Analysis, proposed when East and West were at odds in political and economic relationships. Also, scientific exchange is often the leading and sometimes the only agreement reached when political leaders seek to improve relationships generally. In many ways, scientific collaboration is a useful international political tool. If properly handled, it can be an excellent one, for all sides tend to gain because of the positive impact on economic well-being.

If the climate is right and the funds are there, scientists in all disciplines benefit from international exchange of information, equipment, facilities, and people. Their attitudes are almost universally positive with regard to international exchange.

Question 6. What does "world leadership" in a particular field of science mean? What particular benefits accrue to the "world leader" versus "number two"? Why should a nation's policy makers care whether or not the nation is first, second or third in a given field of science?

Perhaps it is a good and timely question for our national policy makers to ask whether they should care if our nation is first, second or third in a given field of science. Certainly I believe that the answer should be that U.S. science should be "world class" in all major fields of science, which probably would mean we were first in many fields, given our dominant economic role in the world and our defense burden. And we must be careful for we have often depended on our world leadership in science to substitute for other leadership factors in maintaining our strength. In military affairs, our high technology emanating from our leading science position has been relied upon at the expense of manpower in the armed forces, and number of ships, planes, tanks, ballistic missiles and other weapons. Similarly, we have relied upon high technology in production rather than many paid laborers to maintain our industry. If we are to reexamine our world leadership in science, perhaps we should also reexamine the implication of any change throughout our society as well.

Question 7. Has there been an overinvestment or underinvestment in "big science" such as high energy physics or magnetic fusion energy relative to other subfields of physics or other disciplines? How can the appropriate levels of investment in different subfields or disciplines best be determined?

The question of overinvestment or underinvestment in "big science" should be broadened to all disciplines and all "sizes of science". Science disciplines, and their subfields differ greatly in nature. Each should be permitted within its own expertise to determine what mix of "big vs. little", "national vs. international", "academic vs. governmental vs. industrial setting", "etc. vs. etcetera" is the optimum mix at any time in making that field of science progress best. Then the complex advocacy process of a given science versus all the others should take over. The advocacy process makes it tough on leaders of the ultimate sources of funds, which fortunately are several relatively independent sources, including federal and state government, industries, foundations and universities, as well as private philanthropy. Certainly the Committee on Science and Technology is playing a powerful role in conducting the advocacy process.

Perhaps national government leaders are overly influenced by the special scientific demands of the mission agencies. Certainly the sciences close to the missions of the Departments of Defense, Energy and Health, and the National Air and Space Agency have flourished. On the other hand, the National Science Foundation was created just for the purpose of insuring balanced support for all the sciences. It should be held responsible for conducting that balancing act and funded well to accomplish it.

Question 8. Are the experiences of international cooperation in one field of science directly applicable to other fields of science? What lessons may be learned?

Yes. The different fields of science face many common or similar problems in their varied international collaborative ventures, over and above those particular to each field. However, I do not believe that there are serious common matters which cannot be handled by existing scientific research institutions in academe, industry, and government, either within their own academic and professional associations, societies and academies or working with the agencies of government assigned responsibility for solving such problems, provided those agencies do their jobs properly.

At present, the State Department does not appear as a strong leader in solving some of these problems, and the Office of Science and Technology has other higher priorities, though it can do a good job if its priorities coincide with an international issue. The National Science Foundation could and should be asked to take a stronger hand, and it already has the required statutory authority.

Summary Comment

The international aspects of the the conduct of the science and engineering enterprise is complex. The federal government has no strong center where the policies of international activities are broadly and affectively viewed. The National Science Foundation could be strengthened to aid the State Department and the Office of Science and Technology Policy perform their statutory policy and programmatic functions in coordinating federal activities in this sphere. The NSF could aid in data gathering, analysis and evaluation in such a role.

Thank you very much for inviting me to testify and to answer these questions by letter.

Sincerely yours,

H. Guyford Stever

Mr. Fuqua. Our last witness is Ken Pedersen, Director of NASA's International Affairs Division. He will testify on NASA's international cooperative activities, and particularly the prospects for international cooperation in the Space Station.

Ken, we are very pleased to have you here this morning.

STATEMENT OF KENNETH S. PEDERSEN, DIRECTOR, INTERNATIONAL AFFAIRS DIVISION, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, DC

Mr. Pedersen. Mr. Chairman, it is nice to see you again, and members of the task force.

As a nonscientist, I am pleased to be here in such distinguished company to testify on international cooperation in science and also a little bit on the prospects for international cooperation and particularly on the Space Station.

I know that many members of your task force, and particularly you, Mr. Chairman, are extraordinarily familiar with NASA's programs and are well aware of the extent to which international cooperation is a fundamental aspect of most all of the activities we undertake.

I have included in my written statement and will not attempt to repeat here a number of the major projects, big science-type projects, that we have undertaken in the past and that we are in the process of undertaking or contemplating at the moment.

I fully expect that the trend toward international cooperation in space science will continue. As you are probably well aware, NASA believes that many scientific, technical, financial, and political benefits result from such cooperation. As a result, I would like to try to address a couple of the questions that were raised in the study which your science policy study, currently being conducted by Congress and in which I know the task force is interested. It is an important topic and one we ought to be addressing.

With regard to several specific questions, I notice that the task force has posed the query as to whether, in fact, joint programs really result in cost savings for the partners, given the added complexity of international management. I would be the first to deny that international cooperative programs do not add an element of complexity in the management, and they can make problem-solving and management decision making more difficult. It's true that additional funds may be necessary for travel abroad and for some of the more complex administrative activities associated with these projects.

At the same time, international cooperation allows us to gain significantly greater capabilities with respect to a given project or mission at no significant additional cost to the U.S. Government for development. And in other forms of cooperation, the travel and administrative costs rarely combine, in our judgment, to equal the cost of developing and providing the hardware ourselves. In fact, the ratio is in most cases quite small.

By far, the greatest benefit of international cost sharing, however, is that of sharing the cost burdens in a constrained budget environment which we have and in which we probably will continue to live. The time to completion of a project can be shorter than if the same amount of money had to be spread over many years by one country alone.

As you know, while it may solve near-term problems, stretching out a program is always more costly in the long run, and this is especially true for large, relatively expensive space facilities.

I also know that you are interested in technology transfer in international cooperation. This is a concern on which I have spoken on several occasions to your committee, Mr. Chairman, and it is one NASA shares. To reap the benefits of cooperation without jeopardizing the Nation's national security interests or the competitive position of U.S. industry requires that care be exercised in selecting, defining, and implementing joint programs. In projects where there is foreign involvement, we make every effort to structure it so as to avoid unwarranted technology transfer, and I believe that the record indicates that we have been highly successful in this regard.

The way we operate is that foreign participants undertake to provide a discrete piece of the overall project, and they are responsible for developing that portion with their own technology and with their own funds, and only the technical information necessary to ensure effective interfaces and to assure that the project is proceeding appropriately is exchanged.

In this way, we have found that we can enjoy successful cooperative endeavors while protecting legitimate U.S. technological interests. I also might note, as other countries have developed strong technology bases, I sense that they share very similar objectives in this area.

Another question raised by the task force report is how we can assure that we are supporting science that has a clear focus, that is not science for science's sake or international for international's sake, and how we can make optimum use of our resources.

In the case of NASA's programs, we have no separate budgetary line items for international projects. We are not committed to spending a certain amount of money on international projects in any given year. Instead, all of our science projects must first gain the support of our own communities, of our scientific advisory committees, and they must compete with other scientific projects through our peer review and advisory committee structure.

What this means is that the projects first and foremost must satisfy an objective, a programmatic objective which NASA has identified in collaboration with the communities, with Congress, and with the administrative branch.

This process ensures that NASA pursues the highest priority science. In addition, a basic ground rule of our international projects is that the project be of mutual interest, since each side will have to fund its respective responsibilities. We believe this also ensures that the project will enjoy equally high priority on the part of our partners.

Earlier, the word was used by one of you, I believe, "altruism." We have never felt that international cooperation ought to be looked at, at least from NASA's point of view, as a charitable undertaking. It ought to proceed out of self-interest and assuming that all partners are approaching the project in terms of benefits to themselves. I think that is the most solid and the most enduring basis upon which to build cooperation.

Another interesting question which your task force has raised is whether the United States should attempt to be the world leader in all areas of science or whether we should let other countries take the lead in certain areas. I would like to point out that in areas where the United States has made a decision that a given scientific discipline is good science but not high enough on our priority list—I am speaking for NASA now—to warrant extensive funding, international cooperation has allowed us to benefit from other countries' activities.

For example, NASA has no current plans to carry out a dedicated astronomy mission; but there is a small community in the United States with expertise and interest in this field. The European Space Agency has such a mission, called Hipparcos, and they recently have put out a call for proposals, which after many years of similar treatment by the United States provides for reciprocity to our scientific community, and it was indeed open to all American scientists. As a result, some 20 U.S. scientists were selected and are involved in planning the observation strategy with this mission, with only modest funding from NASA.

I would like, if I might divert from my testimony just for one moment, I would like to respond to a point made by Dr. Friedman in his testimony, in which he spoke about ISPM and ISTP. I think that there is a danger if one draws too much analogy between these two programs. ISPM, International Solar Polar Mission, was a mission that was an approved program on both sides with an existing international agreement which was modified as a result of the budgetary situation in this country and about which I can assure you most people were not pleased or happy to be part of having to do that.

The International Solar Terrestrial Physics Program, on the other hand, is an unapproved program which NASA is considering, and has been considering, and has been discussing with our international partners with a full understanding on all sides that it is not an approved program. But it is necessary to have good, thorough discussions so that we can all assure ourselves that it is something that we want to do and is worth doing.

I am terribly concerned in a program like this if it is represented that if NASA or the administration or this Congress chooses not to fund that program or not to decide to go ahead with that program, that that would be viewed as a reneging on a commitment of the same order of Solar Polar. They are not analogous, and my concern would be, if we begin treating them in that manner, it may chill the important prediscussions that go on before these missions that are absolutely essential in determining the self-interest that I spoke about earlier. If each discussion we undertake with other countries in which we thoroughly represent our views and make very clear that the program is not approved, it is later represented to be a backing away of a commitment on the order of Solar Polar, I am terribly afraid the effect will be that we would be reluctant to undertake those sorts of discussions. And I think that would be most unfortunate.

Thank you for permitting the digression.

You also asked me in the letter that the task force sent for my appearance, to provide some information on the progress of the Space Station. I have done so in my written testimony, Mr. Chairman.

I very briefly will say that we have recently signed the formal MOU's with the European Space Agency, with Canada, and with Japan to begin the parallel phase B efforts. In each case, the partners are making significant financial contributions of their own, funding their own design and technology efforts.

We will begin this fall the discussions leading to the possible phase C, D, and E agreements. This will be a lengthy and difficult process, many difficult issues that will need to be dealt with. I think we are all extremely encouraged by how the process is going so far.

I would say in response to one question you asked earlier, Mr. Chairman, that one thing we attempted to do in the Space Station was, long before the program was an approved program, we went to Europe, Canada, and Japan and said, "We do not want to wait and come to you at the last moment and say, Here is a program. If you see something there you like, go ahead, but don't make any changes." We went very early to them and invited them to work with us in designing or looking on a planning basis at what a Space Station might do and specifically how it might serve their constituent and user interests.

The feedback I have had on that is that that was a very important part, a very important step that we took that allowed them to feel not only a part of the project, but allowed them the necessary time to develop their own constituency and political support, that when the President did issue his invitation, allowed decisions to be made in times that I think many people predicted would be unable to be met.

I would be happy to respond to questions, Mr. Chairman, on the Space Station or on my earlier comments. I believe that the written testimony will suffice to give you a progress report on that. Thank you.

[The prepared statement of Mr. Pedersen follows:]

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PRESENTED BY WITNESS

June 19, 1985

Statement of

Kenneth S. Pedersen
Director
International Affairs Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Task Force on Science Policy
Committee on Science and Technology
House of Representatives

Mr. Chairman and Distinguished Members of the Subcommittee:

I am pleased to be here today to testify on international cooperation in science and on the prospects for international cooperation on the Space Station.

As you know, international cooperation has been a key aspect of NASA's programs since the inception of the agency, particularly in the field of space science. NASA's cooperative programs have been very successful over the years, so that today we find that virtually every major project in NASA has some form of international involvement. This involvement ranges from major hardware contributions to ground-based studies and data analysis. Since you are mainly interested in "big science," I would like to briefly touch on a few of our major current missions. Next year, three major cooperative projects will each reach a key milestone. I am referring to the launches of Ulysses, Galileo and the Hubble Space Telescope. With their launches, the joint development with our European partners will end, but the scientific operations will just be beginning. We are looking forward to continued international callaboration on this next important phase of these programs. As we look ahead, nearly every major proposed new initiative in the area of space science has an international component: Topex with the French, the International Solar Terrestrial Physics program with Japan and the European Space Agency, and the Comet Rendezvous Asteroid Flyby Mission with Germany are examples that come to mind.

I fully expect this trend to continue. As you know, NASA believes there are many scientific, technical, financial and political benefits resulting from such cooperation. That is why I would like now to turn to the review of U.S. science policy that this Task Force is conducting.

I read with interest the goals of the Science Policy Study being conducted by Congress. This is certainly an important topic which needs to be addressed. I will attempt to respond to specific questions about international activities raised in your Statement of Purpose for these hearings and in the Agenda prepared by the Task Force on Science Policy.

The Task Force has posed the question as to whether in fact joint programs really result in a cost savings for the partners given the added complexity of international management. It is true that additional funds may be necessary for travel abroad and more complex administrative activities associated with international projects, but in many cases the international cooperation allows us to gain greater capabilities at no additional cost to the U.S. government and in other forms of cooperation the travel and administrative costs rarely combine to equal the cost of providing the hardware ourselves. By far the greatest benefit of international cost sharing, however, is that by sharing the cost burdens in a constrained budget environment, the time to completion of a project is shorter than if the same money had to be spread over many more years by one country alone. As you know, while it may solve near term problems, stretching out a program is always more costly in the long run. This is especially true for large, relatively expensive space facilities.

I note your interest in technology transfer. NASA, too, shares this concern. To reap the benefits of cooperation without jeopardizing this nation's national security interests or the competitive position of U.S. industry, care must be exercised in selecting, defining and implementing joint programs. Projects leading to the early development of commercially useful technology are not usually open for international participation. In projects where there is foreign involvement, that involvement is structured so as to avoid technology transfer. Generally, foreign participants undertake to provide a discrete piece of the overall project and are then responsible for developing the resulting technology and hardware with their own funds. Only the technical information necessary to ensure effective interface among the various elements of a project is exchanged. In this way, we can enjoy successful cooperative endeavors while protecting U.S. technological interests. As other countries develop strong technology bases, they share very similar objectives in this area.

Another question raised by the Task Force Report is how we can assure that we are supporting science directed at specific goals (not science for science's sake or international for international's sake), and making optimum use of our resources. In the case of NASA's programs, we have no separate budgetary line item for international projects. All of our science projects must gain the support of our scientific advisory committees in competition with other science projects through our peer review and advisory committee structure. This process has always ensured that NASA pursues the highest priority science. In addition, a basic ground rule of our international projects is that the project be of mutual interest since each side will fund its respective responsibilities. This also assures that the project enjoys equally high priority on the part of our partners.

Another interesting question before the Task Force is whether the U.S. should attempt to be the world leader in all areas of science or whether we should let other countries take the lead in certain areas. I would like to point out that in areas where the U.S. has made a decision that a given scientific discipline is good science but not high enough in our priority list to warrant extensive funding, international cooperation allows us to benefit from another country's lead. For example, NASA has no plans to carry out a dedicated astrometry mission but there is a small community in the U.S. with expertise and interest in this field. The European Space Agency's Call for Proposals to develop the observing program for its Hipparcos astrometry mission was open to American scientists. Some 20 U.S. scientists were selected and are involved in planning the observation strategy for this mission with only modest funding from NASA.

Of course, there are science programs which can only be done on an international basis. For example, to understand tectonic plate movements requires measurements from many locations around the world. In addition, the ability to interpret data from earth-looking sensors requires the gathering of ground truth data from areas outside our national borders.

I would now like to turn to the Space Station Program. I believe the Space Station is the kind of program that demonstrates how leadership, international cooperation and opportunities for space science endeavors can be brought together in a mutually beneficial way. We have made much progress since President Reagan's invitation in his 1984 State of the Union message to America's friends and allies to join us in developing a permanently manned Space Station. Shortly thereafter, NASA Administrator James M. Beggs traveled to Canada, Europe and Japan to initiate discussions about possible cooperative efforts and to lay the groundwork for the Space Station's being raised at the London Economic Summit. Following the Summit discussion of the President's invitation and its commitment to consider cooperation on the program, Canada, Europe and Japan all moved rapidly to make the policy and budgetary decisions needed to join us in this program.

At the March Reagan-Mulroney "Shamrock" Summit, Canada formally accepted the President's invitation to participate in the Space Station Program. The Canadian

Government is in the midst of developing a long term space plan which is expected to be unveiled late this year. At that time we will know what Canada plans to ultimately spend on its participation in the Space Station. However, we know that Canada is interested in becoming a major partner on the Space Station, and believe that it is planning to spend three to five times the funds it spent on Canadarm, the Space Shuttle's Remote Manipulator System (RMS). Canada's Phase B expenditures are estimated at $22 million.

Europe made some key decisions on space policy in January at the ESA Ministerial Conference, where the European Science Ministers met to decide on Europe's long term space objectives. Europe formally accepted the President's invitation to participate in the definition and preliminary design phase of the Space Station Program, while simultaneously approving the development of a man-rated European launcher, Ariane 5. To undertake both activities, the conference endorsed increasing ESA's budget by 65% over the next five years, from the current 1000 Million Accounting Units to 1650 Million Accounting Units--about $1.35 billion at current exchange rates. Of this, ESA plans to spend $2.4 billion on Space Station activities.

Japan took an important step this year when the Diet approved Japan's undertaking Phase B studies on the Space Station. Japan plans to spend approximately $23 million during Phase B, and total Space Station expenditures are expected to exceed $1 billion.

Space Station was again on the agenda of this year's Economic Summit in Bonn, with the Summit participants noting the positive responses of Canada, Europe and Japan to the President's invitation.

Over the past year and a half, NASA has continued to keep our international counterparts abreast of our planning activities, and we have been negotiating three separate Memoranda of Understanding (MOU's) that govern initial cooperation with Canada, Europe and Japan. We have now signed all three MOU's, which cover cooperation during the Detailed Definition and Preliminary Design Phase (Phase B) of the Program. During Phase B, NASA and its partners will each conduct parallel definition and preliminary design efforts. Based on these studies, NASA--and its partners--can then proceed to the Phase C/D part of the Program: detailed design and actual development of the hardware. The Phase B MOU's provide for interaction and information exchange during that period. Our overall goal is to define, design and build the most capable Space Station achievable with our combined efforts.

The Space Station hardware that our partners will be studying during Phase B could be welcome additions to the Space Station. Canada's main interest is in a construction and servicing system based on its experience in developing the RMS that could significantly add to the construction and servicing capabilities that the U.S. plans to develop for the Space Station. Canada is also interested in the remote sensing and solar array areas in relation to a polar platform.

Based on its Spacelab experience, ESA is concentrating its efforts on pressurized laboratories and platforms, resource modules, and ground facilities for mission preparation and support. Japan is focussing its Phase B efforts on a pressurized multi-purpose experiment module which has pressurized workspace, an exposed portion with a manipulator, and an experiment logistics module.

Over the next two years, we also will be negotiating separate agreements with each partner that will govern the Development, Operation and Utilization Phases. The long term relationship the U.S. and its partners are seeking poses many challenges for the negotiations. These include the nature and level of agreement we will want to cover this partnership; each partner's responsibilities in the development, operation and utilization of the Space Station; access to and use of the Space Station; protection of intellectual property rights and technology; operations costs; and Space Station crewing. While NASA and its partners have many important areas to discuss and negotiate over the next two years, our past successful cooperative relationships and our mutual enthusiasm for the Space Station afford the basis for confidence that we will produce a stable and mutually beneficial partnership.

Throughout our discussions with our partners, we have emphasized the importance of each partner having long term utilization plans for the Space Station. Key to the Space Station cooperation we have been discussing is that partners in Space Station development will have access to all Space Station capabilities provided by the partners. Over three years ago, mission requirements studies parallel to our own were conducted by Canada, Europe and Japan. We have maintained a steady dialogue with our partners in this area, and they have played a key role in the development of the performance envelope for the Space Station Phase B Studies.

In the Phase B MOU's, we have continued to emphasize utilization by asking each partner to develop utilization plans and by establishing a multilateral utilization group to focus our efforts in this area. Our partners are also observers on the Peter Banks' Task Force on the Scientific Uses of the Space Station. I believe that out of this healthy dialogue will come many payload endeavors that will utilize the new capabilities the Space Station will offer.

Up to this point, I have restricted my remarks to partners in the development of the Space Station. I would like to emphasize that, while participation in the development of the Space Station itself may require a level of resources and experience beyond many nations, this need not be the case for utilization. The availability of a permanently manned facility in space opens exciting new prospects for cooperation in the development and use of instruments and various scientific and applications-oriented experiment packages for use on the Station. We have kept many space agencies around the world informed of our Space Station plans, and the opportunities the Space Station will provide. As you know, NASA has had cooperative agreements with agencies in over 100 countries. We anticipate that this tradition will continue, and much cooperative work will be done on the Space Station.

That concludes my statement. I would be pleased to answer any questions.

DISCUSSION

Mr. **Fuqua**. Thank you very much.

You were here when I asked some previous witnesses about should there be a single agency that either coordinates all of this or kind of plays the dominant role in international cooperation in science. I think I know the answer, but I will let you give it.

Mr. **Pedersen**. My own view is, speaking for NASA, that I think our international cooperation programs have been extremely successful, and as I said earlier, I think one of the reasons they have been successful is that we do not approach them from the outset as international programs. We look at them in terms first of NASA's objectives and so on.

I would be concerned that if there were, may I call it a superagency or some central point, that there would be a strong impetus directed toward international cooperation for international cooperation's sake, starting out with the presumption that things ought to be done on an international basis.

I have a very strong feeling in this regard that one of the strengths of our program is that we don't start out that way. We look at programs in terms of our interests. Our experience has been, with some exceptions, which I will certainly acknowledge, that we work very, very closely with most of the agencies in town. In the Space Station agreements that we have just concluded, I thought the relationship with State Department, with the White House, with the Science Adviser's Office, with a number of agencies around town, was extremely good.

I think when you start to do something like that or propose that, I think it's extremely important that someone work very hard in defining what are the problems you are trying to solve, just exactly what are the problems that such an agency would be designed to solve, and what are some of the possible adverse consequences that might fall out as a result of it.

I am not sure that any single agency has the capability to make the kinds of judgments and the kinds of decisions across the sweeping range of scientific disciplines as the individual agencies can. I think there is room for some improvement in coordination, particularly true I think in some cases between State Department and the program agencies. That is getting better, but as this committee knows, it has not exactly been a model in past years.

I think that setting up a superagency to correct something of that nature, though, may be a remedy that is larger than the disease.

Mr. **Fuqua**. What kinds of administrative problems do you run into, such as tariffs, visas, proprietary rights to intellectual information and so forth in these multinational cooperative projects?

Mr. **Pedersen**. Quite frankly, again with one or two exceptions which I will mention, this has not been a serious problem for us. I have heard it has been serious in the case of other agencies in some cases. We have not had serious problems, for example, with visas as a matter of course.

We had one—someday it will be a landmark, I suppose, for young lawyers to look at—we had one problem, as you know, with the question of bringing Spacelab into the country because Customs wanted to treat it as an imported good because we were going to put it into space but we were going to bring it back, and that required some assistance from the committee. But that is almost, I think, a unique situation. By and large, we have had very little difficulty with Customs, with visas and that sort of thing.

There have been isolated instances where visas were held up as a result of State Department reviews, or political concerns emerged, sometimes dealing with the political persuasions of a particular scientist abroad. But those have been fairly rare and readily easily taken care of.

Mr. FUQUA. How about proprietary rights?

Mr. PEDERSEN. Proprietary rights, yes. Proprietary rights I think could well become a much larger problem for us with the Space Station. It's one of those issues we have identified that is going to take a great deal of work.

However, we have already faced up to some of those questions, Mr. Chairman, with respect to Spacelab. As you know, Spacelab is for hire. It is a user facility. And later this year the German Government, for example, will be flying a dedicated Spacelab mission on which they will be performing certain experiments, as will some of our users in industry in the future. And we have already put in place some of the protections necessary, we believe, to protect proprietary data, while learning enough about what is going to take place to assure the safety and the interfaces, but at the same time to protect the proprietary data that needs to be protected.

On the other hand, the Space Station I think is going to present us some very real challenges in that regard. And in talking with the lawyers, they suggest to me that we probably will have to undertake some major efforts here, probably on both the national and international legal basis to resolve these problems.

But I am not aware in my little area, Mr. Chairman, of the problem to date in protecting proprietary data where that is necessary.

Mr. FUQUA. Mr. Packard.

Mr. PACKARD. Mr. Chairman, thank you.

You asked a very interesting question on proprietary rights, and I had not thought of that in terms of the Space Station, but obviously that is going to be of great concern. From your response I assume then that the arrangements that have been made with other foreign participants is on a cooperative basis rather than a purchase-sell basis? In other words, they will have a vested interest in the Space Station as we will?

Mr. PEDERSEN. Yes, sir. What they are doing, the ground rules as we have established them, is that they are looking toward developing discrete elements of the Station, in some cases pressurized modules, in other cases platforms of various types which they will develop and fund with their own money and technology, which they will have a continuing responsibility for maintaining and keeping up, but which will be available to the various partners for use.

So that the plan is very much one of cooperation but with a continuing obligation and responsibility in the program.

Mr. PACKARD. So that those individual parts become a part of the whole and they inherently have rights of the whole?

Mr. PEDERSEN. That is right. And these are some of the principles that are going—when I mentioned earlier, Mr. Packard, that the negotiations for the next phase, which is the development utilization phases, are going to be difficult and long, I suspect, is that the principles governing use of the various facilities and their appropriate role in the operation and management of some of the Space Station activities and the crew of the Station and so on, those are going to have to be elaborated and worked out.

I don't think any partner, including ourselves, will sign up until they feel satisfied that the benefits are commensurate with the risks.

Mr. PACKARD. In developing your agreement in your phase B agreements—and I suppose the same question will proceed with other phases in the future—have they been developed on a nation-to-nation basis, or have they been a multinational agreement, and will future agreements be on a case-by-case basis, or do you see us moving in the direction of a multinational consortium that will resolve or develop all future agreements in terms of the Space Station and other types of facilities that are multinational?

Mr. PEDERSEN. Well, certainly on phase B and with respect to the C-D-E negotiations, we will proceed on a bilateral basis. That is, our agreement in phase B is NASA-Science and Technology Agency of Japan, NASA-European Space Agency, which is, of course, a multilateral organization but is treated for our purposes as a single entity, and with Canada.

There are several reasons for doing that, not the least of which is, each agreement is a fairly tailored specific document with regard to obligations, responsibilities, and so on, and there is a great deal of uniqueness here in terms of the systems they are interested in looking at, in terms of their differences, interestingly enough, in such things as how each country approaches liability and how each country approaches their funding process or procedures and so on, and all of these need to be taken into account.

So we have found that for simplicity and for keeping a good, solid line of accountability and responsibility, which we believe is extremely important in these projects, the bilateral agreements are the best. At the same time, we are using many multilateral mechanisms to facilitate the exchange of information and the sharing of data necessary to make sure that we are all working toward a common objective, and we have a number of multilateral groups, regular meetings of these groups, to assure that we are all operating in the same way.

I cannot look out too distant in the future and see whether some time way out there, 20, 30, 40 years, whether the Space Station evolves in such a way that international consortiums or international management structures might be the rule of the day. But certainly, in our current approach, we are proceeding on a bilateral basis.

Mr. PACKARD. Then NASA has become the prime coordinator and actually the sponsor of the project, and they have developed their bilateral arrangements and agreements with individual partners, but they have still basically retained control as an umbrella organization?

Mr. PEDERSEN. Well, I think that is a rather fair depiction. In terms of the overall for prime contractor of the international effort, if I could use that term, clearly NASA is playing that role.

However, from the point of view of the Japanese and Canadians and the Europeans, I think they see their investment in the Station as being significant—we are talking multiple billions of dollars here on the part of Europe and over 1 billion for Japan—see themselves as very much participating here as full partners, but with the recognition that you need someone pulling it all together. And I think there is an understanding that for efficiency and just good management, that that needs to be the United States.

But that does not mean that the United States will, of course, in all cases be able to call all the shots. This will necessitate compromise. Again, that is where you weigh the benefits and the risks and have to make judgments.

Mr. PACKARD. Up to this point it has been rather loosely structured then, with perhaps some specific agreements, but in the future do you see us moving more and more in the direction of where it's going to require a very well delineated agreement and structure so that we do not assume to take the leadership role, it becomes something that is negotiated?

Mr. PEDERSEN. Well, what will have to happen as you do the agreement for development and operation is the responsibilities, decisionmaking structures, who set priorities for utilization of the facilities, how are those set, how are crews put together, how is the Space Shuttle system and other transportation systems organized and optimized for logistics, for taking payloads up, bringing them down, all of these kinds of decisions that will have to be made that will influence each of the partner's activities, those mechanisms will have to be spelled out, I believe, in great detail. Those are the questions people will want to know.

Let me give you one example, if I may. Sharing of costs, the operating costs of the station—power, you know, heat, light, depreciation, consumables, water—all of these costs will have to be shared by the partners.

Mr. PACKARD. Even the manpower.

Mr. PEDERSEN. Yes. And the formula by which those costs are allocated and how that is worked out both in forms of direct payment or bartering are going to have to be very carefully spelled out and worked out.

So I view the next agreement—up till now we have some sort of a confederation; that is, a number of partners studying in a parallel manner possible participation in a Space Station. The next phase will involve dealing with issues and resolving issues that are much, much more complicated and get to the very heart of the management and operation of an international facility which, in addition to being international, will be used for intense competition.

I think that's one of the interesting things about the Space Station. We are cooperating, if it goes ahead as a cooperative project, to build a major piece of space infrastructure that will be used as the site of intense commercial competition, and that makes it all the more interesting. And that's how it should be, by the way, I believe.

Mr. PACKARD. Thank you, Mr. Chairman.

Mr. LUJAN. I was interested in your saying that NASA doesn't start off by saying, "We want something in the international field," but you have the program and if it fits into it, then that is fine.

And I think that's good in a sense, although as an international relations tool, the whole Space Station thing has been tremendous, at least in my limited international involvement in it, all of the different countries that I have visited which are going to participate with us, with the European Space Agency and all those.

You know, you can feel that getting closer and closer as allies, even with the Soviets if they are going to get into production and launching of satellites, there will be an interesting milestone that they will have to open it up for inspection, because while maybe they won't let the U.S. Government go in and inspect their defense establishment, no company is going to let them build a satellite and launch it without somebody being there. So, you know, it's kind of an opening of the "Don't come in and see what we're doing."

That takes me to something that we are going to discuss later, this whole involvement of Latin America into it. I don't have any idea what their capabilities are, except that they have perhaps as a user community, but I was thinking more in terms of our closeness, you know, with the western hemisphere and that sort of thing, to use it as an international relations sort of tool.

I just wanted to kind of impart that because I think that ought to be part of NASA's objective as well. I know you are not the State Department.

Mr. PEDERSEN. May I respond briefly to that?

Mr. LUJAN. Yes. Surely.

Mr. PEDERSEN. My point was that even—let's take the Space Station—even there, if NASA had concluded that it had no interest or no use for a Space Station, I think while it perhaps would have been a bad decision to decide to build a Space Station just because it might involve international partners in a project that would be visible and would involve heads of state and so on in its planning. All I am saying is that once a project is envisaged and we feel it is a useful project, then most of the issues you have just talked about come very much into play.

We, of course, look at questions of who are potential partners and how might they play into other broader U.S. foreign policy objectives. And we talk to the State Department about these types of things. Even in Latin America, I would suggest that there are a number of areas that NASA is working in that we have defined as important scientific areas, where I believe Latin America has some interesting capabilities—geodynamics, for example.

I would feel that if you are going to seek to establish a relationship with them which might have broader political goals, that you are more likely to build a strong and mutually satisfying relationship if you begin in areas where both parties sense they have real interests, not the least of which is in the real world if an agency feels mild or cool about a project, that feel they are going into it just because when budget difficulties arrive, those are the first to go and you wind up doing more damage internationally than if you had done nothing at all. And I think we all want to avoid that.

Mr. LUJAN. Yes, I think that is a good position. Just as a matter of curiosity, the two satellites that were launched now, Arabsat and the next one, I would like to know did U.S. companies build those?

Mr. PEDERSEN. Arabsat was built in a partnership between Aerospatiale and Ford Aerospace. I will have to go check on Morelos. Well, it was integrated at Aerospatiale, but Ford Aerospace built large portions of it. We see that happening more and more, that satellites are built in contractor-subcontractor relationships, and quite often the subcontractor has a piece almost as big as the prime contractor.

Mr. LUJAN. Aerospatiale was the prime?

Mr. PEDERSEN. Aerospatiale was the prime for Arabsat, I believe. And I will have to check, Mr. Chairman, Morelos. I think I know the answer but I would prefer not to give a wrong answer. I would be happy to supply that.

Mr. LUJAN. You made an interesting point in your written testimony, and maybe you mentioned it while I was out, that you don't have a line item for international projects. Do you think that would be useful?

Mr. PEDERSEN. I would rather not.

Mr. LUJAN. You would rather not?

Mr. PEDERSEN. My feeling is, Congressman Lujan, that if you have particular amount of money that you are told to spend on international projects, then you tend to not go through the kind of careful scrutiny in looking at self-interest and what your own basic programmatic objectives are. The danger is that you feel that you're going to have to spend that money, you are going to have to spend it on your international projects and you go out and, by gosh, you find international projects, and they may not be the best ones.

For the very same reason, NASA as a rule does not enter into umbrella agreements. We do project by project. We don't do umbrella agreements that say, "NASA and party X will spend over the next 4 years $30 million in pursuing space."

I think that we have done rather well. In fact, there are very few programs—well, you are so close to NASA you know this—but there are very few programs that NASA has that don't have international involvement. I think in almost all cases after we have looked around, we have determined the international involvement makes a lot of sense.

So I think you're getting much the same result with a bit more systematic process.

Mr. LUJAN. Thank you. I have nothing further.

Mr. PACKARD. Mr. Chairman, may I just follow up, Mr. Chairman, on one question?

With our discussion earlier on the cooperative efforts on a bilateral basis, later on when we get into the use of Space Stations, actually the commercialization of Space Stations, countries that have not been involved, where there are no agreements and they have not been involved in the actual development and construction of the Space Station, may want to come in and actually use the facility on a specific call basis. That in and of itself will bring about some international negotiating relationships in terms of how to actually commercialize an international facility and yet divide up closely. There are lots of little intricacies here that I can see would have to be worked out.

Mr. PEDERSEN. Yes.

Mr. PACKARD. I would like to know if you perceive these problems.

Mr. PEDERSEN. Oh, yes. We have made very clear that this is going to be a user-oriented facility. It is there, and one for customers to use. One of the advantages of international cooperation, I believe, is that in addition to the other things that have been mentioned here today—cost sharing and expanded capabilities, these sorts of things—it also has the effect of building a broadened worldwide customer base because countries investing in a Station obviously want to see some returns on their investments, and they have an incentive to go out and encourage this activity.

As a country that believes in the value of competition, I think we ought not to be—and I was happy to hear Joe Gavin, I think, say this—that our industries ought not to be afraid that the Japanese and the Canadians and the Europeans are interested in the commercial possibilities of space microgravity and so on. They ought to take that as a challenge, and I think that there is nothing like some competition to get people interested in moving. And I see that in our industry already.

But we have said to other countries as well, developing countries, Third World countries, nonparticipants in the development phase, that it will be open and available to them on a fair basis, fairly priced, and we have had already, I might add, some very serious inquiries from other countries, both Third World and developed countries, about using the Station, building experiments to be used on it, building instruments to be used on it.

Mr. PACKARD. I agree with that. It simply will inject a new set of negotiating——

Mr. PEDERSEN. Oh, yes.

Mr. PACKARD [continuing]. Problems that have to be worked out in terms of the distribution of the revenues and the taxing mechanisms and all the problems that are associated with business will now become an international sphere.

Mr. PEDERSEN. Well, Mr. Congressman, I have said many times I would rather have to deal with the problems of more people wanting to use the station than we can handle and have to negotiate ground rules than open a Station and have no one there wanting to use it. So those kinds of problems I think I or my successor will welcome.

Mr. PACKARD. Thank you. I would agree with that.

Mr. LUJAN [acting chairman]. Thank you very much, Mr. Pedersen, for very enlightening and enjoyable testimony.

Mr. PEDERSEN. Thank you.

[Answers to questions asked of Mr. Pedersen follow:]

QUESTIONS AND ANSWERS FOR THE RECORD

Mr. Kenneth S. Pedersen

1. **You mention in your testimony how NASA takes into account technology transfer considerations in its selection, definition and implementation of joint projects so that we do not jeopardize either our national security interests or the competitive position of U.S. industry. Do similar restrictions apply when, for example, we collaborate with the European Space Agency?**

   The process of selecting, defining and implementing all of our joint projects includes careful attention to the technology transfer consideration.

2. **What roles do nongovernmental organizations, such as professional societies or various National Academies play in the development, implementation, and funding of NASA's international space programs? Should they or can they do more?**

   NASA has no separate approach or budgetary line item for its international programs; rather, foreign scientists and engineers may participate in NASA-funded programs. As a result, non-governmental organizations play essentially the same role whether or not a program has international involvement. NASA's international programs are identified first on the basis of scientific and technical value and are reviewed by advisory committees such as the Space Science Board of the National Academy of Sciences. In addition, non-governmental organizations assist in planning for future international programs by providing a forum for discussions of potential scientific goals. For example, the National Academy of Sciences summer study on future space activities at Woods Hole last year and again this year involves scientific expertise from abroad so that the international dimension is fully explored. Professional societies and associations, such as the American Institute of Aeronautics and Astronautics, also provide for a scientific, technical and even philosophical discussions of international issues among representatives of government, industry and academia from around the world. All of these are helpful to NASA in formulating its program plans and that is the most appropriate role for non-governmental organizations. As far as development, implementation and funding are concerned, non-governmental organizations are organizations are involved in recommending priorities and levels of funding. In summary, we believe the activities of non-governmental organizations are at an appropriate level and do not need to be increased.

Mr. LUJAN. The committee will stand adjourned until 10 tomorrow morning, where we will take up the third of the four planned hearings on international cooperation in science.

Thank you very much.

[Whereupon, at 12:58 p.m., the task force was adjourned, to reconvene at 10 a.m., on Thursday, June 20, 1985.]

INTERNATIONAL COOPERATION IN SCIENCE

THURSDAY, JUNE 20, 1985

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to recess, at 10:12 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. Today's hearing is the third of a series of 4 days of hearings on international cooperation in science. These hearings are considering three sets of issues: One, international cooperation in "big science"; two, the impact of international cooperation on research priorities; and, three, the coordination and management of international cooperative research.

Today's first witness is Dr. John McTague, Deputy Director of the Office of Science and Technology Policy. Dr. McTague is a distinguished scientist in his own right and served as Director of the National Synchrotron Light Source at the Brookhaven National Laboratory prior to assuming his present duties.

Dr. McTague, we are very pleased to have you, and you may proceed.

[A biographical sketch of Dr. McTague follows:]

Dr. John P. McTague

Dr. John P. McTague was appointed Deputy Director, Office of Science and Technology Policy, Executive Office of the President, on November 8, 1983. Following nomination by President Reagan he was confirmed unanimously by the U.S. Senate.

Dr. McTague was born in Jersey City, NJ, on November 28, 1938. Upon completion of high school in the New York area he entered Georgetown University and received his B.S. degree in chemistry with honors in 1960, and his Ph.D. in physical chemistry from Brown University in 1965.

From 1964 to 1970, Dr. McTague was a member of the technical staff at the North American Rockwell Science Center. He then became professor of chemistry and member of the Institute of Geophysics and Planetary Physics at the University of California at Los Angeles until 1982 at which time he was appointed chairman of the National Synchrotron Light Source Department at Brookhaven National Laboratory. Dr. McTague was also adjunct professor of chemistry at Columbia University.

Dr. McTague is the author of over 80 experimental and theoretical papers in condensed matter physics and chemistry. He is a member of the American Chemical Society and a fellow of the American Physical Society, and has served as associate editor of the *Journal of Chemical Physics.* Dr. McTague has received senior fellowships from A.P. Sloan, John Simon Guggenheim, and NATO. In 1975 he was honored with the California Section Award of the American Chemical Society.

Dr. McTague is married, has four children and resides in Potomac, MD.

STATEMENT OF DR. JOHN P. McTAGUE, DEPUTY DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT; ACCOMPANIED BY DR. WALLACE KORNACK, ASSISTANT DIRECTOR FOR ENERGY, NATURAL RESOURCES, AND INTERNATIONAL AFFAIRS, WASHINGTON, DC

Dr. McTAGUE. Thank you, Mr. Chairman. I am pleased to have this chance to meet with the committee and its Task Force on Science Policy. We have a small luxury here this morning because we are not focusing on particular legislation or programs, but on a sense of how Federal science policy can best address the future.

So, taking advantage of that opportunity, I would like to approach this topic of international science from a different perspective than usual and present our sense of some major concerns that are now emerging.

As I am sure these series of hearings have been illustrating, we are in the midst of momentous and rapid changes in both science and technology themselves, as well as in the means by which government assesses, supports, and uses the results of research and development.

Dr. Keyworth, the President's Science Advisor, has appeared before this committee on many occasions to offer his own perspectives on these changes and to discuss the rationale and expectations that underlie the administration's science and technology policy.

That ferment cannot help but spill over into the way in which we cooperate with other nations in the pursuit of mutual interests in science and technology. Yet I suspect that we all have some concerns that the mechanisms—indeed, the attitudes—that still influence our international science relations may be rooted in a different era, one characterized by a slower pace of technological advance, by an almost unquestioned dominance by the United States of the world's science and technology, and by unspoken assumptions in the United States that international cooperation would inevitably be one-sided and done more in the sense of providing U.S. assistance to science and technology in other countries than of receiving comparable technical returns ourselves.

Too many of our programs have been cooperative more in name than in reality. It is well past time to discard those outdated assumptions and rethink what we expect and need in our international programs.

Mr. Chairman, in a very real sense the primary force driving science policy today is a product of the success of science policies in the fifties and sixties. Our postwar institutionalization of Federal support for basic research— as embodied in the then-new agencies like the AEC, NSF, NIH, and NASA, and in the enormously influential support for basic research within the Defense Department—today is paying back our investment virtually across the spectrum. One would be hard-pressed to find a discipline that isn't pushing hard at new frontiers and isn't developing new research tools and techniques of immense investigative power.

No question, this U.S.-led scientific blossoming has been the wellspring of today's new technologies and new industries, ranging from the microchip to biotechnology.

So, in a very direct way, we have shown others that the most promising route to economic growth and prosperity in the late 20th century lies in scientific and technical knowledge and its application. In a very real sense, we have been the inspiration and even the benefactor of the growing industrial development that we now see throughout the world.

A number of examples come readily to mind including, of course, the way Japan studied us and very successfully used the emerging tools of technology to fuel their own economic boom. But the example that I find most intriguing, and perhaps of most pertinence to the discussions here today, is the People's Republic of China.

In spite of the fundamentally different philosophies of government that guide our two nations, we have found a strong mutual bond in science and technology. Over the past 10 years, that shared interest in both basic research and in how technology can speed industrial modernization has been the essential basis on which we have steadily narrowed the gap between countries and dramatically improved relations.

What I find fascinating about the two examples of Japan and China is that they remind us that today it hardly matters what the stage of a country's development is; all agree that science and technology are major factors in determining their economic future.

And that is not to say that all nations embrace technology to the same degree. Obviously, technology also brings change, and we are coming to realize that a key issue before us all is how nations are going to cope with and manage the changes being made possible, and being thrust upon them, by this science and technology revolution.

I saw an example of that very directly last week when I had a chance to meet with various industrial and scientific groups in Brazil. In fact, I had the opportunity there to address the Brazilian counterpart to this committee and was intrigued to hear their strong interest in many of the same things we talk about here, such as stronger support for basic research and improved university-industry relations.

I came away with a strong impression that they, like so many other developing countries, see their futures clearly tied to progress in science and technology.

Interestingly, that is not necessarily the case in the most industrialized nations. For example, much of Europe is as fearful of the impacts of new technology on its frightening unemployment problems as it is hopeful that new technology is the answer to lagging economic growth.

Meanwhile, a country like Japan is beginning to worry about its still weak science infrastructure and the possibility that it won't be able to sustain its technological brilliance unless it also develops stronger science.

Nor have we in the United States gone through the changes of these recent years untouched. Even while rebuilding our science base through increased Federal support for basic research, we have been concerned about the weakened institutional ties among the institutions that do R&D—and by that I mean the universities, industry, and Federal laboratories—and struggling to find ways to reassert the technological leadership that our competitors have been chipping away at over the past decade.

We believe a fundamental issue to address at the international level is how countries are going to deal with these changes. How are they going to respond to the rising expectations of their citizens that science and technology will carry them into a better future?

One of the problems we have to face up to now is that our traditional programs for international science and technology cooperation have rarely addressed these kinds of larger issues. Yet, year by year, those are the issues dominating how we think about science and technology in our own countries and how we think about programs we may wish to undertake together.

One approach that we are working on in OSTP, initially suggested by the Japanese, is to bring the ministers of science and technology of industrialized countries—or individuals who, by whatever title, oversee their governments' R&D efforts—together for an informal working conference.

This ministerial meeting, which could take place some time later this year, would allow each of the ministers to bring his own concerns to a common meeting ground for discussion. For our own part, we would hope that the discussions would enable us to address several problems that particularly concern us. One is the precarious situation I mentioned in Europe, notably the difficulty there in creating new jobs.

As a point of calibration, over the past 15 years, we in the United States have created 26 million new jobs, while the Europeans have maintained essentially the same number of jobs. Obviously, the economic vitality of Europe is of fundamental importance to worldwide stability.

If it seems that this is an awfully large problem to expect the science and technology ministers to cope with, I would respond in two ways. First, as we ourselves hear from people throughout this country, and as reflected in these ambitious hearings being held by the task force this year, science and technology are vitally important, not simply to the people in white coats or to the high-tech high flyers, but to everyone who thinks about their jobs over the next decade and to everyone who worries about what kinds of futures their children will have.

And second, as we have seen time and time again, probably the most effective channel we have found for nations to cooperate has been through science and technology. The example I cited earlier of the People's Republic of China may be the most spectacular success, but there are plenty of others as well.

Let me add that we would also hope to have a chance to raise another issue at a ministerial meeting, and that is to talk about mechanisms for planning international research programs. It goes without saying that, in an era when frontier research is becoming exceedingly expensive in many areas, we will have no choice but to collaborate on world-type research projects.

Yet too often we wind up with a situation where one country, or some small group of countries, carries a proposed project well into the design stage and only then starts to solicit participation from other countries. That is not what we would call a real partnership. Among other deficiencies, it fails to take advantage of the kind of creativity and innovation that is available from getting others involved in these stages.

Mr. Chairman, I appreciate having the opportunity to share OSTP's perspectives on international cooperation in science and technology with the task force. We face challenges of a substantially different nature than we have in the past, and we clearly have our work cut out for us in devising better ways to respond to them.

I hope I have been able to give an indication of why we think this whole area deserves a new level of attention. I would be pleased to answer any questions that the committee may have.

[The prepared statement of Dr. McTague follows:]

PROPOSED TESTIMONY OF DR. JOHN P. MCTAGUE
DEPUTY DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY
EXECUTIVE OFFICE OF THE PRESIDENT
TO THE TASK FORCE ON SCIENCE POLICY
COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES
JUNE 20, 1985

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

I'M PLEASED TO HAVE THIS CHANCE TO MEET WITH THE COMMITTEE AND ITS TASK FORCE ON SCIENCE POLICY. WE HAVE A SMALL LUXURY HERE THIS MORNING, BECAUSE WE'RE NOT FOCUSING ON PARTICULAR LEGISLATION OR PROGRAMS, BUT ON A SENSE OF HOW FEDERAL SCIENCE POLICY CAN BEST ADDRESS THE FUTURE. SO, TAKING ADVANTAGE OF THAT OPPORTUNITY, I'D LIKE TO APPROACH THIS TOPIC OF INTERNATIONAL SCIENCE FROM A DIFFERENT PERSPECTIVE THAN USUAL AND PRESENT OUR SENSE OF SOME MAJOR CONCERNS THAT ARE NOW EMERGING.

AS I'M SURE THESE SERIES OF HEARINGS HAVE BEEN ILLUSTRATING, WE'RE IN THE MIDST OF MOMENTOUS AND RAPID CHANGES IN BOTH SCIENCE AND TECHNOLOGY THEMSELVES, AS WELL AS IN THE MEANS BY WHICH GOVERNMENT ASSESSES, SUPPORTS, AND USES THE RESULTS OF RESEARCH AND DEVELOPMENT. DR. KEYWORTH, THE PRESIDENT'S SCIENCE ADVISOR, HAS APPEARED BEFORE THIS COMMITTEE ON MANY OCCASIONS TO OFFER HIS OWN PERSPECTIVES ON THOSE CHANGES AND TO DISCUSS THE RATIONALE AND EXPECTATIONS THAT UNDERLIE THE ADMINISTRATION'S SCIENCE

AND TECHNOLOGY POLICY.

THAT FERMENT CAN'T HELP BUT SPILL OVER INTO THE WAY IN WHICH WE COOPERATE WITH OTHER NATIONS IN THE PURSUIT OF MUTUAL INTERESTS IN SCIENCE AND TECHNOLOGY. YET I SUSPECT THAT WE ALL HAVE SOME CONCERNS THAT THE MECHANISMS--INDEED THE ATTITUDES--THAT STILL INFLUENCE OUR INTERNATIONAL SCIENTIFIC RELATIONS MAY BE ROOTED IN A DIFFERENT ERA, ONE CHARACTERIZED BY A SLOWER PACE OF TECHNICAL ADVANCES, BY AN ALMOST UNQUESTIONED DOMINANCE BY THE UNITED STATES OF THE WORLD'S SCIENCE AND TECHNOLOGY, AND BY UNSPOKEN ASSUMPTIONS IN THE THE UNITED STATES THAT INTERNATIONAL COOPERATION WOULD INEVITABLY BE ONE-SIDED AND DONE MORE IN THE SENSE OF PROVIDING U.S. ASSISTANCE TO SCIENCE AND TECHNOLOGY IN OTHER COUNTRIES THAN OF RECEIVING COMPARABLE TECHNICAL RETURNS OURSELVES. TOO MANY OF OUR PROGRAMS HAVE BEEN COOPERATIVE MORE IN NAME THAN IN REALITY. IT'S WELL PAST TIME TO DISCARD THOSE OUTDATED ASSUMPTIONS AND RETHINK WHAT WE EXPECT AND NEED IN OUR INTERNATIONAL PROGRAMS.

MR. CHAIRMAN, IN A VERY REAL SENSE THE PRIMARY FORCE DRIVING SCIENCE POLICY TODAY IS A PRODUCT OF THE SUCCESS OF SCIENCE POLICIES IN THE FIFTIES AND SIXTIES. OUR POST-WAR INSTITUTIONALIZATION OF FEDERAL SUPPORT FOR BASIC RESEARCH--AS EMBODIED IN THEN-NEW AGENCIES LIKE THE AEC, NSF, NIH, AND NASA, AND IN THE ENORMOUSLY INFLUENTIAL SUPPORT FOR BASIC RESEARCH WITHIN THE DEFENSE

DEPARTMENT--TODAY IS PAYING BACK OUR INVESTMENT VIRTUALLY ACROSS THE SPECTRUM. ONE WOULD BE HARD-PRESSED TO FIND A DISCIPLINE THAT ISN'T PUSHING HARD AT NEW FRONTIERS AND ISN'T DEVELOPING NEW RESEARCH TOOLS AND TECHNIQUES OF IMMENSE INVESTIGATIVE POWER.

NO QUESTION--THIS U.S.-LED SCIENTIFIC BLOSSOMING HAS BEEN THE WELLSPRING OF TODAY'S NEW TECHNOLOGIES AND NEW INDUSTRIES--RANGING FROM THE MICROCHIP TO BIOTECHNOLOGY. SO IN A VERY DIRECT WAY WE'VE SHOWN OTHERS THAT THE MOST PROMISING ROUTE TO ECONOMIC GROWTH AND PROSPERITY IN THE LATE TWENTIETH CENTURY LIES IN SCIENTIFIC AND TECHNICAL KNOWLEDGE AND ITS APPLICATIONS. IN A VERY REAL SENSE WE'VE BEEN THE INSPIRATION AND EVEN THE BENEFACTOR OF THE GROWING INDUSTRIAL DEVELOPMENT THAT WE NOW SEE THROUGHOUT THE WORLD.

A NUMBER OF EXAMPLES COME READILY TO MIND--INCLUDING, OF COURSE, THE WAY JAPAN STUDIED US AND VERY SUCCESSFULLY USED THE EMERGING TOOLS OF TECHNOLOGY TO FUEL THEIR OWN ECONOMIC BOOM. BUT THE EXAMPLE THAT I FIND MOST INTRIGUING, AND PERHAPS OF MOST PERTINENCE TO THE DISCUSSIONS HERE TODAY, IS THE PEOPLE'S REPUBLIC OF CHINA. IN SPITE OF THE FUNDAMENTALLY DIFFERENT PHILOSPHIES OF GOVERNMENT THAT GUIDE OUR TWO NATIONS, WE'VE FOUND A STRONG MUTUAL BOND IN SCIENCE AND TECHNOLOGY. OVER THE PAST TEN YEARS THAT SHARED INTEREST IN BOTH BASIC RESEARCH AND IN

HOW TECHNOLOGY CAN SPEED INDUSTRIAL MODERNIZATION HAS BEEN THE ESSENTIAL BASIS ON WHICH WE'VE STEADILY NARROWED THE GAP BETWEEN COUNTRIES AND DRAMATICALLY IMPROVED RELATIONS.

WHAT I FIND FASCINATING ABOUT THE TWO EXAMPLES OF JAPAN AND CHINA IS THAT THEY REMIND US THAT TODAY IT HARDLY MATTERS WHAT THE STAGE OF A COUNTRY'S DEVELOPMENT: ALL AGREE THAT SCIENCE AND TECHNOLOGY ARE MAJOR DETERMINING FACTORS IN DETERMINING THE ECONOMIC FUTURE. THAT'S NOT TO DAY THAT ALL NATIONS EMBRACE TECHNOLOGY TO THE SAME DEGREE. OBVIOUSLY, TECHNOLOGY ALSO BRINGS CHANGE, AND WE'RE COMING TO REALIZE THAT A KEY ISSUE BEFORE US ALL IS HOW NATIONS ARE GOING TO COPE WITH AND MANAGE THE CHANGES BEING MADE POSSIBLE--AND BEING THRUST UPON THEM--BY THIS SCIENCE AND TECHNOLOGY REVOLUTION.

I SAW AN EXAMPLE OF THAT VERY DIRECTLY LAST WEEK WHEN I HAD A CHANCE TO MEET WITH VARIOUS INDUSTRIAL AND SCIENTIFIC GROUPS IN BRAZIL. IN FACT, I HAD THE OPPORTUNITY THERE TO ADDRESS THE BRAZILIAN COUNTERPART TO THIS COMMITTEE AND WAS INTRIGUED TO HEAR THEIR STRONG INTEREST IN MANY OF THE SAME THINGS WE TALK ABOUT HERE--SUCH AS STRONGER SUPPORT FOR BASIC RESEARCH AND IMPROVED UNIVERSITY-INDUSTRY RELATIONS. I CAME AWAY WITH A STRONG IMPRESSION THAT THEY, LIKE SO MANY OTHER DEVELOPING COUNTRIES, SEE THEIR FUTURES CLEARLY TIED TO PROGRESS IN SCIENCE AND TECHNOLOGY.

INTERESTINGLY, THAT'S NOT NECESSARILY THE CASE IN THE MORE INDUSTRIALIZED NATIONS. FOR EXAMPLE, MUCH OF EUROPE IS AS FEARFUL OF THE IMPACTS OF NEW TECHNOLOGY ON ITS FRIGHTENING UNEMPLOYMENT PROBLEMS AS IT IS HOPEFUL THAT NEW TECHNOLOGY IS THE ANSWER TO LAGGING ECONOMIC GROWTH. MEANWHILE, A COUNTRY LIKE JAPAN IS BEGINNING TO WORRY ABOUT ITS STILL-WEAK SCIENCE INFRASTRUCTURE AND THE POSSIBILITY THAT IT WON'T BE ABLE TO SUSTAIN ITS TECHNOLOGICAL BRILLIANCE UNLESS IT ALSO DEVELOPS STRONGER SCIENCE.

NOR HAVE WE IN THE UNITED STATES GONE THROUGH THE CHANGES OF THESE RECENT YEARS UNTOUCHED. EVEN WHILE REBUILDING OUR SCIENCE BASE THROUGH INCREASED FEDERAL SUPPORT FOR BASIC RESEARCH, WE'VE BEEN CONCERNED ABOUT THE WEAKENED INSTITUTIONAL TIES AMONG THE INSTITUTIONS THAT DO R&D--AND BY THAT I MEAN THE UNIVERSITIES, INDUSTRY, AND FEDERAL LABORATORIES--AND STRUGGLING TO FIND WAYS TO REASSERT THE TECHNOLOGICAL LEADERSHIP THAT OUR COMPETITORS HAVE BEEN CHIPPING AWAY AT OVER THE PAST DECADE.

WE BELIEVE A FUNDAMENTAL ISSUE TO ADDRESS AT THE INTERNATIONAL LEVEL IS HOW COUNTRIES ARE GOING TO DEAL WITH THESE CHANGES. HOW ARE THEY GOING TO RESPOND TO THE RISING EXPECTATIONS OF THEIR CITIZENS THAT SCIENCE AND TECHNOLOGY WILL CARRY THEM INTO A BETTER FUTURE?

ONE OF THE PROBLEMS WE HAVE TO FACE UP TO NOW IS THAT

OUR TRADITIONAL PROGRAMS FOR INTERNATIONAL SCIENCE AND TECHNOLOGY COOPERATION HAVE RARELY ADDRESSED THESE KINDS OF LARGE ISSUES. YET YEAR BY YEAR THOSE ARE THE ISSUES DOMINATING HOW WE THINK ABOUT SCIENCE AND TECHNOLOGY IN OUR OWN COUNTRIES AND HOW WE THINK ABOUT PROGRAMS WE MAY WISH TO UNDERTAKE TOGETHER. ONE APPROACH THAT WE'RE WORKING ON IN OSTP, INITIALLY SUGGESTED BY THE JAPANESE, IS TO BRING THE MINISTERS OF SCIENCE AND TECHNOLOGY OF INDUSTRIALIZED COUNTRIES--OR INDIVIDUALS WHO, BY WHATEVER TITLE, OVERSEE THEIR GOVERNMENTS' R&D EFFORTS--TOGETHER FOR AN INFORMAL WORKING CONFERENCE.

THIS MINISTERIAL MEETING, WHICH COULD TAKE SOMETIME LATER THIS YEAR, WOULD ALLOW EACH OF THE MINISTERS TO BRING HIS OWN CONCERNS TO A COMMON MEETING GROUND FOR DISCUSSION. FOR OUR OWN PART, WE WOULD HOPE THAT THE DISCUSSIONS WOULD ENABLE US TO ADDRESS SEVERAL PROBLEMS THAT PARTICULARLY CONCERN US. ONE IS THE PRECARIOUS SITUATION I MENTIONED IN EUROPE, NOTABLY THE DIFFICULTY THERE IN CREATING NEW JOBS. AS A POINT OF CALIBRATION, OVER THE PAST 15 YEARS WE IN THE UNITED STATES HAVE CREATED 26 MILLION NEW JOBS, WHILE THE EUROPEANS HAVE MAINTAINED ESSENTIALLY THE SAME NUMBER OF JOBS. OBVIOUSLY, THE ECONOMIC VITALITY OF EUROPE IS OF FUNDAMENTAL IMPORTANCE TO WORLDWIDE STABILITY.

IF IT SEEMS THAT THIS IS AN AWFULLY LARGE PROBLEM TO

EXPECT THE SCIENCE AND TECHNOLOGY MINISTERS TO COPE WITH, I WOULD RESPOND IN TWO WAYS. FIRST, AS WE OURSELVES HEAR FROM PEOPLE THROUGHOUT THIS COUNTRY, AND AS REFLECTED IN THESE AMBITIOUS HEARINGS BEING HELD BY THE TASK FORCE THIS YEAR, SCIENCE AND TECHNOLOGY ARE VITALLY IMPORTANT--NOT SIMPLY TO THE PEOPLE IN WHITE COATS OR TO THE HIGH-TECH HIGH FLYERS, BUT TO EVERYONE WHO THINKS ABOUT THEIR JOBS OVER THE NEXT DECADE AND TO EVERYONE WHO WORRIES ABOUT WHAT KINDS OF FUTURES THEIR CHILDREN WILL HAVE. AND SECOND, AS WE'VE SEEN TIME AND TIME AGAIN, PROBABLY THE MOST EFFECTIVE CHANNEL WE'VE FOUND FOR NATIONS TO COOPERATE HAS BEEN THROUGH SCIENCE AND TECHNOLOGY. THE EXAMPLE I CITED EARLIER OF THE PEOPLE'S REPUBLIC OF CHINA MAY BE THE MOST SPECTACULAR SUCCESS, BUT THERE ARE PLENTY OF OTHERS AS WELL.

LET ME ADD THAT WE WOULD ALSO HOPE TO HAVE A CHANCE TO RAISE ANOTHER ISSUE AT A MINISTERIAL MEETING, AND THAT'S TO TALK ABOUT MECHANISMS FOR PLANNING INTERNATIONAL RESEARCH PROGRAMS. IT GOES WITHOUT SAYING THAT, IN AN ERA WHEN FRONTIER RESEARCH IS BECOMING EXCEEDINGLY EXPENSIVE IN MANY AREAS, WE'LL HAVE NO CHOICE BUT TO COLLABORATE ON WORLD-TYPE RESEARCH PROJECTS. YET TOO OFTEN WE WIND UP WITH A SITUATION WHERE ONE COUNTRY, OR SOME SMALL GROUP OF COUNTRIES, CARRIES A PROPOSED PROJECT WELL INTO THE DESIGN STAGE AND ONLY THEN STARTS TO SOLICIT PARTICIPATION FROM OTHER COUNTRIES. THAT'S NOT WHAT WE'D CALL A REAL

PARTNERSHIP, AND AMONG OTHER DEFICIENCIES, IT FAILS TO TAKE ADVANTAGE OF THE KIND OF CREATIVITY AND INNOVATION THAT'S AVAILABLE FROM GETTING OTHERS INVOLVED IN THE CREATIVE STAGES.

MR. CHAIRMAN, I APPRECIATE HAVING THE OPPORTUNITY TO SHARE OSTP'S PERSPECTIVES ON INTERNATIONAL COOPERATION IN SCIENCE AND TECHNOLOGY WITH THE TASK FORCE. WE FACE CHALLENGES OF A SUBSTANTIALLY DIFFERENT NATURE THAN WE HAVE IN THE PAST, AND WE CLEARLY HAVE OUR WORK CUT OUT FOR US IN DEVISING BETTER WAYS TO RESPOND TO THEM. I HOPE I'VE BEEN ABLE TO GIVE AN INDICATION OF WHY WE THINK THIS WHOLE AREA DESERVES A NEW LEVEL OF ATTENTION. I WOULD BE PLEASED TO ANSWER ANY QUESTIONS THAT THE COMMITTEE MAY HAVE.

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DISCUSSION

Dr. McTague. I would like also to introduce Dr. Wallace Kornack, who is our Assistant Director for Energy, Natural Resources, and International Affairs.

Mr. Fuqua. Dr. Kornack, we are very pleased to have you with us this morning.

Dr. Kornack. Thank you. It is a pleasure to be here, sir.

Mr. Fuqua. Dr. McTague, you mentioned a suggestion for having, possibly later this year, a meeting of the ministers of science, research, and technology, however appropriately that applies to the various countries. And in most of those countries, there is one sole, central repository where R&D is carried forth. I am really speaking basic research, not R&D.

But we do not have that in this country. Do we need something like that to coordinate our international affairs, or is the structure such that it is better left within the various agencies to initiate their own programs and maybe some coordination through your offices and that of possibly the State Department?

Dr. McTague. I think it is particularly important that we have a center which sets policy direction. Ours is a government of vast and differing interests, but it is important that we make sure that we have a central area for policy direction, and I believe that the implementation can be handled in different ways, depending upon the kinds of cooperation that we are talking about.

Clearly, cooperation involving a large facility such as an accelerator or a fusion facility is rather different from programs, cooperative programs, which have a significant component which involves foreign affairs direction. So I think perhaps our office or some other office should be clearly in the lead in the policy direction area. Obviously, the State Department must be involved in all aspects. But that particular program will dictate which agencies should be involved.

Mr. Fuqua. You also mentioned big science. That has been a topic that we have discussed in the course of these hearings. Should all big science projects routinely be offered for international cooperation, or arrangements be made, or should it be on an individual basis depending on which discipline it is?

Most of them, though, such as the SSC or the fusion program, or, in the most recent cases, Space Station—and there may be others that come along and others that escape my memory at this time—but should we routinely subject big science projects to the possibility of international cooperation?

Dr. McTague. I think it is important that we make sure that we keep discussing with other nations what we see as our interest in specific big projects, solicit their own interests in large-scale projects, and find mutual ways of proceeding.

I think we have been learning more and more how to do that. For example, the Summit Working Groups have been participating in this activity. I think the ministerial meeting will do likewise. Certainly, in several areas of science, we already have very good international cooperation without formal mechanisms, necessarily. High energy physics is an obvious example of that truly international community.

But it definitely is important, in all of these cases, that we have discussions with potential partners, or those even just interested in particular areas, at the earliest stages in the formulation of projects.

Mr. **Fuqua**. Yesterday, one of the witnesses suggested that, particularly in the fusion program, the United States needed to, in effect, get its act together, to come forth with a proposal.

Now, in the Space Station, just the opposite was suggested by our international friends: "Don't have a program and come tell us what part do we want; we would like to be on the planning for it."

How do we accommodate these conflicting procedures, possibly? And maybe there is a reason to do that. Maybe the Space Station is different—well, it is different than fusion, of course—but it still is big science. How do we accommodate those differences and yet still be reliable partners in international cooperation?

Dr. **McTague**. I think the two examples that you have mentioned, Mr. Chairman, indeed are probably at the extremes of approaches. In the fusion area, in particular, we are reexamining, from a fundamental level, what our fusion program should be. And fusion, of course, has in it mixtures of research and development.

We have been reaching the conclusion that our efforts, from a national point of view, should be focused more on long-term research and on determining the underlying physics, so that eventually, when the need comes about, some several decades downstream, to actually develop fusion as an economical renewable source of energy, we have the underlying physics.

Whereas, in the past, we have been expending perhaps much more effort on short term, rapid development and demonstration projects, that, in particular, does create difficulties in international cooperation, as any one nation—especially as you get toward the development end—changes its goals either for economic reasons or for other strategic reasons.

That is not so much the case in basic science, however. It is fairly easy to lay out—well, I should not say easy, but it is a more regularized process—to lay out a program of interest in basic science. The fundamentals don't change. The frontiers move forward, but the fundamentals don't change so much.

So I think, in the area of basic research in fusion, for example, as we are developing our own goals, then discussing them with other nations to see if their goals match, we will be in good shape.

Mr. **Fuqua**. Would you include such projects as the SSC?

Dr. **McTague**. Absolutely, and SSC is an example of a pure science project, where in fact, right from the beginning, we have been very actively soliciting cooperation in the design phases and in the goal phases from other countries. In particular, we have been having some very fruitful discussions along these lines with Japan.

Mr. **Fuqua**. Mr. Packard.

Mr. **Packard**. With the constraints on budget that we are now experiencing, it requires that we divide up the dollars. We just don't have sufficient funds for all the research that we would like to accomplish. It means that we have to pick and choose a little bit more carefully. As we move more and more into the cooperative efforts internationally, will that curtail or reduce the commitment to our local efforts—by local, I mean our national efforts—in terms of our progress in science research?

Are we looking at a choice, one with the other, or do you feel that we can—and if there is a choice, how is it best that we make such choices? Should we look more and more in the direction of international cooperation at the expense of national commitment, or vice versa?

Dr. McTague. I think the proper way to look at this is that international cooperation should be a mechanism for support of national goals. As we set our own national goals in the areas of science, we should take a look at those areas where we can get a benefit from international participation, and other countries should also make sure that their cooperation with us is in their own interest.

So I don't see it as one subtracting from the others. Clearly, there should not be a set-aside of funds, for example, for international cooperative projects. The projects should be done on the basis of their own merits and of mutual interest.

Now, where one does run into problems, that will have to involve negotiation or, for example, siting of facilities. Everyone, of course, wants everything on their own turf.

One should make certain that when one does develop international cooperative efforts—for example, involving a large facility—that it indeed be a facility in a field where international travel, et cetera, is a feasible activity.

High energy physics is an example of that where you literally cannot tell what country you are in at a high energy physics facility by the people that you talk to. This community has adjusted very well. Other communities have not yet because they have not had to participate for so long at this level.

But I think the important thing is that we find ways to negotiate siting of facilities that enable all of the partners to participate effectively.

Mr. Packard. More and more, Dr. McTague, we are finding the private sector and the industrial community becoming more and more involved in our scientific research, both on a cooperative basis and striking out on their own.

Do you think that the international effort will compromise that move and reduce the involvement of the private sector, or do you think that it would increase it?

Dr. McTague. I think, if properly handled, it could be of benefit in fact, also, to the private sector. Let me give you some examples of the European experiences, where for many years they have had to cooperate on large-scale projects. As they do so, they make sure that each—for example, building a facility at CERN—they make sure that each nation's industrial base has the opportunity to participate.

Now, they tend to do it by allocating, let's say, vacuum equipment to Italy, electronics to Britain, or whatever, and that perhaps might not be the best style for us in international agreements. But we should make sure that our technological base in industry can both participate as a supplier and can get joint information from cooperative projects, and I believe that that can be done by proper negotiation.

Mr. PACKARD. Do you believe that the trend is moving toward international cooperative efforts?

Dr. MCTAGUE. It is inevitable. It is inevitable both because large-scale facilities are becoming more expensive as a fraction of gross national product, for example, than in the past.

But more important than the economic issue, I think, is the opportunity for distributing the benefits of technology throughout the world as a two-way street, and by increasing technological capabilities in other countries, we then open up new markets for ourselves and, I think, help stabilize the world situation.

Mr. PACKARD. Your comments and your illustration of mainland China, I think, verify what you have just said. Do you see that kind of example expanding into the Soviet bloc countries in the future and a possible same type of response in terms of improving relationships between our country and theirs?

Dr. MCTAGUE. I think, in particular, when one talks about the Soviet Union and certain other Eastern European countries, we have to make absolutely certain that our scientific and technological efforts act in consonance with our other foreign policy objectives.

At the proper time, and as programs are of mutual benefit, I believe, indeed, science and technology can play an important role. It is important that we do this at the time that the President determines, and in consonance with, other foreign policy objectives.

Mr. PACKARD. Well, in view of those comments, were there any different circumstances? Was the environment different with Red China than it is with other Eastern bloc countries? And if so, in order to bring about what you have already used as an illustration of developing closer ties and better relationships through the cooperative efforts of science and technology, do you see a different scenario there than you presently see with the rest of the Eastern Bloc countries?

Dr. MCTAGUE. I think there are two substantial differences, one of which is external, and the other, internal to those countries.

The Soviet bloc has a clearly expansionist policy right now—Afghanistan is an example—as opposed to the internal policies where it is clear that the People's Republic of China has decided to make a very major effort to utilize science and technology to modernize its nation, to increase its industrial base, to increase the standard of living of its people, to open its markets with the West.

I don't see signs of similar things happening in the Soviet Union. Were that time to come about, and were the external circumstances to change, I think we would greatly enjoy further cooperation with the Soviet Union.

Mr. PACKARD. One last question, Mr. Chairman, if I may. Do you think we can overdo the international cooperation? Do you think there is a limit beyond which we ought to be more cautious?

Dr. MCTAGUE. It is not a panacea, and it shouldn't be a giveaway. We should all make sure that things are of mutual benefit, and science cooperation with other nations should be as related to our own internal scientific goals.

Mr. PACKARD. Thank you very much, Mr. Chairman.

Mr. FUQUA. Mr. Lujan.

Mr. LUJAN. Thank you, Mr. Chairman.

Just one question. If it is inevitable, as you say, that research moves into the international field—and I agree with you that it is inevitable—are we then at a point where we should establish those mechanisms by which we go into international cooperation; for example, the European Space Agency, with all of the nations participating? One ingredient to that is that it should be in pursuit of national goals. As a matter of fact, ESA does operate on that basis. The French put more money into Ariane; the Germans put more money into the Space Station, because that meets their national goals.

I was thinking that even perhaps through—just a first thought—through the International Atomic Energy Agency or through the International Energy Agency, do the research in fusion, gas-cooled reactors, waste disposal, all of those things that we are involved in. Would it help, or do you think the time has come, perhaps, that we set up those mechanisms; and, being that you are from OSTP, using OSTP as the lead agency to establish those mechanisms, and everybody would go with their projects to OSTP and see if we move them into the international field?

Dr. McTague. I think we should make use of existing international agencies where appropriate. I don't believe we should try to promote the idea of a single, centralized international science cooperative agency.

I think the one lesson that I have learned in my time in Washington is to fear the growth of bureaucracy. I think it is important that, at the very highest levels in various countries, there be some single center where one can turn for policy direction and for policy discussion, and I believe that this science ministerial meeting which we hope will take place later this year may provide a good informal beginning to such a process.

We presently do utilize many different types of approaches; for example, the Economic Summit Working Groups, cooperation with IAEA, cooperation through many international science unions. I don't believe a single mechanism would work well.

The present system is not perfect, but it offers the flexibility that we may be able to make further progress. I think, in particular, what is occurring nowadays in almost every country is the realization that science and technology in general, and in particular international cooperation, is important. Addressing that at the very highest levels is a good beginning, and then talking between peoples at these very highest levels, I think, will help set mutually beneficial policies.

Mr. Lujan. I was thinking more in terms of something like ESA, which works very well. They have made a commitment in space research, and they have their members, and they have their regular meetings and what is eligible for it.

We are at a disadvantage in that we don't have someone like a science minister, period, that directs research. That is why I thought OSTP could very well evaluate those things that go in there. I wasn't thinking in terms of OSTP making all of the arrangements. NASA would be part of a worldwide ESA-type thing; Department of Energy would be the one involved with the worldwide nuclear research; NIH, or HHS, or one of those, in health research.

I was more interested in whether you thought that those formal mechanisms should be established, or whether it is better just to continue as we are.

Dr. McTague. I think, as you pointed out, it is important that there be a central focus for these multiple types of activities. At the policy level, at least, I think OSTP is an appropriate agency.

We are not an operations office, and we should not become a pass-through point for paperwork. But I think, as you pointed out, playing a role in the policy level for discussions, international discussions, is highly appropriate for our office.

Mr. Lujan. What role did OSTP play in the decision to do the Space Station on a cooperative basis?

Dr. McTague. We had discussions directly with NASA on this in the very earliest stages. We had discussions internally, of course, in the administration. We have been engaged directly in international discussions, although most of them have been through NASA, as I believe was appropriate.

Mr. Lujan. NASA has done them directly with other countries and not through OSTP?

Dr. McTague. Yes; but there has been very close and effective coordination.

Mr. Lujan. Thank you, Mr. Chairman.

Mr. Fuqua. Mr. Stallings.

Mr. Stallings. How do we determine which international project we get into? Do we have a clearinghouse that says this looks good and this one isn't, or what is the procedure?

Dr. McTague. It depends on the scale of the project. If it is of a scale that is essentially appropriate for a single agency, and which does not have other broad foreign policy implications, discussions are often held on the basis of an agency in the United States with its counterpart agency abroad.

When there are very significant foreign policy implications, obviously, the State Department must get involved and we must get involved.

On very, very large-scale items such as the Space Station, that is a decision in which the whole Government plays a role; the State Department and we play policy roles, and the individual agency or agencies will play the operational role.

So it varies from activity to activity and with the purpose of the activity. I don't think there is a single model that would work very well, and I don't believe that a central clearinghouse is necessary. It is clearly necessary that very significant projects—significant for whatever reason—must be participated in by both the State Department and by our office.

Mr. Stallings. And then once the determination is made, how is the funding decided?

Dr. McTague. The funding is decided mainly through the agencies themselves. These issues must be important to the agency missions, and I think that is the appropriate way. There should not be set-asides. Whatever we do should be in our own national interest and the interest of the mission of the agency that is involved.

Mr. Stallings. I would assume that most of the countries would operate the same way. Does that complicate this international research if we have our own agenda, as they obviously do?

Mr. McTague. It certainly does complicate things, and we are not unique in being involved in complication. If one looks, for example, at the experience in Europe, many projects get slowed down quite a bit; siting of projects gets complicated by international political considerations, by relative funding situations. One nation is emphasizing science and technology one year; that same year, another nation may have very austere budgets and not wish to emphasize large-scale projects.

So it indeed gets complicated. But I think that is unavoidable. The important thing is that all countries make sure that whatever they do is in their own national interest. Otherwise, the project would not be sustained.

Mr. Stallings. Thank you.

Mr. Fuqua. Thank you very much, Dr. McTague and Dr. Kornack. We appreciate your being with us this morning.

Dr. McTague. Thank you, Mr. Chairman.

[Answers to questions asked of Dr. McTague follow:]

QUESTIONS FOR THE RECORD

DR. McTAGUE

Question:	What is OSTP's role in the formulation, development, and implementation of international cooperative science programs? How does OSTP interact with the State Department and the various mission agencies such as DOE or NASA?
Answer:	OSTP plays a major role in formulating policy regarding selected international science programs. We tend to focus primarily on those areas where S&T cooperation is judged to be an effective tool in accomplishing significant foreign policy objectives, e.g., China and India, or where the cost of the facilities required to carry out the science is such that shared funding and planning are desirable. When OSTP takes an active role, it consists of working with mission agencies to develop programs that will benefit the agencies as well as the cooperating partners, with the State Department to formulate agreements and coordinate policy, and with relevent representatives of the countries and international organizations involved.

Question: What role, if any, does the Federal Coordinating Council for Science, Engineering and Technology play in the coordination of international science activities? Could it play a stronger role, or is it too unwieldy a forum?

Answer: At the present time, FCCSET plays a minor role in coordinating international activities. Each of FCCST's 10 subcommittees deals with international science as it has relevance to the work of the subcommittee, but none is tasked solely to address the international aspects of its subject area.

In other words, the focus of these subcommittees is on a discipline or technical area, rather than on a policy area. We are presently considering the desirability and feasibility of selected policy subcommittees. If created, it would be important that they operate in such a mode that they not interfere with the traditional prerogatives of Department and Agencies.

Question: How do international programs in science help the various mission agencies accomplish their goals?

Answer: As I have stressed in my earlier testimony, our international programs evolve from the pursuit of national goals. Mission agencies use international programs to gain access to materials or environments not easily accessible in the U.S., to learn how other countries manage problems similar to those in the United States, and collaborate with colleagues working in similar fields. A few typical examples:

- Climate scientists are looking at tree ring growth in India to acquire historical climate data in that part of the world;
- Agricultural scientists have acquired germ plasm from China for experimentation in the control of gypsy moths;
- Measurement scientists are working with many countries to establish standardized measurement and testing techniques - in support of international trade as well as science;
- Earthquake scientists are measuring crustal movements and characteristics in many countries to enhance earthquake prediction and gain a better understanding of geologic phenomena.

Question: What roles do nongovernmental organizations, such as professional societies, private foundations, or various National Academies play in the development, implementation, and funding of international science programs? Should they or can they do more?

Answer: Some nongovernmental organizations such as the National Academy of Sciences, play a very active role in government programs through oversight functions and in recommending policy for the nation. The National Academies also develop and implement their own international programs. While these are independent of the government, they often are carried out in part with Federal funds.

Many professional societies have an international arm that encourages or initiates cooperation among individuals at the professional level. Professional societies also play a very useful role in networking and providing linkages between individuals and organizations across national borders. The contributions of nongovernmental organizations are useful and welcomed. Professional societies in particular can and should do more along these lines.

Question: Should Federal science funding include the aim of keeping the U.S. first in every field of science, and if so, will international cooperation help us to achieve this aim?

Answer: International goals for science should support our national objectives - one of which is to strive toward U.S. leadership in all fields of science. This is not to be interpreted as a requirement for the U.S. to be numerically number one in every field of science. Emphasis on excellence and creativity, however, should be sought in all fields and international cooperation, to the extent it supports and fosters this excellence, should be pursued.

Question: What does "world leadership" in a particular field of science mean? What particular benefits accrue to the "world leader" versus "number two"? Why should national policy makers care whether or not the nation is first, second, or third in a given field of science?

Answer: Being the world leader in a scientific field produces benefits far beyond the obvious prestige and recognition. A recognized leader becomes a magnet for talent and creativity impacting far more than the relatively small number of people who work directly in the field. The world leader sets the direction and pace in the field. It attracts the best talent from a worldwide talent base and spurs the healthy competition that leads to success. Being first in a particular field brings with it a sense of excitement and pride that doesn't exist with being number two or three. The best and brightest talent are attracted to number one, not number two. Leadership stimulates interest in science and excellence far across society inevitably spinning off new ideas and new technologies.

National leaders should be concerned about U.S. scientific leadership because being a world leader ultimately brings with it the technological spinoffs and trained talent base to develop and support a growing economy as well as national security requirements.

Question: Has there been an overinvestment or underinvestment in "big science" such as high energy physics or magnetic fusion energy relative to other sub-fields of physics or other disciplines? How can we best set priorities so that the appropriate levels of investment in different subfields or disciplines can be determined?

Answer: As in other areas of human endeavor, science is not immune to the improved vision accompanying hindsight. This is especially true when the science has a close relationship with a potentially economically important technology, such as magnetic fusion or solar energy. In such cases it is important to clearly distinguish the science base, and its susceptibility to rapid advancement, from economic and market force aspects.

High energy physics is one of the most rapidly advancing, most fundamental areas of science, and one that truly attracts the best and the brightest. Here, our significant investments have paid off at a high rate of return, and there is every sign that making the new investments to keep us at the forefront will be prudent.

The best criteria for setting science investment priorities are the rate of advance of a field and its attraction to our best young minds. Some of these fields will require large scale facilities and some will not. So, it is not so much a matter of "big" versus "little" science, but investing where we will enable the greatest gains.

Mr. FUQUA. Our next witness is Mr. Charles Horner, Deputy Assistant Secretary for Oceans and International Environmental and Scientific Affairs for the Department of State, and he will provide us with an overview of the State Department's role in international science activities.

Welcome, Mr. Horner, and we would be pleased to hear from you.

[A biographical sketch of Mr. Horner follows:]

CHARLES HORNER

Charles Horner has been Deputy Assistant Secretary of State for Science and Technology since October 1981. Previously, he had been adjunct professor and research associate of the Landegger Program in International Business Diplomacy in Georgetown University's School of Foreign Service. He was also a member of the U.S. Delegation to the United Nations Conference on the Law of the Sea. His earlier service in Government had been in the U.S. Senate, where he was a member of the professional staff of the Subcommittee on National Security and International Operations and, later, senior legislative assistant in the office of Senator Daniel P. Moynihan.

Horner is a graduate of the University of Pennsylvania and did postgraduate work at the University of Chicago. He also studied overseas in Taiwan and Japan.

Horner is married and has two children.

STATEMENT OF CHARLES HORNER, DEPUTY ASSISTANT SECRETARY OF STATE FOR SCIENCE AND TECHNOLOGY; ACCOMPANIED BY DR. JACK BLANCHARD, DIRECTOR, OFFICE OF COOPERATIVE SCIENCE AND TECHNOLOGY PROJECTS, U.S. DEPARTMENT OF STATE, WASHINGTON, DC

Mr. HORNER. Thank you very much, Mr. Chairman.

I would first like to say that I am accompanied this morning by Dr. Jack Blanchard, who is the Director of the State Department's Office of Cooperative Science and Technology Projects.

I am pleased to appear before the task force in order to offer the perspective of the Department of State on international cooperation in science and technology.

Science is certainly an international undertaking, and as much as the advancement of science in our own country contributes to progress throughout the world, there are times when advances in other countries, or advances made in conjunction with other countries, can benefit us here at home.

In particular, we have learned in recent years that international cost-sharing for so-called big science can mesh with ongoing domestic activities and enhance our own future prospects. Basic research has become an expensive activity, and nations are no longer well advised to duplicate each other's facilities. Instead, there has grown up a kind of international division of labor and a strong impulse toward greater cooperation.

Yet any successful international endeavor on our part must begin with strong domestic capabilities. It is our own strength in science, technology, and engineering which establishes America's bargaining position in international scientific affairs. Our strength in these areas rests on more than Federal activities alone; in our society, much of our capability originates in universities and in private enterprises.

We have developed, over the years, a way of managing federally funded international science and technology activities. It begins in the various departments and the technical agencies. The agencies determine which of their needs can be met through international cooperation and how international activities will allow them to fulfill their domestic missions.

The Office of Science and Technology Policy, headed by the President's Science Advisor, contributes the Presidential perspective on the allocation of Federal research resources. The Department of State contributes its sense of how science objectives and foreign policy goals can be made to reinforce each other.

Just as it often enlists the aid of the technical agencies in support of a foreign policy objective, it works to create the conditions for the efficient and effective operation of the Federal science establishment overseas. In particular, it oversees all Federal activities which occur under bilateral science and technology agreements. It advises agencies on opportunities overseas and how to pursue them and helps ensure the appropriate awareness of foreign policy generally.

What we seek, in short, are international activities with both scientific and foreign policy benefits. We recognize that in the competition for Federal science dollars and science manpower, any international program should be able to stand on its merits. But, at the same time, international science cooperation, by its very nature, opens doors, expands communication, and oftentimes paves the way for commercial transactions.

However, there are also times when scientific cooperation must also conform to political and diplomatic realities. We must distinguish among potential partners—between those who understand cooperation as we do and those who see cooperation as an opportunity for the cynical exploitation of American capabilities or as the occasion to gain legitimacy for wholly unacceptable political behavior.

But overall, the United States can be proud of its achievements in science, and equally proud of its role as pioneer in creating an international community committed to scientific progress. Our tradition and the ever-exciting new possibilities for the advancement of knowledge will guarantee for international scientific work a place in our relations with other nations.

We would be happy to do what we can to respond to questions you have.

[The prepared statement of Mr. Horner follows:]

TESTIMONY OF CHARLES HORNER
DEPUTY ASSISTANT SECRETARY OF STATE FOR SCIENCE & TECHNOLOGY
BEFORE THE SCIENCE POLICY TASK FORCE OF THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES
THURSDAY, JUNE 20, 1985

I am pleased to appear before the Task Force in order to offer the perspective of the Department of State on international co-operation in science and technology. Science is certainly an international undertaking and as much as the advance of science in our own country contributes to progress throughout the world, there are times when advances in other countries -- or advances made in conjunction with other countries -- can benefit us here at home.

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We have developed, over the years, a way of managing federally-funded international science and technology activities. It begins in the various departments and the technical agencies. The agencies determine which of their needs can be met through international co-operation and how international activities will allow them to fulfill their domestic missions. The Office of Science and Technology Policy, headed by the President's Science Advisor, contributes the Presidential perspective on the allocation of Federal research resources. The Department of State contributes its sense of how science objectives and foreign policy goals can be made to reinforce each other. Just as it often enlists the aid of the technical agencies in support of a foreign policy objective, it works to create the conditions for the efficient and effective operation of the Federal science establishment overseas. In particular, it oversees all Federal activities which occur under bilateral science and technlogy agreements, advises agencies on opportunities overseas and how to pursue them and helps insure the appropriate awareness of foreign policy generally.

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DISCUSSION

Mr. FUQUA. Thank you, Mr. Horner.

Does the State Department have any scientific panels and so forth that they call upon to advise them of scientific objectives and goals, or do you rely on the agencies to provide that information?

Mr. HORNER. Well, we do rely primarily upon the agencies, but we do have in the Department of State an Advisory Committee on Oceans and International Environment and Scientific Affairs, which consists of distinguished citizens from various realms. Their immediate responsibility, I suppose, is to advise the Bureau on its operations. But from time to time, it is very helpful to gain their perspective about the general sense of priorities in the international area.

Mr. FUQUA. Does the Department provide any funding for scientific work other than maybe travel funds or maybe assist in arranging meetings and so forth?

Mr. HORNER. Well, if one looks at the amount of money that is actually spent on international scientific activity, and then one looks at how much money of that is represented in the State Department budget, the percentage is in fact minuscule.

There are two programs with other countries which are financed out of funds appropriated to State Department, those being Poland and Yugoslavia. In addition, there is—though not technically a State Department item—the funds for financing our participation in our program with Spain, also are listed independently. But in general, programs by country do not have a separate budgetary status.

Mr. FUQUA. What is the Department doing to strengthen the science part of it, particularly within the Department, as well as the Foreign Service? I know you have science advisers or science counselors at many of the diplomatic posts abroad, and I might say that I have found them to be most cooperative and very knowledgeable in my experience with them. But are you doing anything else to strengthen science as part of a foreign policy tool?

Mr. HORNER. Over the years, it has become apparent that the advance of science will create new and novel international diplomatic and political problems and issues, and many things have been created to deal with that over time, especially in the last 40 years.

Now, it was a little more than 10 years ago when a separate Bureau for Oceans, Environment and Science was established in the Department of State by statute. This was a formal recognition by the Congress of the importance that these things had acquired in the conduct of foreign relations overall.

As time has gone on, there have been additions made to that, as, for example, when we recognized the importance of telecommunications, a new mechanism was established for dealing with that.

Recently, Secretary Shultz has taken a strong personal interest in what we might call consciousness raising, in the first instance, which is to remind the entire diplomatic establishment of the importance that science and technology now play in the conduct of international relations.

He has dealt with this directly in communication with missions overseas and has also been a strong supporter of what has become known in the Department of State as the Oceans, Environment and Science Action Plan. This is essentially a plan to do two things: To gain greater visibility and recognition for science and technology and foreign policy generally, and to update the capabilities of our Foreign Service in this area, so that there is just a closer connection among these various areas.

I just might also mention that the educational training arm of the Department of State continues to add new programs and courses of study for people in the Foreign Service and other senior managers at the State Department.

Mr. FUQUA. At how many foreign outposts do you have people that you would classify as science-oriented or science-trained in the Embassies?

Mr. HORNER. We have specifically designated science counsellors and/or attachés, I think, in about two-dozen missions. In the other missions, there are officers who devote a fraction of their time to scientific affairs, and that varies by the country, obviously, depending on the state of its own interest and its development.

Mr. FUQUA. You stated in your testimony that science policy and foreign policy kind of reinforce each other; I think those are the words you used. Do you find that science is the most paramount objective, or are we doing it just to say we are cooperating?

Mr. HORNER. Well, I think it is one of the features of our system which sometimes our foreign friends find exasperating, but which is an important source of its strength we think; that is that anything that is to be done internationally must meet a fairly strict test within each of the so-called mission agencies.

And so it is hard to imagine a science program conducted internationally which would not meet a very rigorous test in the mission agency itself as to its merit, as to what it contributes to that agency's mission and the scientific benefit to be gained from it.

The notion of doing these things for their own sake may have had some appeal, but, in fact, I think it is a very unusual occurrence for that to happen. The competition for these funds and for these resources is just too intense for that to happen.

Mr. FUQUA. Do you feel there is adequate coordination between your role as the State Department and the various mission agencies and also OSTP in coordinating these cooperative efforts?

Mr. HORNER. I think, certainly on the major projects and those of greater significance, there has been very close cooperation and coordination and trading of views and information back and forth among all of the parties of the Government that are interested.

Now, we have to recognize, of course, there is an enormous range of Federal science activity which is conducted overseas. All of our departments and agencies are involved in it. We carry out activities in dozens of countries. Some of these are well established and routine activities by now, and others are not. But I think that we have the coordination and the implementation that we need when we do need it.

Mr. FUQUA. Mr. Packard.

Mr. PACKARD. Thank you, Mr. Chairman.

I believe, if I am not mistaken, our total foreign aid budget is somewhere around $16 billion. Is that about correct?

Mr. HORNER. I think it depends how you calculate it.

Mr. PACKARD. OK. Well, I am not going to recalculate here. But approximately how much of our total foreign aid budget goes to foreign countries in terms of scientific programs?

Mr. HORNER. Well, there is a certain difficulty, I suppose, in figuring out what one ought to include and what one ought not to include. For example, the Agency for International Development conducts programs to develop scientific and technical capacity in other countries. I don't know offhand how one would establish an absolute dollar amount.

Mr. PACKARD. Compared to social aid and economic aid and military aid, it would be perhaps a very small amount?

Mr. HORNER. I should think so.

Mr. PACKARD. Yes, I would think so, also.

Is there an advantage of trying to find and seeking ways to increase—I think we are talking about now giving a fish compared to teaching people to fish, that concept. Is there something more that we can do that would enhance actually building the infrastructure of a country where they can become more self-sufficient in contrast to just simply giving them medicine and food and economic aid?

Mr. HORNER. Well, I think that is quite right, and I think that is one of the things that we have tried to do over the years in various programs in efforts to develop capacities in these countries.

But I think we need to recognize that sometimes, in some of these countries, the absorptive capacity, if I may use that term, is limited, and that, secondly, the single most important thing in the advancement of various countries is the policies which they, themselves, decide to pursue.

We cannot really be a substitute for that. We have an extraordinary educational system, extraordinary university system, which is the most open in the world and which is available to people. We have programs of training of various different sorts. But, in the final analysis, perhaps the most important limiting factor is not so much what we contribute to it but what other countries' national policies are in this area.

Mr. PACKARD. I would hope, however—and I agree that there are some limiting factors—that perhaps we can rethink our foreign aid policy in terms of where we can do those people the most good. And often we do not. We find the easy and the bureaucratic way is to simply transfer funds and leave it up to them to determine the distribution and how to handle it.

Perhaps we can encourage policies and ways of developing their educational system, developing their scientific approach, and maybe inviting some of their students, through assistance programs, like we do our own students, to come and maybe be trained in our own universities, which are capable of sending them back to their countries. And I am sure we are doing some of that; I am just curious to know if, in your judgment, we are doing as much as we ought to do in terms of the use of our dollars, our foreign aid dollars.

Mr. HORNER. Well, once again, I think it is difficult to say what is more or less. For example, in some of the countries that I have mentioned—we have now at least 10,000 students from China who are studying here. We have from time to time had enormous numbers of students from various developing countries. Sometimes the number falls off based on their own political and economic circumstances. But we have had tens of thousands of scientists and engineers training in this country, some of whom have stayed here and some of whom have gone back.

We have established over the years venerable institutions overseas for the training of doctors and engineers and others.

The question of how one identifies the potential talent, especially in so-called developing countries, and then reaches it and organizes it in such a way that people are trained and educated and then finally brought back to their own countries and then put to some useful purpose, it is extremely difficult.

Mr. PACKARD. I can appreciate the difficulty. I hope we don't lose sight of our overall objective, and that is to assist countries to develop and to become self-supporting. Obviously, our country and a few other developed nations are graphic and very obvious models of what a good scientifically oriented and development oriented type of process can do for countries.

The best thing that can happen to our developing countries is for them to learn from the models of those countries that have really successfully implemented, and received benefit from, their technical research in terms of actual economy, our economy and many others concerned.

That is all I have to say.

Mr. FUQUA. Mr. Stallings.

Mr. STALLINGS. No questions, Mr. Chairman.

Mr. FUQUA. Mr. Horner, thank you very much, and Dr. Blanchard, we appreciate your being here with us this morning.

[Answers to questions asked of Mr. Horner follow:]

QUESTIONS AND ANSWERS FOR THE RECORD

Mr. Charles Horner

1. **Should there be a single U.S. government agency to provide oversight, management, and funding for U.S. participation in international science activities? Is a new agency required, or could OSTP, or State, or NSF serve this role?**

   The government offices which coordinate U.S. participation in international science are OSTP, State and NSF. Funding is provided through Congressional appropriations and is monitored by OMB. The roles of each of these agencies in the management of international cooperation were included in Deputy Assistant Secretary Charles Horner's testimony of June 20, 1985. One has only to look at the large number of successful agreements in which we now participate to be convinced that the cooperations are well managed by integrated efforts in the Federal Government. In our view, the creation of yet another agency to handle international science would at best create more bureaucratic entanglements and at worse unnecessarily complicate U.S. participation in international science.

2. **What are the relative advantages and disadvantages of bilateral and multilateral cooperative arrangements?**

   U.S. international scientific cooperation is conducted in both bilateral and multilateral programs. Each has clear advantages and disadvantages. The U.S. uses both to maintain its position of scientific leadership in the world. Bilateral agreements have the advantage of simplicity. Multilateral programs, on the other hand, have the advantage of pooling the resources of several countries. Ideally, multilateral programs provide the quickest route to share new data among countries, prevent unnecessary duplication, and allow for shared costs. The disadvantage of multilateral cooperation is, of course, the complexity of any undertaking; the greater the number of participants the more cumbersome the arrangements.

3. **How does the State Department take into account technology transfer considerations in its selection, definition and implementation of joint projects so that we do not jeopardize either our national security interests or the competitive position of U.S. industry?**

   The issue of technology transfer is one which must be addressed in international scientific cooperation. Detailed written explanations of all federally sponsored activities are required prior to the start of any cooperation. Concerned offices in the Department or agency are then consulted for clearance of the proposed activity. Thus, new projects are given consideration prior to being presented to a foreign government. Further, daily activities in the implementation of bilateral agreements are closely tracked in the Bureau of Oceans and International Environmental and Scientific Affairs, for continued coordination of science policy with foreign policy and national security interests, as well as for monitoring of technology transfer issues.

4. **What are the administrative obstacles, such as tariffs, visas, export controls, national security considerations, and proprietary rights to international cooperation? How might these best be mitigated?**

To protect U.S. interests in international scientific programs, most bilateral S&T agreements signed today include intellectual property copyrights and patent protection provisions. Agreements without such provisions are being revised to include them. Thus, at every level of bilateral S&T cooperation, from the negotiation of a new agreement, through its signing and implementation the Department is constantly involved in assuring that U.S. interests are protected. This includes promoting the smooth progress of projects despite the necessary controls on exports, visas and tariffs. When appropriate, controls which may seem to be obstacles to cooperation (but are designed to protect U.S. interests) are reviewed to determine if they can be altered to eliminate the problem area.

Mr. FUQUA. Our next witness is Dr. John F. Clarke, Associate Director of the Department of Energy's Office of Fusion Energy.

Dr. Clarke will provide us with a historical perspective on the international aspects of the Fusion Materials Irradiation Test Facility, as well as other ongoing international activities in magnetic fusion energy.

Dr. Clarke, thank you for being here this morning.

STATEMENT OF DR. JOHN F. CLARKE, ASSOCIATE DIRECTOR FOR FUSION ENERGY, OFFICE OF ENERGY RESEARCH, U.S. DEPARTMENT OF ENERGY, WASHINGTON, DC

Dr. CLARKE. Thank you, Mr. Fuqua.

As you will gather from my testimony, the topic of international collaboration is a central one in fusion these days, and I truly appreciate the opportunity to be able to speak to you about it.

As you requested, I will attempt to give you a historical perspective on the subject of the FMIT. However, before I get to that, I would like to introduce that topic with some perspective on collaboration in fusion in general.

Recently the Magnetic Fusion Program plan was adopted by Secretary Herrington and sent to the Congress. In this plan, international collaboration is viewed as a resource, actually a vital resource, to establish an adequate fusion science and technology base in a timely fashion.

At present, we have several agreements or mechanisms for carrying out this collaboration. We have agreements which cover every aspect of our program. They are with the U.S.S.R., Japan, the People's Republic of China, Spain, United Kingdom, on a bilateral basis, and, through the auspices of the International Energy Agency, with the European Community, Japan, Canada, and Switzerland. In addition to that, a bilateral agreement with the European Community and three other agreements are in the final stages of negotiation.

We began to consider enhancement of international collaboration 2 years ago. At that time, I commissioned a study by the National Academy of Sciences to evaluate past collaborations, to consider the consequences of greater involvement with other countries in the future, and to recommend appropriate actions. I believe Mr. Gavin summarized that study for you the other day.

In general, the panel found that in the years ahead for the fusion program, a program with increased international collaboration was the preferable course. We have accepted this advice and implemented the key recommendations of that panel, including the development of a program plan which explicitly addresses the role of international collaboration in our program.

Over the years, there has been a significant evolution in the nature of the topics which we undertake on an international basis in fusion. Initially, the collaboration was in areas which had technical validity but were considered on the margin in terms of priority for our program.

I think Dr. McTague touched upon the reason for that. At the time when there was a considerable urgency for arriving at a definite product from the fusion program, I think you can understand why we took that attitude. But it was an attitude shared by our potential collaborators. On all sides, we found a reluctance to place a dependence upon others in areas that were considered vital to the progress of programs.

Now collaborations are being considered in areas which have high priority for the success of our program. This evolution is the result of increasing budget stringency and also as a result of the success which we have experienced with the collaborations that are undertaken.

The Department strongly supports collaboration in high-priority areas in the fusion program, in recognition of the fact that it may be the key to the achievement of our goals in the face of limited resources.

The key point that I would like to establish with these general remarks is the importance of the policymaking process in the establishment of effective collaboration. Each of the fusion programs with which we deal in the United States, the European Community, and Japan are structured differently. The government funding process is different; program management is different; institutional arrangements and the underlying perception of urgency and goal are different.

Furthermore, what constitutes success for a program is not necessarily the same thing as success for the institutions involved. Given these nontechnical factors, successful collaboration absolutely requires a policy-level commitment over an extended period. I might remark that that period precedes and follows the establishment of a collaboration.

Over the last several years, the administration has provided this kind of support for collaboration in fusion through the Summit. A Fusion Working Group has been established to provide a political framework for developing collaboration. In addition, a Technical Working Party has begun to establish a technical consensus on the nature of collaboration in fusion under the Fusion Working Group.

It is with real interest, therefore, that we look to the Summit process as a possible means of regularizing political input to the program and developing a technical consensus in all of the participating countries.

Our years of experience in international collaboration and fusion have led us to appreciate fully the difficulty involved in reaching agreements and implementing those agreements, even among political allies.

Among the important lessons that we have learned in this process are: One, that time spent in understanding foreign institutional relationships and cultural nuances is well spent. Second, confidence in the integrity and capability of the partners on both the political and technical level is required by all sides.

Third, careful planning, preparation and domestic coordination are essential. Fourth, early consultation to identify mutual needs and to develop the best approaches to meet those needs is crucial.

Fifth, agreements must clearly define objectives, roles, and responsibilities. And, finally, firm commitments, once established, must be honored.

To illustrate these points, I would like to review and contrast the results of extended cooperation in two areas, one dealing with materials testing facilities and one with plasma physics experimentation.

International cooperation on materials testing—namely, the FMIT facility—has been discussed since 1974, and it was in fact one of the first actions of the newly formed International Energy Agency to consider cooperation in these expensive materials testing facilities.

At that time, 1974, the Atomic Energy Commission had decided to construct one such facility, known as the Intense Neutron Source; and a second, more powerful, facility which eventually came to be known as the FMIT, was under discussion.

By 1976, an International Energy Agency agreement to cooperate on the research and development for the construction of such a facility had been signed. That was the INS agreement. However, the year before that agreement was signed, the United States, in an effort to establish early involvement with foreign countries, had convened an international conference to consider all aspects of materials testing facilities. The result of that conference was the establishment of the idea that a more powerful facility than the INS was required.

In 1977, the United States decided to construct the FMIT facility to fulfill that need. Recognizing that the United States could not support the construction of two similar facilities, we terminated the INS project in 1978. However, we invited the participants in the research agreement on INS to participate in the new FMIT project research.

In 1980, a new IEA agreement on fusion materials development was signed, and the FMIT R&D was included as an annex.

Unfortunately, by 1982, due to budget constraints that were experienced in the early 1980's, it had become clear that it would not be possible to finish the FMIT construction. The United States at that time proposed to its IEA partners that they join us in completing the construction of this facility and in operating it, once completed.

Since there had been 8 years of international interest in materials testing, we thought that this interest would allow the financial support required to complete the facility. To reaffirm that interest, in 1983, the International Energy Agency chartered a Senior Blue Ribbon Panel to consider the role of materials and materials testing facilities in fusion.

This international panel represented the highest level technical judgment that could be brought to bear on the subject. The panel presented a very positive recommendation, and it was endorsed in this country by Presidential Science Advisor George Keyworth.

With this panel report, the need for the FMIT was reaffirmed, and we expected that the prospect for our proposal to share the remaining construction costs would be enhanced. But it was not.

In a letter to Dr. Trivelpiece, Director of the Office of Energy Research, EC Vice President Davignon supported the technical objectives. However, he only expressed interest in participating in the operations of such a facility and not in its construction.

In Japan, there was vigorous informal support in the technical community. However, although the Japanese Government did initiate a review process, there was no expression of governmental support for a joint construction project in time to affect necessary U.S. budget decisions. As a result, the project was terminated in 1984.

The question is why, after early planning in the technical community and continued technical level support, no progress toward a joint facility was forthcoming. The answer, I believe, rests on two factors: the nature of the early planning and the nature of the political level support for collaboration.

Throughout most of the seventies and the early eighties, the development of long-term fusion technology, particularly in the materials area, was not of high priority in the European Community or in Japan. In contrast, the United States put more emphasis on fusion technology, which we felt was needed for the practical applications, and we were the clear leader in the development of fusion technology throughout this period.

In the European Community, scientists were interested in learning about the U.S. technology, but at the time of the FMIT proposal, their funds for the next 3 to 5 years were already committed. They were committed to scientific projects of their own and to building up a technology program of their own.

The low priority that was then accorded to materials work did not warrant the required shifting of funds. There was also no large institutional advocate for FMIT within the European Community, so that when our posture changed from a willingness to host visitors on our facility to one of requesting participation in the construction, there was just no institutional constituency to support the change.

As for the early efforts of planning, these were initiated by the United States in 1975, but they had not borne fruit because of the different technical priorities which then existed in the world's fusion programs. In the European Community and Japan, the role of materials technology, in particular, simply had not received the high priority it had in the United States.

Furthermore, there had been no prior political pressure for common program planning that could have formed the framework for supporting such new proposals. In the absence of this multinational political framework, the internal political decision made by the United States to limit the fusion budget was, by itself, insufficient grounds for altering the priorities of these other nations.

Now, there have been positive results from this experience. We have learned the importance of early coupling of joint program planning with the necessary political commitment. We are emphasizing this in all areas where there may be a need for a major international fusion facility.

In particular, to ensure the prospects for success in a practical undertaking, early joint planning must begin with the development of common priorities and then proceed to technical planning.

In regard to fusion materials, we are pursuing an initiative within the IEA framework by means of a new Blue Ribbon Panel. This Panel is aimed at developing a consensus on technical priorities for an international fusion materials research and development program. This international initiative can help us avoid the mismatch of materials sciences with other development priorities that led to the FMIT disappointment.

The entire FMIT experience has served to strengthen the planning, development, and management of our international fusion program activities.

And now, to conclude on a happier note, I would like to contrast this experience with one of the genuine successes that we have had in fusion, and I think this equally serves to illustrate the points I have tried to make. The United States-Japan cooperation on the Department's Doublet-III facility in California is truly one of our great successes.

In 1979, as a consequence of a meeting between Japanese Minister Fukuda and President Carter, the Japanese Foreign Minister and the Secretary of Energy signed a 20-year agreement for cooperation in energy R&D, and fusion was one of the main areas of this cooperation.

This provided the requisite political support for cooperation at the very highest levels. This political support in this case was particularly important because the Japan Atomic Energy Research Institute had already formulated plans for a facility similar to the Doublet facility to address the same technical issues, and they were called upon to make the difficult judgment decision to depend upon a foreign facility in place of their own domestic facility.

Following these 1975 actions, JAERI has provided approximately $70 million to upgrade and operate jointly the Doublet-III facility. JAERI supports a team of Japanese physicists who share experimental operating time equally with GA technology scientists.

The scientific and programmatic success of this collaboration is illustrated by the record plasma parameters achieved during this period. It is my evaluation that these parameters were obtained earlier and at less cost than either side could have managed alone.

Important factors in implementing this cooperative activity were the level of political support, the high priority both participants assigned to the work, and the continued senior program management involvement in steering committee activities.

The Doublet-III represented plasma physics concerns of equal priority to both the Department of Energy and the Japanese fusion programs. Further, the technical results of the collaboration are important to both programs today and not in the far future.

In conclusion, I would like to reiterate that the Office of Fusion Energy is committed to international collaboration in fusion as an important resource to achieve the goal of our program. We are managing these activities so that they support high priority program needs.

I have attached to my written statement some additional comments which might be of interest to you with regard to other questions that your committee is interested in, and I would be pleased to entertain any questions on my oral testimony.

[The prepared statement of Dr. Clarke follows:]

Statement of John F. Clarke

Associate Director for Fusion Energy

Office of Energy Research

Department of Energy

before the

Task Force on Science Policy

of the

House Science and Technology Committee

June 20, 1985

Mr. Chairman and Members of the Committee:

Thank you for the opportunity to speak on the topic of International Collaboration in Science. As you requested, I will give you a historical perspective on the international aspects of the Fusion Materials Irradiation Test Facility (FMIT). However, I would like to introduce that perspective with some general remarks on international collaboration in fusion.

Recently the Magnetic Fusion Program Plan was adopted by Secretary Herrington. In this plan, international collaboration is viewed as a resource to establish an adequate fusion science and technology base in a timely fashion. At present, we have several vehicles to pursue fruitful collaboration. These include agreements on various topics in both science and technology, either as bilateral agreements with the leading nations in fusion research, or as multilateral agreements through international organizations. These agreements cover every aspect of our comprehensive program and are with the USSR, Japan, Spain, the PRC, and the UK bilaterally, and through the auspices of the International Energy Agency (IEA), with the European Community (EC), Japan, Canada and Switzerland, multilaterally. A bilateral agreement with the EC and three other agreements are in the final stages of negotiation.

We began to consider enhancement of international collaboration two years ago. At that time, I commissioned a study by the National Academy of Sciences to evaluate past collaboration, to consider the consequences of greater involvement with other countries in the future, and to recommend appropriate actions. This panel found that in the years ahead a program with increased international collaboration was preferable to a predominantly domestic one. We have accepted this advice and implemented the key recommendations including early consultation with prospective collaborators and the development of a Program Plan which explicitly addresses the role of international collaboration.

Over the years, there has been a significant evolution in the nature of the topics for collaboration. Initially, the collaboration was in areas which had technical validity but were considered "on the margin" in terms of priority. There was reluctance on all sides to place dependence upon others in areas regarded as essential. Now collaborations are being considered and started in areas which have high priority for our program. This evolution is a result of increasing budget stringency and a largely successful record of international cooperation. The Department strongly supports collaboration in high priority areas in recognition of the fact that it may be the key to achievement of common goals in the face of limited resources.

I believe an essential element of collaboration in fusion deals with the policy-making process. Each of the fusion programs in the U.S., EC and Japan is structured differently. The governmental funding process, program management, the institutional arrangements, and the underlying perceptions of urgency are all different. Furthermore, what constitutes success for a program is not necessarily the same for the institutions involved. Given these non-technical factors, successful collaboration requires policy-level commitment over an extended period. In addition, success with new initiatives for collaboration on large facilities will require early encouragement of joint planning. Over the last several years, the Administration has provided this kind of support for international collaboration in fusion through the Summit process. A Fusion Working Group (FWG) has been established through the Summit process to provide a political framework for developing collaboration. In addition, a Technical Working Party has begun work to establish a technical consensus on the nature of this collaboration. It is with real interest, therefore, that we look to the Summit process as a possible means of regularizing political input to the program and developing a technical consensus in all the participating countries.

Enhanced, effective international collaboration must also be built on the success and good will cultivated in previous small-scale activities. Each national program recognizes that for increased collaboration to succeed, a strong domestic program must be maintained in order to make use of the results from the collaboration. Therefore, significant trust will be required to conclude collaborative agreements and to manage their implementation in concert with national program activities.

Our years of experience in international collaboration have led us to appreciate fully the difficulty involved in reaching and implementing agreements, even among political allies. Among the important lessons learned in fusion from previous collaborations are that:

- time spent to understand foreign institutional relationships and cultural nuances is well spent;
- confidence in the integrity and capability of the partners on both the political and technical level is required by all sides;
- careful planning, preparation, and domestic coordination are essential;

- early consultation to identify mutual needs and to develop the best approaches to meeting those needs is crucial;
- agreements must clearly define objectives, roles and responsibilities; and
- firm commitments must be honored.

To illustrate our experiences, I would like to review and contrast our extended cooperation in two different areas, one dealing with materials testing facilities and the other plasma physics experimentation.

International cooperation on FMIT has been discussed since 1974. One of the first actions of the newly formed IEA was to consider cooperation on the fusion materials testing facilities. At this time, the Atomic Energy Commission (AEC) had decided to construct one such facility, the Intense Neutron Source (INS) and a second more powerful facility, the FMIT, was under discussion.

In 1976 an IEA agreement to cooperate on the R&D needed for the INS was signed. The previous year, the U.S. had convened an international conference to consider future materials testing requirements. This conference established the need for a more powerful facility than the INS and in 1977 the U.S. decided to construct the FMIT facility. Recognizing that the U.S. could not support the construction of two facilities, we terminated the INS project in 1978 and we invited the participants in the IEA INS R&D agreement to participate in the new FMIT project R&D. In 1980 a new IEA agreement on fusion materials development was signed and FMIT R&D was included as an annex.

By 1982, due to budget constraints in the early 1980's, it had become clear that it would not be possible to proceed alone with FMIT construction at the planned pace. The U.S. proposed to its IEA partners in the materials agreement that they join in both completing the construction of the facility and operating it. Since there had been eight years of international interest in materials testing, we thought that interest would allow international financial support for the construction of the required facility. To reaffirm that basic support, the IEA chartered in 1983 a Senior Blue Ribbon Materials Panel to consider the role of materials and testing facilities in fusion. This Panel represented the highest level technical judgment that could be brought to bear on the question. The Panel presented a very positive recommendation that was endorsed by Presidential Science Advisor Keyworth. With this panel report, the need for the FMIT was reaffirmed and we expected that the prospect for our proposal to share remaining costs for construction of FMIT would be enhanced. But it was not.

In a letter to Dr. Trivelpiece, Director, Office of Energy Research, EC Vice President Davignon supported the technical objectives and expressed interest in participation in the operation of such a facility but not in its construction. In Japan, there was vigorous informal support in the technical community. However, although the Japanese government initiated a review process, there was no expression of its Governmental support for a joint construction project in time to affect necessary U.S. budget decisions.

The question is why, after early planning in the technical community and continued technical level support, no progress toward a joint facility was forthcoming. The answer, I believe, rests on two factors: the nature of the early planning and the political level support for collaboration. Throughout most of the seventies and early eighties, the development of long-term fusion technology, particularly materials, was not a high priority for the EC or Japan. In contrast, the U.S. put more emphasis on the fusion technology needed for practical applications and was the clear leader in developing fusion technology throughout this period. In the EC, scientists were interested in learning about U.S. technology, but at the time of the FMIT proposal their funds for the next three to five years were already committed to scientific projects and to building up a technology program of their own. The low priority then accorded to materials work did not warrant the required shift of funding. There were also no large institutional advocates for FMIT within the EC so that when our posture changed from a willingness to host visitors to a need for financial participation, there was no institutional constituency to support that change in the EC.

The early efforts at joint planning initiated by the U.S. in 1975 had not borne fruit because of the different technical priorities which then existed in the world's fusion programs. In the EC and Japan, the role of materials technology in their program simply had not received the high priority it had in the U.S.

Further, there had been no prior political pressure for common program planning that could have formed the framework for supporting the new proposals. In the absence of this multinational political framework, the internal political decision made by the U.S. to limit the fusion budget was by itself insufficient grounds for altering their programmatic priorities.

There have been positive results from this experience.

- o We have learned the importance of early coupling of joint program planning with the necessary political commitment. We are emphasizing this in all areas where there may be a need for a major international fusion facility. In particular, to ensure the prospects for success in a practical undertaking, early joint planning must begin with development of common priorities and then proceed to technical planning.
- o In regard to fusion materials, we are pursuing an initiative within the IEA framework by means of a new Blue Ribbon Panel to develop a consensus on technical priorities for an international fusion materials R&D program. This international initiative can help us avoid the mismatch of materials science with development priorities that led to the FMIT disappointment.
- o The entire FMIT experience has served to strengthen planning, development and management of our international fusion program activities.

Now, I would like to turn to one of the genuine successes resulting from our international activities, namely the US-Japan cooperation on the Department's Doublet-III tokamak research facility at GA Technologies, Inc., in La Jolla, California. In 1979, as a consequence of a meeting between Prime Minister Fukuda and President Carter, the Japanese Foreign Minister and the Secretary of Energy signed a ten-year agreement for cooperation in Energy and Related R&D. Fusion was one of the main areas for cooperation. This provided the requisite political support for cooperation at the highest level. This political support was essential because the Japan Atomic Energy Research Institute (JAERI) already had its own institutional plans for a facility to address the technical issues and had to make a difficult decision to depend upon a foreign facility in its place. Following these 1979 actions, JAERI has provided approximately $70 million to upgrade and operate jointly the Doublet-III facility. JAERI supports a team of Japanese physicists who share experimental operating time equally with GA Technology scientists. The scientific and programmatic success of this collaboration is illustrated by the record plasma conditions achieved during this period. These parameters were obtained earlier and at less cost than either side could have managed alone.

Important factors in implementing this cooperative activity were the level of political support, the high priority both participants assigned to this work and the continued senior program management involvement in the Steering Committee. Doublet III represents plasma physics concerns of equal priority to both the DOE and Japanese fusion program. Furthermore, the technical results of this collaboration are important to both programs today, not at some unspecified time in the future.

In conclusion, I would like to reiterate that the Office of Fusion Energy is committed to international collaboration in fusion as an important resource to achieve the goal of the fusion program. We are managing these activities so that they support high priority program needs and protect the Nation's interest in fusion. I have attached to my statement some additional comments on the major issues of interest to the Committee as they pertain to the Fusion program. I would be pleased to address any of your questions or expand on any of the topics I have touched on. Thank you.

Additional Comments
on International Cooperation

The U.S. fusion program has been involved in international cooperation for about 30 years. Based on that experience, I feel we can contribute to the discussion on the three sets of issues which the Science Policy Task Force is considering in its hearings on international cooperation. The oral testimony has addressed some of the points and focused on two examples. What follows are my additional comments on the major issues identified in your letter, namely, (1) major international cooperation in fusion, (2) the impact of international cooperation on research priorities, and (3) coordination and management of international cooperative research. I will confine my remarks to the Fusion program. Others are addressing these points for the Department of Energy and for the Government as a whole.

Major International Cooperation in Fusion

Over the past several years, the level of scientific cooperation in fusion has increased as measured by the number of agreements and personnel exchanges. Earlier exploratory efforts are now leading to new agreements. As domestic funding for new facilities in each program becomes more limited, the incentive for international collaboration to help fund these facilities is also expected to increase. There has been a substantial increase of cooperative activities in the technology development area recently. This has come about because other programs in the EC and Japan are beginning to assemble and implement technology-oriented plans comparable to ours. This comparability provides the necessary basis for collaboration.

The future prospect for major international cooperation in fusion could be very promising. Political commitment to support significant initiatives is necessary to overcome institutional rivalries and to provide stability necessary to engage seriously in long term planning. Even with such a commitment, implementation requires considerable effort. The U.S., Japan, and the E.C. have fusion programs of comparable size which have worked together well in the past. All realize that the cost of large facilities is great and that cooperation in principle would minimize costs. To make cost-sharing feasible, good communication in the joint development of plans is needed from the start to develop common priorities for tasks, to define the mission of major joint fusion facilities and to divide up responsibilities. As an example, the Fusion Working Group in the Summit process is presently attempting to identify possible future large facilities.

As discussed in the NAS Report on international cooperation in fusion, the advantage of cost-sharing is that it is possible to build in common those large projects which individual members would have difficulty pursuing separately in a similar time frame. This leads in principle to avoiding unnecessary duplication and to assuring that the best ideas are included. The main disadvantage is that each side must relinquish some control over its program planning and approach. Two other factors should be noted. First, since the contribution of each partner is based on technical strength and interest, equitable sharing is sometimes difficult to define. Second, in a recent international cost evaluation of a large fusion facility design, it was found that collaboration provided significant cost savings to each participant. However, each member's cost was not a pro rata share of the total but rather somewhat more since some parallel effort was needed to insure that all involved acquired expertise in the key scientific and technology areas. We have concluded that for fusion the advantages of international collaboration outweigh the disadvantages and it has a key role in our Program Plan.

According to the NAS Report, the major factor facilitating international cooperation is the recognition by both the Governments of the leading fusion programs and by the technical community that a window in time for large-scale collaboration is now open. Fusion also has unique attributes which facilitate collaboration. These include the unclassified nature of the research, the long timescale before commercialization, the 30 year history of cooperation, and the large number of long standing personal relationships which have grown out of that history. Such relationships help to develop trust and credibility. One factor necessary for international collaboration is the maintenance of a strong national program so that there is something of value to contribute. Potential inhibiting factors are commercial and defense concerns for some of the evolving state-of-the-art fusion technology.

Impact of International Cooperation on Research Priorities

The Magnetic Fusion Program Plan is directed toward providing the U.S. with the scientific and technology base for fusion energy in a way and pace suited for U.S. national needs. International cooperation is used as a means of enhancing the productivity of U.S. funds and efforts devoted to this field.

For fusion, the most meaningful consideration for having the capability to participate in major international cooperations appears to be competitiveness rather than outright leadership. If a program is to be able to collaborate, it must be comparable in relevant size and comprehensiveness and competitive in terms of ideas and capabilities. Therefore, we are concerned about satisfying the requirements for vigorous competition that lead to substantial international collaboration rather than to world leadership.

The intrinsic value of being first in fusion science is moot in my opinion for several reasons. First, at this stage of fusion development, being first is nearly impossible to define since the ultimate objective, an economically attractive reactor, is well into the future. The leading nations are easily identified; however, each national program has strengths and weaknesses which are difficult to quantify. Moreover, leadership can mean having the largest research facilities, the most advanced confinement concept experiments, the most comprehensive set of activities, the best integration of experiment and theory, the highest budget or the most stimulating innovation. Second, the leading nations have somewhat different plans and approaches so that what is very important for one nation could be undervalued by others.

Nonetheless, it is clear that, for successful international collaboration, programs must have comparability in the areas of potential interest, leadership in at least some of the elements, unique skills worth obtaining and a home base capable of benefitting from the new information. Finally, even if a single program could be identified as being first, the differences in the quality of the programs of the leading nations are small enough that the ordering could be changed rapidly due to new experimental, theoretical, or technological developments.

Decisions on fusion international activities must be made in the context of the overall fusion technical program. The first decision to be made is whether or not the particular information in question needs to be obtained next. If so, then the second decision is on the method of obtaining the information. This question involves the use of existing or new facilities, whether here or abroad. Each facility decision competes with other possible resource needs and is framed in the overall technical situation. Determination of appropriate levels of funding for various facilities is certainly a complex matter. When making the judgment about a participation on a facility sited outside the U.S., the additional factors of maintaining a technical home base into which our assignees can contribute their knowledge and the opportunities represented by the assignments are also taken into consideration.

Coordination and Management of International Cooperative Research

Recommendations were made to the Economic Summit leaders at their recent Bonn meeting by an Administrative Working Group on changes needed to lessen administrative barriers to international cooperation. The working group included U.S. representatives in high energy physics and fusion. Specific recommendations by the Group included: revision of tax and tariff provisions to lengthen the time exemption to ten years or more on contributions of scientific equipment and components from one nation to another; facilitating the exchange of scientific staff by simplifying the administrative admission formalities in the host country, and by direct support for the social integration of the researcher and family; reviewing the charging policies for transmitting scientific data across borders; and promoting effective data communication standards for compatibility. Technology transfer and export controls can also create difficulties in international cooperation particularly with nations such as the USSR. We are participating in the effort to have a clear definition for basic scientific research which would be exempted from the technical information provisions of the Export Administration Act.

Another important management concern is that the technical issues now involved in major collaboration require multiyear program plans. Multiyear funding would assure continuity for the tasks by clearly demonstrating the commitment of the Administration and Congress. This point is important since the EC operates on a multiyear budget cycle and the Japanese, while using an annual budget process, do operate on a multiyear planning cycle and can make firm long-term commitments. This ability to make commitments provides us with confidence in their intentions; if we could reciprocate, our counterparts would have similar assurances. We recognize, however, that multiyear funding is a broad, Government-wide issue and is not limited to funding for the Fusion program. Another concern which will probably become more important in the future is the commercial potential of the technology developed for fusion. In this context, it should be recognized that while fusion as an energy source is long range, some of the technology components have near-term applications outside fusion.

DISCUSSION

Mr. FUQUA. Thank you, Dr. Clarke.

In discussing some of the problems with previous fusion cooperative agreements, you indicated that there was not the political or financial support. Am I paraphrasing that correctly?

Dr. CLARKE. Well, I was emphasizing more the political support than the financial. I think financial support follows.

Mr. FUQUA. That is true. Is that one of the problems we face with all international cooperation, or is it just related to fusion? Is there something in fusion that lends itself particularly to international cooperation, and therefore we should try to secure the political support?

Dr. CLARKE. The reason that I tried to emphasize this particular point was that I do feel it has general applicability. It really flows from human nature. People have a desire to do things themselves if possible, and unless there is some pressure, either a technical pressure because they cannot accomplish their goals themselves or a general sense that it would be better done cooperatively, it is very difficult to get these cooperations started.

Mr. FUQUA. When we are in severe budget constraints, as we are now—of course, since I have been in Congress, I have never seen a time where we had ample funds—it is always a problem, and probably more acute today than it has been in previous years.

But when we are looking at big science—and fusion is certainly one of those—as we get into the more expensive programs of fusion, is it in everyone's benefit to try to share some of this burden? I doubt that the Japanese or the European Community has an excess of funds sitting around burning their pockets that they want to spend by themselves, particularly if there is somebody that they can cooperate with and share in some of the basic research activities that have the potential of benefiting all of mankind.

Dr. CLARKE. I think what you say is quite true, and I think it is very clearly recognized at the political and the policy levels. The problem that will arise, of course, is that the technical community, being more concerned with getting their technical job done, is not as sensitive to the constraints of budget as policy level leaders are.

Mr. FUQUA. I have observed that over the years. [Laughter.]

Dr. CLARKE. This is why a firm and uniform commitment at the policy level is important if only to translate the reality of these budget constraints to the technical community. Only with that kind of an atmosphere will people begin the hard job—and it does involve personal sacrifice on the part of both institutions and individuals involved in these programs—to do the hard technical work to come up with commonly agreed upon projects or collaboration.

Mr. FUQUA. In other words, what you are saying is, we should do our homework more thoroughly than we have in the past before we attempt to involve ourselves in these big projects internationally?

Dr. CLARKE. Yes, sir, both at the political, policy, and technical level.

Mr. FUQUA. Now, do you see this as being detrimental to some of our national laboratories? Is this something that means a zero to them, or do they look upon this as a threat to ongoing programs that they may have?

Dr. CLARKE. The experience that we have had in the fusion cooperation leads me to believe that, in the long run, this will be to the benefit of our national laboratories and institutions. The Doublet experience is one in which there was reluctance at the technical level on both the Japanese and the United States side in the beginning. But the result of that was a superior opportunity for learning on both sides.

Mr. FUQUA. Mr. Packard.

Mr. PACKARD. I have no questions, Mr. Chairman, just simply a comment that I am pleased that GA Technologies' Doublet project has proven to be a good model. That comes out of my area, and I appreciate the fact that it has been successful.

Mr. FUQUA. Thank you very much, Dr. Clarke, and we appreciate your being with us this morning.

Dr. CLARKE. Thank you.

[Answers to questions asked of Dr. Clarke follow:]

POST-HEARING QUESTIONS AND ANSWERS

Relating to the

JUNE 20, 1985 HEARING

Before the

SCIENCE POLICY TASK FORCE
of the
COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

CHAIRMAN: DON FUQUA

Question 1: Do you believe that international collaboration in magnetic fusion energy would be expedited if there was a single US government agency to provide oversight, management, and funding for all US participation in international science activities, or is the status quo working well?

Answer: I think that our international collaboration in goal-oriented programs, such as fusion, would most likely be hindered by having such a single agency. I base this strong view on our experiences with more than twenty formal international agreements during the past decade. International collaboration is an integral part of the fusion program. That means that the identification, definition and management of cooperative activities must be carried out by program staff as a key part of their regular functions.

In carrying out international cooperative activities we have benefitted from the general policy guidance received from the Department of State and the Office of Science and Technology Policy. Neither of those groups, however, can be sufficiently involved with program details to provide specific oversight, management or funding in a manner consistent with a mission oriented program. Even within the Department of Energy, the role of the central office of International Affairs has been one of support to the programs in the formal negotiation process for agreements and in interpretation of general policy guidelines.

In my view, the current system of treating international activities as an integral part of a mission oriented program while measuring the program's performance in the international arena against broad policy guidelines is the appropriate way to conduct these activities.

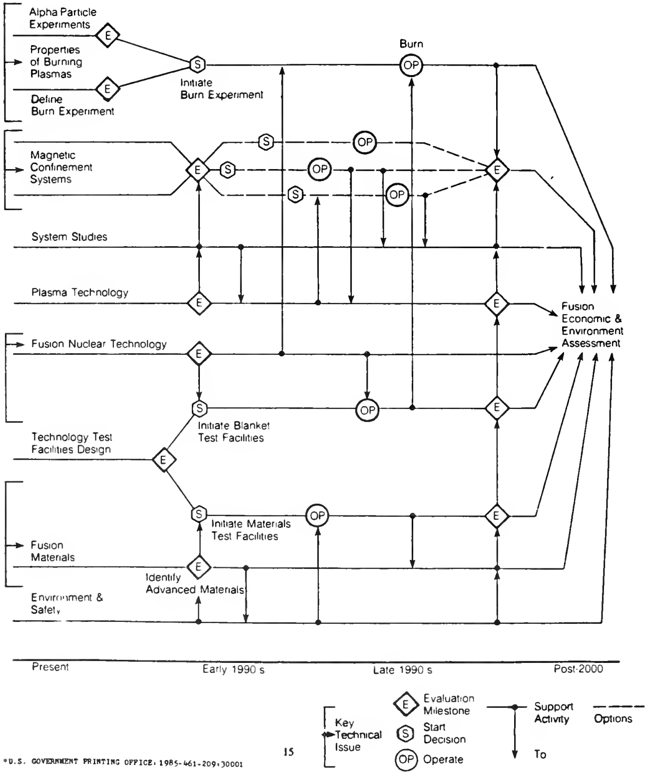
Question 2: What would be the best worldwide configuration of magnetic fusion energy facilities from the point of view of developing its potential? How might this best be determined?

Answer: In the Magnetic Fusion Program Plan, the four remaining key technical issues in fusion are defined as development of acceptable magnetic confinement systems, exploration of the properties of burning plasma, development of satisfactory fusion materials, and the development of fusion nuclear technology. If we knew today which confinement system would ultimately be used for fusion application, two or more of these issues could be addressed in a single multipurpose facility. We do not, however, have that knowledge today. Therefore, for the most effective use of the program funds addressing the interrelated aspects of fusion, these issues should be pursued in parallel, in separate single purpose facilities. Furthermore, currently available resources require the use of lower cost, single purpose facilities to the extent possible. Parallel pursuit is being undertaken, with the timing and pace determined by program need, technical knowledge, and resource availability. As indicated schematically on the Major Technical Milestones and Decisions chart (attached) in the Plan, a major facility for the resolution of each issue will likely be required at some time in the future in order to reach the program goal.

Given these four issues, the significant costs for major facilities to address these issues, and the special interests and skills of the existing major world programs, the best worldwide program would be one of coordinated facilities in which each national program would take the technical leadership for one of the necessary facilities with the active, though modest scale, involvement of the other participants. Such a program would require the assurance that each new facility would be defined and designed on the basis of existing and planned facilities in other nations, the development of consensus on the precise scope of the facilities through multilateral discussions and early joint planning, and the readiness of each national program to proceed promptly with the facility most appropriate to its circumstance.

I believe this program can be best determined through the Summit process now under way. Under the auspices of the Summit, a policy level framework, called the Fusion Working Group (FWG), has been established for fusion discussions. The FWG has chartered a Technical Working Party (TWP) consisting of senior technical leaders from the US, Japan, Member States of the European Community, and Canada. The TWP has just had its first meeting in Japan. The purpose of this meeting was to begin the process of identifying the principal facilities required in a world fusion program. Their first priority is to identify the requirements for resolving the properties of burning plasma issue. In other, more specialized forums, experts are attempting the joint planning of specific programs in the four issue areas. On the basis of these many inputs and their own deliberations on a coordinated set of complementary facility steps, the TWP will recommend to the FWG those major facilities required to reach the goal of the fusion program.

Magnetic Fusion Program Plan
Major Technical Milestones and Decisions



*U.S. GOVERNMENT PRINTING OFFICE: 1985-461-209:30001

Question 3: What is the trend of international collaboration in magnetic fusion energy? Is it increasing, decreasing or remaining relatively constant?

Answer: The trend over the past decade has been one of increasing international collaborative activities in magnetic fusion energy research and development. This increase is manifest in various ways. The number of individual activities has increased. The breadth of the topics included in the international activities has increased from a science orientation to a fully comprehensive set of science and technology activities. The range of participants has also increased to include all major and modest sized fusion programs worldwide. The most significant trend has been from activities whose programmatic priority was modest, relative to those with the highest priority such as the burning physics issue now being discussed in the Summit process.

Question 4: What attributes of magnetic fusion energy make international cooperation easy to achieve? Does the field have attributes that make international cooperation difficult?

Answer: The basic characteristics of magnetic fusion energy clearly lend themselves to international collaboration. The fusion goal of energy for mankind is a common one embraceable by all. The acknowledged technical difficulty and interdisciplinary nature of fusion attracts some of the best scientists and engineers worldwide. The costs of new major fusion facilities result in fewer facilities and more need to work collectively on sophisticated problem solutions. The long time scale for fusion encourages seeking collaborative help on current problems, without the difficulties associated with commercial pressures. The long history of successful cooperation in fusion has built an expectation that international cooperation can be a useful tool in fusion work. The new communication technologies such as the satellite data links allow easier collaborative work among scientists than in earlier times. Finally, there is a strong sense of personal respect and friendship built up over many years by individuals in the program. This interpersonal rapport is an essential reservoir of understanding underlying the successes in collaboration.

Some of these same attributes also lead to difficulties in collaboration. The long time scale for fusion research and facility usage requires long term stability in program planning, especially for international collaborations. This stability has been difficult to achieve within our annual budgeting system. Lack of stability in long term support generates fears that enhanced use of international collaboration will come at the expense of domestic program capability. Satisfying this concern requires additional effort and time for program and policy officials in establishing new cooperative activities. Finally, the use of many advanced and sophisticated technologies in fusion requires careful consideration of technology transfer issues associated with other, non-fusion applications of these technologies.

Question 5: What roles do nongovernmental organizations, such as professional societies, private foundations, or various National Academies play in the development, implementation, and funding of international magnetic fusion energy programs? Should they or can they do more:

Answer: The nongovernmental organizations have been most active in the development and review phases of our international activities. These organizations host general and topical meetings that provide opportunities for exploration of possible technical collaborations. They also organize study groups to examine specific questions on international activities. In these kinds of activities the nongovernmental organizations have been helpful to the fusion program. Continuation of these activities is certainly welcome. However, to make significant contributions to the implementation and funding of collaborative fusion programs would require considerably more staff and financial resources than have been employed by these organizations for their participation in the development and review phases of the program.

Mr. FUQUA. Our last witness is Dr. Eugene B. Skolnikoff, the director of the Center for International Studies and professor of political science at the Massachusetts Institute of Technology.

He served on the White House staff in the Science Adviser's Office in the Eisenhower and Kennedy administrations and was a senior consultant to President Carter's Science Advisor.

Dr. Skolnikoff, we are very glad to have you here this morning.

[A biographical sketch of Dr. Skolnikoff follows:]

DR. EUGENE B. SKOLNIKOFF

Eugene B. Skolnikoff is director of the Center for International Studies and professor of political science at M.I.T. He has served on the White House staff in the Science Advisor's Office in the Eisenhower and Kennedy Administrations, and was a Senior Consultant to President Carter's Science Advisor. His research and teaching has focused on science and public policy, especially the interaction of science and technology with international affairs, covering a wide range of industrial, military, space, economic, and future issues.

STATEMENT OF DR. EUGENE B. SKOLNIKOFF, PROFESSOR OF POLITICAL SCIENCE; AND DIRECTOR, CENTER FOR INTERNATIONAL STUDIES, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MA

Dr. SKOLNIKOFF. Thank you very much, Mr. Chairman, and thank you for inviting me.

I have a statement, but I will not read all of it in the interest of time.

Mr. FUQUA. We will make the statement in its entirety—and also the entire statement of Dr. Clarke, the addendum to it—part of the record.

Dr. SKOLNIKOFF. I won't repeat my long involvement in this subject, both in Washington and at the university in a variety of roles. But it is a subject that has engaged my personal interest and professional activities for a very long time.

The overall subject of the interaction of science and technology with foreign affairs is a very broad one, touching on issues ranging from nuclear war to international competitiveness to agricultural productivity, and often affecting fundamental values and concerns in our country.

Today, I only want to discuss one part of the subject, as you requested, but I ask that that be seen as part of a much larger whole. I am going to focus on details, rather than generalities, about the values of cooperation, because I have found that the details are very often neglected in discussions when we deal with very large objectives.

My remarks are going to be largely concerned with all but the very largest of international cooperative projects which tend to receive relatively unique attention in the policy process, but some of the same considerations will apply.

Many of the ideas I present here are an outgrowth of one aspect of my work with Dr. Frank Press in the last administration, when an attempt was made from the White House to stimulate more international activities in science and technology as a way to achieve both scientific and political objectives. But the efforts often foundered on rather prosaic budget and policy hurdles rather than on the policy goals, hurdles that proved very difficult to dislodge.

The U.S. Government obviously supports international cooperation in science and technology through a number of different mechanisms and to serve a variety of national goals. As was mentioned earlier, every agency is involved one way or another, and through bilateral, multilateral, and private sectors.

There is no precise measure of the funding dedicated to international cooperation, whether for foreign aid or in any other activity, but most of the relevant programs are at least mentioned in the Title V report, which is submitted annually or biannually. I find that not an overly impressive document, notwithstanding its bulk, because the list of activities appears substantial only when one recollects that this represents the international dimension of a Federal R&D budget of over $50 billion, and then it seems to me very minor indeed, to which most of those who have been engaged in attempting to promote international cooperation in science and technology from inside the Government can quickly attest.

In the abstract, one would assume that the shared interests in R&D progress among friendly and even not so friendly countries, the global nature of many problems, the wide diffusion of technological competence, the importance of building science and technology in developing countries, the budgetary pressures that all are experiencing, let alone the political interests that can be served, would all lead to substantial pressure for increased cooperation.

In practice, of course, other pressures conspire to keep the number and scale of Government-supported international programs a quite minor proportion of the total R&D support.

But it was not always so. Even though international cooperation has always been a relatively minor part of the overall budget, I think the present situation is in fact much poorer relatively than it was in earlier years.

Absolute resources going for international cooperation in science and technology may be larger today compared to immediate postwar years, but relative to total research and development budgets, they are a very much smaller portion, and certainly the atmosphere in which cooperation must be developed and funded is less supportive, notwithstanding the discussion at recent Summit meetings about international cooperation.

Among the several reasons, I believe, for the relative lack of support for international cooperation is one family of reasons that has received relatively little attention or analysis. That is the organization of the U.S. Government for policymaking and funding of international cooperation in science and technology.

In fact, the particular structure of the U.S. Government and the Government's budgetary process have a great deal to do with the difficulty of expanding such programs, even under supportive administrations, and much to do with the ease of cutting them back in antagonistic or disinterested administrations.

Astonishing as it may be, the U.S. Government has no clear governmental instrument for international cooperation, and most agencies are restricted to using appropriated funds only for "domestic" R&D objectives. Individual departments and agencies must carry out their own programs of cooperation as part of regular budgets, with little or no recognition of the problems and disincentives to cooperation thus created. It is obviously variable from one agency to another how much that statement is true, but overall, I think it is generally true.

Difficult as it is for cooperation on projects of clear scientific merit and interest, proposals with mixed scientific and political objectives have no natural home or funding resource.

There are many different categories of cooperative programs that need to be considered, for each has rather different issues associated with it. There are, for example, those programs of high scientific quality that contribute to scientific objectives of an American domestic agency; or there are those of primary value to developing countries; or those with political overtones, or others.

I discuss all of the categories in material I am submitting with my statement for the record but will mention here only two: that category of programs that would be of high scientific quality and high interest to a Government agency if it were to be carried out, whoever carried it out, and second, the category of programs with mixed scientific and political objectives, such as, for example, those with the Soviet Union.

In principle, one would expect few problems with proposed programs of cooperation that are of high quality and would contribute to the scientific objectives of an American Government agency. Presumably, the programs could compete in routine fashion for funds within agency budgets and objectives, with relatively clear criteria of choice.

In practice, there are significant problems that serve to create major disincentives to develop such projects or to carry them through to implementation. Dr. Clarke, who preceded me here, I think, mentioned some of those along the way in his testimony. These have to do with the dominant domestic perspective in the U.S. agencies and corresponding lack of international interest, and the detailed processes by which projects are proposed and funded.

The overwhelming domestic orientation of the American R&D enterprise is often a surprise, not only to scientists in other countries but also to Americans used to the view that science is basically an international, or at least a nonnational, enterprise.

Though science is nonnational in its substance, nations do support science and technology for national purposes, and the institutions of government providing support are necessarily oriented to national goals.

In the United States, the development of governmental institutions has historical, cultural, geographic and security roots that result in a policy process that weights domestic interests and concerns to a very much greater extent than is the case in most other industrial countries.

The separation of powers between the Executive and the Congress is a major factor in continuing this dominance of domestic interests. Moreover, the very scale of science and technology in the United States, coupled with the geographic position of the country, has tended to make scientists and engineers as a whole less knowledgeable about, and less interested in, what is happening outside the country.

The result is a policy and budget process geared so automatically to domestic purposes for the use of funds that necessary adjustments for international projects—for example, extra initial costs for project development or planning or funds for needed travel just to get a project started—almost always have to be dealt with ad hoc and are usually viewed with skepticism or worse. There is usually a joke in OMB about international travel for developing scientific projects.

Nor is there a general climate in the Government that recognizes the value to the United States of international cooperation, nor widespread interest and pressure from the scientific community at large advocating more international cooperation as a major policy goal.

It is interesting that in the fusion project that was referred to before, the report of the National Academy of Sciences advocating it in response to the request from DOE in fact had buried in the middle of it a statement that, of course, basically, if all of this could be done in the United States, we would prefer that route, even though it advocated more for international cooperation.

To begin to develop that perspective, to take more advantage of the R&D benefits of international cooperation, and to realize the potential value to this country of an international approach to the problems that loom so large in all societies will not develop naturally.

Agencies, and particularly the lower levels of R&D management, would have to be sure not only that there is high-level executive branch and congressional interest in developing international activities that support the agency's R&D objectives, but also that international programs, if competitive, would be welcomed within their overall program and that the likely greater uncertainties encountered in evaluation of new proposals would be sympathetically taken into account.

From this would also have to follow some changes in the funding process that reflected the fact that international projects cannot be treated identically to a typical proposal that is wholly domestic. Up-front funding may be necessary to explore opportunities and to allow initial development of proposals that may be harder to formulate because of differing research styles or institutional practices.

Some risks may have to be taken for situations in which there could be serious political costs if a jointly developed proposal is ultimately rejected. Recognition of the importance of being a reliable partner may also sometimes require longer commitment of funds than is typical.

In some cases, funding may also be necessary for higher infrastructure and travel costs, even if overall costs of the project would be lower. Those extra funds have always been difficult to appropriate, and in particularly tight budgets, they appear as direct reductions in domestic research funds and thus inevitably very contentious.

Of course, all the obstacles do not reside within the Government, though the process difficulties within Government do have their resonance in the scientific community. Realization of the difficulties in funding international cooperation, or experience in trying to satisfy those difficulties, is often an effective disincentive for scientists to invest the time required to bring cooperative projects to the point at which they could be considered in the research competition.

Aside from the difficulties inherent in obtaining funding, other factors serve as disincentives to scientists considering international cooperation. The time delays necessarily involved; the extra travel, language and cultural obstacles to initiate cross-national interaction; and the different national patterns of allocation of research funds also are important.

Moreover, scientists are not immune from national biases, notwithstanding the nonnational basis of scientific knowledge. Particularly in the United States, many scientists know little about the details of work in other countries, even in their own fields—that is particularly more true as you get away from the research frontier—and have little interest in international cooperation. Some view international cooperation as inimical to the competitive race for national prestige and preeminence and are not inclined to collaborate unless absolutely necessary.

And, of course, the growing national concern with the presumed economic and security costs of transfer of technology has served to put a further damper on official interest or scientific interest in international cooperation.

The considerations above apply to programs with dominant scientific interest. How much more difficult it is for those with important political objectives that may be good science, but are not likely to be competitive within agencies, nor able to be put through a grant approval process even if they were.

In effect, these programs attempt to "use" science for political purposes, often a controversial concept on its own. The bilateral United States-Soviet programs obviously are prime examples, though there are others, and, in my view, there should be many more.

The question is not whether but how to use science and technology in support of the Nation's foreign policy interests. International activities in science and technology can serve a variety of objectives in addition to R&D goals, including contributing to U.S. political and economic interests with other countries, attracting high-level attention to particular interests, creating advantages for American industry in foreign countries, gaining knowledge of scientific and technological progress in other countries, and stimulating work on common or global problems.

Presidents, Secretaries of State, and others in Government have capitalized on the Nation's strength in science and technology for cooperation designed to achieve more than scientific purposes and will continue to want to do so. It seems to me that is perfectly appropriate, for national goals can be served by sensible use of all resources, as long as it is done responsibly and without damage to the primary mission of those resources.

The question is, How to carry out such programs responsibly, from both scientific and political perspectives? Sadly, and surprisingly, I think, the U.S. Government has no adequate mechanism for dealing with programs with these kinds of mixed motives.

Individual departments and agencies have no, or extremely limited, formal means to fund programs that cannot be fully justified on scientific and mission criteria, nor have they the capability to interpret foreign policy objectives in order to design and choose projects. The Department of State has also neither the funds nor the capacity to initiate and manage worthwhile scientific programs on its own.

Interagency mechanisms are often used as a way to plan such mixed-purpose programs or to secure funds for them from regular budgets, but that is a cumbersome mechanism at best; it necessarily can be used sparingly only for programs of overriding political interest. It is not calculated to provide efficient program management and oversight, and at times it may lead to rather improper or inappropriate use of regular budget funds.

In the accompanying material submitted to the task force, I discuss some pros and cons of various other solutions to this problem of how to plan, fund, choose and implement cooperative programs with mixed political and scientific motives, ideas for approaches such as appropriating funds to the State Department or allowing line-item budgets in mission agencies or other possibilities.

My preferred course, one attempted during the Carter administration in part for this purpose, was and still is the creation of a new agency expressly for international cooperation in science and technology that would be able to contribute to development as well as political objectives.

That proposal, known as the Institute for Scientific and Technological Cooperation, you may remember, was authorized but not funded by the Congress. I assume it is not a live option for some time to come.

Barring that, it seems to me that for the bulk of international science and technology activities justified in part on foreign policy grounds, it is the resources of the mission agencies themselves, whether in an international budget or as part of regular programs, that will have to be relied upon. The other choices are simply not commensurate with the nature and scale of the overall objective.

This conclusion that the bulk of the resources must come from the agencies, however, requires coming to grips with the difficulties associated with that route. If these are not dealt with, it is unrealistic to expect any administration or any Congress to approve.

Primarily, these difficulties have to do with evaluation and choice when a foreign policy motivation is involved. Who is responsible and/or qualified to represent the foreign policy interest? How should the project be compared with scientific evaluations, or how should the foreign policy evaluations be compared?

How can activities with different countries, different fields, different agencies, be compared across them? What can provide the discipline that is required to force hard choices rather than simply to approve everything because everything is good? How objective can foreign policy criteria be in any case?

I will skip over the particular suggestion I make here in the testimony in the interest of time and just say that whatever the mechanism that could be used for managing agency budgets for international cooperation, that will not be enough.

The need for planning flexibility, especially for broad programs of cooperation of high political value and White House interest, such as with China and the Soviet Union, and the need for initial funds to define and develop projects dictate a requirement for some prior segregated, noncompetitive funds able to be used for new international initiatives. The amounts can be reasonably limited on the assumption that programs once initiated should move into a competitive process of some kind as rapidly as possible.

Under that assumption, the Department of State could be the logical repository of such segregated funds; perhaps more realistically, they could be line items in the appropriate domestic agency budgets and/or dedicated international funds in the National Science Foundation. In particular, I must say that I believe NSF could have a much larger cross-agency role in stimulating and supporting the development of international cooperation.

I have gone into this much detail on an apparently small part of the overall problem—and, obviously, only lightly touched many of the issues—because it seems to me that international cooperation in science and technology is increasingly important to this country for scientific, technological, economic, and political reasons.

We may be the world's strongest scientific nation, but we are being overtaken piecemeal by aggressive competence in many other countries. We need increasingly to work with others for our own scientific and economic purposes, as well as to meet the growing costs of science.

Nor have we learned how to use satisfactorily or sufficiently our unparalleled scientific strength for broader foreign policy purposes. The U.S. Government has a large institutional/process problem here that deserves very much more attention than it generally receives.

Mr. Chairman, you also asked for some comments on multilateral versus bilateral cooperation, but I think I will leave that for the statement for the moment, but I will be happy to answer any questions.

[The prepared statement of Dr. Skolnikoff follows:]

COORDINATION AND MANAGEMENT OF INTERNATIONAL COOPERATIVE RESEARCH

Testimony of Eugene B. Skolnikoff
Director, MIT Center for International Studies
to the Task Force on Science Policy
Committee on Science and Technology
House of Representatives
June 20, 1985

Congressman Fuqua, Members of the Task Force on Science Policy: I very much appreciate the opportunity to testify before you today on a subject that has been a major interest throughout my professional career. In 1958 I joined Dr. James Killian's newly created Presidential Science Advisory staff in the White House with responsibility for the international dimension of the interaction of science and technology with national policy. Since then I have been intensely involved with that dimension, staying on in the White House until 1963, teaching and writing on the subject as a Professor at MIT, serving on a variety of advisory panels (including one on science and foreign affairs to the Secretary of State from 1973 to 1975), and returning part time to Dr. Frank Press' office in the White House during President Carter's Administration.

The overall subject of the interaction of science and technology with foreign affairs is a very broad one, touching on issues ranging from nuclear war to international competitiveness to agricultural productivity, and often affecting fundamental values and concerns in our country. Today, I will discuss only one part of the subject, as you requested, but it should be seen as part of a much larger whole. Many of the ideas I present are an outgrowth of one aspect of my work for Dr. Press in the 1970's when the attempt was made to stimulate more international activities in science and technology as a way to achieve both scientific and political objectives. The efforts often foundered on prosaic budget and policy hurdles rather than policy goals, hurdles that proved extremely difficult to dislodge.

The U.S. Government supports international cooperation in science and technology through a number of different mechanisms and to serve a variety of national goals. Almost every agency of the Federal Government is involved to some extent, and cooperation takes place through bilateral, multilateral, and private sector channels. No precise measure of the funding dedicated to international cooperation is available, but most of the relevant programs are assembled in the annual report to the Congress, colloquially known as the Title V report.[1]

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[1] "Science, Technology and American Diplomacy, 1984," Fifth Annual Report Submitted to the Congress by the President Pursuant to Sect. 503(b) of Title V of PL95-426, April 1984, Committee on Foreign Affairs and on Science and Technology, USGPO, Washington, D.C., 1984.

It is not an overly impressive document, notwithstanding its bulk; the list of activities appears substantial only until one recollects that this represents the international dimension of a Federal R&D budget of over 50 billion dollars. Then, it seems minor indeed, to which most of those who have been engaged in attempting to promote international cooperation in science and technology from inside the Government can quickly attest. In the abstract, one would assume that the shared interest in R&D progress among friendly and even not so friendly countries, the global nature of many problems, the wide diffusion of technological competence, the importance of building science and technology in developing countries, the budgetary pressures all are experiencing, let alone the political interests that can be served, would all lead to substantial pressure for increased cooperation. In practice, of course, other pressures -- economic and scientific nationalism, domestic institutional interests, concern over technological leakage, bureaucratic difficulties, ignorance of developments overseas, a commitment to leave it to the private sector, and the general domestic orientation of the U.S. Government (of which more below), conspire to keep the number and scale of government-supported international programs a quite minor proportion of total R&D support.

It was not always so; even though international cooperation was always a relatively small part of the budget, the present situation is in fact poorer than in earlier postwar years. Following the Second World War, and particularly after the Marshall Plan and the onset of the Cold War, there was a substantial U.S. interest in science and technology cooperation with OECD countries. Research was supported directly by U.S. agencies in Europe, and the climate was generally supportive for expansion of cooperation wherever possible. A major program of cooperation was begun with Japan in the late 1950's, and formally in 1961. NASA's legislation, passed in 1958, explicitly called for an international approach, as had the NSF legislation in 1950. Early objectives in NATO included major interest in joint research and production, and the NATO Science Committee was started in 1957 with grand ideas of spurring cooperative R&D. Even the OECD, when it was reconstituted out of the former Marshall Plan OEEC, included science policy cooperation among member countries as an important segment.

But the climate substantially changed. Absolute resources going for international cooperation in science and technology may be larger today, but relative to total research and development budgets, they are a much smaller portion. Certainly, the atmosphere in which cooperation must be developed and funded is less supportive, notwithstanding the discussion at recent Summits about international cooperation.

From economic, budgetary, political and scientific perspectives, this is unfortunate. Public sector goals in science and technology could benefit from a different climate toward international cooperation, and certainly this nation's objectives in foreign affairs and in technical assistance to developing countries would benefit from much greater ability to tap American scientific and technological resources.

Among the several reasons for the relative lack of support for international cooperation is one "family" of reasons that has received relatively little attention or analysis. That is the organization of the U.S. Government for policymaking and funding of international cooperation in science and technology. In fact, the particular structure of the U.S. Government and the Government's budgetary process have a great deal to do with the difficulty of expanding such programs even under supportive Administrations, and much to do with the ease of cutting them back in antagonistic or disinterested Administrations. The lack of clear understanding of this aspect of the subject, though by no means the only critical element, nevertheless can frustrate efforts to build international cooperation even when the political will exists to do so. And it certainly goes a long way to explain why more projects and possibilities for international cooperation do not arise spontaneously, whatever the interest of a particular Administration.

Astonishing as it may be, the U.S. Government has no clear governmental instrument for international cooperation, and most agencies are restricted to using appropriated funds only for "domestic" R&D objectives. Individual departments and agencies must carry out their own programs of cooperation as part of regular budgets, with little or no recognition of the problems and disincentives to cooperation thus created. Difficult as it is for cooperation on projects of clear scientific merit and interest, proposals with mixed scientific and political objectives have no natural home or funding resource.

There are many different categories of cooperative programs that need to be considered, for each has rather different issues associated with it. There are, for example, those programs of high scientific quality that contribute to scientific objectives of an American domestic agency; or there are those of primary value to developing countries; or those with political overtones, or others. I discuss all categories in material I am submitting for the record, but will mention here only two: that category of programs that would be of high scientific quality and high interest to a government agency if carried out; and, second, the category of programs with mixed scientific and political objectives, such as those with the Soviet Union. (My remarks are not meant to include very large international cooperative projects or programs, such as a major high energy accelerator, because those proposals tend to be considered as unique proposals outside the typical policy process. Some of the same considerations will apply, however.)

Cooperative projects of high scientific quality and agency interest

In principle, one would expect few problems with proposed programs of cooperation that are of high quality and would contribute to the scientific objectives of an American government agency. Presumably, the programs could compete in "routine" fashion for funds within agency budgets and objectives, with relatively clear criteria of choice.

In practice, there are significant problems that serve to create major disincentives to develop such projects or to carry them through to implementation. These have to do with the dominant domestic perspective of U.S. scientific agencies, and corresponding lack of international interest, and the detailed processes by which projects are proposed and funded.

The overwhelming domestic orientation of the American R&D enterprise is often a surprise not only to scientists in other countries, but also to Americans used to the view that science is basically an international, or at least a non-national, enterprise. Though science is non-national in its substance, nations do support science and technology for national purposes, and the institutions of government providing support are necessarily oriented to national goals. In the U.S., the development of governmental institutions has historical, cultural, geographic and security roots that results in a policy process that weights domestic interests and concerns to a much greater extent than is the case in most other industrial countries. The separation of powers between the Executive and the Congress is a major factor in continuing this dominance of domestic interests. Moreover, the very scale of science and technology in the U.S. coupled with the geographic position of the country, have tended to make scientists and engineers as a whole less knowledgeable about and less interested in what is happening outside the country.

The result is a policy and budget process geared so automatically to domestic purposes for the use of funds that necessary adjustments for international projects, e.g., extra initial costs for project development or funds for needed travel, almost always have to be dealt with ad hoc and are usually viewed with skepticism (or worse). Nor is there a general climate in the Government that recognizes the value to the U.S. of international cooperation, nor widespread interest and pressure from the scientific community at large advocating more international cooperation as a major policy goal. It is anomalous in an era in which high-quality R&D capability exists (and is growing) in many countries that share U.S. interests, in which the problems facing these societies are increasingly common and intertwined with those of the U.S., and in which the costs of R&D increase so as to limit the ability of any one country, even the U.S., to seek answers entirely on its own, that so little of an international perspective is in evidence.

To begin to develop that perspective, to take more advantage of the R&D benefits of international cooperation, and to realize the potential value to the U.S. of an international approach to the problems that loom so large in all societies will not develop naturally. Agencies and particularly the lower levels of R&D management, would have to be sure not only that there is high-level Executive Branch and Congressional interest in developing international activities that support the agencies' R&D objectives, but also that international programs, if competitive, would be welcomed within their overall program and that the likely greater uncertainties encountered in evaluation of new proposals would be sympathetically taken into account.

From this would also have to follow some changes in the funding process that reflected the fact that international projects cannot be treated identically to a typical proposal that is wholly domestic. Up-front funding may be necessary to explore opportunities and to allow initial development of proposals that may be harder to formulate because of differeing research styles or institutional practices. Some risks may have to be taken for situations in which there could be serious political costs if a jointly-developed proposal is ultimately rejected. Recognition of the importance of being a reliable partner may also sometimes require longer commitment of funds than is typical. In some cases, funding may also be necessary for higher infrastructure and travel costs, even if overall costs would be lower. Those extra funds have always been difficult to appropriate, and in particularly tight budgets, they appear as direct reductions in domestic research funds, and thus inevitably contentious.

It is also worthwhile noting not only the difficulty, but also the importance, of making the "domestic" agencies of the U.S. Government conscious of the international framework in which R&D is actually embedded. The potential practical payoffs are obvious: U.S. R&D can benefit from work in other countries, much more of which is now equal to U.S. R&D in quality, and more frequently there will be parallel work of direct relevance to U.S. R&D objectives, and increasing opportunities for cost sharing or for faster progress toward R&D goals.

Of course, all the obstacles do not reside within the Government, though the process difficulties within government do have their resonance in the scientific community. Realization of the difficulties in funding international cooperation, or experience in trying to satisfy the difficulties, is often an effective disincentive for scientists to invest the time required to bring cooperative projects to the point at which they could be considered in the research competition. In many cases, of course, the opportunities and appropriateness, because of special equipment, skills, or the nature of the subject, make the effort to overcome the difficulties worth the candle. But, in marginal or less clear cases, the disincentives loom large.

Aside from the difficulties inherent in obtaining funding, other factors serve as disincentives to scientists considering international cooperation. The time delays necessarily involved; the extra travel, language and cultural obstacles to initiate cross-national interaction; and the different national patterns of allocation of research funds (which can result, for example, in disparities of funding and uncertainties of the results of priority ranking); also are important. Moreover, scientists are not immune from national biases, notwithstanding the non-national basis of scientific knowledge. Particularly in the U.S., many scientists know little about the details of work in other countries, and have little interest in international cooperation. Some view international cooperation as inimical to the competitive race for national prestige and preeminence, and are not inclined to collaborate unless absolutely necessary.

And, of course, the growing national concern with the presumed economic and security costs of transfer of technology has served to put a further damper on official interest in international cooperation. Though that does not affect many scientific fields, it certainly is relevant to those in which the distance between the laboratory and application is shrinking -- such as electronics and biotechnology. The target of the concern, still largely focused on security, will almost certainly turn increasingly to economic issues. Growing pressures for "technological protectionism" cannot help but prove to be a deterrent to international scientific cooperation.

Thus, impediments and disincentives, even for projects entirely justified scientifically, can be substantial. They arise from the general domestic orientation of the U.S. Government, and a policy and funding process that provides little recognition of the special requirements for organizing and implementing international cooperative projects. Not all possible international projects should be supported, of course, but the growing importance of such cooperation to the U.S., as well as to others, dictates greater efforts to modify the existing climate, and to make the governmental process more flexible and responsive.

Cooperative projects with mixed scientific and political objectives

The considerations above apply to programs with dominant scientific interest. How much more difficult it is for those with important political objectives that may be good science, but are not likely to be competititve within agencies, nor able to be put through a grant approval process even if they were. In effect, these programs attempt to "use" science for political purposes, often a controversial concept on its own. The bilateral U.S./U.S.S.R. programs obviously are prime examples, though there are others, and in my view should be many more.

The question here is not whether, but how to use science and technology in support of the nation's foreign policy interests. International activities in science and technology can serve a variety of objectives in addition to R&D goals, including contributing to U.S. political and economic interests with other countries, attracting high level attention to particular issues, creating advantages for American industry in foreign countries, gaining knowledge of scientific and technological progress in other countries, and stimulating work on common or global problems. Presidents, Secretaries of State, and others have capitalized on the nation's strength in science and technology for cooperation designed to achieve more than scientific purposes and will continue to want to do so. That is appropriate, for national goals can be served by sensible use of all resources, as long as it is done responsibly and without damage to the primary mission of those resources.

The question is how to carry out such programs responsibly, from both scientific and political perspectives. Sadly (and surprisingly), the U.S. Government has no adequate mechanism for dealing with programs with these kinds of mixed motives. Individual departments and agencies have no, or extremely limited, formal means to fund programs that cannot be fully justified on scientific and mission criteria, nor have they the capability to interpret foreign policy objectives in order to design and choose projects. The Department of State has also neither the funds nor the capacity to initiate and manage worthwhile scientific programs on its own.

Interagency mechanisms are often used as a way to plan such mixed-purpose programs or to secure funds for them from regular budgets, but that is a cumbersome mechanism at best, necessarily can be used sparingly only for programs of overriding political interest, is not calculated to provide efficient program management and oversight, and at times may lead to rather improper or inappropriate use of regular budget funds. Moreover, it certainly is not a way to imagine expanding the legitimate and disciplined use of scientific cooperation as a contributor to the nation's foreign policy objectives.

In the accompanying material submitted to the Task Force, I discuss the pros and cons of various other solutions to this problem of how to plan, fund, choose and implement cooperative programs with mixed political and scientific motives, such as appropriating funds to the State Department, allowing line item budgets in mission agencies, or other possibilities. My preferred course, one attempted during the Carter Administration in part for this purpose, was -- and still is -- the creation of a new agency expressly for international cooperation in science and technology that would be able to contribute to development as well as political objectives. That proposal, known as the Institute for Scientific and Technological Cooperation, you may remember was authorized but not funded by the Congress. I assume it is not a live option for some time to come.

Barring that, it seems to me that for the bulk of international science and technology activities justified in part on foreign policy grounds, it is the resources of the mission agencies themselves, whether in an "international" budget, or as part of regular programs that will have to be relied upon. The other choices are simply not commensurate with the nature and scale of the overall objective though all mechanisms are, and ought to be, used to some extent.

This conclusion that the bulk of the resources must come from the agencies, however, requires coming to grips with the difficulties associated with that route. If these are not dealt with, it is unrealistic to expect any Administration, or any Congress, to approve. Primarily, those difficulties have to do with evaluation and choice when a foreign policy motivation is involved. Who is responsible and/or qualified to represent the foreign policy interest? How should it be compared with scientific evaulations? How can activities with different countries, different fields, different agencies be compared? What can provide the discipline that is required to force hard choices? How objective can foreign policy criteria be in any case?

An argument can be made that almost any science and technology interaction with a country of interest is "good." Traditionally, the Department of State has tended to be rather uncritical in its support of international science and technology activities of other agencies within broad foreign policy constraints. But that is inadequate, if it ever was otherwise, in a period of growing interest in more effective use of U.S. science and technology capacity internationally. Even if funding constraints were not as serious as they are today, responsible use of public funds and resources would require more appropriate discipline.

In thinking about possible mechanisms for disciplined choice of international projects, it is useful to remember that except in very unusual circumstances, good politics requires good science. That is, political goals are unlikely to be achieved unless the scientific project designed to achieve them is legitimate and competent. The scientific quality cannot be expected to be completely competitive with the best in the U.S. -- that is the point of considering projects with mixed objectives where, by definition, the science may not be in the forefront -- but it should be appropriate in quality to its setting.

In practical terms, therefore, cooperative projects with these mixed motives should only be considered for funding if they would rank only marginally below the cutoff point in a mission agency's competitive ranking of research projects based on scientific criteria. (Leaving aside, for the moment, the question of how international projects can be developed to the point of being competitively ranked.) Proposals above the cutoff can be funded whatever the foreign policy interest because of their inherent scientific interest to the agency. Proposals that fall near the bottom of the ranking are presumed to be of little scientific interest to an agency and should proceed only if there is a special foreign policy interest in having them implemented. In that case, external (to the agency) funding is clearly appropriate and, in fact, essential. Only those that are roughly in the middle of an agency ranking -- below but near the cutoff -- need to be considered further, for they have reasonable scientific merit and agency engagement.

This logic leads to the suggestion that it would be useful to attempt to rank international science and technology programs across departments and agencies according to foreign policy interest. Such a ranking, if it could be done, would be compared with the independent ranking within departments and agencies based on their normal scientific criteria. Projects that are marginal on an agency ranking, but high on foreign policy ranking, would be given an extra boost. Those marginal within the agency but low on the foreign policy ranking would be dropped, while those low in agency ranking, but particularly high on foreign policy grounds, would proceed only with funding provided by the Department of State or other external source.

Such a cross-department ranking makes sense in theory, but in practice can it be done with competence and credibility? A separate agency for international science and technology cooperation could have been the chosen instrument, but the attempt to create that agency did not succeed. The State Department is unlikely to be able to carry out such a ranking with sufficient support from technical agencies, or with adequate authority to implement the results. A possibility is an interagency working group, chaired by the Department of State, that provided the locus for a government-wide ranking. Or, OMB or OSTP could chair the group to provide more objective leadership.

Whatever the mechanism that could be used for "managing" agency budgets for international cooperation, that will not be enough. The need for planning flexibility, especially for broad programs of cooperation of high political value and White House interest such as with China and the Soviet Union, and the need for initial funds to define and develop projects, dictate a requirement for some segregated (non-competitive) funds able to be used for new international initiatives. The amounts can be reasonably limited on the assumption that programs once initiated should move into a competitive process of some kind as rapidly as possible. Under that assumption, the Department of State could be the logical repository of such segregated funds; more realistically, they could be line items in the appropriate domestic agency budgets, and/or dedicated international funds in NSF. In particular, I believe NSF could have a much larger cross agency role in stimulating and supporting the development of international cooperation.

I have gone into this much detail -- and obviously only lightly touched many of the issues -- because it seems to me that international cooperation in science and technology is increasingly important to the U.S. for scientific, technological, economic and political reasons. We may be the world's strongest scientific nation, but we are being overtaken piecemeal by aggressive competence in many other countries. We need increasingly to work with others for our own scientific purposes, as well as to meet the growing costs of science. Nor have we learned how to use satisfactorily or sufficiently our unparalleled scientific strength for broader foreign policy purposes. The U.S. Government has a large institutional/process problem here that deserves very much more attention than it generally receives.

Multilateral vs bilateral cooperation

You have also asked for comments on the relative merits of bilateral and multilateral cooperation. That would require an extended paper on its own. There are a few key points, however, which I will make almost in list form. One is the obvious one that they are only occasionally in competition -- both are required.

Where there is choice, that selection should be made in the light of an assessment of both direct and indirect objectives. For example, immediate progress and results on a project are likely to flow faster from a bilateral approach. That may be the overriding consideration. On the other hand, the development of international capacity in particular subjects, which may be important for future progress, is likely to be better served with a multilateral approach. If that is the critical consideration, a multilateral approach would be indicated.

For some projects, an independent actor is important, perhaps for political acceptability; multilateral organizations are likely to be essential for that role. In other cases, the U.S. may be legitimately concerned about loss of control of a project, or politicization, which would tend toward selecting a bilateral approach. In some cases, it may be possible to get funding more easily for multilateral than for bilateral projects, though that can work in reverse as well, depending on the subject and the country.

In short, in an ideal policy process, each proposal for cooperation would be examined on its merits, based on the general objectives of the project and the situation in which it is embedded, and with consideration of long-term as well as immediate national objectives.

There is no such thing as an ideal policy process, but I am afraid that we are particularly far from that situation today; instead, it appears to me that there is a strong intrinsic bias against multilateral projects and organizations, quite independently of the broader interests of the U.S. I do not believe it is possible for any country to maintain complete independence of national action, as many would like to believe possible, in a world changing and interlocking as fast as this one is. Much better would be to try to build the multilateral institutions the world does and will need in ways that will make them viable and effective for this country's and everyone's interests. That is a tall and very important task, but I see only negative actions, and very few positive ones attempting to serve that goal.

Thank you for inviting me to testify. I will be pleased to answer any questions.

DISCUSSION

Mr. FUQUA. Thank you very much.

Do you feel that the Federal Coordinating Council for Science, Engineering, and Technology could play a larger role in our international science activities, or is it too unwieldy a forum?

Dr. SKOLNIKOFF. I am totally out of date on its current status or powers or activities. I can only say that when I was up to date on it, my answer would be a very clear no.

Almost inevitably, with a few exceptions, when it was seized with a particular issue that had an ad hoc nature, kind of one-shot aspect to it, it could do very well; but on a continuing basis, continuing function, it acted as a coordinating body only in coordinating in the very dullest sense of that word, of comparing information rather than doing any kind of development of programs or ideas.

Mr. FUQUA. As one of cosponsors, who helped get it through the House, of the Institute for Scientific and Technological Cooperation, I agree with you that it may not be the most opportune time right now to renew that, but in lieu of that, do you think there should be a lead agency in international cooperation under the current mechanisms that exist?

Dr. SKOLNIKOFF. I think the only way that that could work to do some of the goals, at least, that were intended to be achieved by that agency is for OSTP and OMB to take the lead. If they took the lead—that is, the policy lead, and a very substantial one—but if they did, it would be possible to develop a lead agency among the agencies. But I really doubt that. I think the structure and the impetus and the support has to come from those two bodies.

Now, that does not mean that they have an operating role in the programs; it does mean that they have to both be willing to provide the support, the pressure, and the funds that are required, and then I think the agencies can do it on their own with the kind of rough coordination that exists all the time.

Mr. FUQUA. What about agencies such as OSTP, State, and, say, the National Science Foundation?

Dr. SKOLNIKOFF. Combined together?

Mr. FUQUA. No, not combined together but in a larger role than they currently have. As we discussed yesterday—and you are familiar with OSTP—it is not a mission agency.

Dr. SKOLNIKOFF. No, it is not.

Mr. FUQUA. And we should not bog that agency down with day-to-day operating roles, so to speak. It is more an advisory capacity, really, for the President, and in helping him coordinate overall policy in science and technology.

As one who worked very closely during the Ford administration in trying to establish that Office, we went to great lengths not to make it a mission agency. That puts in an inherent conflict of interest with the other agencies that it is advising about. But certainly as a coordinator of the policies of the administration or the President—and an example is some of the initiatives that have resulted in the Economic Summits that have been held and agreements that have been signed—certainly the OSTP had some role in coordinating that, and that is a proper role, but not one of administering funds or working out final agreements and so forth.

Dr. SKOLNIKOFF. That is right.

Mr. FUQUA. But maybe through that and the State Department, since it does involve foreign policy objectives—and you had indicated that as one of the weaknesses of the current system—and also maybe the NSF, which is involved in some small way, in some of the programs. That does not mean to leave DOE, or NASA, or NIH, or some of the other mission agencies out of that, but maybe there could be a coordination through that. I am not advocating that; I am asking for advice.

Dr. SKOLNIKOFF. Well, I have always felt for many years that the Department of State could have a much stronger role, play a much larger role, on issues of this kind. In practice, it has rarely done so, and I think the reasons for that are, some of them, internal to the State Department, but some of them have to do with the State Department's general position in the Government on foreign policy issues that affect science and technology.

It has been very hard for the State Department to really follow, coordinate, everything that goes on. One could not expect it to do that with agencies the size of Defense, Energy, NASA, and so forth. But I think it has done less than it could.

It seems to me possible—and part of what I did not read here in the testimony was that it might be possible to, in effect, develop a cross-agency or government-wide rank list of international scientific cooperation projects. If something like that were attempted, the State Department, it seems to me, would have to have a very central role in that, and it would need help in doing that.

Now, one of the other agencies that has a clear mandate for international activities—and one always would hope it would do a lot—is the National Science Foundation. It has tended to stay away from major activity outside fundamental research in international activities.

I think if there were a possibility for the Science Foundation to work closely with State on that kind of cross-government ranking of projects, I think it could be very useful. But it could not do it without very strong support from OSTP and, I emphasize, from OMB, because without OMB's participation in this and willingness to see certain kinds of funds be earmarked for these purposes, it would come to naught.

Mr. FUQUA. Mr. Packard.

Mr. PACKARD. Thank you, Mr. Chairman.

Dr. Skolnikoff, I find your testimony very interesting and somewhat different than what we have heard.

You feel that we have moved in the opposite direction of international cooperation over the last few years. That is what I gather from your testimony.

Dr. SKOLNIKOFF. No, not the last few years. I would say the last 20 years.

Mr. PACKARD. OK.

Dr. SKOLNIKOFF. That was not a partisan remark.

Mr. PACKARD. And, also, contrary to many of the other witnesses, you have suggested, apparently from your involvement previously in government, an agency that would supervise and coordinate the international activities. Apparently you still feel that that would be the appropriate way to go even though, politically, it probably is not possible.

Dr. SKOLNIKOFF. Yes.

Mr. PACKARD. Now, would that agency, in your judgment, not only supervise and take precedence over international relationships in cooperative efforts but also over mission agencies and mission efforts in terms of the same scientific areas?

Dr. SKOLNIKOFF. No. The bulk of whatever happens has to reside in the mission agencies. Not only would it be impossible to take it out, but it would be foolish to do so. That is where the expertise exists.

That agency that was proposed some years ago actually had a broader function that was mentioned here. A good part of it was related to the development concerns, such as of dealing with developing countries in science and technology, and in fact the goal is almost the opposite of the way you phrased the question; and that is to say, we are so badly or inadequately utilizing the scientific and technical resources of mission agencies and of the private sector in the United States, that one purpose of that agency was to try to better use those resources, rather than to take them over.

It was never intended to be a large agency; it was very much more intended to be a smaller agency working with existing expertise, able to do this kind of cross-agency ranking, and in fact it was that particular point that interested OMB at the time, and that was that it might be possible—they saw it as a way of possibly allocating funds for international projects where there was a genuine discipline; where there was an agency that could exercise some genuine discipline in the process.

Mr. PACKARD [as acting chairman]. I appreciate your interesting testimony. Thank you very much.

It appears that the chairman has been called elsewhere, and so I believe, if there are no further remarks, that concludes our task force hearing this morning. We will now recess until next Tuesday, June 25.

We want to thank you, Dr. Skolnikoff, and all others who have testified this morning.

Dr. SKOLNIKOFF. Thank you, Mr. Packard.

[Answers to questions asked of Dr. Skolnikoff follow:]

QUESTIONS AND ANSWERS FOR THE RECORD

Dr. Eugene B. Skolnikoff

1. **What roles do nongovernmental organizations, such as professional societies, private foundations, or various National Academies play in the development, implementation, and funding of international science programs? Should they or can they do more?**

Nongovernmental organizations obviously play an important role in the development and implementation of large scale programs of international cooperation. The IGY and its successors would not have happened without ICSU and its sister organizations.

My view is that the roles of nongovernmental organizations could be more substantial in stimulating international cooperation because of the kinds of limitations of government action and funding that I alluded to in my testimony. The nongovernmental organizations cannot replace government funding, clearly, but perhaps they could more self-consciously attempt to provide the initial discussions and planning that are so very difficult to carry out in a governmental framework. It is not possible to specify offhand how such activities could be organized, but it might be worth some additional thought by the organizations concerned.

2. **What role, if any, does industry have in international cooperative science activities?**

Industry obviously has a very substantial role in international cooperation in technology, but much less in scientific cooperation. I think there may be cases where industry would be involved directly and with its own funds in international cooperation in science, but offhand I do not see this to be a major issue or opportunity. Obviously, industry will be involved as a contractor in various cooperative projects.

3. **What sort of multilateral entities might be established to deal with the contemporary and future requirements of international science cooperation? Are new mechanisms needed?**

It appears to me clear that the universe of multilateral institutions for international scientific cooperation are now particularly inadequate given the serious and perhaps fatal problems with UNESCO. For all of UNESCO's shortcomings, it was in many ways an important organization in stimulating and coordinating international activities in science. Some replacement or alternative is likely to have to be found to fill the multiple roles that UNESCO played. The situation is not yet shaken down, so it is not clear what is needed. But one can expect that in a very short period of time there will be important demands placed on governments, and particularly this government, to consider how to carry out the international planning and coordination role among governments that UNESCO filled in several substantive areas.

Some of the projects could, in principle, be transferred to other existing international organizations if other governments agreed. Others could be done on a more restricted basis among the countries particularly interested. But others will require a new mechanism that does not now exist. The National Academy of Sciences report on this last year provided an excellent coverage of alternatives to UNESCO in specific project areas.

I would add a more general comment that we have not adequately recognized the need for successful operation of international organizations to deal with the many "governmental" functions that must be performed in an international framework (e.g., regulation, coordination, mediation, etc.). The system of international organizations performs reasonably, and in many cases very much better that the public realizes, but the demands on adequate performance are likely to become more serious rather than less so as time goes on. This is an important topic that has received very little attention in recent years; the issue of institutions required for international cooperation in science is but one piece of that larger topic.

4. **What specific steps would you recommend be taken to strengthen existing entities such as OSTP, the Department of State, and the National Science Foundation in the area of international cooperation?**

My testimony and the accompanying materials had many references to the steps that I believe need to be taken to strengthen existing government agencies to deal with international cooperation. I would not try to summarize that here, but I do believe that all of those mentioned in the question -- OSTP, DOS, NSF -- are in fact central for the U.S. Government to do a better and larger job in the area of international cooperation.

5. **Should some or all future "big science" facilities be developed on the basis of international cooperation?**

I do not know whether all future "big science" facilities should be developed internationally or not, for it seems to be a matter of deciding what are the appropriate criteria. Some of those criteria are scientific, some are budgetary, and some are also political. By and large, we have found it so difficult to cooperate well and fully in science and technology with other countries that I would recommend bias in favor of cooperation, especially on forefront scientific projects, as a way of exploring fully the real problems in doing so. It seems on the face of it to be unwise that each nation must be as nationalistic even in its science as it seems to be (though appropriate competition is clearly also healthier <u>for</u> science), and one would expect that faster progress could be achieved in many fields if there were adequate pooling of competence and resources.

But all that can be said as a general proposition is that a preference <u>for</u> cooperation should color examination of specific "big science" cases.

6. **Should federal science funding include the aim of keeping the U.S. first in every field of science, and if so, will international cooperation help us to achieve this aim?**

I personally think it is foolish for the U.S. to attempt to be first in every field of science, and I also think it is not an achievable objective any longer. It is clearly important that we be strong in science, and I would argue that it is also important and valuable for us to be, in general, the strongest scientific power. But that does not mean that we must be first in very science, even if we could be, and in fact the effort to try to be first in everything would undoubtedly be so large as to make it impossible of achievement.

There are, however, fields of science in which it is important for us to maintain a lead. I doubt if we could all agree on which those are, but I do believe there is an argument to be made for maintaining not just excellence but leadership in those fields that in our best judgment are likely to be the most important for future economic, security, welfare, and intellectual benefits.

International cooperation can, in fact, help to achieve this aim, especially in those areas where we have close competitors. Cooperation is an important and useful technique for maintaining close involvement and knowledge of work in progress, of generating new ideas, and of multiplying purely domestic efforts. It is a complement to cooperation, not an alternative.

7. **What is the appropriate level of funding or national research efforts versus international efforts? How should these levels be determined? What prioritization scheme should be used?**

It would not be possible to answer in the abstract what the appropriate level of funding for national vs. international efforts should be. Nor how these levels should be determined. At the moment, the level of funding for international activities is so far below funding for purely national activities that it seems to me not an issue to be posed in that way.

More appropriately, the questions should simply be asked how substantial numbers of international projects can be developed to the point of even being considered in the policy process, how they can be sensibly evaluated, and how some kind of ranking for them can be achieved to allow policy choices. I deal with some aspects of this question in my testimony, though there I was primarily concerned with those projects that are not purely scientific in payoff, but have mixed scientific and political motivations.

For those projects of competitive high quality science, it seems that we will have to rely primarily on existing scientific assessment mechanisms, as inadequate as they may be. The problem is in part the same one faced in attempting to make judgments across disciplines. The comparative judgment of international projects vs. purely domestic ones have to rely on rather subjective criteria, very much more subjective than the evaluation of the quality of the science itself.

My guess is that this question will ultimately be answered only under the duress of domestic budgetary limitations that force relevant communities to look abroad for ways of achieving their objectives at lower domestic costs. It is unfortunate but only too true that even when dealing with science, the policy decisions cannot be made on "scientific, rational" grounds but are subject to the same judgments, pressures, and personal motivations as are other nonquantitative, nonscientific subjects.

Mr. PACKARD. The task force stands in recess.

[Whereupon, at 11:58 a.m., the task force recessed, to reconvene at 10 a.m. on Tuesday, June 25, 1985.]

INTERNATIONAL COOPERATION IN SCIENCE

THURSDAY, JUNE 27, 1985

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to notice, at 8:30 a.m., in room 2325, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. Today's witness is the distinguished director of the Joint European Torus [JET] Joint Undertaking Project, Dr. Hans-Otto Wüster. Prior to his appointment as director of the JET Project in December 1977, Dr. Wüster served as deputy director general of CERN, the European Laboratory for Particle Physics.

We are very pleased to have you here today as we conclude the fourth hearing on international cooperation in science.

STATEMENT OF DR. HANS-OTTO WÜSTER, DIRECTOR, JOINT EUROPEAN TORUS [JET] JOINT UNDERTAKING, ABINGDON, OXFORDSHIRE, GREAT BRITAIN

Dr. Wüster. Thank you, sir.

I have sent over a written statement, which I would not like to go through in detail, but it is maybe appropriate to make a few points which are partially in the statement, partially not. The first point is certainly not.

Also in Europe, international collaboration in its formalized institutionalized form is not an organizational scheme with which you start normally. International collaboration on the scale as we have it in our laboratory is the result of general insight that research in separate national laboratories could not, for reasons of resources, be as much in the forefront of science as a joint effort.

The fusion research in Europe, as you well know, is a program which is coordinated by the European political body, the Commission of the European Communities. But it started out in financing research—co-financing research in national laboratories.

However, in the early seventies, when size seemed to be necessary to make progress, and things got bigger and bigger, it became clear such an apparatus could not be financed and also staffed in the framework of a single national laboratory. This was the hour of birth of the idea of the JET Joint Undertaking. It has taken considerable time to get this project off the ground, 5 years of design study of which 2 years were certainly mainly based on the problem to agree on a site for the project.

And when we started in 1979, people were still not too clear if this Joint Undertaking would be a good approach because, as I have jokingly given talks on JET on the theme why JET normally couldn't work, it contains in its basic conditions things which would be considered abnormal in many places: staffed at very different pay levels, and a majority shareholder which has only 5 out of 38 votes in all decisions and can be outvoted in everything except the budget by a simple two-thirds majority.

Many of these conditions, when you look at them in a textbook for organization for the management of laboratories, look very much out of place, and that is what we called the JET project. In spite of this, the project started in 1978 with a flying start, has fulfilled its first aim, namely, a 5-year construction period with, in real terms, a budget overshoot of about 8 percent and a time delay of less than a month, and is continuing to flourish and is now strongly supported by the whole fusion community.

Also, in Europe we are encountering problems with the budgets for research because they have a tendency to grow. And the Council of Ministers of the European Community has made a decision in December to reduce the financial appropriations available in the 5-year program in comparison to what the Commission of the European Communities had proposed quite strongly.

Of course, this is due to be reviewed in about a year or a year-and-a-half from now, and we have strong hopes they will have the right arguments to take back some of these cuts, but nobody knows.

In the meantime, however, the fusion community has to arrange its own priorities, and I am very happy in the knowledge that, in the first round of discussions, the absolute priority of the JET project in that program has been recognized also, and mainly by those who are responsible for the national laboratories. That is, in spite of all the difficulties, the importance of the Joint Undertaking has now been absolutely accepted by those who are responsible and have their worries about the continuation of their own programs.

So in this respect, the European fusion program and the JET Joint Undertaking can be considered to be in a good state also where the morale of the troops is concerned.

I think I shall stop here, Mr. Chairman, and give you more time for questions and discussion.

[The prepared statement of Dr. Wüster follows:]

The JET Joint Undertaking

Statement by Dr Hans-Otto Wüster, Director
to the Task Force on Science Policy
Committee on Science and Technology
U.S. House of Representatives
Thursday 27 June 1985

JET Joint Undertaking
Abingdon
Oxfordshire
United Kingdom
OX14 3EA

The JET Joint Undertaking

JET, the Joint European Torus, is an important experiment in three respects:

- as an experiment in fusion physics;
- as an experiment in European collaboration;
- as an experiment in project organisation.

JET as an Experiment in Fusion Physics

JET is one of three large tokamaks in the world: TFTR in the United States, JET in Europe, and JT-60 in Japan. TFTR was the first to start operating in December 1982, followed closely by JET in June 1983. JT-60 had its first plasma in April 1985.

The main features of the three tokamaks are illustrated in Fig. 1. JET has the largest dimensions, the longest pulse time and will operate at the highest plasma currents. In fact, in June 1985, JET reached a plasma current of 5 million amperes, a level which actually exceeds the maximum performance specified.

The total cost of the project from the start of construction in 1978 to the scheduled completion of its scientific programme at the beginning of the 1990s will in round terms be $1 billion at today's prices. Of the total, about half will be capital costs, a quarter personnel costs, and the remaining quarter other operating costs.

About one-third of the total was spent in the construction phase, at a cost that was only some 8 per cent above the original estimate made in 1975. Moreover, the first plasma was achieved within 25 days of the original five year schedule. The Project has thus proceeded very much to cost and to time. This is a creditable achievement bearing in mind the developments in the meantime in the underlying physics.

JET as an Experiment in European Collaboration

JET is the largest element in the Fusion Programme of the European Atomic Energy Community (Euratom), one of the European Communities. Its funding is divided as follows (see Fig. 2 for additional details):

- 80% from the general budget of Euratom, which is financed by the ten member states of the European Communities, but, which as far as JET is concerned, includes contributions to the Community from Sweden and Switzerland;
- 10% from the United Kingdom Atomic Energy Authority, which, as the Host Organisation, provides technical, administrative and general services to the Joint Undertaking;
- 10% from those Members of the JET Joint Undertaking having Contracts of Association with Euratom, and divided in proportion to the contribution from Euratom towards the cost of their Association contracts.

As part of the Euratom Fusion Programme, JET operates under the procedures of the European Communities. In brief (see Fig. 3), every three years, the Euratom Fusion Programme is the subject of a Programme Decision covering a five-year period. The Programme Decision is taken by the Council of Ministers, on the basis of a proposal by the Commission, after receiving the opinion of the European Parliament. In relation to the JET element of the Programme, the Commission has hitherto always based its proposals closely upon the decisions of the JET Council. Every year, the Budget of the European Communities is decided jointly by the Council of Ministers and the European Parliament, on the basis of proposals made by the Commission. The Budget proposals of the Commission include explicit provision for JET, again based on the decisions of the JET Council. JET's accounts are audited by the Court of Auditors of the European Communities.

The Members of the JET Joint Undertaking are represented by the JET Council, which is responsible for establishing the JET programme and for supervising its execution. It is the JET Council which nominates the Director and senior staff of the Project and which approves the annual budget, as well as the Project Development Plan and Project Cost Estimates. The JET Council is assisted by the JET Executive Committee, which in particular approves, in accordance with the rules established by the JET Council, the awarding of contracts, and by the JET Scientific Council, which advises on scientific and technical matters. The JET Director is the legal representative of the Joint Undertaking.

The voting balance in the JET Council has been structured (see Fig. 4) so that the delegations from Euratom and the four large countries—France, Germany, Italy and United Kingdom—require the support of at least one other delegation for a decision. The voting rights are:

5 votes each:	Euratom, France, Germany, Italy, United Kingdom;
2 votes each:	Belgium, Denmark, Netherlands, Sweden, Switzerland—countries in which establishments have Contracts of Association with Euratom;
1 vote each:	Greece, Ireland, Luxembourg—countries which have no Contract of Association with Euratom.

In total, therefore, there are 38 votes, of which 26 are required for a decision.

JET as an Experiment in Project Organisation

Although the JET Joint Undertaking is a separate legal entity, it has no permanency. It is a single project, not an institution. The Undertaking has a finite life. It began in June 1978 and will terminate at the beginning of the 1990s when the experimental programme on the machine comes to an end.

The organisation of JET will stand as a model for future international research projects, if it can succeed in demonstrating its aim that such a project can be set up, run and closed without any serious long term obligations, particularly social ones. To this end, the Undertaking is not an employer. Staff are seconded to JET either directly by the UKAEA or by the other Members via temporary contracts of employment with Euratom. With the Undertaking set up in this way, it will have no social obligation to staff at its termination.

The JET Paradox

In the early days of the Project, many commentators claimed that some of its characteristics would make it ineffective and perhaps even unmanageable. For example:

- How could a physics project with all its scientific uncertainties operate successfully and productively within the framework of an international treaty organisation?
- How could a project be harmoniously managed when staff working alongside each other from the two employers—Euratom and the UKAEA—have salaries that differ by a substantial factor?
- How could a team drawn from twelve nationalities and nearly as many mother tongues be managed efficiently?
- How could a temporary project hope to attract staff of a sufficient calibre and retain them particularly once the project is more than half-over?
- How could a project whose costs are in various currencies manage its financial affairs if its budgets are decided in ECU, until recently a currency of only notional value?

Apart from such questions on the organisation and finances of JET, there were also questions about the ambitious nature of the machine itself. The jump in scale and power over previous machines was considered too ambitious by some. These questions are now all answered.

The JET Experience

The main conditions for the success of JET have been first that management has been given the freedom to manage, second that there has been no quota system either for staffing or for contracts, and third that the Project Team has held on firmly to the responsibility for design, development and construction.

Management has the Freedom to Manage. Despite the apparently complicated framework in which the Joint Undertaking must operate, the Director has considerable freedom. The supervisory bodies have never tried to manage the Project.

Freedom from Quotas. JET is free of the principle of "juste retour" that bedevils some other international projects. Contracts are awarded to the lowest technically acceptable offer. Tenders are, however, judged on an f.o.b. basis to ensure that there is no discrimination between firms for reasons of geography. The lowest tender can be rejected, if considered by JET to pose unacceptable technical or commercial risks. The distribution of JET contracts between countries is shown in Fig. 5. Staffing also is on the basis of suitability, not nationality (see Fig. 6).

Strength of the Project Team. The responsibility for design, development and construction has always rested firmly with the Project Team. Components are produced by industry according to JET's detailed specifications. Contractors thus remain in their own areas of competence, where they are closely supervised by JET technical officers. Much of JET's technical success has been due to these factors.

Conclusions

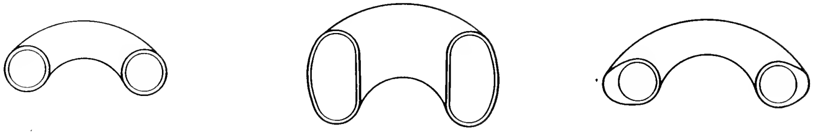
As an Experiment in Fusion Physics. All systems so far commissioned have worked according to specification, and the physics results to date have more than fulfilled expectations.

As an Experiment in European Collaboration. The Project has successfully achieved a Community character, both in its staffing and placing of contracts. It has also demonstrated that an international project can be run at least as productively as a national project.

As an Experiment in Project Organisation. As a model for future large projects, it is important that JET remains a success in this respect. The outcome, however, will depend on the willingness of member organisations to continue to support the aim that the Project should eventually vanish without aftermath.

JET
June 1985

THE THREE LARGE TOKAMAKS IN THE WORLD



TFTR
USA

Minor Radius	0.85m
Major Radius	2.48m
Toroidal Magnetic Field	5.0 T
Plasma Current	3.0 MA
Pulse Length	2 s.
Additional Heating Power	27 MW (total)
D-T Operation Capability	
1st Plasma	Dec 1982

JET
EUROPE

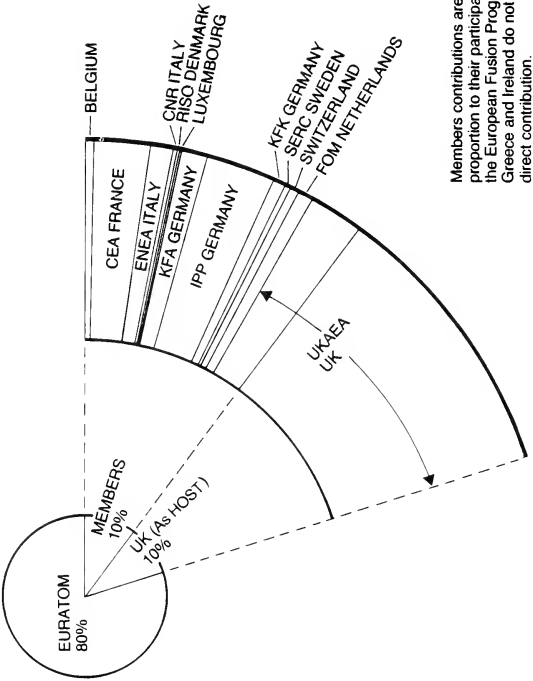
Minor Radius	1.25m (Horz) 2.1m (Vert)
Major Radius	2.96m
Toroidal Magnetic Field	3.5 T
Plasma Current	5.0 MA
Pulse Length	20 s
Additional Heating Power	44 MW (total) [25 MW high grade]
D-T Operation Capability	
1st Plasma	June 1983

JT-60
JAPAN

Minor Radius	0.95 m
Major Radius	3.0 m
Toroidal Magnetic Field	4.5 T
Plasma Current	2.7 MA
Pulse Length	5-10 s
Additional Heating Power	54 MW (total) [30 MW high grade]
Magnetic Limiter Configuration	
1st Plasma	April 1985

Figure 1

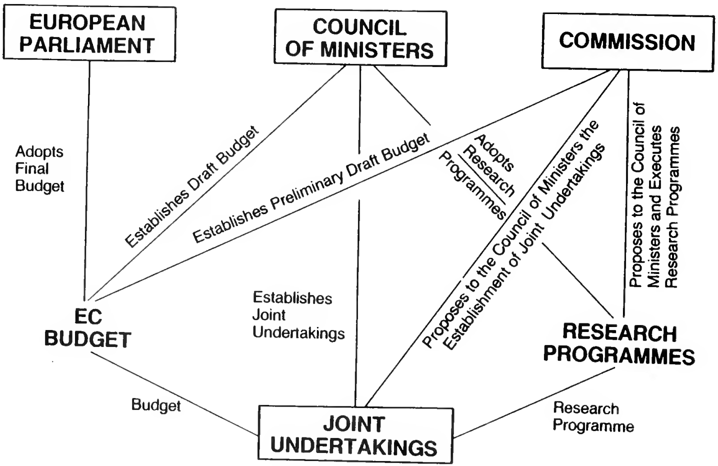
JET FUNDING



Members contributions are in proportion to their participation in the European Fusion Programme. Greece and Ireland do not make a direct contribution.

Figure 2

INSTITUTIONS OF THE EUROPEAN COMMUNITIES



Notes: (1) The European Court of Justice is available to interpret the statutes of a Joint Undertaking.
(2) The Court of Auditors of the European Communities audits the accounts of a Joint Undertaking.

Figure 3

JET COUNCIL VOTING STRUCTURE

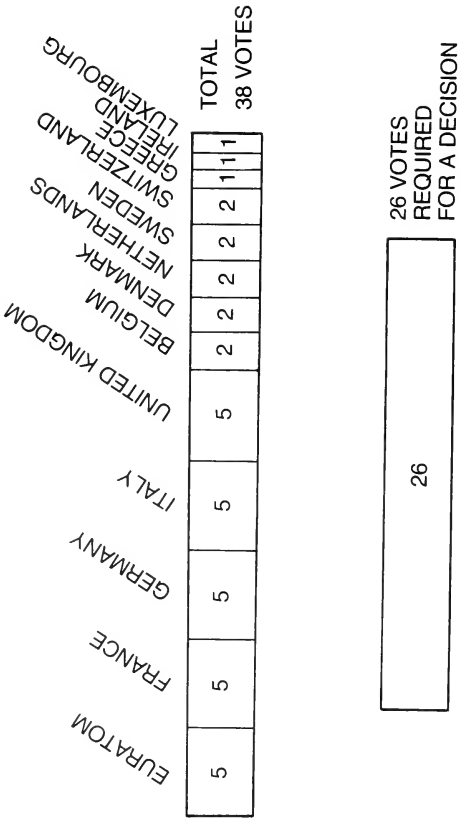
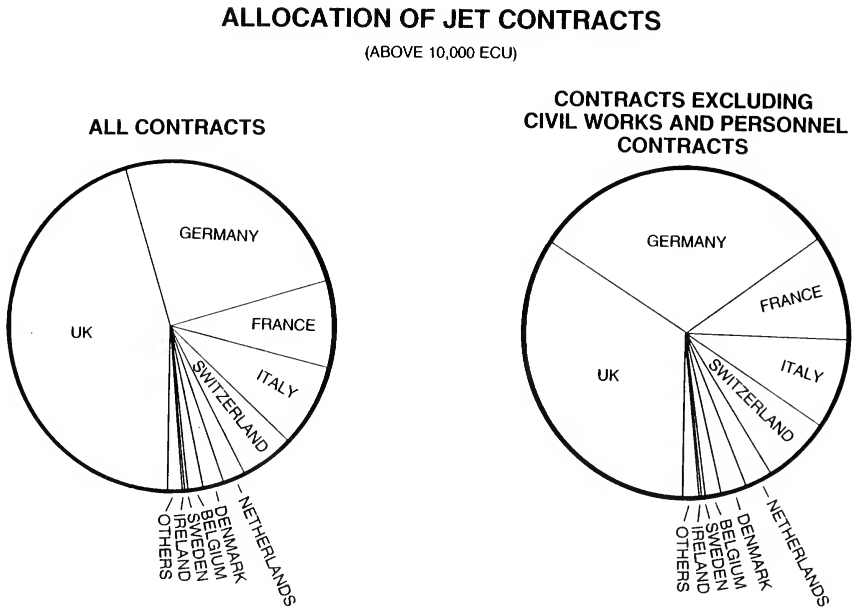


Figure 4



ALLOCATION OF JET CONTRACTS

(ABOVE 10,000 ECU)

ALL CONTRACTS

CONTRACTS EXCLUDING CIVIL WORKS AND PERSONNEL CONTRACTS

Figure 5

JET PERSONNEL

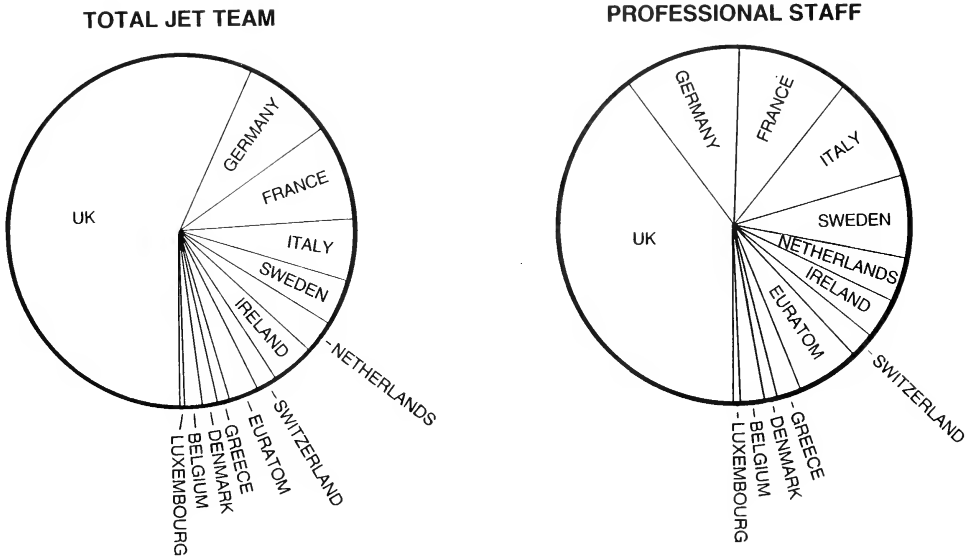


Figure 6

JOINT EUROPEAN TORUS **JET**

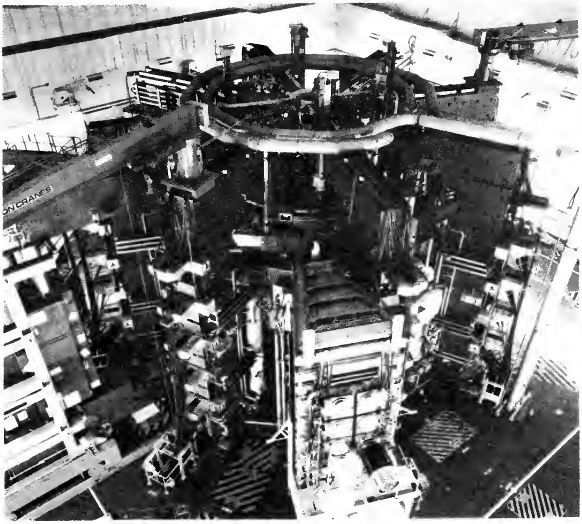
NUCLEAR FUSION

Energy for the 21st Century

The successful development of nuclear fusion for generating power should provide an almost limitless source of energy for future generations

At present, research programmes world-wide are aimed at providing the scientific feasibility of using nuclear fusion for generating electricity Within the next few years it is expected that experiments on the world's largest fusion experiment JET (Joint European Torus), will routinely produce fusion reactions However, before fusion can be harnessed for generating power, it will be necessary to develop suitable technology and to prove economic viability

JET represents the culmination of many years research and is a major step towards the exploitation of nuclear fusion as a new source of energy



A view of JET showing the neutral injection beam line (centre foreground) and the multichannel far infra red interferometer diagnostic (left)

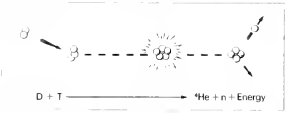
Nuclear Fusion

All matter, whether it be solid, liquid or gas, is made of tiny particles called atoms At the centre of every atom is a positively charged nucleus around which orbit a number of smaller negatively charged particles called electrons

If the nuclei of the lightest elements can be made to join or fuse together to form heavier ones then large amounts of energy are released
This is the process called nuclear fusion, from which the sun and stars derive their energy

For fusion reactions to occur, the fuels, which are gases, must be heated to very high temperatures As the gases are heated, the atoms become ionized, ie the electrons which are orbiting around the nucleus become free This mixture of randomly moving electrons and nuclei is called PLASMA

At plasma temperatures around 100 million °C abundant fusion reactions occur between deuterium and tritium nuclei These two gases which are different forms of hydrogen would be used in the first fusion reactors



Water contains deuterium and therefore there is a plentiful supply of this fuel Tritium does not occur naturally and must be manufactured from lithium of which there are large reserves in the earth's crust

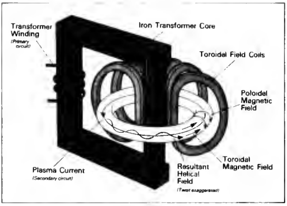
The fusion of deuterium and tritium produces the heavier helium nucleus, and a particle with no electrical charge called a neutron Eighty percent of the energy released during this reaction is given to the neutron, making it travel at very high speed It is this energy that will be harnessed for power generation

JET–The Principles

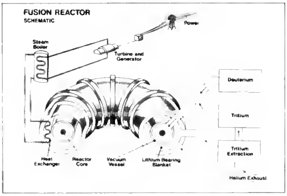
As plasma is a mixture of positive and negative particles, magnetic fields can be used to contain it and so prevent the particles hitting the wall of the containing vacuum vessel

During the operation of the JET experiment, a small quantity of gas is introduced into the doughnut-shaped vacuum vessel–the Torus The gas is heated to form a plasma by passing a large electric current through it This plasma current, of up to 5 million amperes (5 MA), also produces a magnetic field (poloidal) which combines with a second field (toroidal) produced by 32 D-shaped coils equally spaced around the vacuum vessel The combination of these two magnetic fields provides the cage that prevents the hot plasma from hitting the walls of the vacuum vessel This complex system of magnetic fields is called a TOKAMAK, a Russian acronym for toroidal magnetic chamber

A set of six hoop coils around the outside of the machine produces the magnetic field that shapes and positions the plasma centrally in the torus



Tokamak magnetic field configuration



Fusion Reactor

If the work on JET and on future experiments is successful then it will eventually lead to the building of a fusion reactor

In such a reactor the neutrons produced during the fusion reactions would be captured by a blanket surrounding the plasma region

The blanket, which would contain lithium, would enable the tritium needed for the reaction to be manufactured

The captured neutrons would heat up the blanket to temperatures in the region of 500°C so that steam could be raised to drive turbines and generate electricity in the normal manner

JET Joint Undertaking

The JET Joint Undertaking was set up to construct and operate the Joint European Torus (JET)

JET is the largest single project of the co-ordinated nuclear fusion research programme of the European Atomic Energy Community (Euratom) aimed at proving the feasibility of nuclear fusion as a new energy source The project was established in June 1978 for a period of 12 years and the machine was constructed, commissioned and in operation by June 1983

There are nearly 600, scientists, engineers and administrators working on the JET Project, who are drawn from the twelve participating countries

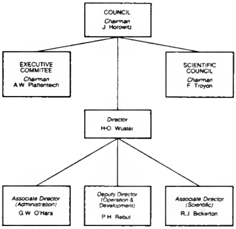
The JET site

Participating Countries

BELGIE (Belgium)
DANMARK (Denmark)
DEUTSCHLAND (FR Germany)
ELLAS (Greece)
FRANCE
IRELAND
ITALIA (Italy)
LUXEMBOURG
NEDERLAND (Netherlands)
SUISSE (Switzerland)
SVERIGE (Sweden)
UK

Management

The management of the JET Joint Undertaking is the responsibility of the JET Council and the Director who is its chief executive and legal representative The JET Council is assisted by the Executive Committtee and advised by the JET Scientific Council



Funding

The expenditure of the Joint Undertaking is borne by Euratom (80%) and the remainder shared between the countries associated with the European fusion programme, of which the United Kingdom, as host, pays an additional 10%

The total projected cost over the 12 year period, at 1985 prices, is £600M

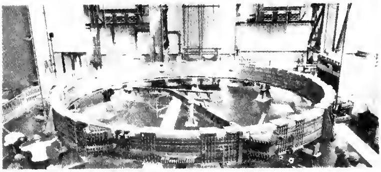
CONTRIBUTOR	%
Euratom	80 000
Belgium	0 2254
CEA, France	2 2774
ENEA, Italy	0 8276
CNR, Italy	0 1186
Risø, Denmark	0 9740
Luxembourg	0 0070
KFA, FRG	0 9470
IPP, FRG	2 5797
KFK, FRG	0 2727
SERC, Sweden	0 1365
Switzerland	0 4302
FOM, Netherlands	0 5601
UKAEA	11 5204
	100 000

JET Construction

2 Construction of one of the large outer poloidal field coils. This is one of a set of six coils used to shape and stabilize the position of the plasma centrally in the torus.

3 One of the three lower outer poloidal field coils being lowered onto the horizontal limbs of the magnetic circuit. After the central section of the machine had been built these coils were raised to their final position and the three upper coils fitted.

2



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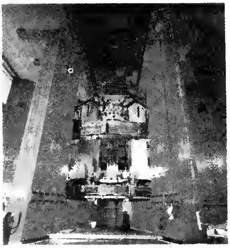

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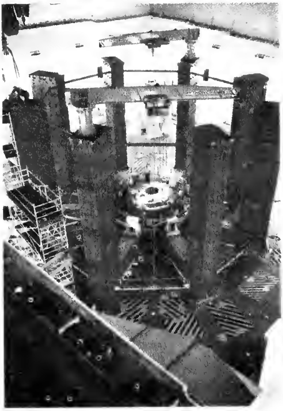
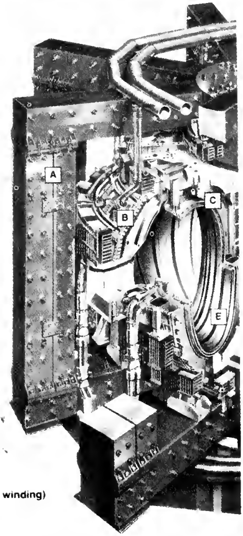
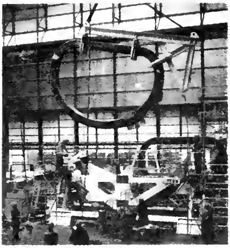


1 Installation of the transformer limbs which provide coupling between the primary winding (made up of the inner poloidal field coils) and the plasma which forms the single turn secondary. By powering the primary winding a large plasma current is produced which has the dual function of heating the gas and providing one of the main components of the magnetic field.



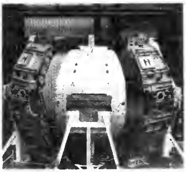
Diameter of JET	15 metres
Overall height of JET	11.5 metres
Weight of transformer limbs	2,700 tonnes
Weight of mechanical structure	470 tonnes
Weight of vacuum vessel	100 tonnes

A. Transformer limbs
B. Mechanical structure
C. Toroidal field coils
D. Inner poloidal field coils (primary winding)
E. Vacuum vessel
F. Outer poloidal field coils



4 One of the toroidal magnetic field coils being lowered into a 1/16 section of the mechanical structure. The magnetic field produced by the 32 D-shaped toroidal field coils together with that produced by the plasma current form the basis of the tokamak magnetic confinement system.

5



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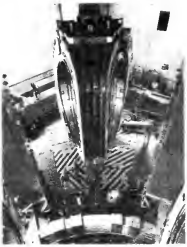
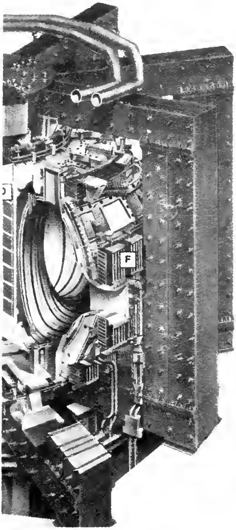




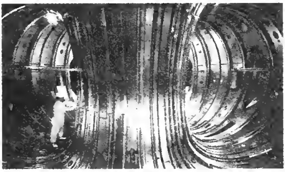
5 The central part of the machine was built up from eight machine octants. Each octant consisting of 4 toroidal field coils and 1/8 sections of the vacuum vessel and mechanical structure. For assembly the vacuum vessel was placed centrally on the special jig with the other components situated on moveable tables on either side. The tables were moved towards each other so that the two sections of the mechanical structure could be bolted together.

6 A completed octant being lifted between two of the vertical transformer limbs ready for positioning between two previously installed octants. The sections of the vacuum vessel were welded together after installation.

7 Cleanliness within the vacuum vessel is essential for successful machine operation. To achieve this the metal vessel is of a welded construction and can be baked to 500°C to remove surface impurities. Each section of the vessel is made from five rigid units joined by sets of flexible bellows. The bellows increase the electrical resistance of the chamber so that the current flows mainly in the plasma rather than through the vessel.

8 The completed machine.

7



8

Additional Heating

In JET the plasma is created and heated by passing a current of up to 5 million amperes through the gas As the temperature increases the heating produced by the plasma current becomes less effective Additional heating methods are therefore needed if the temperatures required for fusion are to be achieved

The two additional heating methods being used on JET are neutral beam injection heating and radio-frequency heating

Neutral Beam Injection Heating

The injection of energetic particles into the plasma is a proven method of raising its temperature

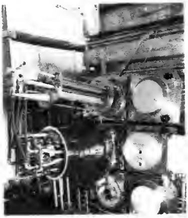
A beam of charged particles is produced in a plasma source and then accelerated to increase its energy For charged particles to cross the magnetic field, used to confine the plasma they have to be neutralized This is achieved by passing them through hydrogen gas

In the plasma the neutral particles give up their energy by collisions, and hence raise its temperature JET will have two injection units producing 10 million watts (MW) of heating

Radio-Frequency Heating

Ions and electrons in the plasma spiral rapidly along the field lines of the magnetic cage Energy can be given to the ions if radio waves of a given frequency are beamed into the plasma

On JET radio-frequency waves in the range 25–55 MHz will be used to increase the energy of the ions in the core of the plasma Ten aerials will be fitted to the interior of the vacuum vessel providing 15 million watts of heating



A Neutral Injector fitted to the testbed

One of the Neutral Injection systems

One of the radio-frequency aerials fitted to the inside of the vacuum vessel

Control Room

JET uses a computerised Control and Data Acquisition System (CODAS) to provide a flexible easy and safe method of operation JET is controlled and monitored from the two control rooms using a network of 32 mini-computers The operation of the machine is controlled from one room while measurements on the plasma are carried out in the other Each computer controls one of the many sub-systems of the apparatus

Signals to and from the CODAS system are transmitted around the site as light signals via 19 fibre-optic loops at a rate of 5 million bits per second

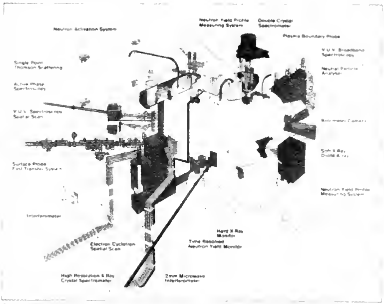
Acquisition of experimental data from the diagnostics equipment requires in excess of 1 million items of data to be gathered during each pulse

Computer and control rooms

JET Diagnostics

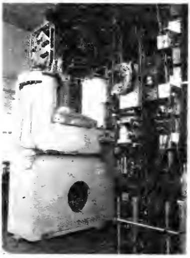
To find out what is happening within the plasma a number of measuring systems are used These systems called diagnostics are used to obtain experimental data from the plasma

Much of the equipment for operating these systems is situated outside the Torus Hall to allow easy access to the instrumentation during machine operation



Diagnostic Systems

Installation of the far infra red interferometer for measuring plasma density



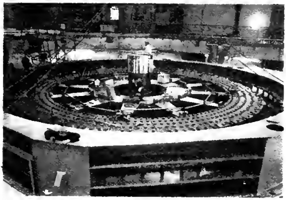
Single point Thomson scattering experiment for measuring plasma density and temperature

JET Power Supplies

The peak electrical power required for each JET pulse exceeds 700 MW and because there is a limit to the power which may be drawn directly from the grid, two flywheel generators are used as a means of storing energy

Each of the flywheel generators consists of a 9 metre diameter rotor weighing 775 tonnes Between each pulse the flywheels are increased to full speed of 225 rpm by 8.8 MW motors When power is needed for a JET pulse the rotor windings are energised and the rotational energy is converted into electrical energy causing the rotors to slow down to about half speed

The generators are each capable of delivering 400 MW of pulsed power



A flywheel generator under construction

JET Scientific Programme

1983	Phase I Ohmic Heating Phase Hydrogen or Deuterium Plasmas
1985	Phase IIA Additional Heating Studies 10 MW of Neutral Beam Heating 6 MW of Radio Frequency Heating Hydrogen or Deuterium Plasmas
1988	Phase III Full Power Optimisation Studies with full remote handling 10 MW of Neutral Beam Heating 15 MW of Radio Frequency Heating Deuterium Plasmas
1989	Phase IV Full Power Operation Deuterium-Tritium Plasmas

The aim of the JET project is to obtain a plasma with a size density and temperature comparable to the values needed in an eventual power producing reactor

During the four phases of the programme the power available for heating the plasma will be increased in stages The first phase, until the end of 1984, was limited to heating the plasma by passing a large current through either hydrogen or deuterium gases Over the next few years increasing amounts of radio-frequency and neutral beam injection heating will be added

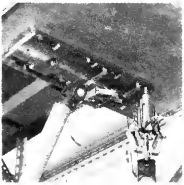
During the final phase of operation a mixture of deuterium and tritium will be used so that abundant fusion reactions will be produced

As a result of these reactions there will be considerable self heating of the plasma Also high energy neutrons will be produced that will make the structure radioactive

Remote Handling

Because the machine will be radio-active during the final stages of the programmes, remote handling systems are being installed for maintenance of the machine

Protection is provided by the thick concrete walls, ceiling and floor of the Torus Hall The main access door to Torus Hall weighs 400 tonnes



Remote handling equipment will be used to remove or replace components in JET

Manipulators will be placed on the arm of the articulated boom to enable work inside the vacuum vessel to be carried out

JET Results

JET has been designed to produce pulses once every ten minutes Each pulse lasting for about 25 seconds with plasma currents up to 5 million amperes

For reactor conditions temperatures in excess of 100 million degrees Celsius will be needed In addition the energy losses from the plasma must be reduced to a sufficiently low level A measure of how well this has been accomplished is given by the Lawson Criterion or confinement parameter—the product of fuel density (number of particles per metre cube) and energy confinement time (the time it would take for the plasma energy to decrease by a half)

The values needed in a reactor are

Plasma temperature	200 million degrees Celsius
Plasma density	2×10^{20} m^{-3} (200,000,000,000,000,000,000 particles per cubic metre)
Confinement time	1 5 seconds

During the first phase of operation the following values were achieved on JET

Plasma temperature	35 million degrees Celsius
Plasma density	0 36×10^{20} m^{-3}
Confinement time	0 8 seconds
Plasma current	4 million amperes
Overall pulse length	greater than 15 seconds

These are the full design values for phase one operation and have established JET as the most powerful tokamak in the world

CR 85 91
Joint Public Relations Section JET Joint Undertaking Abingdon Oxfordshire OX14 3EA

DISCUSSION

Mr. **Fuqua**. Thank you very much.

I had the pleasure of visiting for about an hour-and-a-half with members of the Science and Technology Committee of the European Parliament. This was a subject of conversation and they expressed interest in United States' participation in a joint European-Japan effort in fusion similar to what you are doing in JET.

By the way, we enjoyed very much our visit to the JET facility last fall. It was a very interesting concept.

Do you see any inherent impediments with joint efforts with the European Community and the United States in fusion?

Dr. **Wüster**. No, sir. I think if one speaks of collaboration between any two of the four important geographical units in the world in the fusion work, I would think that due to their similarities in economic structure, in political background, and also common cultural background, collaboration between the United States and Europe ought to be the simplest one, especially since our policies for the responsible organization of research also in industry seem to be more similar than those in other places.

However, I should not hide that there is in my mind, due to previous experience in other collaborative efforts between the United States and other governments, a problem which in my mind is important and ought to be resolved. One of the main advantages which we have traded in for the non-negligible complication of international organizations is that our work maybe will be started slowly, and it is subject to complicated political and administrative decisions. But we get something out of it. We get out of this system of consultation and deliberation and decision, long-term progress which is reliable. In other words, in both fields—I have worked in building accelerators before, and in fusion—the international projects are more stable, have a more reliable medium term, 5- to 10-year planning background than the comparable or smaller national projects.

We are used—and that is a very important thing, indeed—that with a well-constructed international collaboration and organization you have less to worry about after you have once discussed the aim once and for all.

We have, for instance, for the fusion program indeed every three years a program discussion, but that takes about 1 year. So 2 years we just work, and that is better than having a basic discussion which might put everything in question every year.

I believe this is something which you gentlemen ought to take very much in mind, that it needs convincing that appropriations will not be decided in the course of the year, but are reliable. I mean, I write four letters just telling my members how much money is due. I don't discuss how much I get. That is a change from what my colleagues have in this country.

Mr. **Fuqua**. Do you think a project such as the SSC would be conducive to that type of cooperation?

Dr. **Wüster** I believe any very large project which, in any way, will entail considerable problems of selection of experiments, decision on proposals and decisions on program, if it is a very large accelerator or accelerator-type device or a very large fusion experiment, yes, they would certainly be eligible.

I think it would be very much more difficult to do the same in areas with very much more application.

Basic research or, let us say, fusion in the present and probably next experiment stage, are more easy because the immediate industrial interest on follow-up and commercialization of results are a bit further away.

Mr. FUQUA. In a recent meeting with one of the European science ministers, we discussed these issues, and we also discussed the Space Station, which they are participating in. He stated a Space Station was much more easy to cooperate with because you didn't have a site specific to be located. It was over all of the countries. How do you resolve differences of siting? I am sure JET had those difficulties in its earlier days.

How do you resolve those differences?

Dr. WÜSTER. I don't know how to resolve them. I can mention how they were resolved in those two cases, which I, more or less, participated in. The very first decision of the choice for the CERN Laboratory in the fifties was obviously reasonably easy with Switzerland offering a site. Geneva was preferable to other points in Europe where the horrible war in 1945 had left much more traces of destruction.

When it came to the larger accelerator, the idea was originally to have a second laboratory somewhere, and site offers were made. A very intelligent procedure to find the best site was drafted, a committee of wise men who were coming from the countries who had not offered a site was formed, and they came out with a classification which was—of course, nobody was so stupid to offer totally impossible sites—which was not coming to a unique proposal.

And there was an impasse. At the same time, more governments got worried about the amount of money. So in the end, everybody was concerned and the project was taken off the hook by the discovery, which was something that had been more excluded before, that by going underground, you could do it in Geneva and in this way save infrastructure expenditure, which made the project at the same time cheaper by one-third. That was the solution.

In the case of JET—and there was practically no time loss due to that decision—in the case of JET, the situation was more complicated.

I should say because the community involved—and that is the fusion community which drafted technical conditions—and also the Commission had not made up their mind what they wanted really.

You see, the first year was practically lost because a commission of the European Community proposed the site of its largest laboratory, Ispra, as the site for JET.

Now, much of the important, large member states of the community wanted to have it everywhere except there. So a year was lost by finding a criterion which excluded Ispra. After that, with the criterion you had to do it where fusion research was in place, there were only two sites left, a British and German one.

And I think it would be very interesting if we had a Freedom of Information Act to find out really how the decision was made. You can have any rumor, from help against terrorists to anything else.

But I believe in the end the site choice was correct to go to Britain, because when you consider the situation at that time, Great Britain had joined the European Community somewhat late, only in 1975. It was one of the large member states and it was not the site of any European installation organization whatsoever. I think in the end, the strong wish of the then-British Government to have a European installation in the country is a sign that Britain, not only by signature under treaty but also by real activities, belonged to the Community, was the reason which had to be accepted also by the competitors.

The only regrettable thing was the loss of 2 years. But you have to look at this, I think, in the end in a general context, and then you will find in hindsight that whatever the details of the decision were, it makes political sense. Otherwise, it would not have appeared. How you prepare better in the future things—well, there is, of course, always a solution of having two, which is the easiest way out of such situations or discuss this in a hard boiled but nevertheless friendly manner.

After all, if you have the common aim we want to do it, you will find a way how to give in to reason.

Mr. FUQUA. There is always hope.

Dr. WÜSTER. Oh, yes. Otherwise we wouldn't be in business.

Mr. FUQUA. Getting back to the fusion program, how do you feel about the U.S. program for the low-ignition device?

Dr. WÜSTER. Well, I think one has to see here that the general problem situation between the U.S. program and the European Tokamak Program—I wouldn't mention the fact you have a second line and we have two smaller alternative lines.

Let's concentrate on the strategies for awhile. The program strategy is different because you have a front-line device, and ours are somewhat different in aim and scope. For historical reasons, the scope of the JET experiment goes somewhat further, hopefully very close, to ignition conditions, somewhat further than the TFTR. The European program strategies at the moment in its perspective, therefore not foreseen, a physics only in—physics device as a step in the program. Our program strategy is at the moment JET, the next stage, which we call the NET—not too much fantasy on that—the next would be a technology experiment, the next stage after that is demo. But this is a program strategy which is all the time under review, because it would be nonsensical to maintain such a strategy if nature should show that its laws are not allowing such a big step. It is a bigger step than is foreseen at the moment in the U.S. program. That it comes up in the U.S. program earlier than with us is, I believe, mainly based on the fact that our colleagues probably see also that JET may push somewhat further in that direction than the TFTR.

To be frank, gentlemen, if I had the money I would do both, first the physics and then the technology experiment.

Mr. FUQUA. But it would be a compatible program and a joint effort?

Dr. WÜSTER. Well, if we could only agree to it, I would welcome it very much because I think in that way we could by combining these two things make things at the same time more probable to succeed and save money for both.

But you can see where the crux of the matter is. This means we have to go together for 30 years. And nobody—everybody should agree from the start we stick together for that time.

You know international organizations in Europe—fine, the European Community is a political community, but CERN isn't an international governmental treaty ratified by Parliament and a program, for instance the construction of the ISR accelerator, was not part of the basic program and governments who declared their adherence for the construction time declared their intention—not only intention, they took the obligation not to leave this program until it was finished. The only safety they gained on that was a limitation on real time increases to 10 or 15 percent. In other words, whoever signed up for those 30 GEV in 1971 declared they would stick it out until 1979.

Can we do that for 30 years? That is really the crux of the matter. I think if the scientists in the field would see the slightest chance that this could come about they would concentrate their minds fantastically. It is a question who was there first, the hen or the egg.

In European collaboration, very often the scientist could take the initiative. How to take that initiative across the Atlantic is a bit more difficult.

We are both, I think, feeling like fish out of the water because the political systems are somewhat different.

Mr. FUQUA. Let me ask you my final question. I apologize to my colleagues for going on so long, but how long do you think it will be before we have ignition and ready for commercialization of fusion?

Dr. WÜSTER. A commercial fusion reactor in my mind is an animal which can come in existence in the second quarter of the next century, and it depends on the laws of nature. And with our luck and intelligence, it will come at the beginning or at the end.

Mr. FUQUA. The second quarter of the next century?

Dr. WÜSTER. Twenty to thirty years if we are very lucky; thirty to fifty if we have to work harder. It is the idea of a nonplasma physicist.

Mr. FUQUA. The reason I asked, lay people and politicians seem to think it is kind of like finding the pot of gold at the end of the rainbow, it is very elusive. I remember 10 years ago scientists were saying probably 20 to 25 years. Sixteen years have gone by, and now you are saying—and I certainly respect your judgment, and I think that is probably a more realistic question.

The question we are faced with is, is it going to be worth that with the amount of money we spend in the program for that many years? Will it be that beneficial?

I don't know the answer to that.

Dr. WÜSTER. I would like to point out one detail which might give rise to misunderstanding. The demonstration reactor that is the vehicle to prove economic viability in my mind is due between 2000 and 2010.

So what I was speaking of was the real commercialization that is when all the types like myself and governments can drop out and industry can start hopefully making money with these things, and that is, in my view, the second quarter of the next century.

I believe there are three motivations. One is for the scientist working now. It is a field which, because it is difficult, it is immensely challenging.

I have been living, not as an expert elementary physicist, but an accelerator builder among physicists, and, God, have they got an easy one there, understanding what symmetries are, in comparision to the people trying to understand why the plasma disrupts under certain conditions.

The field is complicated and, therefore, can come in a ditch, I think. That is an explanation why people get stuck with it and why they also hope. Their second point is I believe we can be more optimistic than those people who maybe told you 10 years ago it will be 20 years. In these 10 years, progress has been dramatic. Sometimes a nonplasma physicist gets angry when our experiment does 920 milliseconds instead of 1 second of confinement time. And I say, "We said in this one, we said we would make 1 second, why didn't we?" Somebody pipes up from the corner and says, "You just forgot 5 years ago we were glad to measure 10 milliseconds, look how far we have come."

I am not content, because we wanted to do 8 percent better. So we have gone a long way and we are feeling that as far as scientific feasibility and the proof goes, we are close to striking pay dirt.

I mean, when you express it in the simplest way, what you have to do is achieve a product of density temperature and energy confinement time, which in suitable units, is 5×10^{21}. In JET we have reached 10^{20}. Our aim is a factor of five, only more, and we haven't started yet, you might say. So we are very optimistic to make it for the early nineties. But we also have to admit that around the corner in this complicated field can be difficulties, and my figures are assuming 20, 30 years for almost straight on, but solving a lot of problems, 20 to 50 years, then there has been a bandit around the corner and has held us up for 10 years.

If it is worth it, I believe so, yes, because it is the only method of energy production in my view which has prime materials which exist everywhere. And we have seen how sensitive our world can be, and especially our world and our standard of living can be, if some prime materials are not equally spread over the surface of the earth.

I believe that is the final motivation, which in my view makes it necessary. As long as we have the quality in our ideas and the means to do it, we would be fools if we didn't try very hard.

Mr. **Fuqua**. Mr. Packard.

Mr. **Packard**. Thank you, Mr. Chairman.

I was intrigued by your comment that it may be as much as 30 to 50, 55 to 60 years before we—I didn't think anything we knew about we would have to spend that much time getting to. The rate of progress—we tend to think anything we can conceive we can achieve within a matter of 20 years or less.

So it is hard for some of us who recognize we probably won't be around 50 years from now, we couldn't achieve most anything we put our mind to, but, of course, there are factors. Money, the commercialization part of it, would probably take as long as the development part and so forth.

I didn't mean to get into that, but I was intrigued we are projecting 40, 50 years from now certain things.

Mr. Fuqua. About four generations.

Mr. Packard. When we see how far we have come in the last 50 years, you would think we could probably do most anything in the establishment of JET and some of your other international projects and programs in Europe. Have you felt or found that over the last decade or so it has had an adverse or a complementary affect, or has it improved or hurt your national laboratory programs?

Dr. Wüster. We have had in some fields the unavoidable situation that if the information from research changes from national to international facilities, that the national laboratories suffer, because nobody sees the necessity to finance third-class facilities which are not for nothing when he can participate in a first-class facility.

However, one has to be very careful. When you take, for instance, high energy physics, then it is true that except for Germany all member states of CERN have closed their own accelerator facilities, high energy accelerator facilities, or transformed them into nuclear physics facilities.

But this has not changed the situation that expenditure in this field in the large member states of CERN has remained approximately on the level of the budget contribution to CERN, so for some time when I was at CERN in the seventies, we were able to take this as a distinguishing criterion between the large and the small member states.

The large member states were those—and these were the large ones—who spent as much at home—that is in their universities, in their national laboratories, which they used partially as staging posts for experiments in CERN or for creating heavy equipment for use at CERN, and on their contributions to CERN while these smaller member states, who were always somewhat problematic, because they were complaining they were not getting enough out of CERN, they were spending decidedly less in their own countries in comparison to their CERN contribution.

In that field, therefore, I would say that what you save money on is the large device. What you do not save money on is on research teams and their equipment. But you keep that under your own control.

The situation in high energy physics is, of course, that those who do that research are only in a minority, part directly of the staff of the international organization, and it comes from that structure that you have this situation.

In fusion, it is different. The national laboratories in Europe have in general not yet, I should say, suffered by the creation of JET. In fact, the national laboratories in the larger member states of the Community are at the moment all constructing smaller experiments which in their specialization have the character of focusing attention on the same subject where JET is the expert.

How this will continue when we leave the scientific feasibility stage to the technological stage is difficult to foresee. But when we have problems that are not anymore called plasma physics, things which are called either plasma engineering or technology problems, you need other people. That will be the real mover there.

It depends very much on the field. The existence of an international new entity may, but not necessarily must, change the character of the international institutes and laboratories.

Both cases exist in practice in Europe.

Mr. PACKARD. Doctor, is it true that as you internationalize programs and projects that it becomes more difficult than in the national laboratory programs to involve the private sector? Does international cooperation tend to preclude involvement and cooperation and perhaps even financial assistance from your private sector?

And a second part to that question, Doctor, would be, does that also affect the ability to commercialize the results of your programs both at the international and at the national laboratory levels?

Dr. WÜSTER. From my own experience in both fields, high energy physics, and fusion research, I can only speak to collaboration between international laboratories and industries in the relation of customer and supplier. This is the system which we have exclusively had in both organizations, CERN and JET.

The relations between the international laboratory and industries in this respect is no different at all from what it would be in a national organization of equal character. International organizations in this case have even, in my experience, not unimportant cost advantages. International projects are in Europe considered by many industries as prestige items, and some prices which we have had, and which we have paid, are only applicable to me by the firm will of somebody very high up in a big firm: We want to have our name on that thing in a prominent place. So, in general, we have had better prices at CERN and better prices at JET than in the national laboratories. The collaboration with industries is not more difficult in this international context than in the national context. It takes time for some of us to get used—in the very complicated situation in Europe—to get use to the fact that the law—that the contractual ethics or contractual behavior in different countries has different rules, and the game is not the same. But when you have learned that lesson, in the end it doesn't matter too much.

Mr. PACKARD. You believe that there is going to be a need to call upon the private sector and industry to more and more assist and get involved in the future of technology?

Dr. WÜSTER. I believe that the problem is how do you distribute the risk? I think that in fusion you have a good example when you compare the United States and European situation on one side, and the Japanese situation on the other side.

In our case, and here I can speak in detail, we on the project team are taking all risk and responsibilities. Anything which is complicated and takes very different skills—we design, develop, make project-type tests, with the help of industry, finding out in that way how far we can go in entrusting these different parts to industry in a way where it is absolutely competent in doing things. We do not give development contracts to industry as a matter of policy. This means that our team has to be competent in all fields where such questions might arise.

When you look at the situation in Japan, it is decidedly different. JT-60, the Japanese experiment, has been built on the basis of performance specification by a team of scientists and engineers of a group of firms. When you look at the prices you see, of course, that in this case the budget has paid for the risk, which, of course, industry, which is meant to pay profits to shareholders, had to cover somehow. But have solutions—in the end it depends on what is your political aim.

Do you do such a project to develop the abilities of your industries or to achieve a research end, a science end? I would say the European system in stating the science aim tries to get there. The Japanese aim seems to be at the same time the considerable development of industrial capabilities. If an experiment of the JET or JT–60 class is the right object for that, I would dare to express doubts. Because when you see what you need in the way of a fusion reactor, you can say it is all different from what we are using. We use copper coils, the reactor will have superconducting coils. We have practically no covering for nuclear risk. There you need all the shielding, all the considerations which come in. A reactor is quite different, I believe, and, therefore, I am not sure if industry has learned much—would have learned in our case—much from being responsible for building the JET device as one global item. We kept control and kept the control of the costs at the same time. It was the only way we knew.

Mr. PACKARD. Thank you, sir.

Mr. FUQUA. Mr. Lujan.

Mr. LUJAN. Thank you.

Doctor, you make an interesting observation. You pay less for the facility but more for the operation. As I understand, then, the energy directed within the national laboratory is reduced, or the thrust perhaps, or maybe the involvement perhaps is the word.

Dr. WÜSTER. I must have expressed myself incorrectly. I did not imply that we paid more for the operation.

An international operation pays more for operation to its staff, yes, but normally it gets something back for it in excellence. I would insist that the average level of staff in the European international laboratory, which has an aim like JET has, or which has a good program like CERN has, can stand comparison with any other place in the world on excellence and that the payback, the higher salaries, are handsomely rewarded by better achievements.

Also, one has to say what is wrong, sir. We have a project where in the end we shall have spent 50 percent of all the money in 1992, roughly, will have gone into capital investment. Twenty-five percent will have gone into materials necessary for operation, that is for consumables and all that, and infrastructure, which we don't provide ourselves but the national laboratory on the same side provide to us, we have to pay for that; and 25 percent will have gone into salaries.

Now, admittedly, if you had done it as a British project you probably would have saved a factor of two on those salaries, but you wouldn't have had the same people and probably would have taken more time and spent more in the end.

So I would say the higher personnel costs for international organizations, which is a fact, is justified as long as they have a valued program, and as long as they are project-oriented and really can create something by having the money to do it.

If you have, of course, an organization which is dead on its feet, but cannot be gotten rid of, where 80 percent of the budget ends up in staff, then the net effect of 2, 2.5, is scandal.

The bad stories about international organizations come, of course, from these cases. But as long as that is a vital and really living organization with an aim, with a larger circle to draw your staff resources on by insisting on excellence, you can get to be a world leader. No problem.

Mr. LUJAN. Europeans are very good at international projects where we don't seem to be as good. We have some isolated examples, the Space Station, of course, being the big one, and then we have one here and one there with individual laboratories.

Our industry does a lot better than our Government does. Is it good for us to be looking strongly at international organizations as opposed to doing it by ourselves?

Dr. WÜSTER. Which answer do you expect? Of course, I am positive about this, and I am positive about this because I see that the difficulties in Europe for collaboration can be considered to be even worse, because when you see the real problems, it is not that the French and British had a 100 years war in the 14th century, which is sometimes believed is still being fought, but it is much more, that our different educational systems, our legal systems, our traditions, our way of living are so different.

But you see you can make something out of these difficulties. When you take a British engineer and a French engineer, you will find if you give them the same problem they approach it totally differently. Now, if you are able to weld together a crew to look at a problem with both components, the pragmatism of the British engineer and the logical method of the French engineer, and you see that the pragmatic part is done by the British and the mathematical research by the Frenchman and not the other way around, you have a better result than you would have had by having only British or only French engineers. So I am convinced that we with our different systems get quite a bit out of international collaboration also in that detail.

It takes a constant effort. It is not something which you do once and then it will roll on. I believe it is good. When you consider how many people reached the United States just before the war who were then collaborating in the most important scientific effort this country had during the war, you have seen such international collaboration in its best form in this country. And you have seen how a real aim in these things can bring people together in a wonderful way. I wouldn't be afraid if there is a big brink between us of getting the same situation of collaboration between different people. In the end, they all come back—if they are convinced of what they want to do, they will do it.

Mr. FUQUA. Dr. Wüster, we thank you very much for joining us today. It has been very enlightening, and we again thank you for your warm hospitality when we were visiting the JET facilities last fall.

Thank you very much for being here. We look forward to cooperation.

Dr. WÜSTER. Thank you, we, too.

[Whereupon, at 9:25 a.m. the task force recessed, to reconvene on July 9, 1985 at 9:30 a.m.]

APPENDIX 1

American Association
for the Advancement of Science

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CONSORTIUM OF AFFILIATES FOR INTERNATIONAL PROGRAMS

Briefing of the Staff of the Task Force on Science
and Technology

June 7, 1985, 9:30 - Noon

Room 2318, Rayburn Office Building

PANEL PARTICIPANTS

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*confirmation pending as of 5/23/85

R.D. Anderson
June 7, 1985

Mathematics and International Cooperation

My name is R.D. Anderson. I am a Boyd Professor Emeritus at LSU, a former President of the Mathematical Association of America, a former Vice-President of the American Mathematical Society, and former Chairman of its Science Policy Committee, a former Chairman of the Conference Board of the Mathematical Sciences and am current Past-Chairman of the Council of Scientific Society Presidents. I have served on the NAS-NRC Advisory Committee on exchanges with the Soviet Union and Eastern Europe and have spent two academic years and a number of other months in foreign countries. I am currently chairman of the Committee on Special Funds for the 1986 International Congress of Mathematicians to be held in Berkeley in August 1986.

Of all scientific disciplines, mathematics is probably the one that least knows international boundaries. Research is by individuals or very small groups but is stimulated by larger groups of active people, by quick access to information, and by frequent and easy association with major leaders. Until very recently, mathematical research had almost no dependence on equipment or laboratories. Now computers, and supercomputers, are changing this and certainly will continue to do so in the future. Nevertheless, much of current mathematical research is independent of the use of computers although increasingly influenced by needs of the age of technology.

Publication and talks before international audiences are customarily in English. With only occasional exceptions, there are few issues of security involved in current mathematical communications.

Some computer related activities are experiencing much concern with security issues and export licensing but currently these activities have only peripheral concern with mathematics per se. Such problems could well loom much larger in the future, however. The enclosed appendix on Twentieth Century US mathematics prepared by the Committee on Special Funds for ICM-86 represents a consensus view of both history and current US status. There are some who believe that a significant dimunition of past and current US predominance is developing, particularly in the areas of mathematics not related to computing. Research in such parts of mathematics is a function of an individual's knowledge, understanding and creativity. Thus if other countries, e.g. China, choose to emphasize mathematical research, which is relatively inexpensive, then they can and will produce important research. Historically, Poland's development in mathematics in the first several decades of this century were a result of a conscious decision to push mathematics and very good judgment about which subfields to emphasize.

As with many other scientific disciplines, in the past thirty years there has been a large growth in specialty conferences, both national and international. There are two major quadrennial International Congresses, one in mathematics originating about 100 years ago and one in mathematics education first started in the 1960's.

Graduate Students

In the 10 year period from 1973 to 1983 the percent of non US citizens receiving US doctorates in the mathematical sciences (excluding computer science) doubled, going roughly from 20% to 40%.

There is a widespread belief in the mathematical community that we are not getting the same overall quality (and verve) of US graduate students as we got in the 60's. The pulls of non-academic salaries for Bachelors and Masters recipients and the (deserved) glamour of computer science have helped channel talent in the US away from mathematics per se. However, we seem now to have bottomed out on both quantity and quality and recently have been doing somewhat better. But there will continue to be great benefit to our country's mathematical effort from the importing of top talent from abroad at both the graduate student and post doctoral levels. The relative non-availability of good academic positions in much of the rest of the world provides the United States with excellent recruiting opportunities.

Some needs of the US mathematics community in international cooperation

1. Continued free and open exchange of information.
2. Continued and somewhat expanded funds for international travel and exchanges (both short and long term) and both to and from the United States.
3. Easier access to immigrant visas for permanent residence status for non-US mathematical scientists. The current procedures appear to be unnecessarily tedious and expensive.

The long term

With the computer revolution greatly speeding up the mathematization of society, there is every likelihood that the number of researchers and practitioners in mathematics and its applications will continue to grow. Furthermore the United States preeminence in computing and its applications strongly suggest that the United States will continue to develop as "the world's graduate center" in the mathematical as well as the computer sciences. The need for additional resources to support such activities can be expected to continue unabated.

R.D. Anderson
June 7, 1985

Appendix

TWENTIETH CENTURY MATHEMATICS IN THE UNITED STATES

Until the second world war, American mathematicians lived in the shadow of Western Europeans. With the possible exception of G.D. Birkhoff of Harvard and Norbert Wiener of MIT, the "giants" of the era were Europeans. Even in the United States, many of the important mathematicians were from Europe. Some were attracted by economic and academic opportunities in the United States, others were refugees from Hitler's Germany.

In the U.S. almost all major departments had senior faculty who were trained abroad. Indeed, as late as 1950 at Princeton University, (then, as now, considered to have one of the strongest mathematics departments in the country) half of the full professors of mathematics had been born in Europe. At the nearby Institute for Advanced Study, developed in the thirties into a major continuing force in world mathematics, the majority of the mathematics faculty were Europeans. The mathematicians who came to our shores were from various parts of Europe. They came not only from Germany, France, and England, but from many smaller countries as well, with those from Hungary and Poland being particularly noteworthy.

In the post-war era, mathematics made a massive forward surge, with computing and modern applications in this country and classical mathematics in France leading the way. As evidence of the French influence in traditional areas, we cite the awards of the Fields Medals given at the International Congresses, the most prestigious awards in mathematics. Of the six medals given in the fifties, three were awarded to Frenchmen, with one each to a Norwegian, a Japanese and an Englishman.

But the fifties was a time when the United States mathematics community was coming of age. Of the nineteen medals given since 1960, eight have been awarded to mathematicians from the States, with two more to Japanese and Chinese mathematicians who took doctorates here and who currently hold faculty positions in the U.S. Concurrently, the United States was leading the world in the rapid development of the computer and information sciences and of modern applications of mathematics to real world problems. While traditionally most research mathematicians in the U.S. have been in academe, there is now a growing presence in the private sector. This arises from major groups at Bell Labs and IBM, but also from smaller groups in nearly 500 business, industrial and government installations, and private consulting firms, which extend the use of mathematical methods to many facets of our society.

The past few years have been particularly exciting for the mathematicians in both the theoretical and applied areas. Some famous old problems have been solved, and an entirely unexpected phenomenon has been discovered in four dimensional space. On the practical side, a new method for solving large linear programming problems has been discovered which promises to greatly reduce computing time and to bring much larger problems within the range of our computers.

A World Network for Environmental, Applied, and Biotechnological Research

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) program in environmental and applied microbiology and biotechnological research traces its origins back to 1946, when UNESCO supported research that was geared to the conservation and applied use of microorganisms. The International Cell Research Organization (ICRO) was founded in 1962, with support from UNESCO. Since that time, UNESCO activity in the microbiological field has been done in cooperation with ICRO and with the International Organization for Biotechnology and Bioengineering (IOBB) and the World Federation for Culture Collections (WFCC), both of which were founded in the early 1970s with UNESCO support and encouragement.

After the United Nations Conference on the Human Environment, which was held in Stockholm, Sweden, in 1972, the United Nations Environment Program (UNEP) joined the international scientific community via ICRO in setting forward a worldwide program for preserving microbial gene pools and making these materials accessible to developing countries. Additional support has been given by such United Nations agencies as the Food and Agriculture Organization (FAO), the World Health Organization (WHO), the United Nations Industrial Development Organization (UNIDO), and United Nations University (UNU).

A major development of the UNEP-UNESCO joint venture was the establishment of a world network of microbiological resource centers (MIRCENs). The objectives of the MIRCENs were established as providing an infrastructure for a world network which would incorporate regional and interregional cooperating laboratories geared to the management, distribution, and use of the microbial gene pools; reinforcing efforts relating to the conservation of microorganisms, with emphasis on *Rhizobium* gene pools in developing countries with an agrarian base; fostering the development of new and extensive technologies native to specific regions; promoting the applications of microbiology to strengthen world economies; and serving as focal centers for the training of manpower and diffusion of microbiological knowledge.

The first development of the world network was to establish the World Data Center (WDC) for microorganisms at the University of Queensland, Brisbane, Australia. The WDC was designated a MIRCEN, and at the WDC a master copy of the World Directory of Collections of Cultures of Microorganisms is stored. The WDC serves as a pivotal point for fostering development of culture collections in developing countries and in strengthening interactions with activities concerning culture collections in developing countries and developed areas.

Other MIRCENs which have been established include a regional MIRCEN in Bangkok, Thailand, at the Thailand Institute of Scientific and Technological Research, which serves the microbiological community of Southeast Asia via exchange of economically important microbial strains, training and fellowship programs, and promotion of research on organisms in areas of microbiology appropriate to Southeast Asia. A MIRCEN at the Karolinska Institute in Stockholm, Sweden, serves as a collaborating facility with the WDC in mapping potential metabolic strategies in fingerprinting of microorganisms.

Especially active MIRCENs are located at the University of Nairobi, Nairobi, Kenya, and in Porto Alegre, Brazil, at the Instituto de Pesquisas Agronomicas, and focus on nitrogen fixation. The latter MIRCEN collaborates closely with the Universidade Federale do Rio Grande do Sul in Porto Alegre. A MIRCEN also has been established at the Central American Research Institute for Industry in Guatemala, which serves Central America in the field of biotechnology.

Over the years, the MIRCENs in different areas of the world have focused on specific topics. For example, in the region of East Africa, the Nairobi MIRCEN focuses on *Rhizobium* technology, playing a pivotal role in the conduct of research and training concerning *Rhizobium* holdings in the region and dissemination of cultures and information pertaining to these activities. Training courses have been organized and symposia have been held on agronomy, plant breeding, physiology, crop protection for farming systems, and nitrogen fixation. Similarly, the MIRCEN at the Instituto de Pesquisas Agronomicas, in collaboration with the Universidade Federale do Rio Grande do Sul, has emphasized nitrogen fixation in Latin America, with the objective of promoting *Rhizobium* technology. A large culture collection is being maintained, with cultures distributed to research laboratories and inoculant factories. Training of researchers, extension workers, and industrial technical staff also is carried out.

The Bangkok MIRCEN is very active in culture collection activities and is responsible for the microbial culture collection development in that region, which includes Thailand, Indonesia, Malaysia, the Philippines, the Republic of Korea, and Singapore.

The MIRCEN at Ain Shams University, Cairo, Egypt, promotes activities in the fields of biotechnology and culture collections. More than 1,000 cultures are available in the various laboratories in that region with formal links to the MIRCEN. Training courses on conservation of microbial cultures and development of culture collections have been held at the Cairo facility.

The MIRCENs in the Caribbean region are coordinated through the Guatemala facility. Recently, a seminar, "Fuels and Chemicals from Biomass through Fermentation," was held in San Jose, Costa Rica, with the objective of promoting exchanges between Latin American scientists and eminent North American scientists in the field of energy from biomass. Subsequently, training courses in bioengineering have been held, with participants from Costa Rica, Nicaragua, Honduras, Equador, Guatemala, the United States, Uruguay, Peru, Venezuela, El Salvador, Paraguay, and the Dominican Republic.

The work under way at the MIRCEN at the Karolinska Institute has centered on development of microbiological techniques for applying pattern recognition methods for identification of microorganisms, as well as other rapid methods for identification, including microtiter plate methods. Environmental studies are also under way, as well as production of ethanol in liquid two-phase systems.

Several research projects are under way in the area of biological nitrogen fixation at the MIRCEN located at the University of Hawaii (NifTAL Project). The International Network of Legume Inoculation Trials continues at the Hawaiian facility in the NifTAL Project and MIRCEN, carrying out a three-step program, with the first experiment being development of inoculation recommendations based on strain selection information. The focus of the Hawaiian MIRCEN is nitrogen fixation by tropical agricultural legumes, with core budget support obtained through contract with the U.S. Agency for International Development and special funds also provided by several organizations, including UNESCO. In conjunction with the NifTAL Project, a MIRCEN at the Cell Culture and Nitrogen Fixation Laboratory at Beltsville, Md., also is carrying out studies on collection, characterization, documentation, and preservation of *Rhizobium*, on distribution of cultures of *Rhizobium* for research and inoculum production in developed and developing countries, and on microbial germ plasm of useful nitrogen-fixing organisms. The effort in *Rhizobium* biotechnology is a recurrent theme among the several MIRCENs around the world.

The WDC MIRCEN at the University of Queensland is of obvious benefit to world microbiologists.

As a sequel to a request from the Japanese Federation of Culture Collections, a group of specialists met in Paris, France, in July 1966, under the auspices of UNESCO, to consider problems relating to culture collections, and at that time it was recommended that a survey of culture collections be carried out. The International Association of Microbiological Societies (now the International Union of Microbiological Societies) section on culture collections agreed to survey the world culture collections, with the resulting publication by Wiley Interscience, New York, in 1972, of the *World Directory of Collections of Cultures of Microorganisms*. A second edition of the directory is funded by UNESCO, FAO, WHO, UNU, UNIDO, UNEP, and the European Economic Commission. The MIRCEN is now assembling the second edition of the *World Rhizobium Catalogue*.

A very important part of the MIRCENs are the training courses, such as a 6-week training course in legume-*Rhizobium* technology, which was held from 1 November to 10 December 1982 in Bangkok.

Thus, the importance of applied microbiology for the developing nations is significant, with benefits to be derived in fields as diverse as agriculture, the fermentation industry, public health, water supply and sanitation, environmental conservation and resource management, and production of food fodder and energy. Applied microbiology, now marching under the more trendy term *biotechnology*, is strongly interdisciplinary, interfacing engineering, applied mathematics, medicine, agriculture, the veterinary sciences, food science, toxicology, and other related areas.

The potential of biotechnology has been realized through the formation of the UNEP-UNESCO-ICRO panel on microbiology. The panel includes the U.S. representatives Martin Alexander, Department of Microbiology, Cornell University, Ithaca, N.Y., and David Pramer, Waksman Institute of Microbiology, Rutgers University, Piscataway, N.J. Under the auspices of the panel, "Global Impacts of Applied Microbiology" (GIAM) conferences have been held in major cities of the world over the years, including Stockholm, 1963; Addis Ababa, Ethiopia, 1967; Bombay, India, 1969; São Paulo, Brazil, 1973; Bangkok, 1977; and Lagos, Nigeria, 1980. The conferences bring together about 100 microbiologists from developed countries, with an equal number of colleagues from developing regions, where the conferences are held.

In addition to the GIAM conferences, about 60 training courses, based on a traditional ICRO pattern, have been held in developing countries on nitrogen fixation; fermentation technology; waste treatment and recycling; fermented foods; biological pest control; veterinary microbiology; environmental microbiology, including biomass and biofuel production; culture collection maintenance; and related subjects. The courses last about 3 weeks and include 15 to 30 participants, with not more than one-third originating in the host country. At least half of the conference is spent in bench work, with the faculty consisting of experts from the region supplemented with professors from abroad selected in consultation with the panel.

Clearly, the networks and MIRCENs have made a significant difference in the way microbiology is practiced in developing countries. This program has served to integrate microbiology infrastructures of developed and developing countries by promoting the holding of international conferences in developing countries and helping to introduce problems of developing countries into the programs of conferences held in developed countries. The success of these activities is due largely to a policy of cooperation at the working level, with many governmental, intergovernmental, and nongovernmental organizations participating, all of which provide a constellation of activities, with core funding from UNEP and UNESCO and with additional funding from FAO and UNIDO providing a high multiplier factor.

The MIRCENs network publishes newsletters, including *MIRCEN News*, information about which can be obtained by contacting Dr. E. J. Da Silva, Division of Scientific Research and Higher Education, UNESCO, Place de Fontenoy, Paris 7, France, or Professor T. Rosswall, Secretary of the Panel, Dept. of Microbiology, Swedish University of Agricultural Sciences, S-750 07 Uppsala, Sweden.

Rita R. Colwell

RESOLUTION ON

Continued U.S. Support of Important UNESCO Related Programs

Whereas useful and important microbiological programs, such as the Microbial Resource Centers (MIRCENs) and Global Impacts of Applied Microbiology (GIAM) Conferences, have been developed under the aegis of UNESCO and related international organizations; and

Whereas the United States has been a major financial contributor to these programs through its contribution to the UNESCO budget;

Noting the withdrawal of the United States from UNESCO at the end of 1984, and

Acknowledging the Reagan Administration's stated intent to "continue its support for international activities in the fields of education, science, culture and communication through other existing channels" rather than through U.S. membership in UNESCO;

Be it resolved that the American Society for Microbiology:

1) expresses the concern of its members that the United States continue to provide financial support for international educational, scientific and cultural programs to an extent commensurate with that which was previously obligated to UNESCO, and

2) urges that the Reagan Administration and Congress restore in FY 1986 State Department budget, U.S. funding of important international biological programs such as the MIRCENs and GIAM conferences to the level at which the U.S. has supported under the UNESCO budget in FY 1985.

Proposed by the International Activities Committee

Opening Remarks at the Briefing of the Staff of the House Committee on Science and Technology, Task Force on Science and Technology

Washington D.C., June 7, 1985

By

Dr. Irving Engelson
Staff Director, Technical Activities
Institute of Electrical and Electronics Engineers

The Institute of Electrical and Electronics Engineers, Inc. (IEEE), which celebrated its Centennial in 1984, is the world's largest technical professional society. Worldwide membership is approximately 260,000 of whom more than 210,000 live and work in the United States. We cover a broad spectrum of activities in electrotechnology and computer science and are also concerned with the social implications of our technologies. Through its books and more than 50 technical periodicals, IEEE publishes 15 percent of the world's literature in electrotechnology, and it sponsors over 200 major technical meetings in a year.

I appreciate the opportunity to share with you some of my views regarding long-term issues in international cooperation in science and technology. Although the opinions stated are my own and not official positions of the IEEE, they do represent the thoughtful concensus of many IEEE leaders.

During the next few minutes I would like to touch upon two key areas:

(1) the need for the enhanced exchange of science and technology information and

(2) those areas of electrotechnology which require special R&D efforts.

Cooperation is an important catalyst for technological progress. The channels of communication are the technical journals and presentation of technical papers at meetings. Science and technology are too complex for progress in an isolated environment. There is great concern that recent ill-conceived and poorly defined restrictions on the exchange of technical information of an unclassified nature greatly impedes international cooperation in science and technology to the long-term detriment to technological progress in general and consequently for the United States. When we extend controls beyond certain reasonable limits, we devalue the meaning and importance of the classification process and the respect that engineers and scientists should, and do, have for that process. Unreasonable controls inhibit necessary exchange of information and impedes the development and growth-rate of American science and technology. Therefore, mechanisms must be found for improving opportunities for international scientific and technological cooperation and exchange without compromising national security.

At this time I would like to talk about key areas of technology where there is an urgent need for accelerated international cooperation. These areas are:

(1) Biomedical Engineering Systems
(2) Energy, Resources and Environment
(3) Information and Computing Technology
(4) Manufacturing Systems and
(5) Electronic Materials

Biomedical Engineering

The future of Biomedical Engineering will include the application of robotics to the closed loop control of drug delivery, and to artifical organs and prosthetics. In this field of endeavor the high priority areas which require research assistance are biosensors, medical imaging, cardiac assist devices, medical artificial intelligence and information systems and medical robotics.

Energy

Energy is an issue of great importance. Although there is optimism about the Nation's energy supply, we must not become complacent but must argue for an aggressive government role in energy R&D. Policies and research programs are required to develop alternative energy technologies that could contribute significantly to our energy supply mix. These include:

(1) Coal technology
(2) Nuclear fission technology
(3) Fusion power reactors
(4) Renewable energy sources
(5) Solar power and conservation

In any consideration of these technologies, the highest priority of research must also be conducted on the associated ecological problems, many of which can more easily be solved with international cooperation.

Information-Storage Systems

Giant strides in storage devices in the last two decades have shown the tremendous value of electronically stored information. Information systems have grown from file systems to database systems and more recently to knowledge-base systems. To reach new plateaus requires advances on two distinct frontiers:

(1) High-capacity storage systems, and

(2) Techniques for building and using the knowledge bases that new systems will make possible.

Support for each advancement is required in three areas of information and computer technology which are:

(1) Information storage, including both the storage medium and the organization of the information to be stored

(2) Programming environments for increasing productivity and

(3) Multiprocessor computer systems.

Manufacturing

Manufacturing systems in the U.S. are a major challenge to technology and are a key to national productivity and innovation. They represent a new engineering discipline which involves the broad spectrum from abstract mathematics and experimental science to social, economic and management practices. In this area it is imperative that we concentrate on better knowledge in models and methodology, design philosophy and tools, and in economics and accounting practices to meet the challenge that has been directed at the U.S. International cooperation should accelerate our success.

Electronic Materials

One area of great importance is that of electronic materials. Probably no single field has had a greater impact on the national productivity and quality of life in the United States than that of semiconductor microelectronics. Semiconductor electronics has revolutionized the way we live and work. It has made possible sophisticated navigation and control systems and it has created the computer industry. It is on the verge of creating an information explosion through the related areas of optoelectronics and lightwave technology. Continued research in the area of electronic materials is needed to remain competitive in an increasingly intense environment.

International cooperation does not mean a one-way street. For example Japan has a great lead in all aspects of gallium arsenide (GaAs) which is recognized as the material which has the potential to substantially expand electronic applications. France and England follow, with the U. S. behind them. It is through vigorous international cooperation that we can enhance our own standing.

In conclusion, ours is a most technologically advanced society, but by no means in all areas. Nature tends to be democratic. Brain power is uniformly distributed among all peoples. Through scientific and technical cooperation we can improve the quality of life in the United States.

# # #

American
Psychological
Association

BRIEFING STATEMENT BY

WAYNE H. HOLTZMAN, PH.D.,
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CHAIRMAN (1983-4), COMMITTEE ON INTERNATIONAL RELATIONS IN PSYCHOLOGY,
AMERICAN PSYCHOLOGICAL ASSOCIATION,
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BEFORE THE STAFF OF THE TASK FORCE ON SCIENCE POLICY
HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY

June 7, 1985

General remarks on international science

The Task Force on Science Policy and the Committee on Science and Technology are to be commended for undertaking their ambitious study of science policy. I am pleased to have been asked to contribute, on behalf of the International Union of Psychological Science (IUPsyS) and the American Psychological Association (APA), to this important endeavor. At the outset, I would like to say that both the Union and APA stand ready to lend assistance to the Task Force as it begins to break its mission down into manageable pieces. In particular, we hope that this meeting, and the hearings to be held later this month, will enable the Task Force to refine its sense of the long-term issues in international cooperation in basic and applied research.

It is no simple matter to develop a meaningful view of something as immense and inchoate as "international science," while at the same time formulating recommendations for action as implied in the phrase "science policy." International science does indeed include "big science," as recognized in the Task Force's December 1984 agenda, but it contains a great deal that is more modest, but no less worthwhile. Indeed, international science embraces all of the disciplines found at the national level, and it is practiced in the same great variety of ways. In addition, it suffers from all of the same drawbacks, and more.

The vexations of differing languages, cultural practices, and levels of training across nations, while pervasive and troublesome, are perhaps not so harmful to the pursuit of ideal scientific endeavor as is the jealously guarded sovereignty of nation-states. Indeed, we have detected in recent years an unfortunate trend toward protectionism and neoisolationism in international scientific exchange, exemplified in particular by abortive government efforts to place limits on the dissemination of research in scientific journals or at international meetings. We regard this as unfortunate. An overly narrow pursuit of "science in the national interest,"

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or worse, "science for national security," is capable of doing great violence to science and its longstanding tradition of internationalism by positing cooperation in science as a threat to national competitiveness. This is a false opposition. Participation in multilateral organizations creates access for scientists in many fields inside and outside the ICSU family. Limiting that participation limits access, isolating a nation's scientists. Furthermore, as the record of protectionism has shown, isolation is hardly conducive to long-term competitiveness.

What is at the source of this new intellectual protectionism and of the accompanying impatience with international science here in the United States? One of the problems is that international science is difficult to manage. Without taking the position that "domestic science" is easy to manage, I believe it is safe to say that the resources available for the task domestically are both more ample and more concentrated in terms of the geographic and disciplinary areas in which the scientific tasks are to be carried out. International science resources within the U.S. science establishment (government, foundations, universities, associations, publishers, manufacturers of equipment, corporate research and development departments) must cover all of the same intellectual territory as do our domestic resources. As a result they are spread thinner and their constituencies are less powerful: most exponents of international science have commitments to their discipline and to internationalism; these commitments are not always mutually reinforcing, nor are they always of equal priority. In addition, much international science suffers (I believe that is the correct word) by having to move through diplomatic channels.

It would be useful here to draw a distinction between intergovernmental science programs (including specific megaprojects such as CERN, multilateral institutions like UNESCO, and bilateral and regional agreements such as those administered by the NSF) and government support for scientific activities with an international dimension. The difference lies not only in the average size of the projects involved, but also in the relative locus of authority for setting the research agenda. The larger the project, and the higher the level of authority involved in administering it, the slower the project is likely to move along.

I believe this problem of the pace of multilateral undertakings, compounded by the absence of handy measures of return on the U.S. investment, lay at the root of this country's withdrawal from UNESCO. During the withdrawal process, the Department of State relied on a set of five goals guiding the administration's relations with multilateral organizations. The first of these was to "reassert American leadership in multilateral affairs." We believe that it will always be difficult to pursue this goal successfully without a sufficiently strong concomitant commitment to the agonizingly slow process of international cooperation. (Progress in reorienting a U.N. agency in which so many of the world's nations enjoy their ability to play the active role they see as being closed to them elsewhere, and in which the multinational bureaucracy has become so entrenched, is bound to be difficult.)

Intergovernmental science programs (as distinguished from U.S. government programs that support some science activities in other countries) must involve the Department of State to some degree. In addition, they will, or at any rate they should, involve other agencies as appropriate. The form of the resulting interagency cooperation appears to me to be one of the key issues in the coordination and management of international cooperative research. This question has been considered recently by the National Science Board ("Statement on Science in the International Setting," September 16-17, 1982), the Board's Committee on International Science ("Roles and Responsibilities of the National Science Foundation for Aspects of International Cooperation Related to the Health of American Science," May 11, 1984), the National Research Council ("UNESCO Science Programs: Impacts of U.S. Withdrawal and Suggestions for Alternative Interim Arrangements," Fall 1984), and the National Science Foundation's Task Force on NSF International Strategy and Programs ("International Science and Engineering: The Need for Reassessment," March 20, 1985). The recommendations contained in these three reports are in significant respects very similar, a phenomenon that should not be disdained as merely a chance event. All of the reports urge a more vigorous international role for NSF, and all urge better interagency coordination. In addition, many commentators on international science favor a redefinition of the role of the Department of State, although attitudes on this subject tend to become muted when expressed in report language.

The Department of State's handling of UNESCO, and of alternative funding for multilateral science after the withdrawal, has occasioned much criticism, including some very pointed comments by the House Subcommittee on International Operations in its report on the FY 86 State Authorization Bill. The sad fact is that despite innumerable assurances in hearings and public appearances, the department failed to devise and promote within the administration an effective plan for alternative arrangements for U.S. science activities heretofore supported by UNESCO. (See our statement before the Subcommittee on International Operations, attached.) This failing was perhaps not altogether surprising after several years of systematic reductions in the department's support for the legislatively mandated U.S. National Commission for UNESCO. (The department has even failed--or refused--to spend funds authorized by the Congress for the commission in past years, funds which were again authorized this year.) At present, nearly 100 commissioners appointed by the Secretary of State and representing NGOs with a combined membership in the hundreds of thousands are in limbo. The impasse between the Congress and the Department of State must be broken so that the commission can resume its statutory role of advising the U.S. government on matters pertaining to UNESCO.

FY 86 funding for the International Council of Scientific Unions provides an interesting case study of the politics of international science. Prior to withdrawal, the United States contributed through UNESCO to ICSU (and other international conventions and scientific organizations such as the Intergovernmental Oceanographic Commission, the International Geological Correlation Program, the International Hydrological Program, the Man and the Biosphere Program, and the International Brain Research Organization). At the same time, support of U.S. activities within ICSU and its constituent unions was provided to the National Academy of Sciences through grants from the National Science Foundation. Earlier this year, the Office of Management and Budget approved compensatory funds for ICSU to make up for the U.S. withdrawal from UNESCO (these funds were described in AID's budget presentation as being "essential and important to U.S. interests"), while simultaneously halving the line in the NSF budget where the funds for U.S. ICSU activities were contained. Although NSF director Erich Bloch has since committed himself to level funding for ICSU, it appears that the funds will be found in various NSF program accounts, lending uncertainty to the matter of future funding.

This question of the difficulty of correctly quantifying support for international scientific work is another important matter for consideration by the Task Force. As pointed out earlier, not all international science is intergovernmental science. The relatively small amount of the international line-items at NSF does not reflect the fact that a good portion of the work supported by the program areas has some international content (the Task Force on NSF's International Strategy and Programs estimated this at 20%). Universities, corporations, foundations, and professional scientific associations also carry on significant international scientific activity. In the case of the associations, and perhaps of some of the other entities as well, the extent of the international contribution may not be accurately reflected in program budgets. For example, APA's Psychological Abstracts is an important and unique documentary resource in the world of psychology; however, it is not budgeted as an "international program."

Thus it will certainly be difficult to determine how much we spend on international science. But estimating the benefits we reap is even more difficult. Evaluating the cost-effectiveness of international science, or the return on investments in this field, presents difficult problems not simply of quantification, but of conceptualization. The danger is that too restrictive a conception of benefit may lead to the elimination of support for activities of great long-term promise. Although the Task Force's receptiveness to the use of quantitative methods in policy analysis is commendable, and the level of talent at the GAO and CRS is high, we would urge the greatest care and deliberation in the design of studies intended to measure the costs and benefits of international science. Such care is needed not only because science is a complex, highly ramified and decentralized endeavor, but also because it is an organic part of our society and the world community. Analyses that take into account only easily quantifiable costs and benefits will certainly miss certain systemic facts that are no less real for being difficult to measure. A simple example is the diplomatic goodwill and understanding generated by the exchange of scientists at all levels, on the occasion of international meetings or for longer stays in residence at a university of research center.

International priorities for the social and behavioral sciences

The social and behavioral sciences have a great deal to gain by increasing their participation in existing international science mechanisms and by assisting in the creation of additional such mechanisms. But these comparatively young branches of science (young in the sense of the date of their self-definition as sciences) have an equally great deal to contribute to the international scientific enterprise. I shall confine my remarks largely to the field of psychology. It is vast and varied enough for one commentator.

It is ironic that psychology--the scientific study of behavior--should be as insular and culture-bound as it has remained. This is perhaps due to the very great size of the "domestic market" in psychology in this country and to the lead we have had on other countries in the development of the science. That lead was gained in World War II with substantial government assistance, as psychology proved its utility in the areas of personnel selection, human factors engineering (designing equipment for ease, efficiency, and safety of operation), and treatment of veterans in VA hospitals. While overall U.S. psychology retains its "hegemonic" position in the world, the pockets of excellence outside this country are expanding as other societies and their governments recognize the economic and social benefits of investment in psychology in the areas of health (public health, preventive medicine and environmental psychology), education (child development, learning theory), and organizational productivity. (See attached letter from APA's past president to the chairman of NSB's Committee on International Science.)

With the growth of psychology and its applications around the world, the impetus toward international cooperation grows. There is no need to explain in great detail why a science of human behavior must have access to other areas of the world; the shame is that we have not yet gone abroad more than we have. In part this is explained by the heavy research agenda here at home: there have been plenty of questions to answer in our own back yard. In addition, there has been in some fields a lack of suitable research partners for U.S. psychologists and behavioral scientists, except in Europe and Japan. Even here, psychology has grown and expanded in different ways in different countries, to such an extent that there will be, even today, substantial disagreement from country to country on the question of what psychology is (indeed we have such disagreements here in the United States). This is due to the tangled growth of psychology's roots in moral philosophy, on the one hand, and physiology, on the other. It is also due to the fact that psychology deals with, and can become immersed in, variables such as culture (e.g., in its effect on behavior) which are all too often not even recognized as variables, to the extent they are taken for granted as part of everyday life. Thus psychologists from different countries, where the discipline has grown in different directions, or where the cultures are particularly distinct, may have a difficult time talking with each other. This problem is also found in the other social and behavioral sciences, and less so in the natural sciences and engineering. However, this state of affairs calls for more, not less, international cooperation, particularly in view of the direct contributions the social and behavioral sciences can make in the areas of economic development, public and personal health, and education. For some time now, APA has been studying the economic and social benefits of basic research in psychology (see attached pamphlet). We have learned recently that the European Federation of Professional Psychologists Associations is planning a meeting in Lausanne in September 1986 on the economic contributions of psychological research and practice. In additional, the Division of Mental Health of the World Health Organization has launched a study of the Role of the Psychologist in Health Care, a project in which the IUPsyS is participating. These are important and gratifying developments.

The social and behavioral sciences, and certainly psychology, have not been host to any of the sort of "big science" projects as are described in the Congressional Research Service's report of May 22, 1985 to the Committee on Science and Technology. Of course, each branch of science has its own scale of large and small projects, and it would be interesting to compare the mean, median, minimum and maximum costs of research projects in the various fields of science. Sciences characterized by generally larger-scale projects involving heavy capital investments (as opposed, say, to investments in manpower) may call for different systems of coordination and support than sciences in which projects are smaller or less capital-intensive.

Be this as it may, it should be recognized that psychology--and certainly other social and behavioral sciences--have their place in many big science projects, particularly those that bear directly on social, economic, and ecological problems. One salient example is the International Geosphere/Biosphere Program under study by the International Council of Scientific Unions. As the only ICSU member from the social and behavioral camp, the International Union of Psychological Science will certainly seek to bring psychological knowledge to bear upon the study and proposed resolution of ecological problems resulting from man's use of the earth's resources. In this regard, psychological research on how best to motivate individuals to conserve energy (for example) is directly relevant.

Many other examples of the present and potential contributions of the social and behavioral sciences could be cited. In the areas of toxicology, ecology, agriculture, public health, and the spread of technological innovation, successful application of scientific findings often turns on a correct appraisal, particularly a "culture-correct" appraisal, of individual and social behavior. The area of child development is perhaps psychology's leading candidate for "big science" status. The field is of manifest importance: it deals with the development of our most important resource. It is relatively nonpolitical, although even questions such as literacy and nutrition can become politicized. And it depends for its scientific rigor on samples and studies performed throughout the world. In this way it could benefit from a structure similar to that of the International Hydrological Program, the Intergovernmental Oceanographic Commission, and the International Geological Correlation Program, which provide for the collection of data everywhere they are needed. For some years now, UNESCO has supported the IUPsyS in the creation of a network of child development research centers around the world. The International Society for the Study of Behavioral Development has now joined the Union in the project, adding its wealth of specialized knowledge. The Union is also sponsoring a project in Man-Computer Interaction Research (MACINTER) that is characterized by a good deal of East-West exchange (the project is headed up by Friedhart Klix, the past-president of the Union and a psychologist at Humboldt University in East Berlin).

We view the admission of the IUPsyS into ICSU as an event of the first importance to international science. ICSU's vitality both reflects and contributes to the nonpolitical cooperation of scientists around the world. While it is supported by UNESCO, ICSU is more successful than UNESCO in avoiding politicization. Some would claim that this is because ICSU is solely concerned with science. Just so. And as more social and behavioral sciences gain admission to ICSU, following psychology's model, some of the most heavily criticized of UNESCO's programs should improve, on the theory that the politicization of UNESCO's programs in the social sciences, education, and communications was abetted by a weak and disorganized U.S. presence in these areas within the world body. A shortcut to the improvement of UNESCO, one that would not rely on the relatively cumbersome ICSU structure, would be the development of more effective international programs in the social and behavioral sciences by the U.S. international science community (government, universities, industry, foundations, professional and trade associations, etc.). The United States could also improve the quality and quantity of international cooperation in the social sciences through more active participation in the International Social Science Council. While relatively weak and underfunded, this organization nevertheless performs some important functions, e.g., in the area of social science documentation, which might be one area in which a stepped-up U.S. effort would be appropriate.

Conclusion

We hope that as it plots its agenda for the coming 18 months the Task Force on Science Policy will be sensitive to the very special resources and the particular needs of the social and behavioral sciences and will devote some specific attention to this distinct "region" of science.

If we may suggest a conclusion to the Task Force, we urge that a social and behavioral science component be built into all large multidisciplinary science programs that have application to human society or to human use of the biosphere. In addition to the programs named above, we would suggest that the social and behavioral sciences have a great deal to contribute at present to development agencies at the national (AID) and international (World Bank, World Health Organization, Food and Agriculture Organization) levels. Psychology is a science of motivation, learning, and adaptation, and the successful application of scientific (and clinical) findings always depends to some extent, and often depends totally, on these human factors. Beginning with scientific methods of personnel selection and equipment design, psychologists have worked consistently at smoothing out interactions between man and machine, between technology and society, and between, among, and within individuals and social groups. Furthermore, because their decisions have profound effects on human lives in the areas of health, economics, and education, psychologists have cultivated the habit of evaluating their efforts and the effects they have. In short, psychologists are alive to the human side of science.

I have also touched on some of the particular needs of the social and behavioral sciences on the international scale. Cooperation and exchange is still greatly impeded by the shortage of funds for various aspects of international projects, including travel. APA has for many years received block travel grants from the NSF to support travel of U.S. scientists to international meetings. (APA disburses all funds received, charging no overhead to the Foundation.) We believe such travel grant programs should be expanded in cooperation with professional associations, which are generally both willing and able to administer them fairly and effectively.

International cooperation in psychology is sometimes inhibited by the relative lack of qualified research partners abroad. In many poorer countries psychology is not a high-ranking candidate for scarce government support, although here, too, there are exceptions, particularly in the area of health psychology and behavioral (or preventive) medicine. While there is no way to build up an indigenous research capability overnight, nevertheless certain rather modest and effective contributions can be made. We would suggest, again perhaps in cooperation with private foundations (such as IREX and CIES) or professional associations, increasing the funds available for short-term bidirectional exchanges of scientists and for bibliographic resources. Such exchanges serve to build up areas of science that can contribute rather quickly to health, education, and economic development, while simultaneously contributing to more accurate intercultural perceptions and understanding.

I am very happy to have had the opportunity to contribute to the deliberations of the Task Force on Science Policy. I hope my comments have been useful. Please be assured that I stand ready to provide further assistance, as do the organizations I represent.

CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS
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Statement of the CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS
and the AMERICAN PSYCHOLOGICAL ASSOCIATION
Concerning the U.S. Withdrawal from UNESCO
and Alternative Interim Arrangements
for U.S. Participation in Multilateral Science Activities
March 25, 1985

Hearings on Department of State Authorization Bill, FY 1986
before the Subcommittee on International Operations,
Committee on Foreign Affairs

The Consortium of Social Science Associations groups ten scientific and professional associations with a total membership of 185,000 social scientists in such fields as law, economics, history, political science, and psychology. In addition, the Consortium has 27 organizational affiliates with many more thousands of members.

The American Psychological Association is the nation's leading association of professional and academic psychologists. Its membership totals over 68,000. APA is a member of COSSA and of the U.S. National Commission for UNESCO.

COSSA and its members are concerned with the future of U.S. involvement in international scientific cooperation. It is in the context of this broad concern that we view the questions of the U.S. withdrawal from UNESCO and the administration's plans for establishing alternatives to U.S. participation in UNESCO.

1. Living up to repeated promises of support for international science.

In late 1984, in preparation for the imminent U.S. withdrawal from UNESCO, the State Department elaborated a program of alternative activities in education, science, culture, and communications. The program was based on recommendations from the National Research Council (1). It totalled $47 million, and included $14 million for science activities. The details of this program have not been made public, although the Assistant Secretary of State for International Organization Affairs, Mr. Gregory Newell, stated before this subcommittee on December 6, 1984, that 85% of the resources would go "into other agencies such as UNDP, AID, USIA" (2, p. 121) as "funds in trust" (ibid, p. 126). The goal of these funds was "to forward development in the Third World" (ibid, p. 121). The Department of State would act as a "check writer" and no new personnel would be added to coordinate the activities supported with this $47 million.

The OMB rejected State's proposed program in January. Soon after, Department of State personnel, in consultation with staff at the NRC, arrived at a revised budget figure of $2.75 million that would be used in FY 86 "to continue support for U.S. participation in and to meet U.S. commitments to international conventions and scientific organizations engaged in work considered essential and important to U.S. interests" (3, p. 32). The activities supported by the $2.75 million, which forms part of the

American Anthropological Association • American Economic Association • American Historical Association • American Political Science Association
American Psychological Association • American Sociological Association • American Statistical Association
Association of American Geographers • Association of American Law Schools • Linguistic Society of America

International Organizations and Programs account of the Foreign Aid Bill, are indeed important (3, pp. 32-34). However, the administration has yet to respond to a number of pressing questions, among which are the following.

(a) How will the U.S. commitments referred to be met for the year 1985, given that the United States has ceased to contribute to UNESCO effective December 31, 1984?

(b) How was the $2.75 million figure arrived at? Mr. Newell has stated that 85% of State's $47 million proposal was intended for Third World development. Even if this 85% must all now be considered nonessential to U.S. interests (as defined by some unspecified criterion), by what criteria was the remaining $7 million pared down to $2.75?

(c) Will the Department allow the recent negative decision of OMB to neutralize its commitment, so often stated in the months prior to the announcement of the U.S. withdrawal on December 19, and indeed in Secretary Shultz's letter of that date to Director General M'Bow, to "continue to make a significant and concrete contribution to international cooperation in education, science, culture, and communications?" Put more optimistically, how will that commitment be pursued in the wake of the OMB action?

2. Planning for future U.S. participation in international scientific cooperation

The Department of State apparently plans to circulate a letter among other federal agencies in an attempt to locate funds for "UNESCO-like" activities. Reportedly, State intends seek out and to identify loci of "excess" funds and expertise within various agencies (NSF, AID ...) which the Department could then coordinate and guide in accordance with some as yet unstated view of priorities in international scientific cooperation. Again, questions arise.

(a) How realistic is it to expect that in the present budget climate the agencies will volunteer funds? At what level of funding? $47 million?

(b) If funds and in-kind contributions are indeed collected, who will coordinate and oversee their administration? Can the State Department now go beyond the role of "check writer" for which it is already set up and fill in for the UNESCO bureaucracy? Instead, should not the responsibility for international science (or education, culture, etc.) be clearly identified as a normal part of the operation of the relevant federal departments and agencies, or else effectively concentrated within some entity created for this purpose? Most would agree that State is not set up for this purpose, that if anything it has moved further away from this role in recent years (e.g., in abolishing the secretariat for the U.S. National Commission for UNESCO in 1981).

(c) What set of priorities will be used to determine how any collected funds are to be used? Has the administration been able to rank science activities in priority order? Has it been able to determine whether a given science program benefits the United States in equal or greater proportion to its costs? If so, have the policies underlying such calculations been spelled out clearly so that they can be debated?

(d) This project is reportedly being carried out in the office of the Deputy Assistant Secretary for Private Sector Initiatives. Will the views and contributions of the private sector (e.g., the U.S. National Commission for UNESCO) be sought?

(e) In a report commissioned by the Department last year (1), the National Research Council suggested that "the time may have come to begin discussions of new models for facilitating international cooperation both for the advancement of scientific knowledge and for strengthening infrastructure in developing countries" (p. 19). The report also cited an unfortunate lack of overall coordination of U.S. involvement in multilateral science cooperation and suggested the development of "a complementary working relationship between a governmental entity, such as the NSF, and a nongovernmental one, such as the National Research Council" (p. 19). We urge that a decision be made to fund a more in-depth study of the U.S. role in multilateral scientific cooperation, as the NRC has recommended (p. 17).

3. The fate of the U.S. National Commission for UNESCO

The U.S. National Commission for UNESCO was not asked to participate as a body in the 1984 Monitoring Panel on UNESCO (although some members of the Commission, including Chairman James Holderman, served on it). Similarly, the USNC was not assigned the role of monitoring the UNESCO reform process. This task has been turned over to a newly appointed Reform Observation Panel that includes one eminent scientist (Dr. Fred Seitz), several members of the 1984 panel, and several new members (including Ursula Meese). The Commission appears to have been bypassed, even though it was founded by Congress in 1946 precisely to advise the U.S. government on matters relating to UNESCO. It is composed of 100 members representing organizations predominantly in the private sector. In 1982, the Commission produced a "Critical Assessment of U.S. Participation in UNESCO" (4) that was unanimous in recommending "that the United States not only continue to remain a member of UNESCO, but that the effectiveness of U.S. participation in the work of the Organization be increased" (1). In December 1983, the Commission again expressed this view, voting 41-8 in favor of the United States remaining a member of UNESCO.

It appears that these positions have made the administration reluctant to call upon the Commission to fulfill its statutory function with regard to monitoring reform within UNESCO. We do not believe that this failure can be justified, particularly in view of the fact that in recent years the Commission's critical analyses of UNESCO's shortcomings, and of the shortcomings of the Commission itself, have been honest and forthright. On every occasion the Commission has shown itself to be willing to cooperate with the Department of State. It is difficult to guess at what role the administration might see for the Commission in the years 1985, 1986, and beyond.

4. The administration's overall goals in multilateral affairs

Mr. Newell has frequently expressed a set of five goals that guide the administration's relations with all multilateral organizations (5). The first of these goals is to "reassert American leadership in multilateral affairs." We believe that it will be difficult to pursue this goal successfully without a sufficiently strong comcomitant commitment to the agonizingly slow process of international cooperation. Progress in reorienting a U.N. agency in which so many of the world's nations enjoy their ability to play the sort of active role they see as being closed to them elsewhere, and in which the multinational bureaucracy has become so entrenched, is bound to be difficult.

Summary

We currently detect an unfortunate trend toward a protectionist and neoisolationist attitude toward international scientific exchange. An overly narrow pursuit of "science in the national interest," or worse, "science for national security," is capable of doing great violence to science and its longstanding tradition of internationalism by positing cooperation in science as a threat to U.S. competitiveness. This is a false opposition. Participation in multilateral organizations creates access for U.S. scientists. Limiting that participation limits our access, isolating our scientists. As the record of protectionism has shown, isolation is hardly conducive to long-term competitiveness.

We endorse the recommendation of the National Research Council that the prorated portion of the U.S. contribution to UNESCO previously devoted to biological, behavioral, and social science continue to be made available through the National Science Foundation and the NRC to support international cooperative research and training (1).

While it appears true, as the NRC points out, that "U.S. social scientists have had limited involvement in UNESCO projects" (1, p. 22) and that "the NSF has not been especially active in the area of *multilateral* scientific cooperation" (1, p. 18, emphasis ours), we believe that our country's withdrawal presents us with an excellent opportunity to strengthen our national performance on both counts. Upon reentry into UNESCO, such increased involvement by U.S. social scientists might well help temper some of the excesses of politicization to which UNESCO has been subject.

For these reasons, we believe with the NRC that "it is extremely important to ensure continuity of funding" (1, p. 17). We urge the relevant committees of Congress, in cooperation with the Director of the National Science Foundation, the President of the National Academy of Sciences, and the Director of the Office of Science and Technology Policy to achieve this goal.

We trust that the Department of State will continue to make known to the Congress its commitment to international cooperation in education, science, culture, and communications.

CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS
By: David Jenness, Ph.D., Executive Director

AMERICAN PSYCHOLOGICAL ASSOCIATION
By: Michael S. Pallak, Ph.D., Executive Officer,
John J. Conger, Ph.D., APA Representative to the U.S. National Commission for UNESCO, and
Wayne H. Holtzman, Ph.D., Chairman (1984), APA Committee on International Relations in Psychology and
President, International Union of Psychological Science

CITATIONS

1. UNESCO Science Programs: Impacts of U.S. Withdrawal and Suggestions for Alternative Interim Arrangements. A Preliminary Assessment, Office of International Affairs, National Research Council (Washington: National Academy Press, 1984).

2. United States, House of Representatives, Hearings Before the Subcommittees on Human Rights and International Organizations and on International Operations of the Committee on Foreign Affairs, 98th Cong., 2nd Sess., July 26, September 13, December 6, 1984 (Washington: Government Printing Office, 1985). Statement of Honorable Gregory J. Newell, December 6, 1984.

3. United States International Development Cooperation Agency (AID), International Organizations and Programs: Congressional Presentation, Fiscal Year 1986, pp. 32-34 (attached).

4. A Critical Assessment of U.S. Participation in UNESCO. Special Meeting of the U.S. National Commission for UNESCO (June 1-3, 1982), Department of State Publication no. 9297, International Organizations and Conference Series 158, Bureau of International Organization Affairs, October 1982.

5. Letter from Gregory J. Newell, Assistant Secretary of State for International Organization Affairs, to Charles H. Percy, Chairman, Committee on Foreign Relations, U.S. Senate, dated February 29, 1984 (transmitting U.S./UNESCO policy review).

American
Psychological
Association

February 29, 1984

William A. Nierenberg, Ph.D., Chair
Committee on International Science
National Science Board
Washington, D. C. 20550

Dear Dr. Nierenberg:

I am responding to your letter of January 27th, requesting information on areas of excellence in science outside the United States. I sought the assistance of my colleagues in the behavioral and psychological sciences, and together we have identified several noteworthy areas relative to scientific efforts in the United States. These areas are by no means to be considered comprehensive, nor, of course, representative of the official view of the American Psychological Association.

- Cognitive Psychology

While the United States remains a leader in this area, there are qualitative differences among countries. The United Kingdom appears to be strong in studies of cognitive processes linked to language ability, the interrelationship of cognition and emotion, and temporal orientation of goal-directed problem solving.

The United States is also relatively weak in cross-cultural studies of cognition, particularly in non-Western cultures which have strategic importance such as the Middle East and South America.

- Developmental Psychology

West Germany is clearly making a greater commitment in developmental psychology, particularly in the study of social and emotional development. Indeed, fundamental research in social and emotional development is a major interest in West Germany, while it is a small one in the United States.

Great Britain and Norway have also made a greater investment in the longitudinal study of birth cohorts than the United States has.

continued

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Support for longitudinal studies has alwaya been relatively small and difficult to obtain in the United States, thus hindering the knowledge base in what is the new frontier in developmental psychology, the study of development over the life-span of specific cohorts. Within the area of longitudinal studies, the United States has been relatively weak in the study of social and personality variables.

- Industrial/Organizational Psychology

Overall the United States maintains a leadership role in industrial/organizational psychology, particularly in studies of fostering worker productivity and of decision making for personnel selection and training programs. However, other countries such as Sweden and Great Britain are leaders in study of group behavior, identification of stressors in the work environment and their physiological and mental health effects, and in the effects of work scheduling on employees' job satisfaction.

Western European countries, specifically the United Kingdom, have made significant advances in understanding the interrelationship of biological, organizational, and environmental influences on human performance, including the interaction of personality and stress. In contrast, the United States has made its mark in the cognitive realm, specifically human information processing.

- Neuropsychology

The United States is strong in some aspects of neuropsychology including conditioning. The U.S.S.R. appears to be most advanced in neuropsychological diagnostics and the etiology of neuropsychological deficits. Neuropsychology is also not as well integrated with allied fields as is the case in West Germany.

- Social Psychology

The European emphasis on the social psychology of groups and on intergroup conflict and mediation is regarded by some as a European superiority. While the European voice could be considered mainly hortatory and programmatic rather than one of achievement, the U.S. effort in group psychology remains comparatively weak.

- Sports Psychology

The U.S.S.R. and some Eastern Bloc countries (Hungary, German Democratic Republic) have cultivated this area; we are only beginning to do so in the United States. A comprehensive review of the state of knowledge in sports psychology is presented in the 1984 Annual Review of Psychology. Basic research in sports psychology focuses on control of autonomic processes and sequences of motor behavior, and covert stimulation. This knowledge has direct application to situations where effective performance and decision-making is critical.

- Behavioral Research with Animals

The United States is preeminent in laboratory studies of primate behavior, particularly in the psychobiological area. We are also leaders in the study of social behavior of primates in semi-naturalistic settings. We are well-represented in naturalistic, ethological studies of primates, but maintain less of a leadership role in this area. Japan and the United Kingdom are our major colleagues in behavioral research with primates.

For the moment, the United States retains its superiority in basic research in the behavioral, psychological, and cognitive sciences. We are clearly leaders in a number of areas, including psychometrics, ability testing, cognitive sciences and artificial intelligence, behavioral toxicology, and instructional psychology. There are areas of qualitative difference in theoretical orientation and strength among countries in these area, but overall, the United States is clearly in a leadership position.

My colleagues and I, however, are very concerned that we may not retain our competitive edge in some of these areas for long. The Japanese government, for example, is investing heavily in artificial intelligence and the cognitive sciences. The Dutch government is likely to follow suit. It is likely that if we do not increase our own investment in these areas, that we will find ourselves in the competitive situation as we now do in computer technology and development. The reductions in research support for fundamental research in the behavioral, psychological, and cognitive sciences in the National Science Foundation and other federal agencies from FY 1980, therefore, constitutes an extremely critical situation for the behavioral sciences community.

I appreciate the opportunity to contribute to the work of the Committee on International Science of the National Science Board. My colleagues and I would be pleased to provide you with additional information on the areas covered in this letter.

Sincerely,

Janet T. Spence

Janet T. Spence, Ph.D.
President

JTS:kp

COMMENT

Bryant W. Rossiter, chairman
Committee on International Activities

International activities and ACS

In 1979, members of the American Chemical Society added a third objective to the society's constitution, specifying that ACS should "cooperate with scientists internationally and [be] concerned with the worldwide application of chemistry to the needs of humanity." It was entirely proper that they should have done so, but many members may well not realize just how important international activities are to ACS.

Some 40% of ACS's general fund revenues come from other countries through sales of books and journals, of abstracting services and products, and of continuing education courses and from the dues that about 10,500 foreign members pay. Earning some $45 million internationally makes it very much in ACS's interest to work closely with chemists and chemical organizations worldwide.

About 75% of the abstracts and 90% of basic patent citations in *Chemical Abstracts* cover work in other countries. It is thus vital that ACS members participate in international projects, conducting some themselves as well as attending those in other countries, if they are to benefit professionally quickly and completely from results produced outside the U.S.

The U.S. chemical industry enjoys a very favorable balance of trade. Whatever ACS members do internationally that makes chemistry more useful in the U.S. by employing findings from other countries contributes to the financial well-being of the industry that employs most of them.

Focal points for ACS international activities, other than those involving Chemical Abstracts Service and the staff Education and Books & Journals divisions, are the joint board-council Committee on International Activities and the staff Department of International Activities. With the foregoing points of the importance of international activities to ACS in mind, the committee and the department in recent years have

- Conducted science and technology exchange projects with Egypt and India that have led to long-term funding of four projects that were recommended to hasten their economic development.
- First suggested and then promoted holding an international meeting as a followup to the 1979 ACS/CSJ Chemical Congress, the result being the very successful Pacific Basin Chemical Congress in Honolulu this past December. Some 2300 papers were presented in 75 symposia and in general and poster sessions. This conference had the best press coverage of any chemical meeting in the U.S. except possibly ACS national meetings in New York City and Washington, D.C.
- Published and distributed free some 3000 copies of a guide to chemical education in the U.S. to help students in other countries prepare themselves better to continue their education in the U.S.
- Written, edited, and helped distribute some 3000 copies of the summary, conclusions, and recommendations from the "CHEMRAWN II Conference on Chemistry and World Food Supplies: The New Frontiers."
- Initiated a program to receive donations of textbooks and back issues of journals from ACS members and others and to distribute them to colleges in the U.S. and in developing countries that need such assistance to improve their chemical education programs.

As a result of its experiences in these and other international projects, the committee now sees its goals as being to conduct projects in chemistry to help meet the needs of humanity and to increase interactions among chemists so that chemistry will be a more useful science and so that ACS members will advance professionally. As a result, it and the department have instituted a number of projects.

One such project, in cooperation with the University of Nairobi, is organizing a seminar on advanced analytical chemistry and a short course on instrument maintenance for professional chemists and instrument technicians in Kenya and neighboring countries in Africa.

Another is helping the International Union of Pure & Applied Chemistry conduct briefings on the implications of the CHEMRAWN II recommendations for developing countries, so that persons in policy positions in those countries can set the best priorities for chemical and agricultural research if they are to meet the increasing need for food for their growing populations.

A third project is presenting two symposia at the First Pan American Chemical Congress in Puerto Rico this October—one on chemistry's role in improving world food supplies and the other on material transformations that are keys to economic growth in Latin America.

Those who benefit from these and other ACS international activities know firsthand the contributions they make to scientific progress and to the professional progress of ACS members. There is another reason that is equally important, however. The gap between the developed and many developing countries is widening rather than narrowing, and the resulting growing disparity in life styles ranks as one of the greatest threats to political stability worldwide. Therefore, it is in the economic and political self-interest of everyone, including us as chemists and as ACS members, to work to reduce the disparity.

Although we may act because of our economic and political self-interest, we must also recognize our humanitarian responsibilities as well. Perhaps Albert Schweitzer expressed it best when he said: "It is not enough to say, 'I'm earning enough to live and support my family. I do my work well.' . . . But you must do something more [and] give some time to your fellow man. Even if it's a little thing, do something for those who have a need . . . something for which you get no pay but the privilege of doing it." For

Continued on page 28

remember, you don't live in a world all your own. Your brothers are here also."

Schweitzer spoke of individuals, but his reasoning applies to organizations, too, that have the ability to improve conditions worldwide. Having the ability, we as chemists and as ACS members also have the responsibility to address needs in an ongoing way. Indeed, it is more than a responsibility; it is, as Schweitzer noted, a privilege, for in serving others we also serve ourselves. □

Barbara Hodsdon new ACS meetings head

Barbara R. Hodsdon has been named head of the Department of Meetings, Expositions & Divisional Activities, American Chemical Society. She succeeds Albert T. Winstead, who died recently.

Hodsdon has had a long career with ACS. She joined the society in 1954 as the administrative secretary for the Philadelphia Section. In July 1965, she transferred to Washington, D.C., as administrative assistant to the manager of the National Meetings & Divisional Activities Office.

In 1975, Hodsdon was named manager of the Office of Divisional Activities & Regional Meetings, a newly established office within the Membership Division's Department of Meetings & Expositions. Her duties included: general assistance to ACS divisions, liaison to the council Committee on Divisional Activities and the annual Program Coordination Conferences, management assistance as requested by ACS regional meetings and ACS divisional symposia and conference organizers, administration of the Experimental Division Program Development Fund, operational assistance with special domestic meetings, and supervision of ACS travel arrangements.

From 1982 to the present, Hodsdon developed and coordinated the experimental teleconferencing of selected symposia from national meetings.

Hodsdon makes her home in Annapolis, Md. She is the mother of one son and two grandsons. Her son Richard resides in Seattle, Wash. with his family. In her leisure time, Hodsdon enjoys playing bridge, reading, and travel. □

Keynote Address

WHY INTERNATIONAL MEETINGS?

Bryant W. Rossiter
Chairman
Joint Board-Council Committee on International Activities
American Chemical Society

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13th ACS Program Coordination Conference
Roosevelt Hotel
New Orleans, Louisiana
January 25, 1985

WHY INTERNATIONAL MEETINGS?

I sincerely appreciate the invitation of John Whittle to participate with you in this 13th Program Coordination Conference. Its major purpose is to plan symposia and general sessions for future ACS national, regional, and divisional meetings, but it also has a very important additional purpose and that is to begin planning the Third Chemical Congress of North America. This Congress will be held in Toronto, Canada, in June 1988, and it will be sponsored by The Chemical Institute of Canada, the Chemical Society of Mexico, the Mexican Institute of Chemical Engineers, the Mexican Pharmaceutical Association, and the American Chemical Society. It will be an important congress in its own right, but it will also be important by being a regular national meeting of each of the sponsoring societies.

Everyone in this room knows how much time, energy, dedication, and money are required to organize and conduct a successful meeting. It is certainly therefore reasonable to ask ourselves, "Why are we doing this?" When we consider the added complications posed by an international meeting, it becomes doubly important to ask ourselves, "Why are we doing this?" and to have some very clear answers.

As someone who has helped organize and conduct several major meetings--and who has been helped by many in this room--I feel a genuine kinship with you as you seek to make both your national meetings and your international meetings successful. As a meeting organizer, I have enjoyed both easy times and difficult times. I served as chairman of the Third Northeast Regional Meeting a decade and a half ago, and it virtually ran itself. It was held in Rochester, New York, where the company for which I work, Eastman Kodak, contributed many of its resources. Control was easy, and the meeting itself was a scientific success. It was also a financial success, having--as a scientific society says--an excess of revenue over expense, thanks to good attendance and the contributions from industrial organizations in the region.

I also have had the privilege of being the chairman of the CHEMRAWN II International Conference on Chemistry and World Food Supplies. It was sponsored by the International Union of Pure and Applied Chemistry (IUPAC), and it was held in Manila, Philippines, in December 1982. It was the second in IUPAC's series of conferences on the theme CHEMical Research Applied to World Needs. As you might expect, it differed so much from typical meetings conducted in the U.S. and in other developed countries that many persons advised that it not be undertaken. The challenges, they said, were too great.

In the first place, I was told that IUPAC had never undertaken a major meeting in a developing country and that moreover the Philippines did not belong to the established family of IUPAC-adhering countries. I was also told that the meeting would fail, because it could not be put in the hands of long-established and successful professional meeting organizers, such as the professional bodies represented here today. Another supposed high hurdle was our proposed meeting strategy, which was to involve heavily the leaders in developing countries in every aspect of planning and execution, while at the same time muting the role of developed countries--particularly that of the United States.

I was reminded there would be special problems in scheduling a meeting on the other side of the world. For one thing, we would have to avoid the monsoon season. Thus, the timing of the meeting--in mid-December--posed inconveniences for those in developed countries, interfering as it would with year-end festivities and meetings of boards of directors of industrial companies. And, of course, the long distances and time differences would prove to be especially burdensome for communications. They were, to be sure, but in somewhat of an aside I might note not always in ways we expected. For example, for a period we could not communicate with the cosponsoring organization, The International Rice Research Institute, because thieves had cut and stolen the telephone line connecting Manila and Los Baños.

Finally, there would be difficulties posed by finances. Just recently, I was told by the organizer of a major international conference that the budget of three quarters of a million dollars for CHEMRAWN II was far too high and that he could have conducted the conference for one fourth of the cost. When I asked him where he would have held the conference, he replied, "Williamsburg, Virginia."

Despite these challenges, however--or perhaps because of them--CHEMRAWN II proved to be highly successful scientifically. And, like the Rochester meeting, it, too, enjoyed an excess of revenue over expense.

It is from the perspective gained from these and other domestic and international meetings and from my association with the American Chemical Society's Committee on International Activities, the CHEMRAWN Committee of IUPAC, and the U.S. National Committee for IUPAC that I am talking to you this afternoon.

The CHEMRAWN II Conference on Chemistry and World Food Supplies and the just-completed 1984 International Chemical Congress of Pacific Basin Societies are my two prime examples of the importance of international chemical meetings and the benefits they can have. The CHEMRAWN conferences are proving to be such landmark events that the International Council of Scientific Unions would like to see the concept used by scientists in other disciplines. The result would be BIORAWNS, GEORAWNS, PHYSRAWNS, and the like, as scientists and engineers in other disciplines assess their research and development efforts applied to world needs. As for the Pacific Basin Chemical Congress, the general conclusion has been that a second such Basin-wide chemical congress should be held, and the first steps are now being taken for one to be held in December 1989.

Rationale for ACS Participation

In a few minutes, I shall use results from these conferences as evidence of the value of international meetings. Before I do, however, let me provide some general reasons for the ACS to participate actively in international meetings. Some of the reasons are ones you have heard before, but they may well be reasons that many of us may overlook, at least occasionally.

Organizing an international meeting calls for one to invest a large block of time and often much money and to suffer many frustrations. The return on the investment can be equally large, however, and many of the frustrations--in retrospect, at least--may not have been all that great. Nonetheless, when ACS participation in international meetings is proposed, we must be aware that some members have mixed feelings about them. Some see them as simply more meetings to attend. Others believe that efforts should be confined to ACS needs within the U.S., reasoning that costs are increasing, everyone's time is largely committed, and resources are too limited to be used on international meetings.

These are legitimate concerns, and they must be addressed successfully if ACS members are to be persuaded to support vigorous international efforts.

Perhaps the simplest response is that the ACS already is an international organization. Nearly 40% of the Society's general revenues come from outside the U.S. from sales by Chemical Abstracts Service, the Books and Journals Division, and the Education Division and from the dues that some 10,500 foreign members pay. The ACS has a responsibility to serve everyone and every organization that contributes, including those outside the U.S., be they members or customers or both.

Reports on research and development results and informal exchanges during international meetings also benefit ACS members professionally. About 75% of the abstracts and about 90% of the citations of basic patents in Chemical Abstracts are based on work done in other countries. As Americans we benefit enormously from information generated elsewhere, and it is vital that we learn as much about it as possible quickly and thoroughly.

We must also remember that the chemical and allied products industry enjoys a very favorable balance of trade. Whatever we as chemists and chemical engineers do to improve the use of chemistry in the U.S. based on findings elsewhere contributes to the financial well being of the industry that employs most of us.

Need for International Understanding

But it is not only for our professional and scientific benefit that we must foster international exchanges. The late W. Albert Noyes, Jr., may have expressed another reason best some years ago when he said:

> The more we can provide a common basis for culture throughout the world, the better chance we

> have for mutual understanding and confidence. Science has few equals among the other disciplines in this respect. Therefore, (I) make a plea for internationalism in science, not only for the material things it can do in reducing friction by raising the standard of living but in providing a culture which could be common to all people.

In more recent times because of what is now commonly recognized as a growing gap between developed and developing countries, Dr. Glenn T. Seaborg has summed up the reasoning this way:

> The world has reached a stage where substantial interdependence among developed and developing countries is essential to the fulfillment of human needs. We need to match limited global natural resources for providing energy, materials, food, and water with the requirements of (growing populations). Too many people have too little food, are poorly clothed, live in inadequate houses, and have abysmal health care. We need to raise their levels of existence manyfold. The more affluent, meantime, face an uncertain future because of the stresses on their economies by the cost of energy. Everyone, meantime, will suffer from deteriorating environments.
>
> In these efforts, chemistry, perhaps the most utilitarian of all sciences, ... must play a vital role. Success will call for much greater international cooperation. Humanitarian instincts may be a significant motivating force, but inevitably so will our own self-interest. The economic and social futures of the advanced and the developing countries are inexorably entwined.

Evidence from the CHEMRAWN Conferences

Just about everyone may readily admit that ACS participation in international meetings helps foster a favorable climate for ACS products and services; keeps us as American chemists and chemical engineers up to date on important research and development findings in other countries; helps us keep the American chemical industry strong; and contributes to scientific, technological, and economic progress in developing countries. We might still well ask for concrete evidence that we do indeed enjoy these benefits.

Let me discuss the CHEMRAWN conferences first. Widespread hunger, malnutrition, and starvation are among the tragedies of our time. The recent report of the Presidential Commission on World Hunger states, "At least one out of every eight men, women, and children on earth suffer from malnutrition severe enough to shorten life, stunt physical growth, and dull mental ability." One out of eight translates to 550 million people, or double the population of the U.S. Even more tragic, consider the nightly news reports from Ethiopia.

Several years ago, the CHEMRAWN Committee of IUPAC compiled a list of world needs amenable to solution through chemistry and submitted it to leaders in the world chemical community for comment and discussion. Nearly every one of them placed at the top priority the application of chemistry to alleviate malnutrition and hunger.

Unfortunately, the magnitude of the food problem is so large that it is difficult to know where to begin. If the hougry, the malnurished, and the starving were collected into cities the size of New Orleans, there would be more than a thousand of them. As the population expands from today's four-plus billion to more than six billion by the year 2000, 80% of the people will live in what are today's developing countries. Most people will live in urban centers, and food isn't grown in urban centers. There will be more than three thousand cities larger than New Orleans. By comparison, there are 28 such cities in the U.S. today.

It was in light of such frightening facts that IUPAC organized the CHEMRAWN Conference on Chemistry and World Food Supplies. The ACS was not a formal sponsor, but I have told many people--and I am pleased to tell you now--that the conference could not have succeeded without the Society's help. It managed all the funds in the conference's budget of about half a million dollars and provided invaluable administrative and editorial support.

The conference spanned five days. The some 600 leaders from government agencies, industrial companies, financial organizations, foundations, and universities had an opportunity to hear 75 experts describe the latest findings and list present and future challenges in the different subdisciplines involving chemistry and agriculture. They also had a chance to listen to the advice from eight international experts on the social, political, and economic factors relevant to solutions for the world food problem.

Exit polls are popular these days, and we accordingly conducted one at the Conference's end. All of those answering the exit questionnaire agreed that their attendance benefited them and their organizations. Probably more important, however, are the follow-up activities that have occurred and are continuing to occur.

First, the National Academy of Sciences' Board on Science and Technology for International Development conducted a workshop in Manila immediately after the Conference. Supported by a grant from the Agency for

International Development (AID), the workshop's purpose was to evaluate the Conference's lectures and discussions and determine what the implications were for AID as it considers supporting research and development in agriculture and food processing in the future. In part because of the Conference and the follow-up workshop, AID has singled out agricultural research as one of five priority areas as it evaluates applications for support of research and development.

Finally with respect to the CHEMRAWN Conference, IUPAC with support from the ACS Committee on International Activities plans a series of briefings in developing countries to discuss the implications of the Conference's recommendations with persons in positions to affect agricultural and food processing research and development. Six of us associated with the Conference conducted the first such briefing early in January 1985 in Colombo, Sri Lanka, at the invitation of that country's president, J. R. Jayewardene. Some 30 secretaries of government ministries, directors of research institutes, and heads of universities attended, and within a few days we shall send President Jayawardene a summary of the discussions and our observations.

We now expect to conduct similar briefings later this year and in 1986, one in Southeast Asia, two in Africa, and two in Latin America. They represent the type of follow-up activity that helps ensure concrete results based on a major conference.

Before I turn to the Pacific Basin Chemical Congress, let me say just a few more words about the CHEMRAWN conferences. As many of you will recall, the first conference in the series was held in 1977. It dealt with future sources of organic raw materials, a topic of high concern in the mid-1970's in light of oil embargoes, rising oil prices, and disappearing oil reserves. That conference also led a number of organizations to revise their research and development strategies. A major American oil company, for example, abandoned a significant area of research, and it relocated a research facility following its participation in CHEMRAWN I. In addition, it helped raise money for the second CHEMRAWN Conference even though it is not in the food business. Instead, it did so because of the value it sees in such international meetings.

Another example comes from Japan, whose leaders in the chemical industry told me later that they had decided as a matter of national policy to concentrate on research and development related to C_1 chemistry--that is, the chemistry of carbon monoxide--as the basis for future developments in industrial organic chemistry in Japan.

As a final example, another group from a developing country later explained that they had gone to the conference full of confidence over the possibilities for making a liquid fuel from natural products only to abandon their efforts once they got a clear understanding of the economics of production as a result of attending the conference.

Evidence from the Pacific Basin Conference

Earlier I singled out the Pacific Basin Chemical Congress held this past December in Honolulu as another prime example of the benefits from ACS participation in international meetings. This meeting is too recent for me to have concrete examples of actions taken specifically as a result of anyone's attendance. I can tell you, however, that the Executive Committee responsible for organizing and conducting the Congress was almost overwhelmed by the interest shown by persons wanting to attend and to give papers. The end result was about 3,700 registrants, some 700 above the original estimate. More than 2,300 papers were accepted for presentation in some 75 symposia and in general and poster sessions. The demand for meeting rooms was so great, in fact, that the Committee had to abandon its original plan of reserving one morning for only plenary lectures for all registrants. To do so would have resulted in a loss of some 30 half-day sessions, which would have been intolerable. The Committee therefore scheduled the plenary lectures for the mornings of the first three days at the rather early hour of 8 a.m. before the scientific sessions began at 9 a.m. Despite the attractions of Honolulu, attendance every morning was outstanding.

If you have had a chance to read the December 24, 1984, and January 7 and 14, 1985, issues of Chemical & Engineering News, I expect you have been as impressed as I have with the quality of the research and development findings reported in Honolulu. You might also be interested in knowing that television, radio, and newspaper coverage has been extensive. Fifty reporters covered the Congress, which is more than normally cover ACS meetings except possibly those held in New York and Washington, D.C. As of last week, more than 300 clippings had been received by the ACS based on newspaper and magazine coverage, and they are still coming in. Since improving the public's understanding of chemistry ranks high on the Society's list of priorities, you can see the benefit from such an international meeting.

Let me end this discussion of the Pacific Basin Chemical Congress by sharing with you another one of the very important dimensions of international meetings. In one major way, the Congress was a typical scientific meeting, bringing together as they do a large number of chemists and chemical engineers who report on their latest findings. It might readily have been held in any developed country of Europe or North America. It was held in the middle of the Pacific Basin, however, and it was conceived from the beginning as being not only a typical scientific meeting but also a meeting that would bring together chemists and chemical engineers from countries with very different backgrounds and needs.

In his welcoming remarks during the Opening Ceremony for the Congress, Dr. Seaborg noted that the Pacific Basin ranks as the area of the future. Nearly two thirds of the world's four-plus billion people live in countries with Pacific Ocean beaches. In our country's case, trans-Pacific trade now outranks trans-Atlantic trade, the traitional focus for the U.S. Moreover, Basin countries range from the highly developed ones of North America, Japan, and Australia/New Zealand to ones with tremendous potential but with great problems.

Dr. Seaborg was preceded by the Governor of Hawaii, George Ariyoshi, who extended Hawaii's official welcome. He was followed by the first of the plenary lecturers, Prof. Takashi Mukaibo, Acting Chairman of the Japan Atomic Energy Commission. The three of them were followed on the mornings of Monday, Tuesday, and Wednesday by the other three plenary lecturers. So far as I can determine, none of these six people consulted any of the others about their talks. It was striking, therefore, that they independently made the same point: the need to provide opportunities to foster cooperation among chemists and chemical engineers from developed and developing countries. As Dr. Seaborg wrote in his message in the final program for the Congress:

> This dimension is especially important, since disparities in conditions between developed and developing countries represent one of the most important threats to peace facing the world today. It is absolutely essential that these disparities be reduced and indeed eliminated as rapidly as possible ...

To which I might simply add that the Society's Constitution specifically specifies that an object of the ACS is to "cooperate with scientists internationally and (to be) concerned with the worldwide application of chemistry to the needs of humanity."

Number and Nature of International Meetings

The ACS now has a history of sponsoring international meetings. It held a joint meeting with The Chemical Institute of Canada in 1970. In 1975, the ACS, The Chemical Institute of Canada, and the three societies in Mexico represented here today sponsored the First Chemical Congress of the North American Continent. The same five societies then sponsored the Second Chemical Congress of the North American Continent in 1980, and they have now agreed to sponsor the third in the series in 1988. The Canadian and American societies met together a second time in 1977. In 1979, the ACS and The Chemical Society of Japan sponsored the ACS/CSJ Chemical Congress, with the Australian, Canadian, and New Zealand institutes of chemistry as official participant organizations. The just-completed Pacific Basin Chemical Congress completes the list, with the ACS and the Canadian and Japanese chemical societies as sponsors and with two federations of chemical societies and 19 chemical societies in Pacific Basin countries as official participant organizations.

The trend to jointly-sponsored international meetings is firmly established around the world. Latin American chemical societies held their sixteenth chemical congress last year. The Federation of Asian Chemical Societies held its first chemical congress in 1981, its second in 1983, and it will hold its third this coming April. In Africa, the Chemistry Committee of the Association of Faculties of Science of African Universities held the First International Chemical Congress in Africa in 1981. It held the second in 1983, and it is now planning the third in the series. The ACS's record, therefore, is well in step with the worldwide trend.

When a society such as the ACS decides to sponsor an international meeting, it is essential that it have a genuine commitment to full international participation. For many organizations, such a commitment is an ideal more often honored than achieved. Certainly that has often been true of many meetings sponsored in the U.S. by scientific societies. The ACS, for example, is the largest scientific and educational association in the world devoted to a single science. As a result, a danger always exists that U.S. participants will dominate any international meeting that the ACS sponsors. Such meetings, regardless of where they are held, simply can become ACS meetings to which other people happen to be invited, if we are not very careful.

Of course, including participants from other countries involves increased effort, and usually markedly increased effort when they are from developing countries. Communications are more difficult, partly because of the distances involved but often more so because of different customs and organizational structures. Planning and organizing take more time, and funding can be problematical. Thus, it is not surprising that it is easier to conclude to "do it ourselves" rather than to put forth the effore needed to assure a truly international partnership. Nonetheless, the CHEMRAWN conferences and the Pacific Basin Chemical Congress demonstrate that the advantages from making that extra effort are striking.

If a meeting is to be truly international, cooperative planning must begin at the very earliest stage. Everyone must make a conscious and continuous effort to understand the other person's point of view and to be willing to compromise for good of the whole. Our equally gifted but less numerous colleagues in other countries must be given the full opportunity --and indeed the full burden--of leadership. Only by taking these steps shall we have the full benefit of everyone's creative powers.

When planning an international meeting, incidentally, you need not automatically think only of a full-scale meeting involving all or at least most ACS divisions. An international meeting on the divisional scale, in which you focus quite closely on a particular chemical subdiscipline, can meet the need for international exchange; and a number of ACS divisions have a tradition of sponsoring such meetings.

Those who benefit from international meetings do not have to ask why they are held or why they attend. They know firsthand that such activities make a significant contribution, not just to facilitating exchanges of scientific and engineering information but to the solution of pressing world needs and the betterment of mankind as a whole. As Thomas Jefferson said many years ago, "Scientific societies are at peace even though their nations might be at war."

Less obvious, but perhaps just as important, is the value of international involvements to our our organization, and perhaps Albert Schweizer expressed it best:

> It's not enough merely to exist. It's not enough to say, "I'm earning enough to live and support my family. I do my work well." That's all very well. But you must do something more; every man has to seek in his own way to make his own self more noble and to realize his own true worth. You must give some time to your fellow man. Even if it's a little thing, do something for those who have need of help, something for which you get no pay but the privilege of doing it. For remember, you don't live in a world all your own. Your brothers are here also.

Dr. Schweizer was speaking of individuals. But it seems to me his words apply equally to any organization--such as the American Chemical Society--that has the capacity to make the world a better place. Why international meetings? Because, having the ability to help provide for the needs of humanity, chemists and chemical engineers also have the responsibility to address those needs in an on-going fashion and in a worldwide way. Indeed, it is more than a responsibility; it is as Dr. Schweizer noted a privilege, for in serving others we also serve ourselves.

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Comments to the Staff of the Task Force on Science and Technology

Washington, D.C., June 7, 1985

by David Wiley, Director, African Studies Center
Michigan State University, and representing
the American Sociological Association

A. Some U.S. National Interests in S&T Cooperation with Third World Scientists

1. **Humanitarian cooperation consistent with our national self-definition**
   - **assist Third World scientists and scientific institutions in research to satisfy basic human needs and to avoid natural and human disasters.**
   - particularly for research and social planning on issues of:
     - population,
     - food crop adaptation and growth,
     - urbanization and demography,
     - social planning for the changing structure of populations, of the family, of age cohorts, and of public opinion formation,
     - tropical disease (increasingly in the USA) and health,
     - climate, human habitation, and natural shifts,
     - scientific development for indigenous growth.

2. Creation of an international community of nations where there is confidence that science and its benefits are not just commodities of the wealthy nations but a property of the human community which when shared will inhibit international conflict, political polarization, and hostility to those who possess great scientific capacity.

3. Increased access to strategic materials available in Third World nations and to sales of U.S. products - agricultural and manufactured.

4. U.S. scientific access to foreign research sites for measurements and assays for "global science" based in the USA and to the ever-shrinking genetic heritage of the world for improvements in U.S. agriculture.

5. Maintaining and increasing the free flow of international scientific labor, ideas, data, and information as a shrinking proportion of the world's science is located in the USA - now probably at one-third of global science.

6. Increasing the scientific assessment of foreign nations, societies, populations, and opinions for the more careful and more successful development and enactment of U.S. foreign policy.

B. Some Urgent Steps for Accomplishing these Goals

1. **For U.S. Scientists:**
   - a. Increased federal funding for:
     - pre- and post-doctoral grants for study of foreign nations,
     - university-to-university linkage grants in the sciences,
     - obtaining data and publications from Third World nations,
     - international colloquia, seminars, and individual scholar travel,
     - participation of scientists in international meetings of key concern for U.S. foreign policy (e.g. UN and UNESCO, nuclear treaty negotiation, ICSU, and other professional meetings.)

   b. Greater access of U.S. scholars to social, economic, political, and other scentific data and publications now held by U.S. military and intelligence agencies under restriction or classification.

   c. Clear separation of U.S. intelligence and military activity from academic scholarly study of foreign peoples, nations, and regions.

   d. Congressional action to mandate either:
      1) creation of a national Institute for Science and Technical Cooperation, or
      2) international S&T activities in especially U.S. AID and NSF, where they are secondary to agriculture and to domestic science respectively, as well as in other U.S. scientific and science-relevant agencies (USDA, NIH, NOAA, etc.).

2. **For Third World Scientists**, **U.S. Funding for:**

   - dissemination of U.S. science and science education capacities (esp. development-relevant science) to Third World university and government research centers,

   - graduate education in the USA in development-relevant science,

   - re-orientation of individual scholars, teams of researchers, and institutions toward "development science,"

   - research grants for Third World science and for collaborative science in order to provide small amounts of hard currency for the purchase of critical scientific materials, equipment, travel, consultation, or literature,

   - long-term linkage grants for collaboration with U.S. scientific institutions (incl. professional and technical associations) and for manpower development and institution building,

   - transfer of surplus scientific books, journals, and equipment from U.S. donors.

(See author's proposal for a U.S. Fund for African Science and Technology for Development.)

A United States Fund for African Science and Technology for Development

A Proposal for the Scientific Community and Donors in the United States

(Preliminary Version)

by

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ABSTRACT

A UNITED STATES FUND FOR AFRICAN SCIENCE AND TECHNOLOGY DEVELOPMENT

In response to the needs for self-sustaining and indigenous scientific and technical institutions to support Africa's development, this proposal is offered to create a "United States Fund for African Science and Technology Development" (US FASTD). This Fund would select strategic opportunities for awarding small grants to individual scholars, departments, research institutes, and universities, where a crucial intervention can make the difference, on the one hand, between no research or irrelevant research and, on the other, applied research which makes a genuine contribution to the pressing basic human needs and the increased productivity of the society.

The Fund is proposed for investing in key points of intervention to strengthen the institutions for science and technology (S&T) in Africa in order to increase their productivity by:

1. Assisting directly with the costs of particular research projects chosen on a competitive basis,
2. Providing training for African development specialists, laboratory technicians, and other scientific personnel in particularly crucial fields where the numbers are insufficient to the needs,
3. Offering opportunities to African scientists whose education is not directly appropriate for development-relevant projects to re-train for limited periods of time,
4. Investing grant funds to increase the flow of needed scientific and technical documentation to African university and research institute libraries, solving the current impasse created by the shortage of foreign exchange,
5. Increasing the voluntary contributions of scientific equipment, journals, books, and other materials not available for African scientists and technologists by American scholars, universities, and others, and
6. Expanding the scholarly cooperation, liaison, and linkages between US scientists, universities, research institutes, and scientific associations in fields of direct relevance to development in order to increase the exchange of scientific knowledge, experience, skills, and training.

The Fund would require a sustained effort for at least 10 to 20 years, with an evaluation at least every five years, in order to build on African initiatives and to provide an enduring catalyst for African S&T institutions. In addition to increasing S&T research for development, the Fund also would create immense good will for the USA among a strategic African elite. By strengthening the African university as one of the key S&T research institutions, the Fund also would improve the quality of leadership in the various nations and of the primary source of analysis and self-criticism in these sometimes one-party states.

Several administrative arrangements for the operation of the Fund are offered as alternatives for consideration. In each of the several alternatives, it is assumed that the Fund will operate as a national resource with members of a governance board drawn from S&T specialists in government and in the community of scholars who are concerned with Africa.

Introduction

The 1950s and 1960s witnessed a period of large scale building of institutions of higher learning and research in Africa when there was great optimism about the opportunities of Africa for broad and deep economic development. The universities, it was thought, gradually would produce the scientists and administrators needed for the rapid economic and social development of the continent. Primarily composed of expatriate staff and administration, the universities were indigenized only slowly in this era due to the movement into government of many educators and the lack of Ph.D.-trained faculty.

Largely continuing the tradition of the metropolitan universities, the African institutions did not place highest priority on the production of scientific research for pressing human problems. As a result, research and extension activities for development were largely left by the universities to government ministries and research institutes. The first institution of higher education in Africa modelled on the American "land-grant university" with primacy given to academic excellence in the service of basic human needs through applied research and extension was developed in Eastern Nigeria and, unfortuantely, was subsequently decimated by the civil war in the late 1960s. In the early 1960s so dominant were the "humane letters" in much of Africa that the largest academic department in West Africa's premier university was the Department of Classics. Academic work on many campuses did not reflect a sense of urgency. Frequently, it had little or only indirect relevance to the diverse institutional needs of agriculture, public health, medical services, urban planning, and general institutional growth and efficiency. Standards and patterns for development of such subject areas with direct potential relevance to development such as sociology and anthropology usually were set by expatriates from universities in the West which could afford science in and for its own sake without regard to social or economic relevance.

As a result, many governments in Africa came to regard the universities and colleges assites of privilege and elitism whose function was limited to manpower training. The universities were expected to produce neither research nor action on the pressing basic human needs of the common peoples. Ministries and institutes absorbed some of the research and extension functions rejected by the university faculties, but that work frequently was not of highest quality because it had not emerged in association with the core conceptions and definitions of "Science" and because the institutes sometimes did not command the best scientific man and womanpower of the nation.

Foreign donors had provided large sums of funding for developing African universities during this period; however, as the food and ecological crises of the 1970s worsened, those monies were diverted toward the more immediate needs for food production, food security, institution building, and development of agricultural research and planning capacity in the government ministries.

Simultaneously, however, more and more African men and women were completing MA, MS, and PhD degrees. Increasing numbers also moved into scientific fields instead of the earlier concentration on arts, letters, history, language, and politics. Governments also began to place more pressure on the universities to train larger numbers of students, and enrollments were increased markedly, sometimes by as much as fivefold. As a result, even those institutions seeking to become more relevant to the nation's development were increasingly inundated with teaching activity, which deterred the more difficult and costly research process.

Even in the best of circumstances, research on science and technology for development has been undercut by a) the economic crisis of the entire continent, b) the resultant shortage of foreign exchange, and c) the institutional upheavals affecting many governments and even whole societies. These crises have undercut the capacity and production of science on the continent in a variety of ways: (1) Due to the economic and foreign exchange crisis, universities and research institutes sometimes are at the end of the queue for foreign currencies to purchase scientific equipment, books and directories, scientific journals and technical data reports, and even ordinary but absolutely essential equipment such as refrigerators, fluorescent lights, and calculators. Some laboratories founder for lack of portable generators to provide insurance against power failures and the resultant loss of refrigeration or incubation of cultures, serums, and samples. (2) The inability to complete excellent research damages the general academic quality of articles and reports, thereby lowering the standards of publications, peer review norms, and even the quality of the production of scholars and scientists. (3) The large class size in lecture rooms and laboratories and the high ratio of students to staff decrease the time available to scientists to complete research. (4) Because of lack of funds, senior research staff, and adequate libraries, the universities have only developed token graduate programs if any at all. This lack of graduate seminars and a cadre of advanced students deprives the faculty and their laboratories of the intellectual context that is productive of advanced research in university settings. (5) The lack of funding for teaching assistants decreases the pool of knowledgeable and trained advanced students to act as research assistants for scientists in the laboratory and library. (6) The shortage of instructional positions and of funding impedes the retraining of staff because of the difficulty of releasing them for periods of retraining. (7) The shortage of travel funding which usually requires foreign currencies hinders scholars with similar research problems from consulting actively with each other. This problem is accentuated by the low quality of telephonic communications and the slowness of the postal services. (8) Even though much of the research requires the best of international science, there is a great shortage of travel funding to attend seminars and conferences to keep abreast of the latest techniques and to develop the collegial cooperation with other scientists as well as simply to maintain morale.

As a result of these and related factors, morale among African scientists is often very low. One group of 27 Nigerian scientists recently wrote a book entitled What Science?, asserting the virtual impossibility of scientific research and its application in the face of a multitude of impediments in their nation. This low morale often leads scientists to seek opportunities elsewhere in Western laboratories and universities. Their migration is a crucial loss to already beleaguered faculties, which further decreases the mass of scientists and increases the ratio of students and government civil servants to faculty member.

In spite of all these hindrances, some individual scientists and departments persevere and garner the minimal requisite resources to conduct science and to apply it to development problems. Various articles and reports from African institutions testify to the success of these motivated and resourceful scientists and scholars. The institutional, economic, and political crises of the 1970s and 1980s are no longer new, and most African scientists are cognizant that no science will develop if they await ideal conditions.

Simultaneously, some African ministries and governments have realized that the small-scale scientific establishments in their nations are inefficient in isolation and that scientists in diverse private and public institutions need to cooperate. As a result, governments are turning more to universities as loci of research and for whatever contribution they are capable of making to the development problems of the nation. The scarcity of funding, especially of foreign currency, hinders this new resolve; however, it does provide a foundation on which to build in a small and targeted way toward a physical, natural, biological, and social science of development concerning particular problems of human need, especially in the arena of food production.

The provision of science and technology funding for African universities and research institutes also creates the potential for long-term relationships between US and African scholars, their departments and universities. Over time these relationships create immense good will and enduring linkages which can outlast the changing winds of political policy and regime. African scholars who benefit from these research projects for development are an important elite who are consulted by the governments of Africa about their policy toward US universities, firms, and the government. Real contributions to the nations' development creates long-term goodwill toward the United States and its institutions.

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NEEDS AND GOALS FOR A FUND FOR SCIENCE AND TECHNOLOGY FOR DEVELOPMENT

The type of assistance which is needed to respond to opportunities for science and technology (S&T) development is not only the large contract for a single institution but a more efficient provision of many small and highly targeted grants which respond to the particular needs of individual researchers and institutions.

The exact nature and focus of the needs have been detailed already in the US submissions from the Department of State, prepared by the National Research Council and other US S&T institutions, for the 1979 United Nations Conference on S&T for Development in Vienna. The needs and approaches noted in this proposal build on those observations and add a competitive granting system which maximizes individual and institutional initiative and which rewards administrative and research efficiency.

The specific goals of this project add the following to the general needs for S&T development:

1. Increasing the cooperation and linkage of all S&T manpower for development in the many institutions where they now often work in isolation - universities, ministries, research institutes, corporations, etc.
2. Reorienting the S&T research in these institutions toward development priorities in the nation.
3. Reinvigorating the S&T research institutions and increasing morale of individual researchers by providing new, though small-scale, resources for research embedded in an incentive system.
4. Increasing the productivity of the African science establishment by providing certain small but key missing elements of research infra-

structure, including scientific information, equipment, training, retraining, and outlets for research results (publications, associations, and conferences).

5. Strengthening the indigenous production of new S&T personnel in African universities and institutes.

6. Enlarging the linkages and exchanges between African S&T institutions and individuals with those of the USA in order to increase the flow to Africa of voluntary contributions from the US S&T private sector and to ensure the incorporation of African research into science in the wider world.

Particular Opportunities in the mid-1980s - A fund for science and development can make a large impact in Africa at this time because of a series of new conditions there, including:

- the enlarged commitment in African governments and universities to S&T research and application.
- the readiness of university scholars and administrators to reorient their faculty, departments, and university away from the liberal arts fixation on the humane letters, as was common in the paradigm universities in Europe, and toward greater emphasis on S&T applied research and extension for development.
- the increased density of PhD-trained indigenous scholars instead of expatriates in African institutes and university departments, which provides the potential for longer-term contributions to the institutional development of S&T in the African institutions than is possible with the temporary foreign researcher.

- the larger number of physical, biological, and social scientists with advanced laboratory and methodological training in the pool of African scholars, who were focused more on liberal arts, history, languages, and the descriptive sciences in the 1950s and 1960s.
- the potential incentive of hard-currency funding for research to encourage African scientists to remain in Africa instead of evacuating their departments and institutes where progress so far has been nearly impossible due to the lack of resources.
- the realization by African governments that there must be a marshalling of the nation's scarce S&T human and material resources from the diverse sources of the universities, research institutes, ministries, private companies, and foreign donors to focus on targeted research and applications to problems which promise concrete gains.
- the greater experience of African institutions of higher education and research in targeting resources and operating with fewer resources, as well as their greater appreciation of scarce foreign currency grants for research projects - both resulting in much greater efficiency in utilizing research awards.
- the existence in some institutions and nations of a critical mass of science facilities and personnel to make research possible with a small amount of funding for training, retraining, small research grants, etc.
- the legacy of the economic crises of the 1970s augmented by the regional droughts and, in some nations, institutional collapse or political upheaval which have focused the attention of many administrators and planners on the key points of intervention in tackling basic issues of human need and productivity.

A. The Subject Areas for Attention of the Fund

In general, no discipline or arena of S&T should be excluded for funding whenever scientists and scholars, together with national and international policy-makers, identify the key problems inhibiting the welfare of the human populations of Africa. Priority will be given to the following areas of S&T in both pure and applied fields:

1. Physical Sciences, Engineering, and Mathematics - These fields will be essential as foundational disciplines with direct application to agricultural and industrial development. For example, the refurbishing of chemistry teaching and research in Brazilian universities had a marked impact on industrial growth and is similarly needed by some of the more industrialized African countries. Geological science theory and research are urgently needed for mineral and petroleum exploitation. And basic and applied mathematics skills are required to support the increasing computerization of functions even in the Third World. Several of the national US disciplinary associations in fields such as mathematics, physics, geology, and engineering could undertake important upgrading of that field in Africa.

2. Biological and Medical Sciences - There are acute needs for research in biology of various forms, including microbiology on tropical disease, pharmacology and toxicology, zoology, botany, plant and animal genetics, and various subfields of human and veterinary medicine. These sciences have the potential for solving many of the basic African needs for food by maximizing agricultural and natural biological production on a continent with long growing seasons but great scarcities of water, frequent inundation by insect predators, and the resultant human problems of malnutrition and disease.

The current lack of investment in tropical disease research (estimated in the 1970s as under one percent of the total world medical research funding) suggests the urgency of cooperative efforts from the USA to increase African productivity. The biological attacks on disease in Africa have great potential for scientific breakthroughs and reduction of the costs of control and treatment **precisely because** African disease has had so little attention. These breakthroughs will not only improve human welfare in and of themselves but also indirectly may increase productivity.

3. Social Sciences - Research and applications in the behavioral and social sciences are needed to integrate innovation and agricultural change into African social structure (farming systems research) and to identify ways to increase social adaptation to changes in methods of production. Applied social science is especially needed in social and ecological impact assessment, evaluation research, project design and analysis, project administration, and in social policy development for social and psychological welfare. Many African social and behavioral scientists, however, have not been introduced to these applied fields and need opportunity for retraining. The more applied orientation of these disciplines of anthropology, sociology, political science (public administration), geography (spatial aspects of development and remote sensing subfields), psychology and social psychology, criminal justice, and social welfare in the USA in the last decade suggests their growing utility for African development problems.

4. Other Professional Fields - A number of professional fields in the USA which combine scientific methods of research with attention to development problems also should be candidates for grants from the

fund, including: a) **Agriculture and Natural** Resources - Chief among the areas of needed applied and scientific research is this professional area which deals with the life-sustaining production of 80 percent of the continent. Agronomy, crop and soil science horticulture, food science and human nutrition, animal science, agricultural engineering, agricultural economics, fisheries and wildlife, and natural resources already are receiving some support from donors. Because agriculture already is a prime recipient of S&T research funds, this fund will not invest in agriculture exclusively. b) **Education** - New pedagogies of language learning, science education, and educational dissemination require scientific research to identify methods relevant to the particular distributions, scale, and level of technology of different African societies. c) **Human Ecology** (or Home Economics and Family and Environmental Science) - African nutrition, textiles, family organization, and the public health of the family as well as other areas are important research for directly improving the quality of life in the African village and home. d) **Public Health** - Applied research and actual application of this field is a high priority in ministries, medical schools, and institutes throughout Africa. e) **Communications and Mass Media** - Applied research has been developed in US schools of mass media and communications to identify and evaluate mechanisms of reaching particular target audiences with important messages concerning development and health practices. This use of research also is needed in Africa in both communicating information concerning public health, sanitation, nutrition, and farming practices, and also for increasing the national integration and the stability of the African polities.

f) **Commerce and Business Administration** - Applied scientific research is needed concerning African business, public and private, in order to encourage the commercial expansion and efficiency of the African economies.

B. Eligible Recipients for Funding S&T Research

Funding will be granted in small amounts to individuals and institutions which distinguish themselves with creativity, efficiency, and particular projects of research or with creation of infrastructure for research. Peer panels in various S&T areas will provide rigorous competitive review.

The range of types of entities which could receive funds would include:

- individual researchers proposing a research project
- teams, groups, or laboratories, possibly geographically dispersed, with a common project of research
- research institutes or departments thereof
- university departments or institutes of research and their libraries, laboratories, and computer centers
- government ministries or subdepartments and institutes
- disciplinary and professional associations which facilitate the regional or continent-wide cooperation in S&T
- US scientists, teams/groups of scientists, universities, colleges, departments, laboratories, libraries, computer centers, research institutes, or professional associations for the purpose of expanding collegial cooperation in African S&T research
- international agencies and associations which provide needed services of the same character.

C. Specific Targets for Funding S&T for Development

Because grants made will be small, targets will be chosen which are a) of high priority in the development needs of the region and the particular nations and b) of high potential to increase the S&T research capacity of the institutions. Some of the particular targets in this category are:

1. **Re-orientation Grants** - Grants would be made which reorient an institution from more abstract or "pure" research toward research applied to development issues. These awards could be given either to individuals seeking retraining or refurbishment of their knowledge of theory, methods, and techniques or to institutions which require assistance in reorienting, upgrading, or reinvigorating their applied S&T research.

a. **For Individual Scientists** - Most scientists and scholars in Africa have been trained in the classrooms and laboratories and at the feet of mentors in Western universities. Usually, their educations have been of excellent basic scientific quality; however, the topics and foci of the research areas have been embedded in the priorities of advanced industrial nations. As a result, frequently African scholars continue the same research focus which is relevant to advanced Western science but much less relevant to the needs of the less developed country. Often their universities cannot afford the expensive equipment and documentation to enable the scientist to keep abreast of Western laboratories and literatures. Funds would assist the individual scholar to attend special institutes and seminars to reorient research to the more development-relevant aspects of the scientific field in which he or she was trained, usually in a Western university laboratory concerning Western S&T and development issues. Grants might assist in purchasing literature or special equipment to facilitate the reorientation, or provide travel to another Third World or US institute conducting research and application in the same scientific arena. In special instances, stipends and tuition might be provided to offer a post-degree (MA, MS, or PhD) internship or training.

b. **For Institutions** - Funding might be provided to bring external assessment teams of US and other African scientists to review the program and make recommendations for reorientation. A US scientist experienced in some particularly relevant S&T for development field might be brought for a short or long-term consultancy. Travel might be provided to an institute or department head/director to visit other model institutions, although travel grants would not duplicate the Fulbright and State Department international visitor programs. Administrators of S&T institutions might be provided assistance in learning new administrative control of research or the linkage of research to the extension (or outreach) functions as is found in the US land-grant university.

c. **Special All-Africa S&T for Development Seminars** - Especial funding is needed for seminars in particular research fields utilizing an ad hoc faculty of US and African scientists. These seminars would be of crucial importance in setting the norms for applied research as an acceptable and valued enterprise, for communicating advances in theory and methods based on new findings of US and African scientists, and for creating the needed context for African scholars to establish linkages with their colleagues in the USA and Africa for longer term cooperation on similar lines of research and application to development problems.

2. Research Grants - Grants will be awarded to individual scholars, teams of scientists, or institutions for applied research in the area of S&T for development. Research must be a high priority for African human and economic development as determined by peer review teams of US and African scholars (perhaps supplemented on occasion by experts from international agencies). All awards shall be made on a **competitive basis** and generally without regard to geographical distribution in order to reward excellence in research efficiency, administration, and execution.

Research awards may be spent for any of a variety of projects; however, salary and stipend costs for scientists would be supported by the Fund only in unusual circumstances. Ordinarily, the developing country would be expected to provide the space and salary support, as well as the basic infrastructure of physical plant and administration, for the research project. Thus, awards from the Fund would primarily support the direct costs of the project and especially those parts of the project requiring foreign currency, such as the purchase of equipment, materials, supplies, services, consultancy, and travel which are not available in the African country due to foreign currency shortages. Should local currency funds be made available to the Fund by agencies of the US government, local costs could be more liberally supported.

Research funding may be sought also by teams or pairs of US and African scholars for collegial cooperation.

Criteria for Awards - Although particular topical and disciplinary priorities will be developed by the governors of the Fund and the teams of peer reviewers of proposals, projects would be ranked highly which exhibited the following characteristics: a) Applied research with a high priority of making an immediate and direct contribution to the welfare of African societies, particularly their basic human needs for food, health, wealth, shelter, and social and personal happiness. b) Projects which contribute to the reorientation of individuals and institutions to more applied S&T fields of inquiry. c) Projects which link scientists and scholars in diverse institutions within a nation and from diverse universities and institutes from different nations. d) Projects which are highly valued by a combination of the ministries, field development stations and agents, local populations, and scientists. e) Projects which have wide applicability in different regions, nations, ecological zones, and local populations. For instance, a project which promised a direct breakthrough on malaria, onchocerciasis or a unique amelioration of marasmus would have wide application across Africa and would be highly evaluated. f) Projects which are not eligible for other sources of funding from national, international, or local donors. g) Projects which have sought funding elsewhere and been ranked highly but not received funding. h) Projects which provide individual scientists, scholars, and their students with new training, experience, and institutional capacity which are important for long-term growth of applied S&T research.

3. S&T Infrastructure Grants - These awards could be made for increasing the capacity of particular laboratories, libraries, departments, institutes, and associations for support of S&T for development research, application, and extension. Criteria for awarding these funds would be similar to that for research grants in 2. above. Awards could be made to individuals and institutions in

the USA or in Africa. Some of the targets for such awards would be the following: a) Purchases of equipment and documentation for advanced training programs of universities and institutes in particularly crucial development fields. b) Funds for collection, packaging, and transportation of S&T equipment, journals, and print and non-print publications from US scholars and scientists to their African colleagues. Some scientific equipment in the USA, such as used microscopes, slightly out-of-date calculators and word processors, and medical/dental diagnostics, are of value to African institutions. Care must be taken not to send equipment which is so old or expensive to repair that it actually impedes research. Due to the acute shortages of foreign exchange, a number of signal libraries in Africa have ceased subscribing to foreign development-relevant journals and research reports. This interdiction of information results in the duplication of research and the inability to build on the advances of scholars and scientists in surrounding nations who are working on similar problems. A surprisingly large amount of documentation of great value is available in the USA from retiring scholars, scientists changing fields, libraries with duplicate copies, and even bookstores remaindering texts or replacing them with new editions. c) Travel funds to permit African scholars to attend crucial conferences, seminars, and disciplinary associations in order to create the needed reference groups and networks of scientists working on development problems. d) In rare instances, funds to supplement needed alterations of or additions to laboratories; however, these grants will be small and highly specific. e) Grants are needed by S&T associations in Africa in order to plan the activities of the associations, hold meetings in this period of costly airfares, publish the proceedings of the meetings, and pay some small costs of a minimal secretariat with a small clerical staff and office equipment. These associations are of great importance in providing a point of collaboration between African scholars and of meeting with US S&T scholars. At this time, several of these are foundering, and many disciplines have not yet formed associations because of cost constraints in the foreign currency budgets. f) Finally, funding is needed for S&T journals, newsletters, occasional papers, monographs, and various non-print publications. At this time, much scientific research in Africa is retarded by the lack of outlets for publishing the results. There are few S&T journals in Africa because of the earlier fixation on the arts and letters. Even more importantly, journals as an outlet for S&T for development have either failed to develop or have withered after initial publication because of the lack of foreign currency for the needed paper, printing machines, and composers. Africa does not need a plethora of such publications, but it does need a critical minimum of internationally distributed outlets for <u>applied</u> and <u>basic</u> research for development. Linking associations and universities in Africa with US counterparta may provide cooperation to publish materials jointly.

4. <u>S&T Linkage and Exchange Grants</u> - These special grants will facilitate the linkage of African scholars for S&T with their colleagues in the USA. These linkages and exchanges will accelerate research, ensure that the latest methods and theories of science are available for African efforts, and create a repository of good will toward the USA and its institutions and scholars that will outlast political change and upheaval.

a. **Awards to Cooperating Scientists and Institutions** - These awards will be targeted for African scholars and S&T administrators or decision-makers who can make best use of important US and other S&T conferences, seminars, research technique demonstrations, equipment expositions, and particular liaisons with American scholars. Some awards may be made for particular long-term linkages and exchanges between individual scholars, their departments and institutes, or even of entire S&T faculties, when such long-term collaboration promises an increase in the capacity of African institutions. Funds in this category could be spent for travel, per diem expenses, residence, book and equipment allowances, and associated fees to facilitate scholars from two or more institutions meeting and cooperating with each other on S&T for development projects. Such exchange grants already exist for the arts and letters, library, education, and social science fields through the University Linkage Program of the US Information Agency (USIA). According to the USIA the sciences are generally excluded from their funding because "USAID is responsible for the medical, agricultural, and scientific exchanges," even though USAID has no such programs at this time. Such linkages also can promote a) longer-term staff development cooperation with the African institutions, b) the donation of books and journals, and c) the informal provision of support for the needs of African scholars and institutions by US scholars and institutes, thereby maximizing private sector contributions from the USA.

Professional Associations in the USA and Africa - Especial attention will be given to the linkage of American disciplinary and professional associations with their African counterparts in order to strengthen and enlarge the international cooperation existing between the members of the Consortium of Affiliates of International Programs (CAIP) of the American Academy for the Advancement of Science (AAAS). Members of this consortium of scientific and engineering societies already have pledged themselves to increase the participation of Third World scientists in their programs and the flow of their materials to these colleagues abroad. Such programs as that of the American Physics Association to upgrade the quality of teaching and research in physics in Latin America provide a model of what could develop for a range of scientific and engineering societies from the USA in programs for Africa.

5. Training Grants - Funding also would be devoted to training individual scholars and teams of scholars in areas which are peculiarly short of scientists and technologists and which are not being supported by other African government or donor programs such as that of the UNDP and the Training Programs of USAID.

Flexible small grants would be made available for African S&T specialists visiting the USA on other programs to extend their stay in order to add seminars, conferences, and individual consultation with other US scientists.

Other awards could provide for visits by US scientists to Africa to offer seminars, consultation, and other instruction to upgrade Africa S&T for development.

Another category of awards would provide special grants to African scholars in training in the USA for dissertation field research in Africa and in the USA on return from the field. Many young African scholars are completing dissertations on non-African data because of the lack of foreign currency in their home countries to fund their return from the USA for data collection, their return to the USA to complete the analysis, and their lengthened stay in the USA to write up the results in the dissertation.

Project Organization and Budget

B. Budget

The funding for such an enterprise can vary enormously, depending primarily on the availability of funds, because the absorptive capacity is large.

Some approximate costs of project units are provided as examples:

1. **Reorientation Grants** - An individual scholar for one year of retraining could cost circa. $20,000 stipend, $5,000-10,000 transportation, $500 book and supplies allowance, $500 miscellaneous and $7,000-8,000 of administrative costs, totaling perhaps $35,000-40,000.
2. **Reorientation Grants for Institutions** - ca. $50,000-100,000 each for a two or three year period, depending on the size of staff.
3. **All-Africa S&T for Development Seminars** - ca. $100,000-200,000 per seminar, depending on the number of participants and the potential source of funds from African governments and universities.

4. **Research Grants for Individuals** - grants for one year of $5,000-75,000.

5. **Research Grants for US/African Cooperation** - Grants of ca. $10,000- 75,000 per year.

6. **Research Grants for Teams and Institutes** - $15,000-100,000 per annum.

7. **S&T Infrastructure Grants** - from $500-50,000 each. In this category, many effective grants of $2,500-10,000 could be made for specific assistance, for instance in transferring used equipment and documentation to Africa.

8. **S&T Linkage and Exchange Grants** - Awards could be valuable in amounts as small as $25,000 per individual or institution and as large as $75,000 per annum for some large on-going projects, which could achieve the requisite critical mass of assistance.

9. **Linkage Grants for Professional Associations in the USA and Africa** - Awards in this category may be as small as $10,000-20,000 for a conference or seminar and as large as $25,000-50,000 per annum for direct assistance to associations, professional societies, and US institutions. Some very large awards of more than $500,000 could be made in this category for the refurbishment and upgrading of an entire discipline or field in the continent through long-term and extensive exchange and assistance.

10. **Training Grants** - These are well-known among US donors. Costs would parallel those of USAID, AFGRAD (African-American Institute), and similar training programs. One year of training with all associated costs could be as high as $25,000. Dissertation data collection awards could be as high as $40,000 if travel for the faculty advisor, field research costs of interviewing or specimen

sampling, and expensive analysis are required in a project.

11. Administration of the Secretariat - The salary of the executive director, a small office staff, travel, equipment, supplies and services and associated costs would be a minimum of approximately $300,000, because of the expensive communications. Meetings of the Board of Governors and Advisory Council or committees plus the peer review panels also could easily cost circa $40,000-50,000 if full international participation is obtained.

In sum, a small US FASTD program on a pilot basis, initially devoted primarily to planning and assessment, could be mounted in an inexpensive setting for as little as $1.5 to 2.0 million. A fully developed program and secretariat making the full range of awards could easily utilize $5-10 million per annum effectively.

APPENDIX 2

ADDITIONAL MATERIALS FOR THE RECORD

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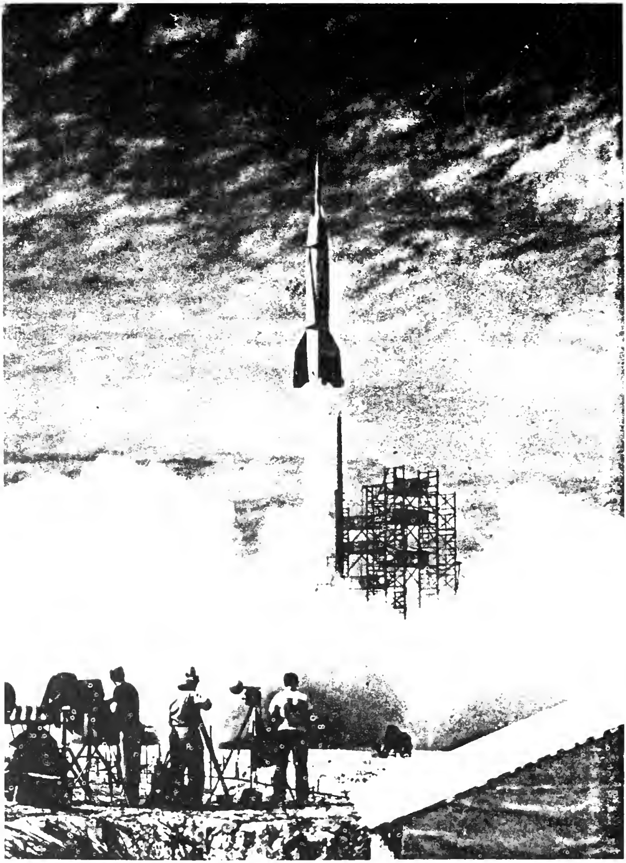
AMERICAN HISTORICAL ASSOCIATION



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Founded in 1884. Chartered by Congress in 1889

Cover illustration. The first rocket test from Cape Canaveral, July 24, 1950. The missile was a German V-2 with a small American second stage perched on top. Photo courtesy of U.S. Air Force. See the article in this issue by Walter A. McDougall, "Technocracy and Statecraft in the Space Age—Toward the History of a Saltation" (pp. 1010–40).

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The American Historical Review

Technocracy and Statecraft in the Space Age —Toward the History of a Saltation

WALTER A. MCDOUGALL

THE "SPACE AGE," born with the first artificial earth satellites in the autumn of 1957, is already twenty-five years old. The origins of space technology have passed into contemporary history even as the Space Shuttle, the European rocket *Ariane*, permanent Soviet space stations, and the prospect of space-based laser weapons open a second Space Age of ineffable potential. What is the Space Age? Did *Sputnik I* mark the beginning of a distinct period in the history of human institutions and collective behavior? These questions matter at a moment in history when our societies, politics, economies, and diplomacy are wrenched by perpetual technological revolution.

The *prima facie* case is impressive for marking the technological turning point of the mid-twentieth century at the birth of the Space Age. The first Sputniks seemed to overturn the foundations of the post–World War II international order. They promised imminent Soviet strategic parity, placed the United States under direct military threat for the first time since 1814, triggered a quantum jump in the arms race, and undermined the calculus on which European, Chinese, and neutralist relations with the superpowers had been based. The space and missile challenge was then mediated by massive state-sponsored complexes for research and development, in the United States and throughout the industrial world, into institutionalized technological revolution and, hence, accelerating social, economic, and perhaps cultural change. Space technology altered the very proportions of human power to the natural environment in a way unparalleled since the spread of the railroads. Machines can now travel, deal destruction, store and transmit information, observe and analyze the earth and universe at orders of magnitude beyond what was possible before 1957. Virtually every field of natural science has leapt forward or been transformed on the strength of space-based experimentation and data. Sputnik would seem to qualify as a historical catalyst.[1]

I thank the staff of the NASA History Office, especially Monte D. Wright and Alex Roland, for their generous assistance in the research leading to this article and Loren Graham, Melvin Kranzberg, Bruce Mazlish, and Reginald Zelnick for valuable suggestions. I also thank the Committee on Research of the University of California, Berkeley, the Woodrow Wilson International Center for Scholars, and my colleagues at Berkeley for their support and encouragement.

[1] See Robert Lapidus, "Sputnik and Its Repercussions: A Historical Catalyst," *Aerospace Historian*, 17 (1970) 88–93. Walt W. Rostow has also described Sputnik as the turning point in recent history without, however,

Has similar distinctly Space Age change occurred in domestic and international politics? The explosion of science and technology and its impact on society in the 1960s inspired numerous suggestions that this was so. John K. Galbraith and Daniel Bell wrote of the postindustrial age, Charles S. Maier of an age in which intense political exploitation of collective human thought replaced that of raw materials and labor. Even Soviet theorists adopted the phrase "scientific and technological revolution" as a stock description of the post-Sputnik world, in which capitalism itself altered its laws and Leninist doctrine was modified to include science as a "direct productive force."[2] The four realms most often cited as the loci of revolutionary change in the Space Age are (1) international politics, (2) the political role of science and scientists, (3) the relationship of the state to technological change, and (4) political culture and values in nations of high technology. This essay describes the literature on the impact of space technology in these four realms and proposes some hypotheses for future inquiry.[3] Its findings suggest that those who speak of the revolutionary consequences of space and related technologies and those who belittle their impact both exaggerate the reality. For the history of the relationship of politics and technology is evolutionary. Since the 1860s governments have steadily increased their interest in the direct fostering of scientific and technological progress. But within that evolution Sputnik triggered an abrupt discontinuity, a saltation that transformed governments into self-conscious promoters, not just of technological change but of perpetual technological revolution. This change above all defines the Space Age as a historical period and helps explain what most alert undergraduates would attest: that history, in our times, is speeding up.

WHY SPACE FLIGHT IN THE MID-TWENTIETH CENTURY? Although the mathematical, chemical, and metallurgical skills necessary for practical research into rocketry were present by the 1920s, the investment required for orbital flight was so large and the immediate military or economic benefits so uncertain that the genesis of spaceflight in our time is no more self-explanatory than Iberian sponsorship of world navigation is for the fifteenth century. Only in the late nineteenth century did Konstantin Tsiolkovsky and others of his generation first establish that rockets were the practical means to break the chains of gravity and realize the ancient fantasy of voyages beyond the atmosphere. As late as the 1930s rocketry still belonged to determined individuals like Robert Goddard in the United States or amateur clubs like Hermann Oberth's *Verein für*

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examining the impact of space-related technologies; Rostow, *The Diffusion of Power An Essay in Recent History* (New York, 1972).

[2] Galbraith, *The New Industrial State* (New York, 1971); Bell, *The Coming of Post-Industrial Society* (New York, 1973); and Maier, Introduction to George B Kistiakowsky, *A Scientist in the White House* (Cambridge, Mass., 1976). On Soviet interpretations of the "scientific-technological revolution," see Bruce Parrot, *Politics and Technology in the Soviet Union* (Cambridge, Mass., in press), chap. 6.

[3] The role of technological innovation as a cause of international political change has recently been argued by Daniel K. Headrick; see Headrick, *The Tools of Empire: Technology and European Imperialism in the Nineteenth Century* (Oxford, 1981).

— С наступающим днем, Африка!

Figure 1: Soviet depiction of Africa saluting the cosmonauts—the "morning of the cosmic era." Moscow, 1961.

Raumschiffahrt or Frederikh Tsander's G.I.R.D. in the Soviet Union. The roots of the Space Age are really lodged. therefore, in the late 1930s when a peripatetic collaboration between the rocketeers and national military establishments was inaugurated.[4]

Sociologist William Sims Bainbridge sought to unravel the relative roles of individuals and organizations in the origins of spaceflight, a development he has seen as scarcely inevitable, and even accidental.[5] He has interpreted rocketry as residing outside "normal science" in the Kuhnian sense, and thus explicable only in terms of "social processes that operate outside the conventional market mechanisms"—that is, a "social movement."[6] Conventional wisdom held that the amateur rocketeers of the 1920s found their work taken up by military authorities, especially in Nazi Germany, who pushed it forward for political ends. In fact, Bainbridge argues, "the Spaceflight Movement caused the German military *to be taken up by* the rocket"—the governments of Germany, and later the United States and Soviet Union, were exploited by the space enthusiasts for their own purposes. This provocative thesis emphasizes not only the technical virtuosity but also the manipulative skills of men like Wernher von Braun and Walter Dornberger, who were able to sell the keepers of the public purse on projects like the V-2 and giant Saturn rockets that really involved a misallocation of government investment.[7] Hence, rockets appeared in a "technologically revolutionary situation, defined as the presence of a rich and incompetent patron beset with problems that might be solved through technological innovation. In such a situation some developments may prosper unnaturally."[8]

There are other conditions besides zealous promotion and foolhardy patronage that make for technological advances. The prototype ballistic missile, the V-2, was also the product of the military and economic restrictions on Germany in

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[4] The collection of articles in *Technology and Culture*, 4 (1963), republished and edited by Eugene Emme as *The History of Rocket Technology* (Detroit, 1964), established rocketry as an important field in the history of technology. Also see R. Cargill Hall, ed., *Essays on the History of Rocketry and Astronautics*, 2 vols. (Washington, 1977); Willy Ley, *Rockets, Missiles, and Space Travel* (New York, 1957; 3d rev. edn., 1961); and Wernher von Braun and Frederick I. Ordway III, *History of Rocketry and Space Travel* (New York, 1966). On the Soviet roots, see Nikolai D. Anoschenko, ed., *A History of Aviation and Cosmonautics*, 5 vols. (Washington, 1977); and Anatoli Blagonravov, *Soviet Rocketry: Some Contributions to Its History* (Springfield, Va., 1966), and *USSR Achievements in Space Research* (Washington, 1969). The NASA Historical Publications series is the best source for program histories; see, for example, Constance M. Green and Milton Lomask, *Vanguard. A History* (Washington, 1970); Loyd S. Swenson, Jr., *et al.*, *This New Ocean: A History of Project Mercury* (Washington, 1966); Barton C. Hacker and James M. Grimwood, *On the Shoulders of Titans: A History of Project Gemini* (Washington, 1977); R. Cargill Hall, *Lunar Impact: A History of Project Ranger* (Washington, 1977); and Homer Newell, *Beyond the Atmosphere. Early Years of Space Science* (Washington, 1980).

[5] Bainbridge, *The Spaceflight Revolution. A Sociological Study* (New York, 1976).

[6] The origins of Sputnik illustrate the "chicken and egg" debate on the connection of inventions and environment described by Roger Burlingame in his "Technology: Neglected Clue to Historical Change" and by Lewis Mumford in his "History: Neglected Clue to Technological Change," *Technology and Culture*, 2 (1961): 219–39.

[7] Bainbridge, *The Spaceflight Revolution*, 4–11. On the cost-effectiveness of the V-2, see *ibid.*, 92–107. Bainbridge relied heavily on biographical data about the leaders of the "spaceflight movement." Recent works include P. T. Astashenkov, *Academician S. P. Korolev: A Biography* (Washington, 1973); I. K. Golovanov, *Sergei Korolev: Apprenticeship of a Space Pioneer*, trans. M. M. Samokhvalov and H. C. Creighton (Moscow, 1975); Milton Lehman, *This High Man—The Life of Robert H. Goddard* (New York, 1963); Esther C. Goddard and G. Edward Pendray, eds., *The Papers of Robert H. Goddard*, 3 vols. (New York, 1970); and Erik Bergaust, *Wernher von Braun* (Washington, 1976).

[8] Bainbridge, *The Spaceflight Revolution*, 107.

the Versailles Treaty, which encouraged promotion of science and technology as an unhindered means of national growth and, incidentally, failed to ban rocket research. The V-2 also stemmed from the growing interwar cooperation among German science, industry, and the army, from the excellence of German metallurgical, chemical, and electrical firms that pioneered private research and development, from the support of a peculiarly "modernist" Third Reich and its hardware-mad Führer, and from the apparent wartime needs of the beleaguered Nazi empire, especially after its loss of air superiority.[9] The V-2 then evolved into Vostok and the Jupiter-C, the first space boosters, through the pressures of Cold War, the strategic needs of the Soviet Union, the military-scientific establishments dating from the Second World War, and, not least, the last-minute creation of the atomic bomb, without which ballistic missiles would have remained nuisance weapons unworthy of large investment.

The most telling argument against the "social movement" thesis is Soviet origination of the first satellites. After *Sputnik I*, Americans indulged themselves with the notion that Soviet space spectaculars were a fluke, the achievement of captured German scientists, or the result of espionage or individual genius. Deliberate scholarship on the history of Soviet rocketry reveals nothing of the sort. Rather, the first assault on the cosmos quite naturally was launched from the world's first technocratic state—and spaceflight enthusiasts by no means bamboozled the Kremlin in order to win its material support. The proximate cause of the opening of the Space Age was the competition for better means of delivering nuclear weapons after 1945. Josef Stalin accelerated his atomic bomb program after Hiroshima, and as early as 1947 he ordered the rapid development of intercontinental rockets.[10] But, whatever their urgent need for a counterthreat to American bomber bases encircling their territory, Soviet leaders could not have been midwives to an ICBM in ten years but for Russian rocket expertise rooted in the 1920s and the extraordinary budgetary and political force-feeding of research and development dating from 1918.

[9] On the accomplishments of the Peenemünde team and its escape to the United States, see the magnificent narrative of Frederick I. Ordway III and Mitchell R. Sharpe, *The Rocket Team* (New York, 1979), which is based on extensive research in published, manuscript, and oral history sources.

[10] See G. A. Tokady (Tokaty-Tokaev) in Emme, *History of Rocket Technology*, 271–84. General works on the Soviet space program include Martin Caidin, *Red Star in Space* (n.p., Crowell-Collier Press, 1963), an alarmist tract from the space race; Nicholas Daniloff, *The Kremlin and the Cosmos* (New York, 1972), a well-researched and balanced popular history; James Oberg, *Red Star in Orbit* (New York, 1981), a bold attempt to penetrate official secrecy and disinformation based on a lifetime of space "Kremlinology"; Evgeny Riabchikov, *Russians in Space*, trans. Guy Daniels (New York, 1971), a glorified account by the Novosti Press Agency, but containing new information; Charles S. Sheldon II, *U.S. and Soviet Progress in Space: Summary Data through 1973 and a Forward Look* (Washington, 1974), a source book based on the meticulous data-gathering of the (now deceased) expert of the Congressional Research Service; William Shelton, *Soviet Space Exploration: The First Decade* (New York, 1968), a mission and hardware summary; G. A. Skuridin, ed., *Mastery of Outer Space in the U.S.S.R., 1957–1967* (Washington, 1975), a NSF-NASA collection of Tass releases, Peter L. Smolders, *Soviets in Space*, trans. Marion Powell (New York, 1973), an "objective" narrative by a Dutchman; Michael Stoiko, *Soviet Rocketry: Past, Present, and Future* (New York, 1970), a standard survey; and Leonid Vladimirov, *The Russian Space Bluff* (London, 1971), an intriguing exposé by an emigre who has claimed that early Soviet space spectaculars, ordered by Khrushchev for political propaganda and executed only thanks to Korolev's genius, concealed the true inferiority of Soviet high technology. On Soviet nuclear policy, see Arnold Kramish, *Atomic Energy in the Soviet Union* (Stanford, 1960); and David Holloway, "Entering the Nuclear Arms Race: The Soviet Decision to Build the Atomic Bomb, 1939–45," International Security Studies Program, Woodrow Wilson International Center for Scholars, July 1979.

The First World War never ended in Russia. There alone the methods of state mobilization of scientific and technical talent pioneered in the first total war became a centerpiece of peacetime policy. Research and development, centralized and liberally funded, amounted to a virtual "second party program," as Lenin said upon inaugurating the Gosplan in 1920. Technological research was the major tool in the drive to industrialize, to overtake the West, and to prove the superiority of socialism. Spaceflight itself, aside from its military uses, appealed to Lenin[11] and, after 1933, to the Politburo, which began to organize and fund rocket research about the same time the German army absorbed its native rocketeers. The nature of the Bolshevik seizure of power and its Communist ideology inevitably placed a premium on the rapid creation of advanced technology as a symbol of the regime's legitimacy. While ignoring the purges of the 1930s Soviet media exalted the feats of record-breaking aviators—Stalin's Eagles—as indicative of the "New Soviet Man" and his soaring technology. As late as 1941, meanwhile, Soviet rocketeers were still the theoretical equals of their German counterparts at Peenemünde. But, while the war accelerated German rocketry, it diverted Soviet efforts for the duration. The capture of V-2 production facilities in 1945 afforded Soviet engineers the rapid practical experience they had been denied, but it by no means created their rocket program. An assault on the heavens remained uniquely suited to the Communist scientific conception of the purposeful, self-confident conquest of nature. When wedded to their military requirements after the war, the inherent Soviet interest in spaceflight made Sputnik only a matter of time.[12]

Certain other characteristics of the Soviet regime undoubtedly impeded the advance of rocket technology. The brilliant chief designer of Soviet spacecraft, Sergei Korolev, and the leading expert on fuels and gas dynamics, Valentin Glushko, spent up to eight years in *sharagas*, prison design bureaus, during the purges after 1937. Countless other technicians had their careers diverted or cut short by Stalinist terror. But the familiar defects of Soviet science—political interference, terror, incompetence in high places, and secrecy—affected high-priority, military-related research far less than that in civilian spheres. Kendall E. Bailes's excellent study of Soviet technology before 1941 lists the salient features of research and development: tension between borrowing abroad and pushing native creativity; lack of internal competitive stimuli; inhibition caused by state terror; resistance to creation of a privileged class resulting from professionalization of research; shortage of skilled workers; traditional Russian preference for pure over applied science; isolation of research and development from production; and the tendency to place technical considerations over economic efficiency.[13] Added to the inherited backwardness of the Russian economy, these features of the Communist system suggest that the precocious leap into space was an anomaly. But military technology was a special case in every respect. It enjoyed a

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[11] Daniloff, *The Kremlin and the Cosmos*, 22.

[12] This thesis is discussed in more detail in Chapter 1, "The Genesis of Sputnik," of my book in preparation, a political history of the first decade of space technology.

[13] Bailes, *Technology and Society under Lenin and Stalin: Origins of the Soviet Technical Intelligentsia, 1917–1941* (Princeton, 1978), 341–42.

priority of talent, funds, and materiel. Close political supervision, harmful in other sectors, aided strategic technology by eliminating bottlenecks. Most of the negative characteristics listed by Bailes did not apply to rocketry, while the regime's political need to demonstrate the military and technological superiority of the Socialist Fatherland was a strong fillip. Given the native Russian talent, the assist (though minor) provided by Helmut Gröttrup's residual German team, and the full support of a peacetime command economy, the Soviet leap into space becomes less mysterious.[14] What still remains to be uncovered, however, is the relationship between high-technology industries (many of which must be integrated in rocketry) and the sophistication of an economy as a whole. The debate over the role, or indeed the origin, of "leading sectors" in the English Industrial Revolution, for instance, has implications for the origins of the Space Age.

THE CENTRAL PROBLEM OF EARLY SPACE HISTORY lies in assessing the worldwide impact of *Sputnik I*.[15] The Soviets successfully tested an ICBM in August 1957, but it was the subsequent launching of the first satellite on the shoulders of that great rocket that upset the preconceptions of Americans, Europeans, and Third World elites. How could the United States, on whose superiority Free World strategies depended, have lost the race into space? The post-Sputnik panic, sustained by a veritable "media riot," yielded two contradictory sets of explanations. Senator Lyndon B. Johnson's Senate Armed Services Subcommittee on Preparedness publicized specific explanations based on Republican mismanagement: interservice rivalry, the antipathy to missiles of the "big bomber boys," and Dwight David Eisenhower's stringent budget ceilings all contributed to the Pentagon's "missile mess."[16] In the country at large, pundits, politicians, and

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[14] See Bailes, *Technology and Society under Lenin and Stalin*, esp chaps. 8–9, Vladimirov, however, regarded the space program as a Russian triumph achieved in spite of the Communist rulers; *The Russian Space Bluff*, 164–74. On science in the Soviet Union, also see D. Joravsky, *Soviet Marxism and Natural Science, 1917–1932* (New York, 1961); Loren R. Graham, *The Soviet Academy of Sciences and the Communist Party, 1927–1932* (Princeton, 1967); Mose L. Harvey *et al.*, *Science and Technology as an Instrument of Soviet Policy* (Miami, 1972); and Zhores Medvedev, *Soviet Science* (New York, 1978). The importance of 1932 lay in the "Gleichschaltung" of the Academy of Sciences by the Communist party and the end of independent organized research in the Soviet Union.

[15] On war as a stimulant to technological change, compare John U. Nef, *War and Human Progress* (Cambridge, Mass., 1950), and Walt W. Rostow, "War and Economic Change: The British Experience," in his *The Process of Economic Growth* (2d edn., Oxford, 1960), 144–67. Rostow has argued for a small impact of war on industrialization. For important correctives, see Samuel E. Finer, "State- and Nation-Building in Europe. The Role of the Military," in Charles Tilly, ed., *The Formation of National States in Western Europe* (Princeton, 1975), 84–163; and William H. McNeill, *The Pursuit of Power: Technology, Armed Forces, and Society since A D. 1000* (in press). On international rivalry and the rapid development of space technology, see William Schauer, *The Politics of Space: A Comparison of the Soviet and American Space Programs* (New York, 1976); and Alain Dupas, *La Lutte pour l'espace* (Paris, 1977). The former is comprehensive but indifferently researched; the latter covers the same ground but suffers from a confessed antisuperpower perspective.

[16] The most thorough research to date is in Edmund Beard, *Developing the ICBM. A Study in Bureaucratic Politics* (New York, 1976). Also see Michael H. Armacost, *The Politics of Weapons Innovation. The Thor-Jupiter Controversy* (New York, 1969); Edgar M. Bottome, *The Missile Gap: A Study in the Formulation of Military and Political Policy* (Cranberry, N.J., 1971), J. L. Chapman, *Atlas: The Story of a Missile* (New York, 1960); and Herbert York, *Race to Oblivion: A Participant's View of the Arms Race* (New York, 1970). Contemporary critiques from irate generals include James Gavin, *War and Peace in the Space Age* (New York, 1958); John B. Medaris, *Countdown for Decision* (New York, 1960), and Maxwell Taylor, *The Uncertain Trumpet* (New York, 1959).

special pleaders portrayed Sputnik as a symbol of a general American malaise: flabby education, denigration of "egghead" scientists, complacency, and consumerism demanded a national soul-searching. LIFE magazine "argued the case for being panicky," and Bernard Baruch prophesied, "If America ever crashes, it will be in a two-tone convertible." But historians must avoid reading back into the 1940s and 1950s the assumptions of the Space Age itself. The Truman administration had cancelled the first satellite and ICBM programs begun in 1945 by the Naval Research Laboratory and the Air Force, because no cost-effective mission for large rockets existed until the building of compact, light hydrogen bombs after 1954. Even then, Nelson Rockefeller was almost alone in warning that the prestige value of the first satellite "makes this a race that we cannot afford to lose."[17] In those years Europe and East Asia were on the front lines of the Cold War, the Red Army and Communist subversion the main threats, the Strategic Air Command and the Central Intelligence Agency the requisite deterrents. A prestige race for "hearts and minds" in a barely emergent Third World in which preeminence in space was to play a major role was inconceivable to Eisenhower before *Sputnik I* and financially reckless thereafter.

Meanwhile, the impending Soviet missile capability, watched closely by the White House throughout the 1950s, suggested not panic but disarmament talks.[18] The Soviet "coming of age," with its implied threat to the United States, was an apt moment for international control of weapons threatening the entire planet. But far from altering forever the ebb and flow of rivalry and balance of power, the new technologies only reinforced political factors to stymie such control. The tempting utility of thermonuclear missile forces in surprise attack, the long lead times of complex missile and defense systems, the possibility of "technological surprise" for purposes of political blackmail, and the insurmountable problems of verification of disarmament—all weighed against a diplomatic formula for arms control.[19] The absence of diplomatic solutions was a boon to space technology, which would have encountered an ironic hurdle if "outer space missiles," as they were called, had been banned or severely controlled at the outset. Other strategic imperatives favored rapid development of space technology regardless of presidential will or world view. First, the simple fact that the Cold War pitted an open society against a closed one placed a premium on surreptitious surveillance techniques for the United States, whether an arms

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[17] On early American satellite proposals, see R. Cargill Hall, "Earth Satellites: A First Look by the U.S. Navy," paper presented at the Fourth History Symposium of the International Academy of Astronautics, held in October 1970; and RAND SM-11827, "Preliminary Design of an Experimental World-Circling Spaceship," May 2, 1946. Rockefeller's comments were attached to NSC 5520, "Satellite Program," May 20, 1955, Dwight David Eisenhower Library, Abilene, Kans.

[18] The American intelligence community estimated in January 1955 that the Soviet Union would have *operational* intercontinental ballistic missiles by 1963—1960 at the earliest; the estimates, though not far wrong, ignored the political impact of the earlier test rockets, such as the ones that launched the Sputniks. "Basic National Security Policy," January 7, 1955, Eisenhower Library, NSC 5501.

[19] Eisenhower had called for United Nations control of "outer space missiles" in January 1957 as well as "Open Skies" for monitoring disarmament in 1955, and he began negotiations for a nuclear test ban in 1958 See James Killian, *Sputnik, Scientists, and Eisenhower: A Memoir of the first Special Assistant to the President for Science and Technology* (Cambridge, Mass., 1977); and Robert A. Divine, *Blowing on the Wind: The Nuclear Test Ban Debate, 1954–1960* (London, 1978).

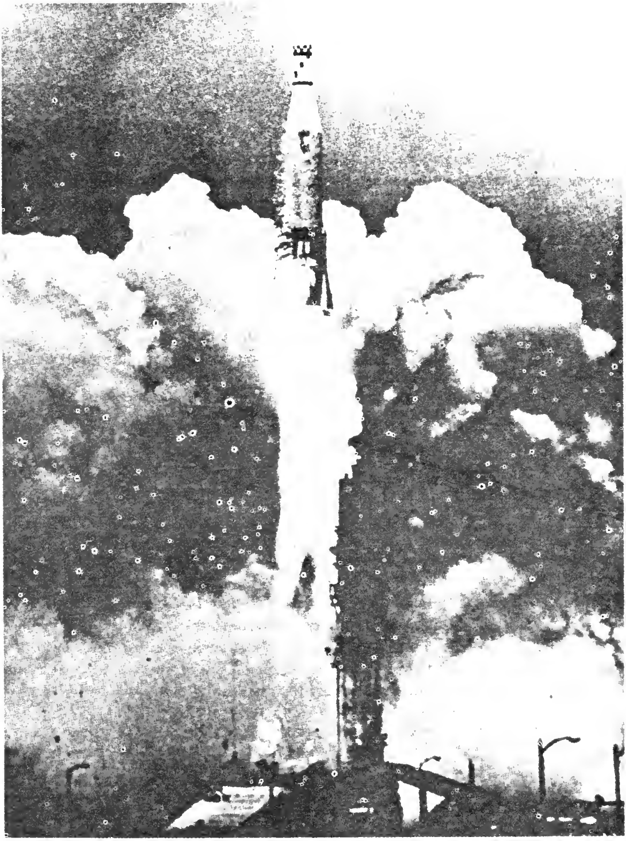

Figure 2 An impressive rocket launch from Cape Canaveral. The Air Force *Midas II*, aboard an Atlas-Agena rocket, was successfully placed in orbit on May 24, 1960—the first American surveillance ("spy") satellite. Official photograph, reproduced courtesy of the U.S. Air Force

race or arms control obtained. Contracts for the development of spy satellites had already been let in 1956, before *Sputnik I*, and there is evidence that concern for the establishment of the legality of satellite overflight (or "freedom of space") figured in Eisenhower's insistence on the civilian Vanguard satellite program and increased risk of losing the satellite "race."[20] A Soviet strategic capability made an American push for a sophisticated and invulnerable surveillance technique—that is, unlike the U-2—inevitable. Second, an ICBM force adequate for any strategy beyond the crudest "city-busting" deterrent required supporting satellite systems for geodesy, meteorology, targeting, infrared early warning, electronic ferreting, and surveillance.[21] The Soviet Union rebuffed American demarches for control of missile and space technology with their habitual demands for removal of foreign bases and "general and complete disarmament" without inspection, while the United States carefully promoted a ban on "aggressive" rather than "military" uses of space, in order to shelter its own military satellites. Thus, while the only objects in orbit—Sputniks, Explorers, and Vanguards—were still contributions to the International Geophysical Year, and hopeful globalists cried "Space for Peace," the militarization of space proceeded apace.[22]

The Soviets were as surprised as anyone by the impact of their Sputniks and Luniks. Their propaganda value contributed to great changes in the Soviet Union, including another jolt upward in research and development expenditures. Nikita Khrushchev initiated his own "New Look" defense policy by sacking the traditionalist war hero Marshal G. K. Zhukov just after *Sputnik I* and giving priority to the new strategic rocket forces.[23] In the United States, the "missile gap" furor helped elect John Kennedy to the presidency and kicked off an arms build-up on the American side (especially the thousand Minuteman ICBMs and

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[20] Donald Quarles, Deputy Secretary of Defense, in Cabinet Minutes, October 18, 1957, Eisenhower Library; and Dwight D. Eisenhower, *The White House Years*, volume 2: *Waging Peace, 1956–1961* (New York, 1965), 210.

[21] These simple facts about the passive militarization of space escaped the understanding of most journalists, politicians, and citizens for years. I found the most succinct early statement of the complementarity of long-range missiles and military satellite systems in Colonel Petkovsek's "L'Utilisation militaire des engins spatiaux," *Revue militaire générale* (July 1961), following the ideas of General Pierre Gaullois. Unlike American leaders, de Gaulle felt it advantageous to popularize, not downplay, the military space effort.

[22] American policy for outer space, including tactics for international legal protection of military satellites, was codified in NSC 5841/1, "Preliminary US Policy on Outer Space," August 18, 1958, and NSC 5918, "US Policy on Outer Space," December 17, 1959. On the politics of "spy satellites," see Gerald M. Steinberg, "The Legitimization of Reconnaisance Satellites: An Example of Informal Arms Control" (Ph.D. dissertation, Cornell University, 1981); and see Philip Klass, *Secret Sentries in Space* (New York, 1971). John Taylor and David Monday's *Spies in the Sky* (New York, 1973) only concerns air-breathing spy planes. Surveys of military space developments include Eldon W. Downs, *The U.S. Air Force in Space* (New York, 1966); Michael N. Golovine, *Conflict in Space: A Pattern of War in a New Dimension* (London, 1962); Robert Salkeld, *War and Space* (Englewood Cliffs, N.J., 1970); and Bhupendra M. Jasani, *Space—Battlefield of the Future?* (Stockholm, 1978). Military space systems can only increase in importance as the United States and Soviet Union move toward operational antisatellite weapons and possibly space-based lasers.

[23] See Herbert S. Dinerstein, *War and the Soviet Union: Nuclear Weapons and the Revolution in Soviet Military and Political Thinking* (New York, 1962); Marshal Sokolovskii *et al.*, *Soviet Military Strategy* ("Voennaia Strategiia"), RAND R-416-PR (1963); Roman Kolkowicz, *The Soviet Military and the Communist Party* (Princeton, 1967); and *The Impact of Technology on the Soviet Military: A Challenge to Traditional Military Professionalism*, RAND RM-4198-PR (1964). On early debate over the military uses of space, see Herbert L. Sawyer, "The Soviet Space Controversy, 1961 to 1963" (Ph.D. dissertation, Fletcher School of Law and Diplomacy, 1969).

Polaris submarines) that created a real missile gap in the Soviet Union and, hence, the effort to recoup through placing medium-range missiles in Cuba. Following the October 1962 Cuban crisis, the two superpowers moved quickly to a Partial Test Ban Treaty, after which the Arms Control and Disarmament Agency revived hopes for a freeze on missile technology before antiballistic missiles, multiple independently targeted re-entry vehicles (MIRVs), increased accuracy, and other "improvements" destabilized the balance of terror. NASA reported with alarm that fully eleven of fourteen anticipated missile improvements the arms controllers hoped to ban were important or vital to the exploration and use of outer space. Control of weapons research (as opposed to deployment) would have strangled space programs in their cradles![24]

The problem of technological change for arms control is not merely one of preventing the military application of new technologies; rather, it often lies in the fact that operational systems for civilian and military use are virtually identical. Nevertheless, there was great hope in the early years of space technology that international agreements might preempt militarization of space and otherwise establish international law for behavior in space. The arcane field of space law burgeoned to promote and interpret a number of limited agreements of space diplomacy (United Nations Outer Space Treaty of 1967, conventions on spacecraft registration, liability, astronaut rescue, communications satellites and radio frequencies, and pending treaties on direct broadcast satellites, remote sensing of the earth, and the exploitation of the moon).[25] The two early schools of space law, the natural and the positivist, debated the wisdom of establishing codes of behavior a priori for activities in space, as opposed to letting space law, like common law on earth, evolve according to patterns of use and interest.[26] The debate hardly seemed an idle one as scholars and statesmen groped for ways to avoid a repetition of the failure to regulate the use of atomic energy after 1945. But technological revolution, as opposed to technology per se, renders law and regulation continually obsolete. International legal commit-

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[24] This suggestion is derived from research in NASA, ACDA, and other materials. Heretofore, space arms control has consisted of the restrictions in the Limited Nuclear Test Ban Treaty, the Outer Space Treaty, and the ABM (SALT-1) Treaty. Signatories have agreed to prohibit nuclear explosions or deployment of weapons of mass destruction in outer space and any interference with each other's "national means of verification" (spy satellites). See Schauer, *The Politics of Space*, chap. 9; Dupas, *Lutte pour l'espace*, chap. 6; Alton Frye, *Space Arms Control: Trends, Concepts, Prospects*, RAND P-2873 (1964); and Walter C. Clemens, *Outer Space and Arms Control* (Cambridge, Mass., 1966).

[25] For useful guides to the literature, see Irvin L. White, *Law and Politics in Outer Space: A Bibliography* (Tucson, 1972); and Kuo Lee Li, *World Wide Space Law Bibliography* (Toronto, 1978). Also see the *Yearbooks of the Institute of Air and Space Law*, McGill University; and United States Senate, Committee on Aeronautical and Space Sciences, *Space Law: Selected Basic Documents* (Washington, 1976).

[26] Early classics on space law include the "positivist" Myres S. McDougal's *Law and Public Order in Space* (New Haven, 1963) and the "naturalist" Andrew J. Haley's *Space Law and Government* (New York, 1963). Another seminal work surveys historical examples of international and nonterritorial legal regimes; see Philip C. Jessup and Howard J. Taubenfeld, *Controls for Outer Space and the Antarctic Analogy* (New York, 1959). Other leading expositions of theory for space law include John Cobb Cooper, *Explorations in Aerospace Law* (Montreal, 1968); Stephen Gorove, *Studies in Space Law: Its Challenges and Prospects* (The Hague, 1977); and C. Wilfred Jenks, *Space Law* (New York, 1965). For an Indian view that cites Third World perspectives, see S. Bhatt, *Legal Controls for Outer Space: Law, Freedom, and Responsibility* (New Delhi, 1973). On Soviet policy and jurisprudence for space, see A. S. Piradov, *International Space Law* (Santa Barbara, 1974); and F. G. Vasilevskaya, *Legal Problems of the Conquest of the Moon and Planets* (Santa Barbara, 1974).

tees move slowly; space technology very quickly. Hence, increasingly prolific technologies, far from engendering more complex laws, have revived the notion of law as principle—a "revolutionary" jurisprudence in which the spirit, not the letter, is of the essence.

The Space Treaty banned national claims on celestial bodies and the orbiting of weapons of mass destruction. It also established free access to space for all nonaggressive purposes. Otherwise, technological and geopolitical exigencies have suggested an essentially laissez faire regime for space. After initial Cold War skirmishing, American and Soviet leaders recognized a common interest in preventing undue United Nations constraints. American officials inside and outside the Pentagon expressed a thesis not unlike that of Sir Eyre Crowe's Foreign Office memorandum of 1907 *re* the German dreadnought challenge. Any nation, Crowe wrote, would prefer to rule the waves itself but, failing that, would rather Britain did so. Similarly, U.S. hegemony would safely uphold the freedom of space for all. Soviet literature on strategic doctrine suggests a different analogy (itself first proposed by Lyndon Johnson): as the Roman empire dominated the land by its road system, the British empire the seas, and the American empire the air, so now was outer space the decisive medium; whoever ruled it could dictate events on earth as well.[27] Neither superpower showed an interest in the kind of multilateral controls proposed at the United Nations. The only path toward detente in outer space was cooperation among sovereigns. As political scientist Don E. Kash noted in the 1960s, cooperation was a "God word, who could be against it?" Yet the sensitivity of the technology for national military and economic interests circumscribed the possibilities for cooperation among the United States, the Soviet Union, and the Europeans.[28] INTELSAT, the global consortium for communications satellites founded in 1963, suggested to some that a technological determinism might substitute for political will in forcing cooperation. By dint of cost and function, this and other economic satellite systems (for example, earth resources surveyors) required functional organizations transcending politics. But experience with international cooperation in space (or the deep sea bed) has not sustained the functionalist hypothesis. INTELSAT was a house of discord until American domination ended in 1971, and the international problem-solving that has occurred did not spill over into other arenas of diplomacy.[29]

The problems in INTELSAT were in part a phenomenon of uneven growth. True cooperation is impossible when one state has a monopoly of technological

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[27] Documents in the Lyndon B. Johnson Library reveal that Johnson borrowed this geopolitical synopsis from his aide George Reedy. On Soviet perceptions of the strategic significance of space, see Sawyer, "The Soviet Space Controversy"; and other works cited in note 23, above.

[28] On United States policy for space cooperation in the early years, see Arnold Frutkin (chief of NASA office for international affairs), *International Cooperation in Space* (Englewood Cliffs, N.J., 1965). United States Senate, Committee on Aeronautical and Space Sciences, *International Cooperation for Outer Space*, ed. Eilene Galloway (Washington, 1965). Early critics of American "conservatism" in cooperation include Leonard E. Schwartz, "When Is International Space Cooperation International?" *Bulletin of the Atomic Scientists* (June 1963), 12–18, and other articles; and Kash, *The Politics of Space Cooperation* (West Lafayette, Ind., 1967), 10.

[29] On INTELSAT, See Jonathon Galloway, *The Politics and Technology of Satellite Communications* (Lexington, Mass., 1972); Judith T. Kildow, *INTELSAT: Policy-Makers' Dilemma* (Lexington, Mass., 1973); and Michael Kinsley, *Outer Space and Inner Sanctums: Government, Business, and Satellite Communications* (New York, 1976).

know-how. But an equitable international division of labor is definable only in political terms. American corporations also proved to be something other than promoters of progress, seeking at times to inhibit exploitation of satellite technology that competed with their oceanic cables. Space applications in general have sparked vigorous European and Japanese rivalry with American space industries, as much for political as economic reasons. And, rather than joining a global communications network, the Soviets established their own INTERKOSMOS system for the Eastern Bloc countries. This, and perfunctory visits by guest cosmonauts to Salyut space stations, hardly constituted genuine sharing of technology. The Europeans, in turn, have had uneven success with their international space agencies.[30] Participants often viewed cooperative programs as a means of hastening national technological *independence*, as the French and Japanese cases illustrate.[31] Even as advanced technology united the world in some respects, the financial, military, and organizational demands of "big science" tended to reinforce the national state as the most efficient *agent* of technological change.

Given this history we may well ask why statesmen and pundits of the early Space Age expected the conquest of space to alter the traditional behavior of states. Perhaps the technological enthusiasm of the 1950s and 1960s had an element of self-justification. Hiroshima and the subsequent absorption of nuclear weapons into the international order were technological *faits accomplis*. But after *Sputnik I* statesmen again proved unable or unwilling to control the accelerating advance of technology; instead they groped for formulas in which technology itself would do the work of the human agency—that is, fashion prophylactics against its own misuse. They professed to see in space exploitation or mutual assured destruction or some other effluence of rocketry an integrative force that would solve its own political problems *en passant*. The evidence suggests rather that nothing in the technology necessarily drew countries together. The poor record of the Atoms for Peace program and later of the International Atomic Energy Agency understandably inclined the pivotal United States toward a conservative policy on space cooperation.[32] The Soviet Union has shown little interest in open sharing at all, and superpower cooperation—most notably, the 1975 Apollo-Soyuz rendezvous—has been the result, not the cause, of political detente.[33]

[30] The European Launch Development Organization (ELDO) and European Space Research Organization (ESRO), founded in the early 1960s to ensure a role for European governments and business in space, were models of how *not* to promote international research and development. Recently, the formation of the European Space Agency (1975) has given European space cooperation a new lease on life, but only by acting as an umbrella for nationally managed programs.

[31] Walter A. McDougall, "The Struggle for Space," *Wilson Quarterly*, 4 (1980): 66, 71–82. On European space programs, see note 56, below; and United States House of Representatives, Committee on Science and Technology, *World Wide Space Programs* (Washington, 1977).

[32] Frutkin, *International Cooperation in Space*, 28–35.

[33] Writers of the 1970s regarded the space race, like the Cold War, as a thing of the past, see, for instance, J. C. D. Blaine, *The End of an Era in Space Exploration: From Competition to Cooperation* (San Diego, 1976). Edward C. and Linda N. Ezell's *The Partnership: A History of the Apollo-Soyuz Test Project* (Washington, 1978) includes an excellent summary of the efforts to establish cooperation with the Soviet Union in space and of the technical difficulties of the joint manned mission. As an official history, it does not attempt to evaluate the charge that the ASTP was a "giveaway" of American expertise. Dodd L. Harvey and Linda Ciccoretti's *U.S.-Soviet Cooperation in Space* (Miami, 1974) is a thorough political history benefiting from access to the papers of NASA administrator James E. Webb.

"The horror of the twentieth century," wrote Norman Mailer, "was the size of each new event, and the paucity of its reverberation."[34] *Sputnik I* was truly the shot heard 'round the world, and its international effects were manifold; but it did not alter the nature of the international system. The national state remained supreme, cooperation remained a muted form of competition, and military rivalry incorporated the strategic canopy of orbital space. The international imperative stimulated the rapid development of space technology, but it was not in turn transformed by it. When President Johnson, for instance, sent to world heads of state in December 1968 the famous photograph from *Apollo 8* of the gorgeous blue earth rising beyond the rim of the moon,"There came a response from Hanoi, from Ho Chi Minh, thanking me." Surely, wrote Arthur C. Clarke, this was the best example "of the way space can put our present tribal squabbles in their true perspective."[35] Perhaps—but the war continued unabated.

DISCUSSING SCIENCE AND POLITICS, Bertrand de Jouvenel wrote of three ages of history: the age dominated by priests, that by lawyers, and that by scientists. The politics of the first age were based on divine revelation and a presumption of popular ignorance, and the politics of the second on "human scripture" and the presumption that "We the people" were capable of judging matters of common interest; the politics of the third age form an anomaly. *Demos* still has the responsibility for public decisions but has lost the competence to judge matters of science and technology. "This great age of science is, by way of corollary, an age of personal ignorance."[36] At some point in this century, advanced societies crossed the line into awareness of democratic incompetence. For the industrial West, Sputnik may have been that point. Did the perplexing, frightening, and apparently sudden appearance of space technology humble the West (and perhaps the Politburo) into a reappraisal of traditional management of power by politicians and interest groups? Is the Space Age a time in which control of public policy must fall by default to a technical elite? This prospect obsessed Mao-Tse-Tung as it had Stalin; it also came to trouble Eisenhower.

The apparent solution to Jouvenel's dilemma after Sputnik was to graft scientific advice onto the existing political corpus, as if science could inform policy without politics informing science. But "where knowledge is power, the pursuit of knowledge is clearly a political activity."[37] Throughout the 1960s scientists and political scientists discussed the relationship of science and government.[38] The considerable

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[34] Mailer, *Of a Fire on the Moon* (New York, 1969), 34.

[35] Clarke, *Report From Planet Three* (New York, 1972), 164–65.

[36] Jouvenel, "The Political Consequences of the Rise of Science," *Bulletin of the Atomic Scientists* (December 1963), 2–8.

[37] Howard J. Taubenfeld, ed., *Space and Society* (Dobbs Ferry, N.Y., 1964), 46. Illustrating the inability of voters to make technical judgments, Taubenfeld cited a straw poll that asked people what they demanded of federal spending for research and development. Three out of five answered "Don't know" or even "Don't understand what you mean."

[38] See especially Harvey Brooks, *The Government of Science* (Cambridge, Mass., 1968); Joseph S. Dupre and Sanford Lakoff, *Science and the Nation, Policy and Politics* (Englewood Cliffs, N.J., 1962); A. Hunter Dupree, *Science in the Federal Government* (Cambridge, Mass., 1957); Sanford Lakoff, *Knowledge and Power: Essays on*

role of the President's Science Advisory Committee in the organization of the National Aeronautics and Space Administration (NASA) has also been subject to historical treatment.[39] It was in these years when the ideal of "good government" informed by "good science" seems to have been best approximated, at least according to the memoirs of the first two presidential science advisors, James Killian and George Kistiakowsky.[40] Leaning on his scientists for support in the effort to quell overreaction to Sputnik, Eisenhower oversaw the establishment of a space policy that emphasized science and defense as opposed to engineering showmanship and prestige. But he had to struggle against military and congressional leaders, the aerospace industry, and the press, all of whom exaggerated Soviet capabilities to justify ever greater budgets for research and development. Despite his affection for "my scientists," who were "one of the few groups . . . in Washington who seemed to be there to help the country and not help themselves,"[41] Eisenhower left office fearful of the impact that a headlong technological race with the Soviets would have on American society. He warned against the acquisition of undue power and influence not only by the "military-industrial complex" but also by a "scientific-technological elite."

By the late 1960s, critics of American policies in technology and defense recalled that "Ike tried to warn us." It marked the advent of an Eisenhower revisionism that is still cresting. But a close reading of the Farewell Address reveals that Eisenhower saw the trends he deplored as inevitable, and that he had no remedy for them. In the late 1950s, he had already encountered the quandary of sharply conflicting scientific advice, as well as the need to overrule even unanimous scientific advice for political reasons. Scientists solidly opposed expensive space missions for prestige purposes, especially manned spaceflight. Yet Eisenhower transferred the manned space mission and the Von Braun rocket team to NASA and personally ordered accelerated development of the giant Saturn booster, for which no military or scientific mission existed. Although he backed scientific opposition to the proposed Apollo moon program, it was the cost that appalled him. He had reluctantly granted the need to compete for reasons of prestige.

Eisenhower's fears were confirmed under the succeeding administrations, but not perhaps in the way he expected. In the 1960s, science and technology penetrated numerous corners of government, while enthusiasm spread for technological fixes abroad (whether in military spending or developmental aid) and social engineering at home. Yet the influence of the scientists themselves faded. Why should the progressive and even technocratic administrations of Kennedy and Johnson have reduced the influence of scientific advisors even as they heavily subsidized the research community? Even NASA ceased to be an agency shaped

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Science and Government (New York, 1971); Ralph E. Lapp, *The New Priesthood* (New York, 1965); and Don K. Price, *The Scientific Estate* (Cambridge, Mass., 1965).

[39] See Richard Hirsch and Joseph Trento, *The National Aeronautics and Space Administration* (New York, 1973); Arthur L. Levine, *The Future of the U.S. Space Program* (New York, 1975); and Robert L. Rosholt, *The Administrative History of the NASA, 1958–1963* (Washington, 1966).

[40] Killian's *Sputniks, Scientists, and Eisenhower* is a memoir of great value. George Kistiakowsky's *A Scientist at the White House* is a diary graced by a long, excellent historical introduction by Charles S. Maier.

[41] Killian, *Sputniks, Scientists, and Eisenhower*, 241.

primarily by scientists and became, thanks to administrator James Webb and the Apollo mission, a juggernaut of the engineers and politicians.

The answer seems to lie once again in the process of technological evolution itself. If artificial—that is, institutionalized—stimulation of science and technology has become a fundamental source of national power, then the political leadership needs to guide the allocation of technical resources according to its version of the national interest. Resistance to a political imprimatur over the creation of new knowledge had complicated legislation for the Atomic Energy Commission and National Science Foundation. But a command economy in state-funded research and development is implicit as political leaders move from choosing social goals for new technology to choosing new technology for social (and political) goals. This is what Eisenhower feared, for that meant abandoning the concept of a free society, which develops naturally according to myriad choices on the local level, and replacing it with a central directorate, which charts the path of social progress and orders fabrication of techniques for traversing it. This transition had already occurred in Western Europe (not to mention in the Soviet Union, which was founded on the principle), but it occurred in the United States only in the 1960s—and the catalyst was the space program.

Eisenhower shaped American space policy, but program funding can tilt the balance of policy. Kennedy defined the character of the American space effort with his commitment of May 25, 1961, to go to the moon. Thanks to Apollo, the space program came to stress engineering over science, competition over cooperation, civilian over military management, and prestige over practical applications. This crucial decision, the first turning point in the history of manned space flight, has been examined by John Logsdon.[42] Why did we go to the moon? Why did $30 billion go into Apollo technology instead of other space projects or nonspace applications? The answer lies not in technology, nor even in the Cold War itself, which might also have dictated a space program centered on military or economic applications, but rather in the conjunction of the early Soviet space triumphs with the emergence of the neutralist Third World. The prestige race to the moon—against the Russians if they were game, against the end of the decade if they were not—followed hard on reverses in Laos and the Congo, on the Bay of Pigs, and on the flight of Yuri Gagarin, first man in space. Vice-President Johnson condensed the wisdom of the new administration: "Failure to master space means being second best in every aspect, in the crucial area of our Cold War world. In the eyes of the world first in space means first, period; second in space is second in everything."[43] So space technology was drafted, in the first months of the New Frontier, into the cause of national prestige.

Apollo was a magnificent achievement, but there is irony in the fact that observers worldwide consider it one of the "good" products of the maniacal 1960s.

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[42] Logsdon, *The Decision to Go to the Moon: Project Apollo and the National Interest* (Chicago, 1970). Also see Vernon Van Dyke, *Pride and Power: The Rationale of the Space Program* (Urbana, Ill., 1964). On the Apollo program itself, see the NASA histories: Courtney G. Brooks *et al.*, *Chariots for Apollo* (Washington, 1979); Roger E. Bilstein, *The Stages to Saturn* (Washington, 1980); and Charles D. Benson and William B. Flaherty, *Moonport: A History of Apollo Launch Facilities and Operations* (Washington, 1978).

[43] Johnson, as quoted in Hirsch and Trento, *The National Aeronautics and Space Administration*, 107.

"They Went Thataway"

Figure 3: "They Went Thataway," by Herblock. The Russian challenge and the necessary U.S. response are implicit in this cartoon, which appeared in the *Washington Post* on December 30, 1960. Reproduced courtesy of Herblock and Simon and Schuster from *Straight Herblock* (New York, 1964).

Figure 4 · "Fill 'Er Up—I'm in a Race," by Herblock. This cartoon of May 24, 1961, preceded by only one day President John F. Kennedy's commitment to go to the moon by the end of the decade. Reproduced courtesy of the author and the *Washington Post.*

Contemporary critics on the Left and the Right considered such diversion of research and development to political goals of uncertain importance a misuse of the tool of state-induced technological change. By 1963–64 left-liberal critics denounced Apollo as wasteful given problems of racism and poverty,[44] while Barry Goldwater attacked the squandering of billions to impress Third World leaders. He bade America to remain secure in the intangible appeal of liberty and redirect the space program toward military and scientific applications.[45] In fact, the moon program was a synthesis of the same liberal mentality that conceived the Great Society at home and the same conservative one that supported containment of Soviet influence abroad. But in neither case did scientists play a significant role in policy.

Since 1957 governments have neither resolved the anomaly of democratic incompetence in technology nor abandoned the rituals of democracy. Instead, they continue to choose scientific advice just as voters choose the politicians, on the basis of promises, persuasiveness, personality, and their own preconceptions. Among the Edward Tellers, Wernher von Brauns, and Barry Commoners, whom do you trust? The Space Age introduced science and technology to the political arena, but it did not transform politics or usher the scientists to power.

FOR THE UNITED STATES, the early Space Age was a critical period of adjustment to the prospect of Soviet nuclear parity, to the emergence of a surly and disobedient Third World, and to the apparition of command technology as a genie in the service of government. Even if the Apollo program reflected the failure of science to reshape politics, it nonetheless unleashed hothouse technological change on an unprecedented scale. Apollo is the best symbol of a revolution in *governmental* expectations that occurred in the decade after 1957, and the roar of the rockets was its tocsin. The revolution in research and development dating from Sputnik can be termed, with only slight exaggeration, "Daedalus Unbound," and here is the institutional and behavioral change that defines the Space Age in history.

The only analyst who has treated the early space program as an integral phenomenon rather than "just an expression" of this or that tendency in American life or the Cold War is Bruce Mazlish in his introduction to *The Railroad and the Space Program: An Exploration in Historical Analogy* (1965). Mazlish characterized the space program as a "complex social invention" that, like the railroads of the nineteenth century, was at once technological, economic, political, sociological, and

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[44] See especially Amitai Etzioni, *The Moon Doggle* (Garden City, N.Y., 1964); and Edwin Diamond, *The Rise and Fall of the Space Age* (Garden City, N.Y., 1964). Also see Harold W. Babbit, "Priorities, Frugality, and the Space Race: A Preliminary Assessment of Congressional Criticism of Project Apollo," NASA HHN-41 (September 1964); William L. Crum, *Lunar Lunacy and Other Commentaries* (Philadelphia, 1965); Lester M. Hirsch, ed., *Man and Space* (New York, 1966); Erlend A. Kennan and Edmund H. Harvey, Jr., *Mission to the Moon: A Critical Examination of NASA and the Space Program* (New York, 1969); and John V. Moeser, *The Space Program and the Urban Problem* (Washington, 1969).

[45] Apollo did have indirect military benefits. Fear of technological surprise was a major impetus for McNamara's and Rusk's support of the moon program. It forged the "building blocks" of space mastery without the provocation of a large Air Force program.

intellectual.[46] If a major new technology or group of technologies catches on, its acculturation can involve pervasive social change. The space program, like the railroads, came to alter law, economic organization, and the fundamental relationship of the public and private sectors to make room for its growth. Like the railroad, the space program was also a cultural expression and influenced not only institutions but also intellectual and artistic sensibility.[47] In short, society was obliged to accommodate the new technological system, and the result was a social invention.[48]

Can space programs be understood in this way, even though they apparently touch few people directly, involve a small percentage of gross national products, and seem absent from popular consciousness?[49] In fact, space technology is at the state of maturity that railroads had achieved in roughly 1860 or that radio had in the 1920s. Most Americans, pursuing their immediate goals in light of immediate experience, could not imagine the revolution abornin'. Yet the patterns of social, economic, and political response to the spread of railroads, or radio, were shaped in their early decades. The railroads in particular have come to stand as the primary symbol of industrial take-off and the transition from agricultural to industrial society. How can we describe the postindustrial society associated with the Space Age? Zbigniew Brzezinski coined the term "technetronic" for a "society that is shaped culturally, psychologically, socially, and economically by the impact of technology and electronics, particularly computers and communications."[50] This neologism is problematical. Every society is shaped to some significant degree by its technology and method of communications, and few would argue that our society is shaped to a quantitatively greater degree, or in a qualitatively different way, than it was during the industrial early twentieth or agricultural eighteenth century. But technetronics do not aid us in understanding the origins or causal connections among the social phenomena of the new age. The familiar word "technocratic" will do instead.

What seems to have happened in the wake of Sputnik was the triumph of a technocratic mentality in the United States that extended not only to military spending, science, and space, but also to foreign aid, education, welfare, medical care, urban renewal, and more. Now, "technocracy" is a familiar word in modern history, meaning the management of society by technical experts. As such it is an ideal type, for such a society has never existed, not even in the Communist world. Despite the post-Sputnik boom in scientific advice, politicians and other influential groups manage society no matter how compelling the occasional technical con-

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[46] Mazlish, ed., *The Railroad and the Space Program: An Exploration in Historical Analogy* (Cambridge, Mass., 1965), Introduction and 1–52, esp. 11–14.

[47] Leo Marx, "The Impact of the Railroad on the American Imagination, as a Possible Comparison for the Space Impact," in Mazlish, *The Railroad and the Space Program*, 202–16.

[48] Mazlish posited some generalities for historical inquiry: all social inventions are part of a complex in origin and result; none is uniquely determining in its impact; all aid some areas of development while blighting others; all develop in stages; all reflect a national "style." Mazlish, *The Railroad and the Space Program*, 34–35.

[49] American spending on space has fluctuated between 0.3 and 1.0 percent of gross national product; Soviet spending is estimated at a steady 1.5 to 2.0 percent, European spending less than 0.1 percent.

[50] Brzezinski, *Between Two Ages: America's Role in the Technetronic Age* (New York, 1970), 9–14.

straints. Let us, therefore, define technocracy as follows: the institutionalization of technological change for state purposes, involving the organization and funding by the state of a national infrastructure for the acceleration of technological change on the assumption that its own foreign and domestic goals will be served by the products of such change.

The transition in the United States to state-supported research and development for the continuous stimulation of technological revolution—this is the essence of the saltation that Sputnik triggered. The evolution of command technology is discernible in isolated cases dating from the eighteenth century. It became a regular feature of procurement in the British navy and German army in the 1860s, and it was vastly increased by all belligerents in the world wars.[51] But Sputnik marked the discontinuity leading to full-fledged technocracy. In the United States, the Progressive era first provided a technocratic ideology, and World War II gave us the model of government-industry-science collaboration; postwar challenges to the passive role of government, the prestige of social science and Keynesian economics, and the American technique of softening social and ideological discord through policies expanding growth and opportunity all prepared the mix. Sputnik was the spark. By suggesting an imminent military stalemate between the superpowers and at the same time lending credibility to claims that Communism was a superior system for rapid national development, Sputnik changed the nature of the Cold War. It made it "total"—a global conflict in which science, education, housing, and medical care were as much measures of Cold War standing as human rights or bombers. Science was first: the creation of NASA, a deliberately civilian agency for purposes of propaganda, then the explosive growth of the National Science Foundation, and the National Defense Education Act. Apollo came next—it tripled NASA's budget, channeled an extra $30 billion into the aerospace industry and universities, and represented the largest open-ended peacetime commitment by Congress in history. The shock of Sputnik and Soviet claims to social superiority then helped to break down longstanding resistance by Republicans and Southern Democrats to federal involvement in education generally as well as other social arenas and began the greatest flood-tide of legislation in American history, a tide that, as Lyndon Johnson recalled, "all began with space."[52]

By the mid-1960s the space program helped convince investment-model economists and their colleagues in think tanks, in corporate boardrooms, and on Wall Street that heavy and systematic investment in technological and "human" resources was not a necessary evil but, rather, the key to continuous growth and, hence, social stability. Large social, military, and space expenditures would be covered by the new wealth created through new technology, thanks to the phenomenon of transfer—from point sectors (like aerospace and computers) to other sectors and from the American economy to developing economies. Forcing more rapid growth from an already superior scientific and industrial base, the

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[51] See McNeill, *The Pursuit of Power*, chap. 8.

[52] The phrase "total Cold War" dates from a speech by Vice President Nixon in San Francisco, December 6, 1957 But especially see Eisenhower's State of the Union Address, January 9, 1958 Johnson's remark was made in an interview with Walter Cronkite, "Man on the Moon: The Epic Journey of Apollo 11," July 21, 1969.

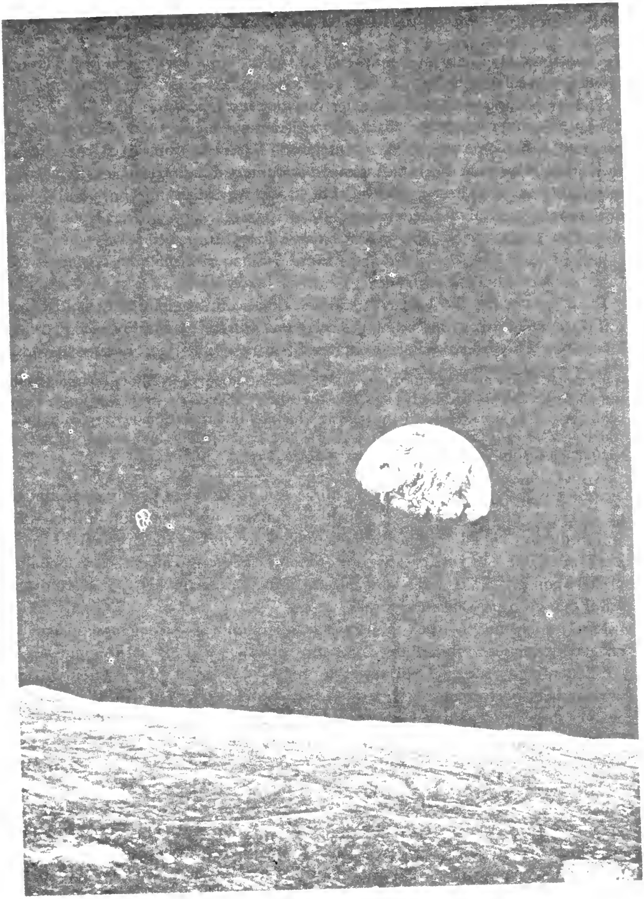

Figure 5 "Earthrise," the famous shot of the earth beyond the rim of the moon, taken by the *Apollo 8* astronauts, Christmas, 1968. Photograph reproduced courtesy of the National Aeronautics and Space Administration, Washington, D.C.

Technological Republic must outfight and outshine the Ideological Republics of Moscow and Peking.

The symbol and vanguard of the technocratic movement was NASA—efficient, daring, scientific, surely the locus of meritocracy. But the scale of the Apollo program called for more, for what James E. Webb dubbed a "managerial revolution." Not only did NASA pioneer streamlined managerial techniques for integrating its own diverse projects, but it also formalized the links within the institutional triad of the federal agency, corporation, and university on which American society rests. This government-industry-university team, consciously cultivated by NASA, mobilized the nation's human and material resources for "war" on the technological frontier.[53]

For a time in the extravagant 1960s the American imagination exhibited that complacent exuberance attending the belief that one has magic, if not the gods, on one's side. "The technological revolution that is now fully upon us," wrote Webb,

> is the most decisive event of our times. . . . Unless a nation purposefully and systematically stimulates its technological advances into the sinews of the system, it will surely drop behind. . . . The great issue of this age is whether the United States can, within the framework of existing institutions, organize the development and use of advanced technologies more effectively than can the Soviet Union.

Success would stem from "our almost miraculous capacity to use existing technology to create new technology."[54] Such encomiums were common. Even Adlai Stevenson proclaimed, "Science and technology are making the problems of today irrelevant in the long run, because our economy can grow to meet each new charge placed upon it. . . . This is the basic miracle of modern technology. . . . It is a magic wand that gives us what we desire!"[55]

Miracles and magic—such faith helped to sustain a sixfold increase in federal obligations for research and development from 1955 to 1965. By the mid-1960s, the federal government had come to fund 80 percent of all research and development performed in the United States, and 90 percent of that under the aegis of the Department of Defense, NASA, and the Atomic Energy Commission. Organized change in the United States had been virtually nationalized. This saltation in the role of the state in creating new knowledge and power was itself transmitted abroad through the international imperative to accelerate technological, and thus economic and social, change elsewhere. Despite the vast lead and greater resources of the United States and Soviet Union, virtually every other major power on earth struggled to duplicate the rudiments of space technology and foster advanced aerospace industries. Public justifications of the vigorous space program of France or Europe as a whole, or of China or Japan, rested on the maxim that security and economic growth in the postmodern age of scientific-technological

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[53] The science of managing large systems in fields promoting rapid innovation owes much to the experience of the Department of Defense and NASA in developing missile technology. General Bernard Schriever, chief of Air Force missile programs in the 1950s, and Kennedy's appointments to head NASA and the Pentagon, James Webb and Robert McNamara, were instrumental.

[54] Webb, *Space Age Management: The Large-Scale Approach* (New York, 1969), chap. 2.

[55] Stevenson, "Science and Technology in the Political Arena," in Xerox Corporation, *Science and Society: A Symposium* (New York, 1965)

revolution required that a state remain in the forefront or become hopelessly dependent and underdeveloped in the near future.[56] Gaullist France reacted to Sputnik by declaring the American nuclear deterrent unreliable and accelerating the drive for French nuclear and missile capacity. Soviet refusal to share missile technology aggravated the Sino-Soviet split and sparked a similar drive into space in China.[57] But the universal impulse to involvement in space was economic: the apparent technological gap that had opened by the mid-1960s precisely because it seemed the United States had discovered the "keys to power" in state-funded research and development in critical point sectors, which sustained technological revolution throughout the economy. *The Economist* wrote, "Prosperity depends on investment, investment on technology, and technology on science; ergo, prosperity depends on science."[58] Charles de Gaulle exhorted France "to invest constantly, to push relentlessly our scientific and technological research in order to avoid sinking into a bitter mediocrity . . . ."[59] French spending for research and development quadrupled during the first five years of the Fifth Republic, and France continued to lead Europe toward aerospace independence in order to overcome the technology gap, "brain drain," and "industrial helotry."[60]

How does a society like that in the United States, or a smaller and less flexible one like that of France, absorb the effects of massive government expenditure for the ongoing creation of new technology? Most historians, whether they view new technology as a first cause or as a random joker in an otherwise ordered deck of historical cards, assume technology to be an independent stimulus of socioeconomic change, which in turn conditions (and usually disrupts) patterns of politics and diplomacy. This is arguable to some degree. But, if complex new technologies are sponsored by the state itself, then the state, whatever its ideology, becomes "revolutionary." We would thus expect regimes to attempt to "socialize" new systems in such a way as to reinforce—not weaken—themselves, at least in the short run. This is the dilemma of the state obliged by foreign competition to foment technical change at home: not only to accommodate society to new technology but also to reconcile the two. Not surprisingly, de Gaulle promised to restore French

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[56] On the European space agencies ELDO and ESRO in the 1960s, see Orio Giarini, *L'Europe et l'espace* (Lausanne, 1968); Jacques Tassin, *Vers l'Europe spatiale* (Paris, 1970); and Georges L. Thomson, *La Politique spatiale de l'Europe*, 2 vols. (Dijon, 1976). A model for study of social and economic effects of state stimulation of technological change is Robert Gilpin's *France in the Age of the Scientific State* (Princeton, 1968).

[57] Even under similar international pressures cultures historically responded to new technologies in different ways. See Eugene Ferguson, "Toward a Discipline of the History of Technology," *Technology and Culture*, 15 (1974): 13–30. But in the 1980s, when China, Japan, and India are scrambling to replicate the nuclear and space capabilities of the Western powers, cultural differentiation in adoption and adaptation of new technologies may be eroding. Post-Mao China calls for only "Four Modernizations," implying the intent to *hold constant* other features of Chinese civilization. How successful is this likely to be if the international imperative in the current technological age is becoming increasingly uniform in its impact?

[58] *The Economist*, October 5, 1963. Robert McNamara and others insisted that the real "gap" was in management, not in technology—that the systems approach, cost accounting, and computers sufficed to explain the advantage of the United States. See Roger Williams, *European Technology: The Politics of Collaboration* (London, 1973), 21–33.

[59] Charles de Gaulle, *Addresses to the French Nation* (1964).

[60] Jean-Jacques Servan-Schreiber best articulated French reaction to the technological gap in his *Le Défi américain* (Paris, 1968). Also see Pierre Vellas, *L'Europe face à la révolution technologique américaine* (Paris, 1969). Britain's confused reaction to the revolution in research and development is treated in Norman J. Vig, *Science and Technology in British Politics* (Oxford, 1968).

grandeur through explosive technological advance, but "without France ceasing to be France."[61] And Webb promised miracles, but only through *existing institutions.*

Gaullist technocracy, therefore, was also a tool of domestic politics. By offering a captivating vision of the French future "in the year 2000," technocracy served to legitimate a Fifth Republic that had, after all, decreed the end of Imperial France and Socialist France and soon forestalled Atlanticist France and European France as well. Can a similar hypothesis be applied to the United States? This problem invites research: the emergence of a "revolutionary centrism" offering technological, not ideological or social, change to play midwife to a future as secure and bountiful, but less threatening, than that offered by either a socialist Left or a laissez faire Right.

The technocratic promise, of course, was not fulfilled, in part because its implicit dynamics were those of a perpetual motion machine. The "future" of the Great Society, like the final attainment of Communism in the Soviet bloc, never arrived. But material change has occurred on a massive scale. How can we measure the effects of Space Age technology? Econometrician Mary Holman analyzed the NASA budget and its impact on given localities (often very great), on economic growth and stabilization in the aerospace industry (positive), on the tendency toward centralization and monopoly in the industry (problematic), and as a stimulus to general economic growth (ineffective).[62] Unfortunately, the best efforts of NASA itself ("more than any other federal agency NASA has tried to understand its social and economic impact"), the Organization for Economic Cooperation and Development, the National Science Foundation, and academic economists have been insufficient to measure the impact of spending on science and technology.[63] The economic cost of research in one sector depends on guesses as to the likely alternative employment of scientific labor and capital as determined by the state or marketplace. There is also no accepted set of values for spending directed toward no specific economic goal. What precisely is the state trying to achieve through federal scholarships, lunar voyages, or oceanography satellites? But one chore historians can undertake is to trace changes in the value-set of the "official mind" according to the educational, scientific, and technical projects that receive the blessing of public funding.

Estimates of the economic fallout from space spending still range from the minute to the cosmic. Critics described the space race as ceremonial waste,[64] and Holman has cited studies promising phenomenal benefit to cost ratios from earth resources satellites (for example, 128:1 in increased rice production and 296:1 in malaria control). And if we assume that space technology never existed (as Robert Fogel assumed away American railroad technology), the cost of alternate systems to perform given jobs is generally many times higher. Of course, mankind may get on

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[61] De Gaulle, Speech of February 5, 1962, as quoted in Gilpin, *France in the Age of the Scientific State*, 3.

[62] Holman, *The Political Economy of the Space Program* (Palo Alto, 1974).

[63] *Ibid.*, 169–95. Raymond Bauer has suggested some procedures for measuring the social effects of space research, but his study was written too early for empirical analysis; Bauer, *Second Order Consequences: A Methodological Essay on the Impact of Technology* (Cambridge, Mass., 1969). Also see the excellent introduction by Wilbert E. Moore to Moore, ed., *Technology and Social Change* (Chicago, 1972), 3–25.

[64] A "potlatch" ceremony; Diamond, *Rise and Fall of the Space Age*, chap. 1.

decently enough without any system for surveying the resources of Amazonia or multiplying by millions the bits of information that can be transmitted between continents every few seconds. But it is another important historical conjuncture that the age of space technology arrived concurrent not only with the Cold War and the emergence of the Third World but also with the peak of the world demographic explosion, which seemed to demand accelerating economic growth from advanced nations to meet geometric increases in global needs. Still another inducement to experimentation with new technology is the rapid decrease in risk capital required after the preliminary breakthroughs—in this case, the plummeting cost per pound of placing hardware in orbit. The Saturn rockets of the mid-1960s had already enhanced cost efficiency a thousand times over the first boosters.[65] The Space Shuttle may reduce that figure even more significantly depending on the amortization schedule for the cost of development.

The most immediate impact of the space program was on the aerospace industry itself, which was declared "America's newest giant" in 1962.[66] Individual NASA and Air Force program histories abound, but histories of the industry as a whole in all its political, economic, and labor facets in the United States and abroad, are nonexistent.[67] This is perplexing, for aviation had become by the 1930s an industry of vital interest to all the major powers, and it poses unique problems for historians of all stripes. Unlike most other industries, aerospace thrives on international discord. It requires vast excess capacity for emergency expansion, saddling firms with inordinate fixed costs. It has an unusually large percentage of highly skilled workers—at Boeing in the late 1950s over 40 percent of the employees were scientists and engineers. Aerospace is essentially a monopsony or oligopsony in which only one or two buyers exist (for example, NASA and the Department of Defense), and they provide both the market and the funds for research firms need to stay competitive. Hence, the industry must be an unabashed suitor of the state: Government agencies in turn have a stake in preserving competition among suppliers, but the very awarding of a large contract to one firm accords it a privileged position for the next assignment in the same field. Firms place a premium on grantsmanship not unlike the way professors learned to hustle in the regime of largesse after Sputnik. The effects of government patronage on universities in the United States and abroad are well known.[68] Similar effects in industry suggest the creation of a "contract state" in which private institutions rely

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[65] Sir Bernard Lovell, *The Origins and International Economics of Space Exploration* (Edinburgh, 1973), 29–32.

[66] The Editors of FORTUNE, *The Space Industry: America's Newest Giant* (Englewood Cliffs, N.J., 1962).

[67] Charles D. Bright's *The Jet Makers: The Aerospace Industry from 1945 to 1972* (Lawrence, Kans., 1978) is a brief but incisive essay. Bright has also decried the lack of attention given one of the nation's largest, most dynamic, and critical industries. A useful study from the peak of the Apollo boom is Herman O. Stekler, *The Structure and Performance of the Aerospace Industry* (Berkeley and Los Angeles, 1965). Stekler has denied that the American aerospace industry is a monopsony, citing the separate procurement processes of the armed services and the inordinate leverage accorded a handful of firms by the governmental practice of choosing prime contractors even for very large projects.

[68] In 1963 the federal cornucopia supplied 88 percent of the entire research budget of Caltech, 66 percent of MIT's, 59 and 56 percent for the University of Chicago and Princeton, 24 percent for Harvard and Stanford; Etzioni, *Moon Doggle*, 68. The Denver Research Institute's *Effects of a National Space Program on Universities* (Denver, 1968), a NASA-sponsored study, praised federal largesse, but found it to be more valuable to the universities than to the government!

on the government even as the state loses all hope of maintaining standards of cost and quality "given the revolutionary size, scope, and pace of the public interest in technological change."[69]

Once funding and contractual decisions fall by necessity to "experts" in arcane technical fields, once benign efforts at "technology assessment" are stymied by the very absence of shared values among scientists, engineers, businessmen, and bureaucrats, once the volume, scale, and complexity of projects invite cost overruns and unpredictable performance, then the state is demoted by its own magic to sorcerer's apprentice. If this is not what Kennedy or de Gaulle or Khrushchev had in mind when they and their advisers seized upon technology as a political tool, then perhaps Mazlish's expectation of stages through which a social invention must pass is borne out. Predictability of effects declines rapidly with the diffusion of new techniques and patterns of management throughout society. The special characteristics of aerospace and related industries suggest that traditional historical categories for policy, labor relations, investment patterns, and other phenomena are proportionally less applicable as integration or "interface" among state agencies and private or semiprivate corporations increases. Above all, it seems that government-industry-university teams to promote technology are inherently contradictory unless the conflicting values they embody are repressed.

The tendency of strategic, high-technology industries to alter the relationship of state and society is evident in Western Europe. Britain, France, Italy, and West Germany have all undergone almost complete concentration of their aerospace industries into semipublic behemoths under government pressure, so that the resulting giants might compete with each other and the large American firms. Monopsony has bred monopoly; exogenous pressures have shaped domestic institutions. Similarly, the Soviet Union, though socialist, actually fosters more competition since it can support several research centers that compete for party favor in design and production.[70]

Take away the Cold War—and, hence, missile and space technology—and what would the American economy look like? This counterfactual question suggests that the journalistic debate on fall-out from the space program (NASA gave us the teflon pan, but was it worth it?) has hindered serious discussion of its historical impact. The role of space research as the intellectual, institutional, or financial progenitor of revolutionary developments in micro-miniaturization, computers, optics, materials processing, robotics, lasers, solar power cells, and more—this is the proper subject of the economic history of the Space Age.[71] And the net gains from space technology should be measured not only against the total cost, or the economic cost, of the program itself but also against the continuing loss incurred

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[69] H. L. Nieburg, "R & D and the Contract State: Throwing away the Yardstick," *Bulletin of the Atomic Scientists* (March 1966), 20–24. Also see H. L. Nieburg, *In the Name of Science* (Chicago, 1966), chap. 10.

[70] See Parrot, "Politics and Technology in the Soviet Union," chap. 5. Also see Alexander G. Korol, *Soviet R & D: Its Organization, Personnel, and Funds* (Cambridge, Mass., 1975).

[71] Robert Fogel, in Mazlish, *The Railroad and the Space Program*, 106: "The consequences of space technology for the biological and physical sciences in general could lead to a technological and commercial revolution far more portentous than that which followed from the scientific breakthroughs of the seventeenth, eighteenth, and nineteenth centuries."

from misdirected military and social spending encouraged by the same technocratic mentality that inspired Apollo. The advent of the technological fix, streamlined large systems-management techniques, compromise of the values embodied in once-autonomous social institutions, the dominance of government by political and social engineering—the entire drift of industrial democracies toward a materialistic, manipulative approach to public policy under the post-Sputnik infatuation with technique—these are also elements in the socialization of space technology.

Depending on the explanation of the comparative responses of regimes and societies to the challenges and temptations of the Space Age, some serious assignments present themselves: rethinking the relationship between capitalism and rationalization as it evolved in the new international technological environment after 1957; reconsideration (or rejection) of the notion of convergence between the political economies of East and West under the similar demands of expensive and complex technologies; and reformulation of the very equation of economic with political stability in an age of perpetual technological revolution.

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THERE *is* SUCH A THING as the Space Age—defined by the discontinuous leap in public stimulation and direction of research and development. Its ramifications have only just begun and they are already obliging us to set aside categories of political and economic history that have served more or less effectively for the whole industrial age. But have these phenomena and the existence and promise of ever more futuristic technology altered the bedrock of cultural values among nations? Is the advent of spaceflight capable, as Tsiolkovsky dreamed, of elevating mankind spiritually? Romantics after 1957 harbored such hopes. There was a certain symmetry in the notion that mankind's escape from the world itself must spawn a global self-consciousness, just as the Age of Discovery sharpened the self-consciousness and self-criticism (as well as hubris) of Europeans. But if space technology permitted some to visualize Spaceship Earth, it led others to see the enemy of cultural values in technology itself. Jacques Ellul argued that technology had so advanced that politics, economics, and art were not influenced by technique but rather were *situated in* a technical milieu, while a technological morality had long since supplanted inherited values.[72] Space technology is an effervescence of the larger milieu that pre-exists and conditions its relation to modern culture.

Lewis Mumford judged space exploration to be "technological exhibitionism" and the latest expression of the "myth of the machine" that has dominated Western civilization since the twelfth century. Embalming astronauts in an artificial skin and blasting them into infinite vacuums in a skyscraper-tall rocket was for him the analogue to pyramid-building in ancient Egypt.[73] Sociologist Amitai Etzioni also interpreted space technology as the expression of an already flawed society:

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[72] Ellul, "The Technological Order," *Technology and Culture*, 3 (Fall, 1962): 394–421.

[73] Mumford, *The Myth of the Machine*, volume 2: *The Pentagon of Power* (New York, 1970), 303–11. Mumford's exquisite imagination failed him in this caricature of manned space flight. The "mummified astronaut" will be a primitive and romantic pioneer to the shirt-sleeved pilots and passengers of the next century, while the giant, throwaway chemical boosters of the early Space Age are already spurned as "big, dumb rockets."

Figure 6. "First Look," an oil painting by Mitchell Jamieson, commissioned by NASA. It is said to depict mankind's awe upon looking out to space; to me it seems, instead, to portray stark terror. Photograph reproduced courtesy of the National Aeronautics and Space Administration, Washington, D.C.

"Americans are apparently psychologically unready for peaceful coexistence and need to best the U.S.S.R. in everything," while the gigantic instruments that this adolescent insecurity demands only "serve those who seek to preserve the America of yesterday as it is confronted with the problems of tomorrow." For Norman Mailer the American space program belonged to "odorless WASPs," "the most Faustian, barbaric, draconian, progress-oriented, root-destroying people on earth." The machine had become art, the astronauts plastic men; and NASA's dubious accomplishment was "to make the moon boring." But Mailer equivocated. "For the first time in history a bureaucracy had committed itself to a surrealistic adventure." He vilified his own abominable army that debauched and dropped out while "they," with cool discipline, "have taken the moon."[74]

These attacks could be matched with enthusiastic affirmations of the space effort and technological revolution from Buckminster Fuller, Krafft Ehricke, James Michener, and others. But whether positive or negative, such comments fall into two groups depending on whether their authors have interpreted the headlong flight of technology in our time as an outside force challenging and perhaps threatening historic culture or as the expression and fulfillment of culture, at least in the West. Is there a process of technological change that operates independently of value systems that would help to explain why Europeans came to explore the world and launch industrialism, or, indeed, why Chinese, Japanese, and Indians are now in such a hurry to get into space? Did Great Britain already have to be a "modern industrial culture" in some way for the factory system to spread, or did the spread of industry help change dominant British values?

We tend instinctively to assume that technological progress is a function of national values. Industrialism is somehow "Western" and the Apollo program very "American." But it is at least possible that our initial impulse is misleading. We also tend to assume that governments devise strategy by identifying their interests abroad and then marshalling the forces required to defend them. In fact, national interests are themselves a function of power—they observedly grow and shrink along with power potential, not vice versa. Similarly, the values of a given society may be in part a function of that society's power over its environment. Did the apparent power of command technology help to shape social values in the early Space Age? Or did the political decisions giving birth to the Space Age express something deeper and older than Sputnik, NASA, or the Cold War? Must the United States already have been "The Republic of Technology" of Daniel Boorstin's title, or the schizoid cult of hero and machine of John William Ward's intuition of the meaning of Lindbergh's flight, for the space technological revolution to have occurred?[75] Have our inherited values, material or transcendental, fed the geometric expansion of power? And if not, if our once-sovereign culture has become trapped within Ellul's technical milieu, then how did this metamorphosis come about?

In 1957, post-Sputnik American editorials drifted naturally between jeremiads

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[74] Etzioni, *Moon Doggle*, Introduction, 152; and Mailer, *Fire on the Moon*, 10, 21, 31, 131, 346, 441.

[75] Boorstin, *The Republic of Technology* (New York, 1978); and Ward, "The Meaning of Lindbergh's Flight," *American Quarterly*, 10 (1958): 3–16.

and lamentations of lost technical supremacy. Ten years later the following was overheard at a State Department dinner: "All inventions for a long time will be made in the U.S. because we are moving so fast in technology, and large-scale, organized efforts produce inventions." The eavesdropper was James Webb; the speaker "a Mr. Brzezinski."[76] What had intervened to change a nation's mood was the space technological revolution. Our technological civilization has evolved for centuries. But the international rivalries of our age, culminating in Sputnik, induced a saltation in the politics of technology through the transformation of the state into an active, all-out promoter of technological progress. Alexander Gerschenkron theorized that the more economically backward a country, the more the state must play a role in forcing change. In the current age of perpetual and rapid progress, *all* states have become "backward" on a permanent basis. Hence, the institutionalization of wartime "emergency methods," the permanent suspension of "peacetime" values, the blurring of distinctions between the state and private institutions, and the apparent erosion of cultural differences around the world. History *is* speeding up, and the leading nations justify their ever-accelerating pace of innovation by the need to maintain military and economic security. Yet that very progress may, at times, undermine the values that make a society worth defending in the first place. This, succinctly stated, is the dilemma of the Space Age.

One is tempted to conclude that the creation and use of still more power as a solution to human problems is as vain as the effort of the American tourist to make his English understood by steadily raising his voice. "The worship of technology," wrote William C. Davidon after Sputnik, "has reduced the differences between totalitarian countries and those where human worth and dignity might be expected to find more devoted champions."[77] The fallacy of the early Space Age was that the pursuit of power, especially through science and technology, could absolve modern man from his duty to examine, affirm, or alter his own values and behavior in the first place. The politicians climbed aboard. It was left to Wernher von Braun to admonish "that man raise his ethical standards or perish."[78]

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[76] Memo, Webb to Frutkin, June 22, 1967, NASA Historical Archives.

[77] Davidon, "Soviet Satellites—U.S. Reactions," *Bulletin of the Atomic Scientists* (December 1957), 357–58. The contradictions of our "humanist religion" have been brilliantly exposed by David Ehrenfeld; see his *The Arrogance of Humanism* (New York, 1978).

[78] Wernher von Braun, a founder of the first Lutheran church in Huntsville, Alabama, and a disciple of Teilhard de Chardin, wrote the chapter on "Responsible Scientific Investigation and Application" in H. Ober Hess, ed., *The Nature of a Humane Society* (Philadelphia, 1976). It amounted to a political and moral testament since he died shortly after submitting it. Von Braun called for a new system of values transcending the "old American standards of material or technological efficiency."

History

The Relation of History to Space Technology

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The Second Giant Step by Lamar Dodd, oil, 38" by 56"

I. Introduction: Nature and Relevance of History

A. Varieties of Space History

There are as many potential varieties of space history as there are varieties of history. At the risk of offending individual sensibilities, they can be broken down. The first category of historians (and the most familiar to the general public) includes the chroniclers of the first two decades of exploration of space. Such historians are drawn primarily from the ranks of journalism and concentrate largely on the manned missions of the U.S. and the U.S.S.R., especially during the putative space race of the 1960s. Such historians write the books that are most exciting to the general public but least interesting to professional historians. Nonetheless, whatever the academic value of their labors, the journalistic historians of the space age go far to create the public enthusiasm that is apparently vital in a democracy for a healthy civilian space program.

A second variety of space historians encompasses the technical or "nuts-and bolts" historians of technology. These writers have described in detail the evolution of rocketry, telemetry, guidance, and all the other

engineering techniques that comprise astronautics. Such historians frequently are former space program participants and/or are sponsored by NASA's own history program. Devotees of technical history often dismiss the more popular histories of journalists or political historians because of the generalists' lack of technical expertise. To a degree, such a view is valid—problems of causation in the history of technology often are warped by writers unfamiliar with the technical constraints on policy.

Space age history analyzed as history of science forms a third category. Like all modern technology, spacecraft evolved initially because of advances in pure science—whether the mathematics of orbital mechanics, the chemistry of high-energy cryogenic fuels, or the physics of solid state electronics. Once satellite launching became routine, space science (the continuing pursuit of all our familiar sciences from the laboratory of space) stimulated revolutionary advances in numerous fields. For example, the astronomical and astrophysical discoveries alone are epochal. To the historian of science, such developments constitute the stuff of space age history, and the engineering feats of the rocketeers pale by comparison.

Finally, there are the historians who focus on the impact of space technology and exploration on political, social, and economic issues. To be sure, the interests even within this group are numerous and include the impacts of space activity on: international strategy and law, government science policy and organization, domestic economies and social change, even cultural and religious values. But these social-scientist space historians represent only one group among many, and works from other historians are indispensable for defining the precise nature of the phenomena that social scientists presume to trace through the "cloud chamber" of society.

This paper focuses on issues of interest to the latter group of historians, whose approach is most relevant to the users of this book.

B. Definition of History

History is a multifarious discipline and hence can be defined only in the broadest and least distinctive terms. History encompasses quite literally everything that human beings have ever done, thought, or experienced. As an academic discipline, history represents the art (not science) of establishing and explaining past events; its scope is therefore potentially limitless. The problem in history is not divining which issues historical research can help us understand or what questions it can help us answer; rather, the task is pruning out all the data and questions of less relevance to whatever problem is at hand. Therefore, history can be described as a discipline of *selection*, and ultimately the value of a given historical work is defined by what material is *left out*.

C. The Historical Method and Space Technology Research

The unique comprehensiveness of history (vis-a-vis other disciplines) in regard to Shuttle technologies constitutes a great handicap and a great advantage. History's fluid and empirical nature acts as the handicap of the historical method in a project analyzing the past and future social impact of technology. The historian seeks the particular, not the general, and tries to identify and explain those qualities that make a given phenomenon *different* from all others. On the other hand, the social scientist seeks to identify and explain those qualities that make a given phenomenon *like* others. Thus, the historian views with suspicion precisely the sorts of models or general laws that represent the very building blocks of the sociologist, economist, or political scientist. To the historian, it is never self-evident how a given datum ought to be understood in a historical context, because both the event and the historian are unique. Consequently, a given fact never will carry the same weight for two different historians nor be subject to the same interpretation. Without probing more deeply into the epistemological vagaries of historical work, analysts simply should keep in mind that history represents a product of the imagination, even of instinct. Of course, historians try to gather data on the past in a more or less scientific fashion, but arranging and making sense of the raw material is not an act of calculus dictated by some general theory or model, but rather an act of creation molded by the historian's insight into the unique circumstances of the historical moment.

The above qualities create difficulties when historians work with other social scientists or analyze events as current as the space program.

Nevertheless, the nature of history also produces an advantage. History is an integrative discipline. By training and instinct, the historian tends to: integrate knowledge about the various classes of human endeavors (political, economic, social, intellectual) at a given historical time and place; break down historical phenomena into constituent parts, according to those same classes; and then relate the parts to the whole. As a result, the alert historian naturally would: become familiar with the chronological history of space technology and policy; think at once of the political, economic, and other factors relevant to the origin and growth of the technology; and finally seek to establish empirically the causal links among such factors. Therefore, technology, in the context of this paper, would not be a "given" to be applied to "political life" or "the economy," but rather would become a mediator within the complex organism of the nation.

By way of introduction, a final issue must be addressed: the troublesome question of history's role in aiding analysis of the *future* social impact of relevant Shuttle-derived technologies. After all, history focuses on the past. Most historians are skeptical of historical study even of events that occurred during the last thirty years, believing it impossible to obtain perspective and adequate sources on such recent happenings. Thus, the entire space age lies outside the "proper" realm of historical study, and historians take professional risks when they concentrate on the space age. But the Shuttle and its social impact lie in the *future*. Other social sciences may claim some predictive capabilities (though even these are suspect), but history certainly cannot stake out the future as its domain. (Or can it? One can argue that, to the extent we can creatively study the future at all, the appropriate approach is not the social scientists' crude extrapolations and models, but precisely the historian's imagination and sense for the *un*expected in human affairs.) How can the historian help society to think about space technology? And how does the advent of the Shuttle and its ancillary technologies help society in turn to think about history? The answers require imaginative, in addition to mechanical, analogical thinking.

D. Summary of Two Approaches

There are thus two historical approaches to the "Shuttle and society" question. The first approach encourages and organizes materials for the study of space technology in the *past* (i.e., to and through Sputnik and up to the present). The second approach begins with the Shuttle and derived technologies and seeks analogies in historical time, literally firing up the imagination about the types of changes made possible by space technology in the political, economic, scientific, social, and philosophical/ethical life of humanity over the next half century.

II. The History of the Space Age

A. Justification

The writing and teaching of the history of the space age (conventionally dated from 1957) must assume increasing importance as the impact and promise of space technologies grow and as young people become increasingly removed from our space heritage. Consider that current undergraduates were born *after* JFK urged us to go to the Moon (May 25, 1961) and barely recall Apollo 11.

The history of the space age possesses great value for contemporary college students, because it requires a basic awareness of the fundamental origins of our own technological and international environment. To understand the evolution of space policy and technology, the student must become familiar with the roots and course of the Cold War, the origins and nature of nuclear weapons and strategic missiles, the logic of the arms race and the interplay of international rivalry and technological progress, the policymaking process in the U.S. and the U.S.S.R., the values and style of government that make the U.S. distinctive, and the exceedingly great power of the modern state to change society—for better or worse—by force-feeding science and technology. Traditional history courses (regardless of sub-discipline) do not necessarily inform the contemporary college student about how the world got to be as it is. But seminars or lecture series focusing on the dawn and development of the space age educate students in precisely the areas of knowledge that equip them to think effectively and analytically about the contemporary world.

B. Themes and Issues

The history of American and world space policies embraces a number of themes that are critically important in this age of perpetual technological revolution, including:

(1) *Cooperation vs. competition among nations in space* Space seemed a natural arena for international cooperation in the late 1950s and early 1960s, yet the space race was born of Cold War military rivalry. Throughout the space age, the dream of a united humanity in space has confronted the reality of competition for security and prosperity—and the blunt facts that competition breeds funding and that technology develops most efficiently when in the hands of coherent national teams.

(2) *Regulations vs. laissez-faire* Soon after the launch of Sputnik, the United Nations formed a standing committee to regulate space activities and/or draw up principles of behavior. Many observers hoped for an international space agency and a detailed Magna Charta for space law, but the politics of the U.N. and of great-power technology investment weigh against such close regulation. Space law negotiations formulated some laudable principles and some pragmatic agreements on lesser issues, but the great powers understandably have opposed U.N. control of their technologies.

(3) *Military vs. civilian control.* During the past twenty-five years, space technology has been applied to military and civilian uses. An important issue is which government agencies should control development and/or use of the technology. The Soviets never have made false distinctions, but the more sensitive Americans have, with some complicated results. To understand the likely impact of the Shuttle, one must thoroughly study the history of bureaucratic and interservice rivalry for control of missile and space technologies.

(4) *Science vs engineering* The world's space programs began as scientific and military enterprises, but soon the engineers predominated over the pure scientists, and space science has been a stepchild ever since. The contrasting attitudes and mindsets of scientists and engineers and their impact on policy constitute an important element of space history.

(5) *Prestige vs. applications* What are the motives for large investments in space technology, and do they conflict with each other? What does the history of various space policies suggest about the societies and political cultures that produced them? Whether applications satellites, military systems, or scientific ventures, practical space programs often are less able to command funds than technological projects designed to serve prestige or political purposes, be it Apollo or the Chinese "East is Red" satellite.

(6) *Technological determination vs political choice* How can societies control the evolution of space technology in the last analysis? Is there a deterministic element in space exploration, and if so, what is its origin—international competition, the innate human desire to explore, the patterns of growth produced by

technology, creation of powerful "military-industrial complexes," or some other factor?

These issues are by no means reducible into "good" and "bad" sides, or even into "realistic" and "idealistic" approaches to space policy and potential futures. Rather, our traditional preferential yardsticks are unreliable. "Cooperation" stifles rapid growth; "regulation" kills investment; "civilian control" is illusory when identical systems can be put to military or civilian uses; and "militarization" of space is not a priori a bad thing in any case. In fact, for all these issues in space history—issues that will challenge the Shuttle and that must be understood in the historical context—there are sound cultural values supporting both sides of the debate. Thus, the study of the history and future of domestic and international space policy constitutes a useful tool for analyzing some of the most crucial dilemmas confronting late twentieth century society.

(C) Selected Research Topics

Specific historical problems suitable for classroom study and research include: (1) the origins of Sputnik and Russian astronautics; (2) the impact of Sputnik on U.S. science policy and society in general; (3) the roots and organization of the U.S. space program; (4) the decision to go to the Moon; (5) the struggle by the U.S. Air Force in the 1950s to control the space program; (6) the impact of Apollo on the space program and society as a whole; (7) successes and limitations of international law and cooperation in space; (8) the origins of the Space Shuttle; (9) the administrative history of NASA and its relations with other agencies, the aerospace industry, and universities; and (10) the history and goals of the Soviet, French, European, Japanese, Chinese, and/or Indian space programs.

(D) Space Age History and the Future

Finally, the whole point of the historical exercise is to comprehend the current political environment in which the Shuttle operates. What is the organizational, international, and programmatic context of the Shuttle, Spacelab, and other related systems? After all, this age still represents the infancy of spaceflight. Barring war or a scientific Dark Age, world operations in space will increase exponentially over the next fifty years. For now, policymakers still are functioning in the formative years, when the patterns and rules of the space game are being established. If the Shuttle is to elevate the space age to maturity—and if "the child is the father of the man"—then policymakers must understand the history of the early decades in space in order to be sensitive to its offspring.

III. The Future as History: Analogical Approach

A. The Use and Abuse of Analogy

What does the space age mean to humanity? How can the world possibly grasp the impact of the revolution precipitated by space technology and resultant pioneering of the limitless medium of space? In 1962, Bruce Mazlish addressed this question, and almost two decades later, it is difficult to improve upon the logic and imagination of *The Railroad and the Space Program: An Exploration in Historical Analogy.* This book must constitute the starting point for discussions of the use of analogy in judging the current and future impacts of space technology.

Historical analogies are irresistibly enticing. The most natural mental processes incline human beings toward conjuring up like things and situations from experience as a means of processing current data acquired through our senses. For space law, analysts find it impossible not to think of the Law of the Sea or the Antarctic Treaty. For space exploration in general, one thinks of the Spanish voyages of discovery. For control of new and forbidding technologies, how can one resist the analogy of the atomic bomb and nuclear power? Yet, all analogies are vain except for purposes of narrow illustration—or to explain how past statesmen themselves may have been influenced by the same analogies. Mazlish correctly identified the space phenomenon as more than a "new frontier," a "new technological breakthrough," or a "new battlefield among nations." He viewed space exploration as a technological complex that came to represent a social invention, as society was forced to restructure itself in many ways to accommodate the new technology. And in searching for a historical analog to the space social invention, Mazlish concluded that the coming of the railroad was most fitting. No other previous invention so changed the very proportions of space and time and power as the railroad. This is a subtle and complex analogy, which Mazlish and the other contributors to his volume examined in depth. Unfortunately, historical analogy is abused far more than fruitfully used. Facile comparisons to Columbus do a disservice to history and to the effort to understand the space phenomenon. But flexible and nuanced consideration of past explorations and inventions can provide insights into possible future paths.

B. Analogy and Imagination

How can an instructor employ analogies like the railroad and its impact on American history to understand the Shuttle-derived technologies and their impact? The answer includes the exercise of historical judgment to temper and stimulate the imagination about the possible pace of change and existing barriers to change, as well as to anticipate novelty, rather than assume continuities. Some examples:

(1) *Item:* The Space Shuttle.

Potentials. Rapid increases may occur in the volume of space activity in fields where practical payoff is assured. Great decreases in cost per-pound of launches may be possible, and tolerance for discretionary and risky enterprises may increase as well. The Shuttle is a likely stimulus to terrestrial technology and industry.

Analogs: The advent of seaworthy "workhorse" merchant vessels, such as the Dutch *fluit* of the seventeenth century, is analogous to the Shuttle. Trade in Asian spices or South American metals is not similar to Shuttle space transport, but the coming of economical *bulk* shipping does represent a useful analog. Space likely will provide little in the way of precious cargo; the Shuttle provides the boon of ready access to a new environment, which in turn will permit greater economic division of labor and differentiation. This compares well to the effect of bulk transport in cereals, in the Baltic Sea in early modern times, and in trans-Atlantic shipping of American grains in the 1870s. Both times the new transportation capability altered world economic patterns (in the early case, with great stimulus for West European economic modernization).

(2) *Item.* Spacelab and Space Telescope.
Potentials: These scientific projects may produce untold revelations about the universe, and data may multiply literally a thousand times at a blow. Spacelab should provide a cheap, flexible, reusable facility for experiments impossible on Earth, generating a substantial increase in the capability and efficiency of space-based R&D in materials processing and basic science.
Analogs The Galilean telescope also enlarged the universe many times and changed forever mankind's view of the world and the cosmos, producing profound scientific, philosophical, and religious changes. Other such "eye openers" would include the Pacific voyages of Cook and Darwin and the advent of spectroscopy.

(3) *Item.* Space applications satellites.
Potentials. A communications revolution promises a "satcom center" (with possible computer links) in every U.S. home, thanks to communication satellites with functionally limitless capacity. Hundreds of cable television stations could supply instant gratification of every visual/audio desire (but with what moral and cultural effects?). For the Third World, satellites can offer direct broadcast television for education and propaganda purposes. Landsat will produce economic benefit from new applications of remotely sensed geophysical data.
Analogs: The common comparison for the communication satellite revolution is the advent of the Gutenberg printing press in the fifteenth century; the cultural revolution that followed needs no elaboration. But another analog usually overlooked is the invention of the linotype machine in the late nineteenth century, which brought the penny press to the masses. Combined with universal education, mass journalism changed the politics and culture of Europe and America as few other innovations.

C. Summary

In all these analogies, one still must be very careful to understand the differences between the historical environment in which the changes occurred and the historical environment in which the Shuttle operates. The most important difference applicable in every case is, perhaps, the all-powerful role of the state, "Leviathan," in the funding, organization, and execution of space activities. The likely effects of space technology would seem ***more*** predictable as a result of state control; in fact, a monopolistic state, for various reasons, also may stifle the revolutionary potential of space technology. Would the printing press have spread freely throughout Europe if a single state had been in monopolistic possession of the technology? One has cause to wonder—great cause.

Appendix Two materials provide insights from two experienced instructors who have integrated space into history courses.

Space-Age Europe: Gaullism, Euro-Gaullism, and the American Dilemma

WALTER A. MC DOUGALL

"It is a far cry from Cape Kennedy," wrote a correspondent for the *New York Times*. "There are no neon signs, no drive-ins—and no night clubs. There are only some scattered huts and towers, lost in a desolate flatland as big as New Jersey, its pebbly floor covered with a pale green haze after a spell of rain. In the huts, which are filled with electronic equipment, one can hear, almost any morning, a calm young voice on a loudspeaker saying 'dix, neuf, huit, sept . . . ' In the distance a needle with a tail of fire slowly rises above the desert and roars into the sky."[1]

The site was Hammaguir, an adobe village where sheep, goats, and a few dromedaries nosed about in the brittle weeds. Colomb-Béchar, the nearest town, lay 80 miles to the north, itself 700 miles into the Sahara from Algiers. Nearby, the parallel lines of an abandoned railroad vanished into the dunes, perhaps to meet at infinity, an artifact of France's first stab at a colonial dream, the trans-Saharan railway. In 1965, the imperative of international competition had brought France's finest engineers back into a desolation that proved congenial to the most advanced technology even as it swallowed the remains of an earlier industrial revolution. For the Algerian civil war prepared the return of Charles de Gaulle, who forestalled a military threat to overthrow the Fourth Republic by overthrowing it himself and pledged to

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[1] John L. Hess, "The Last Countdown," *New York Times*, February 11, 1967.

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restore French greatness through technology, not empire. The Treaty of Évian ended French rule in Algeria in 1962 but reserved to the metropole, for a time, its proving grounds at Hammaguir, whence Gaullist France would become the world's third space power.

French technicians—some in burnooses like a cosmic foreign legion—were mainly men of the *Société pour l'Étude et la Réalisation d'Engins Ballistiques* (SEREB) and the *Centre National d'Études Spatiales* (CNES). Back home the SEREB shared in the design of intermediate-range ballistic missiles to cradle the bombs of the world's fourth nuclear deterrent, and the CNES designed satellites for cooperative programs with the United States and European space agencies. But the Algerian task was final checkout of Diamant, a French-made space booster, and the goal was to place a French satellite in orbit before *FR-1*, another Gallic spacecraft, went aloft aboard an American Scout rocket from Vandenberg Air Force Base. From the start, France's national program was competing with her own cooperative programs, with the Americans, and with other Europeans in the race to become the third nation in space.

The Diamant booster was a three-stage configuration composed of engines developed in previous rocket programs, one propelled by the exotic mix of nitric acid and turpentine, the others solid-fueled. Together they developed 107,000 pounds of thrust, roughly equivalent to that of the Jupiter-C that had launched the first American satellite seven years before. By mid November of 1965, the NASA launch of *FR-1* and a French presidential election were both three weeks away. Forty-three months before, the design for Diamant had been frozen and airframe construction commenced at the Nord Aviation plant for SEREB. Now the identity of Gaullist France, wedded to the prestige and power of technological dynamism more consciously even than Kennedy's America, rode on the outcome. "Trois, deux, un . . . ," the countdown ended on November 26. Preset charges exploded the bolts holding down the sleek cylinder, and its own large exhaust nozzle fired up to full thrust. Soon the tracking stations reported in: *Asterix-1*, a modest 42-kg satellite named for the red-whiskered barbarian of French comics, was transmitting from orbit. Its chemical batteries quit after just two days, but Diamant had glistened, and *Le Monde* proudly proclaimed "La France Troisième 'Puissance Spatiale'!"

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Today, over a quarter-century after *Sputnik*, the political patterns of the space age have undergone a radical shift. Where two superpowers vied alone for prestige and military advantage, now seven nations have launched satellites on homemade boosters, and dozens have participated in cooperative satellite programs for commercial, scientific, and technological motives. Where once international cooperation and "space for peace" were universally touted, at least in rhetoric, now vigorous competition obtains, not only between the United States and the USSR but between the United States and its industrial allies as well. Where once government arsenals monopolized spaceflight, now a spectrum of institutions—public, semipublic, and private, military and civilian, national, bilateral, and multinational—adapt to the demands of space development, operations, and marketing. In the 1980s, the surprising conclusion is that the space age, defined not only by revolutionary technologies but also by mobilization of national resources for the force-feeding of technological change, will be shaped in years to come as much by developments in the "second tier" of European and Asian states as in the Big Two. For the political history of space technology has validated neither the early hopes of a "humanity united in space" nor the fears of a yawning "technology gap" stemming from economies of scale in the United States and the USSR to the detriment of all others. This article examines, from the point of view of the "others," how both these expected outcomes of the space age were forestalled and why the Gaullist model, rather than the American or Soviet, has come to shape the international politics of technology in the space age.[2]

The wartime hero de Gaulle rose to power just eight months after *Sputnik 1*. His mission, brooded over for twelve years, was to save France. This meant military independence, without which no state was truly sovereign; economic independence, without which no state was master of its own house; and technological revolution, without which no modern society could maintain the first two conditions. Sensing that the colonial mission drained French resources and earned opprobrium rather than prestige, de Gaulle liquidated imperial France. Bristling under the Anglo-American "special relationship," he withdrew from NATO command, blocked Britain's entry into the Common Market, and thus proscribed an Atlanticist France. Contemptuous of integration and fearful of German power, he capped progress toward a European France. Needless to say, de Gaulle also abhorred the Left's vision of a Socialist France. Instead, de Gaulle launched a revolution

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[2] Some of the ideas herein were raised in two short papers I was asked to give during the early stages of my research on the political history of the space age: "Space-Age Europe 1957–1980," NASA-Yale Conference on the History of Space Activity (February 1981), and "The Struggle for Space," *Wilson Quarterly* 4 (Autumn 1980): 66, 71–82.

from above to reify his "certaine idée" of Technocratic France, the R&D state.[3]

The unabashed theme of Gaullism was *grandeur, la gloire*—for "la France ne peut être la France sans la grandeur." But "glory" is not a policy any more than "peace" is, and in the case of Gaullist France, *grandeur* was an axiom or self-definition implying that any "France" not willing or able to play the role of a Great Power was not France at all. And if de Gaulle had cherished such beliefs ever since 1940, two events just prior to his return sufficed to persuade his countrymen. The first was the 1957 British White Paper in which Defense Minister Duncan Sandys argued that economic decline, social demands, and superpower dynamism forced Britain thenceforth to rely on cheap nuclear deterrence. Though directed against the Soviets, a beefed-up deterrent would, as Harold MacMillan admitted the following year, also increase British leverage vis-à-vis the United States.

The second event was *Sputnik*. Now that the Soviets were capable of threatening the U.S. homeland with hydrogen bombs and intercontinental ballistic missiles, was the American nuclear umbrella still credible? Would America risk New York to save Paris? Such imponderables reinforced French determination to press on with their own nuclear *force de frappe*. But *Sputnik* gave another ironic twist to Franco-American relations, for the Eisenhower administration, in the post-*Sputnik* panic, expanded strategic cooperation with Britain, while Congress amended the McMahon Act to enable more nuclear secrets to be passed to friendly nuclear powers. In the interest of nonproliferation, friendly *non*nuclear powers received no such aid. When de Gaulle sought to purchase KC-135 tankers for inflight refueling of his Mirage IV jets, the U.S. government hindered the sale. When France concluded contracts with Boeing for missile components, the State Department withheld approval. The French concluded that U.S. policy was designed to keep France a *nation secondaire* for all time, and when de

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[3] This notion of modern technocracy as the R&D state, "the institutionalization of technological change for state purposes," is the theme of my article, "Technocracy and Statecraft in the Space Age: Toward the History of a Saltation," *American Historical Review* 87 (Oct. 1982): 1010–40. For Gaullist ideas on politics and technology, see esp. his *Memoirs of Hope: Renewal and Endeavor* (New York, 1970) and his collections of speeches in Ambassade de France, *Major Addresses, Statements, and Press Conferences of General Charles de Gaulle* (New York, 1964), as well as *De Gaulle parle*, 2 vols., ed. André Passeron (Paris, 1962–66) and the following works on Gaullist foreign policy: Paul-Marie de la Gorce, *De Gaulle entre deux mondes* (Paris, 1964) and *La France contre les empires* (Paris, 1969); W. W. Kulski, *De Gaulle and the World* (Syracuse, N.Y., 1966); John Newhouse, *De Gaulle and the Anglo-Saxons* (New York, 1970); Paul Reynaud, *The Foreign Policy of Charles de Gaulle*, trans. Mervyn Savill (New York, 1964).

Gaulle pronounced on NATO and military matters, his rhetoric aimed, in every case, not at Moscow but at Washington.[4]

But technical independence, the mark of a Great Power abroad, dictated a revolution at home, and, after seven years of the Fifth Republic, France was scarcely familiar to those who had known her in the 1950s. For 150 years French business had distinguished itself by jealousy, traditionalism, and acrimony with labor; and state policy by vacillation between nationalization and laisser-faire. But the constitution of the Fifth Republic enhanced the power of the executive, which in turn reformed the universities, folded small industrial concerns into mighty semipublic corporations, and linked them to state agencies in a coordinated national team for the force-feeding of technological change, with the state itself as managerial czar. In space technology, de Gaulle's technocrats combined the air force's office for aeronautical research and the private firms of Nord Aviation, Sud Aviation, Engins MATRA, and Dassault into the new SEREB. Gradually French public and private aerospace concerns became a single team, with contracts drawn from the Defense Ministry and CNES, distributed among firms, overseen by the tough, ubiquitous *inspecteurs des finances*, and the results exploited by bureaucratic managers. Thanks to this national complex for R&D, solid-fueled IRBMs and submarine-launched missiles entered flight testing as early as 1967, and the first nine nuclear-tipped missiles were put into silos in Haute Provence in 1971. Nuclear-armed submarines entered service the following year, and, together with the Mirage jet bombers, completed France's little triad of nuclear forces.[5]

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[4] For instance, de Gaulle declared early in 1958 that "I would quit NATO if I were running France. . . . NATO is no longer an alliance, it is a subordination" (C. L. Sulzberger, *The Last of the Giants* [New York, 1970], pp. 61–62). Although the official justification of the *force de frappe* was to provide France with a modern deterrent, Gaullist ministers invariably spoke of it as the only way for France to rejoin the ranks of the Great Powers, make herself heard in world councils, receive equal treatment in the Western alliance, and qualify for American nuclear aid. See Wilfrid Kohl, *French Nuclear Diplomacy* (Princeton, N.J., 1971), pp. 98–100. Even Raymond Aron, a friend of NATO, saw the *force de frappe* as a "political trump" in dealings with the United States.

[5] On the domestic revolution promoted by de Gaulle in the name of technological dynamism, see especially Robert Gilpin, *France in the Age of the Scientific State* (Princeton, N.J., 1968). On the evolution of the *force de frappe*, see: Kohl, *French Nuclear Diplomacy*; Wolf Mendl, *Deterrence and Persuasion: French Nuclear Armament in the Context of National Policy 1945–1969* (London, 1970); Bertrand Goldschmidt, *L'Aventure atomique* (Paris, 1962); Lawrence Scheinmann, *Atomic Energy Policy in France under the Fourth Republic* (Princeton, N.J., 1965); Charles Ailleret, *L'Aventure atomique française* (Paris, 1968). French nuclear research was well advanced in 1940 when the German conquest put a halt to the work of the Curies. The Fourth Republic founded the French atomic energy commission, which worked steadily toward the fabrication of weapons-grade plutonium,

De Gaulle also announced plans for an orbital space program in 1959. The Hammaguir proving ground, home for France's share of captured V-2s since 1947, became the most active rocket range outside the United States and the USSR. In 1961, the state combined its various research groups, and CNES emerged as a full-fledged space agency and joined forces with SEREB to build a space-launch capacity. Unlike the American NASA, CNES made no artificial distinction between military and civilian rocketry. Its launchers were developed under military aegis, and its director-general, Robert Aubinière, was an air force general and an advocate of the military uses of space. In the early 1960s the SEREB crept up on orbital capacity with a series of ever more precious stones: the Agate, Topaze, and Rubis solid-fueled stages, the Émeraude liquid-fueled first stage, the Saphir two-stage configuration, and finally the Diamant-A.[6]

Why a French space program? First, if prestige were a primary aim of Gaullist policy, then space beckoned irresistibly. Second, orbital flight could be pursued relatively cheaply as an offshoot of the planned military missile program. Third, a mature nuclear strike force would itself someday require satellite support systems for geodesy, targeting, surveillance, communications, and meteorology. Indeed, French military theorists such as Aubinière, Pierre Gaullois, and Colonel Petkovsek argued the inevitability of space militarization in the missile age more candidly than American officials (who treated the military space program as a public relations albatross).[7] But the fourth and fundamental reason for a French space program was the apparent centrality of space-related technologies in the Gaullist drive for permanent technological revolution.

The traditional "stalemate society" that was France had never adequately adjusted even to the industrial age.[8] But the advent of elec-

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often without official blessing. In 1954 the cabinet of Pierre Mendès-France approved continuation of work leading to a bomb test. By that time French strategists already justified "going nuclear" as an economy move, "more force for the franc," in imitation of Eisenhower's New Look (see, e.g., Charles Ailleret, "L'Arme atomique, arme à bon marché," *Revue de défense national* 10 [1954]: 315–25). Hence, when de Gaulle took over in 1958 he had only to make public France's intention of building its own nuclear force and vastly increase the funding.

[6] On French rocket development, see U.S. Congress, Committee on Science and Technology, *World Wide Space Programs*, 95th Cong., 2d sess. (1977), pp. 142–57.

[7] See, e.g., Petkovsek, "L'Utilisation militaire des engins spatiaux," *Revue militaire générale*, July 1961.

[8] A "stalemate society" (the evocative phrase is Stanley Hoffman's) is one in which conflicting socioeconomic interest groups are strong enough to block implementation of the programs of others but not strong enough to realize their own through a weak, fragmented parliamentary system. Such a society is incapable of major reforms. One

tronics, atomic power, computers, and space technology in the 1950s ushered in a postindustrial age with still stiffer requirements. "It is no longer enough," wrote de Gaulle, "for industry, agriculture, and trade to manufacture, harvest, and exchange more and more. It is not enough to do what one does well; one must do it better than anyone else. . . . Expansion, productivity, competition, concentration—such, clearly, were the rules which the French economy, traditionally cautious, conservative, protected, and scattered, must henceforth adopt." How could such a revitalization come about? First, through state leadership under the French Economic Plan. Second, through priority for international competition, "the lever which could activate our business world, compel it to increase productivity, encourage it to merge, persuade it to do battle abroad. . . . " Thus, the Common Market, in de Gaulle's view, was not a means to submerge France into Europe but a means to expand the market in which French industry might achieve dominance. Third, through statist stimulation of advanced R&D in the fields of nuclear power, aviation, computers, and space "because their labs and their inventions provide a spur to progress throughout the whole of industry."[9]

De Gaulle envisioned a hybrid economy uniquely adapted to an age of continuous technological revolution. He rejected laissez-faire capitalism, for that model carried within it "the seeds of a gigantic and perennial dissatisfaction. It is true that the excesses of a system based on laisser-faire are now mitigated by certain palliatives, but they do not cure its moral sickness." Communism, on the other hand, theoretically "prevents the exploitation of men by men, [but] involves the imposition of an odious tyranny and plunges life into the lugubrious atmosphere of totalitarianism without achieving anything like the results, in terms of living standards, working conditions, distribution of goods, and technological progress which are obtainable in freedom."[10]

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solution to such stalemate is "corporatist" decision making by which labor, business, political parties, and bureaucracies, e.g., compromise to bring about centralized social progress. The French Third Republic proved singularly incapable of effecting such compromise even under the threat of foreign competition or internal disruption. In perverse fashion, it was left to the collaborationist Vichy regime to foster a number of reforms—in industrial organization, labor relations, and scientific research—amounting to a certain "modernization" of the French state. The Fourth Republic then established new research institutes and the Economic Plan after the war, presaging in many ways the Gaullist era. See, e.g., Stanley Hoffman, *In Search of France* (Cambridge, Mass., and London, 1963); Gilpin, *France in the Age of the Scientific State* (n. 5 above); Charles S. Maier, *Recasting Bourgeois Europe: Stabilization in France, Italy, and Germany in the Decade after World War I* (Princeton, 1974); and Robert O. Paxton, *Vichy France: Old Guard and New Order, 1940–1944* (New York, 1972).

[9] De Gaulle, *Memoirs of Hope*, pp. 133–35.

[10] Ibid., p. 136.

Both "world systems" were unsuitable to the space age; de Gaulle sought a *juste milieu*. Competition was indeed the engine of progress but also the solvent of community. Hence the competitive stimulus must be international, while at home French institutions combined in a dynamic unity. The initial results were stupendous: real growth of 7 percent per annum in the early 1960s, zero unemployment despite the influx of demobilized soldiers and *pieds noirs* from North Africa, a fivefold increase in state R&D funding from 1959 to 1964—until the government subsidized three-quarters of all R&D performed in France. To an even greater degree than in post-*Sputnik* America, R&D in France was nationalized. But unlike space-age America, Gaullist France subjected its national effort to a centralized plan. As Michel Debré explained the Five-Year Plan for R&D in 1961, the additional funds were to constitute a "masse de manoeuvre" which the state could target on carefully selected sectors whose "spin-off" effects would advance national technology across-the-board. Master planning fell to various standing committees reporting directly to the prime minister, like the *Comité Consultatif de la Recherche* (known as "The Wise Men") or the *Délégation Générale à la Recherche*. Together with the Ministry of Science, they plotted strategy for the conscious invention of the future.[11]

Despite fundamental restructuring of French political, academic, and industrial life and the huge strides made in the first decade of the Fifth Republic, the evident explosion of technology in America symbolized by Project Apollo seemed only to widen the "technology gap" across the Atlantic. By 1964, de Gaulle was warning of "bitter mediocrity" and the "colonization" of France if she did not push her technology forward even more relentlessly. One economist believed Kennedy's America had found "the keys to power" in command R&D. By means of its favorable "technological balance of payments," superiority in "point sectors," and direct investment abroad through multinational corporations, the United States had adjusted first to the new technological age and threatened to dominate the world. The Fifth Republic, therefore, embraced the assumptions of such American enthusiasts as NASA administrator James Webb that (1) basic research is the cutting edge of national competitiveness; (2) there is a direct relation in R&D between scale and results; (3) multinational entities threaten national

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[11] Debré in "Le Programme pour la recherche scientifique," *Figaro*, May 4, 1961. Generally, see Gilpin, *France in the Age of the Scientific State*, and C. Freeman and A. Young, *The Research and Development Effort in Western Europe, North America, and the Soviet Union* (Paris: OECD, 1965).

independence; and (4) priority of invention is self-perpetuating, that is, leading nations tend to increase their lead.[12]

How could France hope to compete if scale and priority were critical in advanced technology? Many Europeans concluded that the appropriate response to the technology gap was more vigorous integration. Only by pooling their resources and talent might Europeans hope to forestall U.S. hegemony. But this was not the Gaullist conception. France did not flee dependence on America only to become dependent on a European mélange. Rather, France's cooperative programs in nuclear technology, space, and aviation (e.g., the SST) were fashioned so as to draw on the resources of others in the interest of her national programs rather than to donate French expertise in the interest of multilateral progress. In space, as in Euratom, French contributions to Europe were a fraction of the efforts made at home. Cooperative programs were of interest insofar as they channeled foreign funds, ideas, and markets into a technology flow irrigating France's own garden.

The French Five-Year Plan for space, approved in 1961, made room for cooperation with NASA and France's European partners, but the announced goals of CNES were (1) to create a French technological base capable of original experimentation in space and (2) to put French industry in a favorable position vis-à-vis the competition certain to develop in Europe. The first goal meant that France must not merely duplicate, later and on a smaller scale, what the superpowers had done but select technological targets of opportunity in which France might someday compete. The second goal assumed eventual European independence from the United States but that competition within Europe would also obtain. Such goals demanded vigor, not only the world's third largest space program but a precise strategy to guide it.

"La méthode assez française," according to Aubinière, was to fix objectives from the outset, then create the instrument needed to fulfill them. Rather than hasten to "do something about space," letting existing institutions stumble forward, France shaped her institutions to her goals. Aubinière and Pierre Auger, scientific chief of CNES, together forged an "infrastructure technique très importante," a government-industry-university team of the sort James Webb and NASA would soon promote in America. In the early years the French

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[12] Michel Drancourt, *Les Clés de pouvoir* (Paris, 1964). These assumptions buttressed NASA budgetary appeals throughout the 1960s but were challenged by American critics as early as 1962. For the general French adherence to them, see Gilpin, *France in the Age of the Scientific State*, pp. 32–71, esp. pp. 56–57.

still relied heavily on imported American technology. Forty percent of the *FR-1* satellite, for instance, consisted of U.S.-made components. But once in possession of such subsystems, French technicians replicated them at home and gained an advantage over other Europeans. One result of this "competition through cooperation" was the almost total European dominance enjoyed by France in solar-cell systems in the late 1960s.[13]

Space technology was to be a force for global unity, said the academics. But the new age, in de Gaulle's intuition, would be one of heightened self-sufficiency and competition, even neomercantilism, for any state considering itself a Great Power. The cost and complexity of space-age technologies rendered the free market obsolete—capitalism at home was no longer "competitive" in the global arena. French policy on space, in sum, amounted to statist cooperation in science and statist competition in engineering. This was the France that sat down with the other European states in 1962 to build a joint European space program.

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Suddenly, after *Sputnik*, the airy zealots of the British Interplanetary Society no longer appeared to be candidates for Bedlam. For a half-century they had predicted the coming of spaceflight, and now their pleas for a British space policy resounded in Parliament itself. David Price, a Tory backbencher, intoned, "We are now in the space age, whether we like it or not. All public policy must be shaped to accommodate this sudden change in the human environment. . . . Viewed historically, Europe dare not stand apart from the space race." But European states could not compete by themselves, said Price, or be content to lean on the superpowers, or expect a United Nations space program. The only solution was a pooling of resources—and they need not even start from scratch, for the British Blue Streak intermediate-range

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[13] On French competitive strategy for the European market, see Aubinière, "Réalisations et projêts de la recherche spatiale française," *Revue de défense nationale*, November 1967, pp. 1736–49. On the strategy and execution of the French space program in the 1960s, see: U.S. Congress, *World Wide Space Programs*, pp. 139–70; Georges L. Thomson, *La Politique spatiale de l'Europe*, 2 vols. (Dijon, 1976), vol. 1, *Les Actions nationales*, chap. 1; Michiel Schwartz, "European Policies on Space Science and Technology 1960–1978," *Research Policy* 8 (1979): 204–43; "Programme spatiale français jusqu'en 1965," *Figaro*, July 28, 1961; "Le Débat sur le centre d'études spatiales," *Le Monde*, October 19, 1961; "More French Satellites after 'Diamond,'" *Daily Telegraph*, June 1, 1962; Kenneth Owen, "France's Space Programme: The Reasons Why," *Flight International*, July 12, 1962; L. Germain, "Le Recherche spatiale en France," *Revue militaire d'information*, January 1963; Charles Cristofini (president of SEREB), "Planned Cooperation Is France's Aim," *Financial Times*, June 10, 1963.

missile, headed for cancellation before flight testing, could survive as the first stage of an all-European satellite launcher. Price also foresaw coordinated space research in firms and laboratories across Europe; manufacture of components and whole spacecraft in European plants; joint launch facilities; communications and other commercial satellites; nuclear and solar power for spacecraft; hypersonic, reusable winged vehicles; space medicine; and even nuclear, ion, or plasma "space drives." None of this was fantastic, he insisted. The Common Market states plus Britain, Norway, and Switzerland had combined gross national products greater than the Soviet and over half the American. Without the burden of military or manned programs, Europe could surely compete in selected technologies of scientific and economic potential.[14]

Price's assumptions met a willing audience in a Europe searching for its place in the postwar, postimperial world. It seemed the old continent, the cradle of the Industrial Revolution, must decay by the 21st century into a global backwater unless she joined the new technological revolution. By 1959 both British political parties were sponsoring bills for a ministry of science or technology, Gaullist France was embarked on an R&D boom, and the West Germans were eager to master ancillary space technologies (despite a shyness about missilery stemming from the V-2 heritage). So the Council of Europe and a committee of experts at Strasbourg in 1960 endorsed the principle of a European space program. When Minister of Aviation Peter Thorneycroft offered the Blue Streak to Europe the following year, the European Launch Development Organization (ELDO) was born. Britain would perfect the Blue Streak, France would provide a second stage called Coralie, Germany the Astris third stage, Italy the test satellite, the Netherlands the telemetry, Belgium the guidance station, and Australia its test site at Woomera in the outback.

Here was an enterprise in multinational technological cooperation on an unprecedented scale, and a mission for Europe—space-age Europe. In the initial enthusiasm, potential difficulties were brushed aside or unappreciated. While ELDO-financed research was to be shared openly, the French insisted that members not be required to share data acquired in national research. The French also insisted that no restrictions be placed on national military application of ELDO-derived technology, thus killing chances of American aid. The big states insisted that voting power in ELDO reflect contributions, the smaller states feared being pawns. So the convention required that the

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[14] "European Cooperation in Space," *Spaceflight*, January 1961; David Price, "Political and Economic Factors Relating to European Space Cooperation," *Spaceflight*, January 1962; Kenneth Owen, "Europe's Future in Space," *Flight*, July 6, 1961.

annual budgets be approved by both a two-thirds majority and by countries whose total contributions constituted 85 percent of the budget. But how would contributions be distributed? Tortuous costing of the planned rocket stages produced a £70 million project, 38.8 percent of which was Britain's responsibility, 23.9 for France, 22.0 for Germany, 9.8 for Italy, and the remainder for the others. But the costs of each stage were as uncertain as cost overruns were predictable. These and other sources of discord hung over the ELDO convention signed in 1962.

Meanwhile, European scientists led by Eduardi Amalfi, Pierre Auger, and Sir Harrie Massie took the initiative in space science. The "brain drain" of European talent to the United States was the academic equivalent of the "technology gap" that the scientists hoped to stem through a European space science program. Working separately from those discussing launch-vehicle development, delegations from ten countries (Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland, United Kingdom), founded the European Space Research Organization (ESRO), also in 1962. ESRO dedicated itself to peaceful purposes only, free exchange of information, and joint construction of satellites and experiments for launch by NASA and eventually by ELDO. Again, at French insistence, members were released from the obligation of sharing data "obtained outside the organization." The ESRO convention provided for a European Space Technology Center (eventually based at Noordwijk, the Netherlands), a European Space Data Center (later the Space Operations Center) for telemetry and tracking (Darmstadt, West Germany), a sounding rocket range (Kiruna, Sweden), and a headquarters (Paris). ESRO had less difficulty than ELDO with procedure: each state received one vote, with most issues decided by simple majority. The budget would be voted by a two-thirds majority every three years, with national contributions fixed in proportion to the net national income of the member state. Projected spending for the first eight years was a mere $306 million.[15]

Politically, these numbers were acceptable: some half a billion dollars for ESRO and ELDO divided among several countries over six to eight years. This was hardly an excessive entry fee into the postindustrial world. But was it enough? By the middle of the decade the United States would be spending $5 billion per year on civilian space technol-

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[15] On the origins of ESRO and ELDO, see: U.S. Senate, Committee on Aeronautical and Space Sciences, *International Cooperation and Organization for Outer Space*, 89th Cong., 1st sess. (1965), pp. 103–17; U.S. Congress, *World Wide Space Programs*, pp. 237–77; Thomson, *La Politique spatiale de l'Europe*, vol. 2, *La Coopération européenne*, chap. 3; Alain Dupas, *La Lutte pour l'espace* (Paris, 1977), chap. 10.

ogy alone. European aerospace firms, the most enthusiastic but also the most discerning of observers, understood better than the politicians the cost and frustrations of large-scale R&D. Hawker-Siddeley and SEREB accordingly gathered about them an industrial lobby of ninety-nine companies called EUROSPACE to educate and influence the bureaucrats. Almost half the member firms were French, as were the president, Jean Delorme, and secretary-general, Yves Demerliac. In the words of the former, "Unless the European countries wish to join the ranks of the backward and underdeveloped countries within the next fifty years, they must take immediate steps to enter these new fields." A low-orbit launcher, scientific satellites, and half a billion dollars did not suffice for what Delorme called "a matter of survival."[16]

How so? Space technology scarcely promised big profits in the near future—the motives for the superpowers were defense and prestige. Even communications satellites, which held immediate promise, were hardly "a matter of survival." But EUROSPACE took a larger view that might be termed Euro-Gaullism. It advised against importing U.S. systems, even if permitted to do so, in order that Europeans might gain experience in R&D. The payoff was in the means, not just the ends. "European industry," recalled Demerliac, "never considered space as a money-making activity. [Its] main initial motive was to improve its technology so as to remain competitive in world markets. Space was a means of forming or retaining qualified teams capable of delivering advanced items of equipment and also—perhaps above all—to manage the joint development of complex systems or sub-systems. . . . The target for European industry is clearly to acquire prime contractor ability for all space applications systems."[17]

"Prime contractor ability for all space applications"! Even as the French hoped to target specific markets and achieve technological primacy within Europe, so the European aerospace industry as a whole sought competitiveness in targeted world space markets. The impact of

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[16] SEREB and Hawker-Siddeley Aviation, *L'Industrie et l'espace* (Paris and London, 1961); Jean Delorme in EUROSPACE, *Proposals for a European Space Program* (Fontenay-s-bois, 1963), pp. 11–13, 96–97.

[17] Yves Demerliac, "European Industrial Views on NASA's Plans for the '70s," AAS Goddard Memorial Symposium (Washington, D.C., March 1971). See also the testimony of Eilene Galloway, congressional staff expert on space policy, after interviews with European officials in April 1967: Library of Congress, Clinton Anderson Papers, Box 919. EUROSPACE also proposed an ambitious program of space R&D including a reusable "space transporter" or "shuttle." See EUROSPACE, *Proposals for a European Space Program*, pp. 17–67, and *Aerospace Transporter* (Fontenay-s-bois, 1964). The preface to the latter was written by an aging Eugen Sänger, German rocket engineer who designed a reusable "boost-glide" space vehicle during World War II and can be considered the progenitor of the Space Shuttle.

such technological strategies on trans-Atlantic cooperation was profound. NASA was eager to cooperate in space science; the United States might, in its generous moods, even welcome Europeans as subcontractors in expensive missions. But it was not likely to transfer technology sufficient to create full-scale competition for American aerospace firms. NASA was forthcoming with proposals to train foreign scientists and launch scientific payloads on a reimbursable basis. But the State Department tried to discourage the Europeans from forming ELDO and turned a cold shoulder when the Europeans sought help for their Europa-1 booster. De Gaulle insisted, and Europeans listened, that the day might come when American willingness even to launch foreign satellites might cease. Europe must have her own space booster.[18]

Nevertheless, the EUROSPACE plea for an additional £218 million for space failed to persuade European parliaments committed to expanding social welfare in the 1960s. So ELDO and ESRO, underfunded and poorly conceived, came to exemplify all the risks of multilateral R&D. First, the governments delayed ratification of the conventions until 1964, by which time the Americans and Soviets had pulled much further ahead. Then the brick and mortar work of building the centers, especially for ESRO, absorbed several more years, while most of the first triennial budget went for overhead. Not until 1967 did the first experimental satellite *ESRO-1* reach orbit, courtesy of NASA.

The ESRO members also quarreled over disproportionate distribution of contracts, the issue of *juste retour*. National responsibilities in ESRO projects were not fixed in advance, so contracts flowed to the most competitive firms. France, true to her intent, garnered a percentage of contracts up to twice the level of her contribution. Efficiency demanded that business go to the most qualified firms, but politics demanded "affirmative action" for countries playing "technological catch-up." Either the poor subsidized the rich, or the rich subsidized mediocrity in the short run and new competition in the long run. Even as the French deplored American dominance vis-à-vis Europe, they themselves exploited a dominant position within Europe.

Yet American progress obliged Europeans to press on, despite their growing organizational troubles. In 1962 the U.S. Congress passed the Communications Satellite Act. The following year NASA launched *Syncom 1*, the world's first geosynchronous communications satellite,

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[18] A. V. Cleaver, "European Space Activities since the War: A Personal View," British Interplanetary Society Paper (March 1974). The United States cooperated heartily with ESRO, including providing a tracking station in Alaska. When ESRO turned increasingly to commercial applications of space technology at the end of the 1960s, however, American enthusiasm cooled.

while President Kennedy embarked on a hurried campaign for a global communications network. This first commercial application in space was precisely the sort of enterprise in which Europeans hoped to specialize, yet the United States moved so quickly that negotiations ensued for an international telecommunications satellite consortium long before the Europeans had any technical leverage whatever. INTELSAT, founded by nineteen nations in 1964, fell under exclusive American leadership. The United States controlled 61 percent of the voting authority, and virtually 100 percent of the necessary technology, and the U.S. COMSAT Corporation was the only entity in the world capable of deploying and managing the global system. The European Conference on Satellite Communications, formed to provide the Europeans with a united front in negotiations with the American giant, succeeded in making the INTELSAT accord temporary, but for the time being the Americans had a monopoly. All contracts necessarily went to U.S. firms, only NASA had the means to launch the satellites, Americans managed the system (sometimes, it seemed, in the interest of the American common carriers like AT&T and ITT), and NASA was told to refuse launch service for potentially competitive foreign satellites.[19]

After 1966 European parliaments began to grasp what EUROSPACE had understood from the beginning. The entry cost to the space market would be far higher than conceived in the sanguine moments of 1962, and European space spending, to be effective and politically acceptable, must be targeted narrowly on "practical" applications rather than basic science. ELDO's Europa booster, therefore, underwent several upgrades, turning the low-orbit launcher into one capable of launching heavier payloads into geosynchronous orbit 22,000 miles above the earth. Confusion attending these redesigns, made before *Europa-1* had achieved a single success, meant more delay and waste. By 1969 ELDO had still not made a launch despite a budget

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[19] On background and negotiation of the INTELSAT Convention, see: Murray L. Schwartz and Joseph M. Goldsen, *Foreign Participation in Communications Satellite Systems: Implications of the Communications Satellite Act of 1962*, RAND RM 3484-RC (1963); U.S. Congress, Committee on Government Operations, *Satellite Communications*, 88th Cong., 2d sess. (1964), pt. 2, pp. 661–65; Jonathon F. Galloway, *The Politics and Technology of Satellite Communications* (Lexington, Mass., 1972); Delbert D. Smith, *Communications via Satellite: A Vision in Retrospect* (Boston, 1976); Michael Kinsley, *Outer Space and Inner Sanctums: Government, Business, and Satellite Communication* (New York, 1976); U.S. Senate, *International Cooperation and Organization for Outer Space*, pp. 117–20. On the European Conference on Satellite Communications, see Smith, *Communications via Satellite*, pp. 135–41; for European acquiescence in temporary U.S. domination in hopes of gaining future influence over INTELSAT, see U.S. Congress, *Satellite Communications*, pt. 1, p. 28.

three and one-half times the initial estimate. The European Space Conference, at French insistence, debated plans to shift priorities in ESRO from scientific to commercial satellites, while Britain and Italy, pleading straitened finances, threatened to pull out of the European space effort altogether.

Insufficient capital, political disputation, the problem of *juste retour*—any of these handicaps might alone have crippled such an awkward venture in multinational command R&D. But there was more. Systems integration for an international space booster was a boondoggle. Every technical hurdle had to be surmounted by an international committee whose babble of tongues only exacerbated the habitual lack of communication among scientists, engineers, and bureaucrats. One of the more tolerant veterans of those days recalled that whenever an improvisation was called for, the French stubbornly refused to violate any hard-won procedural principle; the Germans endorsed the principle, then listed all conceivable exceptions; the Italians excitedly urged renegotiation of the principle to accommodate the offending contingency; while the British cheerfully accepted any improvisation so long as under no circumstances would it serve as a precedent! Nor did the French send their best men to ESRO and ELDO, reserving them for the national effort, while others were accused of loading the space agencies with deadwood personnel.[20]

By the end of the decade the European space program was a shambles—and this at the peak of concern over the technology gap, brain drain, and "industrial helotry," all presumably products of explosive American technocracy. EUROSPACE tried to capitalize on this mood, best expressed by Jean-Jacques Servan-Schreiber's *The American Challenge*, by warning its cultured countrymen against their tendency to sniff at the technical achievements of boorish Americans: Carthage's flourishing culture did not save it from the Romans, nor did Rome's superior culture fend off the barbarians. Echoing NASA, EUROSPACE identified the real value of Apollo not in lunar exploration itself but in the perfection of techniques for large-scale R&D, national mobilization, and technological spin-offs. If Europe did not steel itself to make the necessary effort toward technological independence, it would soon be too late. The Germans expressed this as *Torschlusspanik*: Europe must jump through the door to the space age before the door

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[20] On the problems of the European space program in the 1960s, see especially: *ELDO, 1960–1965: First Annual Report* (Brussels, 1965) and *Annual Reports (1966–)*; *ESRO, First General Report, 1964–65* (Paris, 1966) and *Annual Reports (1967–)*. Books on the frustrations of the 1960s include Jacques Tassin, *Vers l'Europe spatiale* (Paris, 1970) and Orio Giarini, *L'Europe et l'espace* (Lausanne, 1968). Anecdote on national temperaments from Tassin, pp. 98–99.

slammed shut. The Italian government called for a "technological Marshall plan" and British Prime Minister Harold Wilson for a "European technological community" to supplement the Common Market.[21]

Americans at the time, entering the home stretch in the race for the moon, naturally believed their own advertising about the superiority of the American system for generating high technology. The Atlantic Institute, the Organization for Economic Cooperation and Development, and other Euro-American institutions earnestly inquired into how to bridge the technology gap. Robert McNamara and James Webb argued that the real gap was not in hardware but in management techniques and systems analysis as practiced in the United States. Zbigniew Brzezinski emphasized the importance of scale: "All inventions for a long time will be made in the U.S. because we are moving so fast in technology and large-scale efforts produce inventions."[22]

Dismay and discouragement made 1968–72 years of confusion and cautious rebirth for space-age Europe. The Europa-2 booster failed four times to launch a satellite, and ELDO finally collapsed.[23] The Nixon administration, absorbed in planning for the post-Apollo period, invited the Europeans to collaborate in the proposed Space

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[21] EUROSPACE, *Towards a European Space Program* (Fontenay-s-bois, 1966). On the technology gap generally, see: Jean-Jacques Servan-Schreiber, *Le Défi américain* (Paris, 1967); Norman Vig, *Science and Technology in British Politics* (Oxford, 1968); Pierre Vellas, *L'Europe face à la révolution technologique américaine* (Paris, 1969); Klaus-Heinrich Standke, *Europäische Forschungspolitik im Wettbewerb* (Baden-Baden, 1970).

[22] Atlantic Institute, *The Technology Gap: United States and Europe* (London, 1970); Richard R. Nelson, *The Technology Gap: Analysis and Appraisal*, RAND P-3694-1 (1967); Roger Williams, *European Technology: The Politics of Collaboration* (London, 1973). McNamara cited by Williams, p. 25; Brzezinski cited by James Webb, memo to Arnold Frutkin, June 22, 1967, NASA History Office.

[23] Events in Britain determined the final fate of ELDO. Despite the role of Price, Massie, Thorneycroft, and other Britons in the founding of the organization, British cabinets exhibited a lasting confusion about space and technology policy. Historically, the United Kingdom had the third-highest R&D budget in the world, while its industrial decline periodically raised alarms about the need for new technology. Nevertheless, budgetary pressures and bungling seemed always to prevent a coherent policy on the French model. Officials responsible for space suffered from a bureaucratic minuet that shifted them among nine different ministries over the space of a decade. Having canceled its national missile programs, the British government revived scientific rocket research in 1964 and finally launched a single, homemade satellite on the Black Knight booster in 1971. After 1957 the British depended on the United States for strategic missiles and among the Europeans were the most willing to rely on NASA for access to space, earning them in European space councils the epithet "the delegates from America." In April 1968, Anthony Wedgewood-Benn declared on behalf of the Labour government that Britain would make no further commitment to ELDO beyond her current obligations: "The effort of the Government should be directed to reinforcing the industrial potential which Europe already possesses."

Shuttle program. The Germans were especially enthusiastic, but this seemed to imply the permanent "subcontractor status" that the French in particular despised. The United States also proved accommodating in the scheduled renegotiation of the INTELSAT convention. Europeans, together with Third World members, won the right to outvote the United States in the assembly—for example, on placement of contracts—and an eventual termination of the COMSAT Corporation's management contract. But Europe could not take full advantage of such concessions without its own launch capacity and state-of-the-art comsat technology.

All was not bleak. France and Germany collaborated on a communications satellite named *Symphonie* and Britain on a geosynchronous test satellite of its own. France, of course, pursued her own military missiles, national satellite programs, and limited cooperation with the United States and, after 1966, with the USSR. After 1967, when the Hammaguir lease expired, de Gaulle also approved construction of a new equatorial spaceport in Kourou, French Guiana. Above all, the ELDO and ESRO experiences, however barren of results, gave firms and agencies the apprenticeship they needed in space technology and management. Their work on the Coralie, for instance, taught French engineers to handle hypergolic fuels and the high-energy LH_2/LOX upper stages favored for boosting heavy payloads to geosynchronous orbits. Finally, the organizational flaws that plagued ELDO and ESRO could be corrected. EUROSPACE electronics and aerospace firms formed multinational consortia with names like MESH, STAR, and COSMOS to compete for contracts and alleviate problems of *juste retour*. The European Space Conference sponsored the Bignier and Causse Reports that proposed fundamental reforms of the European space effort. They included a single European space agency, long-range program planning with guaranteed budgeting, centralization of authority for program management and systems integration, and smorgasbord participation by which member states could elect to share in some major programs and opt out of others, overall responsibility for major projects to be vested in the country paying most of the bill.[24]

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[24] Michel Bourely, *La Conférence spatiale européenne* (Paris, 1970); J. Henrici, *An Overall Coherent and Long-Term European Space Program* (Munich, 1969); Théo Lefevre, *Europe and Space* (Brussels, 1972); Laurence Reed, *Ocean-Space—Europe's New Frontier* (London, 1969); C. R. Turner, "A Review of the Third EUROSPACE US-European Conference" and T. H. E. Nesbitt, "Future US-European Cooperation in Space: Possibilities and Problems," *Spaceflight*, January 1968 and May 1969; A. V. Cleaver, "The European Space Program, DISCORDE," *Aeronautics and Astronautics*, October 1968.

In December 1972, after five years of uncertainty about its own and America's future plans in space, the European Space Council adopted the above recommendations and proclaimed a new European Space Agency (ESA). It absorbed ELDO and ESRO and promised common, coordinated, long-term space and industrial policies. ESA grew out of the failures of the 1960s but also from the changed setting of the 1970s. De Gaulle was gone, Britain was in the Common Market, dynamic Germany took up the slack left by Britain and Italy, the United States–Soviet space race seemed over, and all nations were turning attention to the "practical" benefits of spaceflight. Last but not least was the U.S. space program for the 1970s. The Space Shuttle, approved by Nixon in 1972, promised to inaugurate a new era of routine, inexpensive orbital flight and yet offered the Europeans an intriguing target of commercial opportunity. For the Shuttle, a low-orbit workhorse, would not markedly improve American capability to launch payloads into high orbits. The Europeans had not only a political imperative but a technical opportunity to press on with development of a conventional heavy booster.

The ESA rested on a grand compromise. The other Europeans granted a renewed drive for the independent launch capacity demanded by France on the condition that France assume management and provide the bulk of funding. Second, ESA acceded to Germany's wish for a major cooperative program with the United States on condition that the Germans take charge and absorb most of the cost. Third, the British won approval for their pet project, a marine comsat, on the condition that they take the lead. The first program was the L3S launcher, soon to be dubbed Ariane, and 70 percent French; the second was *Spacelab*, made to fly inside the U.S. Shuttle cargo bay, and 53 percent German; the third, Marecs, was 56 percent British. Support of research centers and administration inherited from ESRO remained common responsibilities. But "big R&D" was now a mixture, not a solution, of national inputs; ESA won the loyalty of member states only through a partial nationalization of its international program. Gaullism and Euro-Gaullism coexisted, and the current era of neomercantilist competition in space was born.[25]

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Europe has not escaped all the difficulties of multinational R&D. Member parliaments still have an aversion to long-range planning and

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[25] On the transition to ESA, see: ESA, *Space—Part of Europe's Environment* (Paris, 1979) and *Europe's Place in Space* (Paris, 1981); U.S. Congress, *World Wide Space Programs*, pp. 285–314.

financial commitments, and budgets have remained at a level less than one-tenth that of NASA (see table 1). But ESA's first decade must be judged a success. On Christmas Eve 1979, twenty-two years after *Sputnik* and seventeen years since the birth of ELDO, the Ariane placed a European satellite in orbit from Kourou. Since then the Ariane has had a mixed record but is the first nonsuperpower booster declared operational for competitive commerce. The French (with a 59.25 percent interest) promptly incorporated a "private" company, Arianespace, and won contracts to launch comsats for INTELSAT, Arab and South American states, Australia, European Space Agency (of course), and even some U.S. firms.

In the meantime, the United States spent twelve times the cost of Ariane to develop the Space Shuttle. How is it that the American monopoly in space transportation was broken by a rocket that merely duplicated a capability (equivalent to the Thor Delta) the United States had had for two decades? According to the "méthode assez française," French engineers designed Ariane for one purpose: provide Europe with a sturdy, reliable heavy booster capable of launching satellites for the world market at a price competitive with that of American systems. What French officials foresaw as early as 1972 was that "outmoded" technology could still be commercially viable. The first two stages of Ariane, derived from the French Viking engine, are fueled by UDMH and nitrogen tetraoxide. This combination is not as powerful as LH_2 and LOX but need not be refrigerated to -250°C. The third is a high-energy stage sufficient to boost a 3,850-pound payload into trans-

TABLE 1

GLOBAL SPACE BUDGETS 1982

	Space Budget (in $Billions)	% of U.S. Budget	% of GNP
United States	12.1*	100	.40
USSR	14–28	116–227	1.0–2.0
France	.42	3.47	.08
Japan	.40	3.31	.04
West Germany	.33	3.35	.05
ESA..............	1.52	12.58	.06

SOURCE.—Office of Technology Assessment, June 1984.

*The United States total includes military space spending on less classified programs (including reconnaissance satellites). The U.S. civilian space spending for 1982 amounted to some $5.7 billion, of which the majority went for Shuttle development and operations. Foreign R&D spending, therefore, though merely a fraction of American efforts, sufficed to sustain competition in a number of targeted space applications. The French agency CNES, for instance, spent 1,162.7 million francs, or 39.4 percent of its budget, on space applications, as compared to NASA's $333.8 million, or 5.8 percent of its budget, in 1982.

fer orbit, a highly eccentric path that reaches apogee at the required 22,000 miles above the earth. The final apogee motor that nudges the satellite into a circular orbit at that height is the responsibility of the customer. An upgraded Ariane-4 with a payload of over 9,000 pounds is approved and scheduled for operation by 1990.[26]

Now let us compare Ariane to the Shuttle, the only surviving project in a post-Apollo plan that originally included a space station, a lunar base, and even a manned voyage to Mars. Even to win approval of the Shuttle, NASA had to cut its initial cost estimates in half. Budgetary, technical, and military constraints, as well as the "fully reusable" feature, all dictated concentration on low orbits. The manned capacity of the Shuttle in turn meant cuts in payload and operating envelope. Finally, even the fully reusable feature was compromised, and the Shuttle evolved as an unlikely combination consisting of the orbiter, two strap-on recoverable solid rockets, and the bulky, nonrecoverable external tank.[27] The Shuttle is a spectacular tool for low-orbit operations but does not significantly increase efficiency on high-orbit launches. To meet the needs of communications customers, the Shuttle must be augmented by a perigee stage, or "inertial upper stage," carried in the cargo bay and released at an altitude of 120 miles. The perigee stage then boosts the payload to its apogee of 22,000 miles, whereupon the apogee stage connected to the satellite fires to achieve the circular geostationary orbit. It is a cumbersome process: it was this which French planners perceived in 1972.[28]

Even if the Shuttle-plus system proves reliable—and it too has had mixed results—can it match the Ariane in price? That depends entirely on government policies, for state-funded high technology is a neomercantilist controlled market, as de Gaulle sensed from the dawn of the space age. NASA claimed a cost base for geosynchronous insertion of $30 million, equal to that claimed for Ariane. Either competitor could slash prices, even below cost, in order to capture a greater market share for political purposes. But a liberal pricing policy is harder for the United States: the Shuttle cost $12 billion through 1980, the Ariane

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[26] A. Dattner, "Reflections on Europe in Space—the First Two Decades and Beyond," ESA BR-10 (March 1982).

[27] On the Shuttle decision, see: U.S. Congress, Subcommittee on Space Science and Applications, *U.S. Civilian Space Programs 1958–1978*, 97th Cong., 1st sess. (1981), pp. 445–57; John M. Logsdon, "The Space Shuttle Decision: Technological and Political Choice," manuscript supplied by author. Logsdon, the director of the graduate program in Science, Technology, and Public Policy at George Washington University, is completing a book on the decision to build the Shuttle.

[28] For an excellent summary of the current launch-vehicle competition, see Alain Dupas, *Ariane et la navette spatiale* (Paris, 1981).

about $1 billion. Could not the United States continue to compete with its reliable "old-fashioned" rockets? To be sure, but the United States had such a stake in the Shuttle that it cut back production of disposable boosters in the expectation that Shuttle would revolutionize the industry. The Reagan administration, by contrast, has encouraged a renaissance of disposable launchers, but preferably through private enterprise.[29] Even as the United States pushes space technology forward into a new era, therefore, it is losing its hold on the only commercial rewards of this expensive and vital field.[30]

Yet launchers are not the only arena of competition; nor are France and ESA the only challengers in space technology. Seeking niches for themselves in these and other space markets of the future, the British, Canadians, and Japanese have forged ahead of the U.S. civilian space program in the research necessary to the next age of satellite communications, the 30/20 gigahertz or Ka band of the radio spectrum. Satellites using this broad, high-frequency band will vastly expand overall capacity, alleviate the growing shortage in geosynchronous orbital slots over the equator, and facilitate sophisticated services such as data transmission and conference calling. Meanwhile, France has shown no appreciable decline in technocratic vigor. Indeed, in matters of international technological competition, François Mitterand and the Socialists seem more Gaullist than de Gaulle, pledging to revivify national R&D and realize the old Gaullist vision of "France in the Year 2000." The French space agency CNES has promised "to consolidate our position in the principal means of applications (telecommunications, television, earth observation), to construct a solid space industry, and enlarge our penetration of the international market for launchers,

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[29] Current U.S. policy options in civilian spaceflight are detailed in: U.S. Congress, *United States Civilian Space Programs 1958–1978*, pp. 5–28; Office of Technology Assessment, *Civilian Space Policy and Applications* (Washington, D.C., 1981), pp. 3–77; and the Office of Technology Assessment's new study, *Competition and Cooperation in Outer Space* (Washington, D.C., 1984).

[30] Can the market for satellite launches really be worth the effort Europe has made to break the American monopoly? In strictly commercial terms, the answer depends on how many scientific and commercial satellites will be orbited in coming decades. European analysts expect 170 missions into geosynchronous orbits alone by 1995: 110 for communications, fifty for television, and ten for meteorology. Even NASA estimates between 103 and 163 payloads by 1998 for which U.S. launchers and Ariane will compete (Battelle Columbus Laboratories, *Outside Users Payload Model* [NASw-338, June 1983]). Other analysts, however, predict a glut in communications circuits in the near future resulting from a decline in the rate of increase of demand or improvement in the capacity and durability of satellites or indeed from competition from earthbound fiber-optic circuits. But the "success" of Ariane or satellite systems is not strictly a commercial matter. Their inspiration was largely political.

satellites, and associated services and ground equipment."[31] In 1978 the French targeted remote sensing from space, developed a system called Spot designed to compete with NASA's Landsat, and founded another chartered company, Spotimage, to provide data for minerals prospecting, fishing, land-use analysis, mapping, and soil and agricultural management, especially to developing nations. Since the U.S. government has been unable to decide whether or how to market Landsat data, France threatens again to reap the rewards of a technology pioneered by the United States. And if the United States should determine to make full use of the Shuttle and exploit the prospects for space-based manufacturing in low orbit, the Europeans are ready; ESA is currently evaluating various plans for a minishuttle of its own, either the manned Hermes or the unmanned Solaris, as well as several space-station concepts.

Hence the age of Gaullism and Euro-Gaullism has spawned national and multinational, government-funded and -managed inventions of the future—not to encourage the presumed interdependence and integration stemming from global technologies but to preserve national autonomy and power. As de Gaulle perceived, however, competitiveness abroad necessitated centralization at home. Each of the European governments has absorbed or consolidated its aerospace companies into giant, semipublic behemoths: British Aerospace, France's Aerospatiale, Italy's Aerospaziale, recently the German merger of MBB (Messerschmidt) and VFW. Whatever the power of computers, nuclear weapons, jet aircraft, or space communications to make of our world a "global village," "Spaceship Earth," or a "lifeboat" in which all survive or perish as one, the space age has nonetheless sparked new political-economic fragmentation, even within the non-Communist world. The efforts of the "great" but not "super" powers to mobilize and scrap for an abiding autonomy and self-sufficiency mean that neither the Wilsonian nor the Leninist model, but rather the Gaullist model, of international order is riding the tide of technology in our time.

* * *

Where does all this leave the putative "free world leader"? It seems that the United States, the traditional, secure industrial leader and exponent of free trade, finds itself in a position reminiscent of late-19th-century Britain—not challenged in overall leadership but outmaneuvered first in one market then another by determined local

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[31] Jean-Marie Luton, "La Politique spatiale française," *Les Cahiers français*, May–September 1982, p. 94.

rivals. Space technology, the very symbol of American technological hegemony just a decade ago, now reflects the bitter challenge facing the United States in the 1980s.

Why did Brzezinski's expectation of a growing U.S. lead in high technology prove false, especially since the nation still spends more on space than the rest of the free world combined? First and foremost, it is because of a nefarious division of labor that places on the United States almost sole responsibility for the strategic defense of the non-Communist world. If one counts military interest in the Shuttle, almost 60 percent of American space spending goes toward military research, while less and less money has been available for critical commercial sectors in astronautics (and aeronautics). The military requirements have an even more vexing effect—several technologies now exploited by foreigners have been developed by the Pentagon but cannot be transferred to the private sector for security reasons. These include high-resolution remote-sensing techniques and 30/20 comsat technology. United States corporations, in turn, shy away from risky markets in which foreign competition is heavily subsidized by government.

The Shuttle could still transform the space environment if vigorously exploited. The challenge of the various "Gaullists" might be transcended by a U.S. space station, space-based manufacture of drugs and crystals, or communications "platforms" with functionally limitless capacities, all built with modules boosted by the Shuttle. But to justify such expensive enterprises politically and underwrite them with tax dollars merely to maintain an image of leadership and technical virtuosity would be to adopt a Gaullist approach on our own account, while attempts to justify such a process commercially might not survive limited-range cost-benefit analysis. Nor is it natural for Americans to engage in centrally managed change, in "ten-year plans" dictated by bureaucrats, even assuming that NASA, the Pentagon, the White House, Commerce, NOAA, the aerospace industry, and Congress could agree on a long-term strategy for civilian space exploitation. Gaullism is not an expression of the American culture of technology. These considerations help to explain why Reagan aped Kennedy, in a dramatic presidential appeal, by defining a civilian space station as a national goal to be achieved "within a decade," despite the opposition of the Pentagon, the president's science adviser, and the Office of Management and Budget. Yet we cannot know whether such a station is a bold investment or a folly until decades after its completion—much less its approval.

These perplexing problems, at home and abroad, are not confined to space technology. They exist in more and more sectors as state-driven technological change pushes foreign governments further away from the free-market ideal that flourished in the merely industrial age of the 19th and early 20th centuries. Western intellectuals always assumed that the postcapitalist age would usher in socialism and integration. Instead, it ushered in Gaullism with its rejection of capitalism and communism, its enforced unity at home and Darwinist struggle abroad. The space age is an age of neomercantilism, or competing national socialisms, and for the first time Americans can neither retreat from the world nor hope to make it over. How will they adapt to life in a technocratic world they helped to make but do not like, cannot change, and cannot escape?

DOE/ER-0224

ANNUAL REPORT TO THE WORKING GROUP ON TECHNOLOGY, GROWTH AND EMPLOYMENT

SUMMIT WORKING GROUP ON CONTROLLED THERMONUCLEAR FUSION

April 1985

Prepared by
U.S. Department of Energy
Office of Energy Research
Washington, D.C. 20545

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INTRODUCTION

The Summit Working Group in Controlled Thermonuclear Fusion was established in 1983 in response to the Declaration of the Heads of State and Government at the Versailles Economic Summit meeting of 1982 (Appendix A), and in response to the subsequent report of the Working Group in Technology, Growth and Employment (TGE) as endorsed at the Williamsburg Summit meeting, 1983. Representatives appointed by the governments of the seven Economic Summit countries (Canada, France, the Federal Republic of Germany, Italy, Japan, the United Kingdom and the United States) and a representative of the Commission of the European Communities met in Washington, D.C. on September 29 and 30, 1983 under the co-leadership of the United States and the European Communities. A report of the conclusions of this meeting has been published and a progress report was included in the TGE Working Group report to the 1984 London Summit (Appendix B).

Following the London Summit, the fusion Working Group met in Brussels July 5 and 6 to consider the implementation of collaborative projects taking into account the conclusions issued in the Communique from London (Appendix C) and the recommendations of the TGE report. In particular, paragraph 22 of the report recommended:

> "22. Effective cost sharing is becoming a more important element in the construction of major new facilities. Collaborative projects would benefit if coherent long term plans for the construction and sharing of facilities in our countries were to be developed."

The London Communique had the following invitation:

> "We welcome the further report of the Working Group on Technology, Growth and Employment created by the Versailles Economic Summit and the progress made in the 18 areas of co-operation, and invite the Group to pursue further work and to report to personal representatives in time for the next Economic Summit."

A summary of the progress of the Summit Working Group in Controlled Thermonuclear Fusion, prepared for the Bonn Economic Summit of May 1985, is included as the first section of the Annual Report.

The discussions at Brussels were based on the intermediate term strategies of each Summit Nation and lead to the creation of Subpanels with specific charges for action. The first Subpanel was charged with planning for collaboration on major new fusion research facilities. The second was charged with identifying key areas in physics, technology and reactor concept improvement for near-term, beneficial international collaborations. The Working Group agreed to provide support to a Subpanel established by the Summit Working Group in High Energy Physics, to investigate administrative obstacles that can affect all international collaboration in science and technology. Subpanel membership is listed in Appendix D.

The three Subpanels presented their findings to the Working Group at a meeting in Cadarache, France, January 15 and 16, 1985. Following the reviews and discussions, a report was prepared for the TGE Working Group on the conclusions and recommendations of the fusion Working Group. The papers and reports of the two meetings comprise the Activities section.

PROGRESS REPORT TO THE BONN SUMMIT

3

Area for collaboration :	Controlled Thermonuclear Fusion
Lead Country :	United States of America, European Communities
Participants :	Canada, France, Federal Republic of Germany, Italy, Japan, United Kingdom
Observers :	-
Invited International Organizations :	-

Aims:

1. To accelerate world development of a new energy source using practically inexhaustible fuels and possessing potential advantages from an environmental point of view.

2. To avoid unnecessary duplication of costly equipment and installations, and to enhance collaborative exploitation of existing devices.

3. To study the possibility of carrying out joint projects in the medium term.

Activities:

Since the London Summit in 1984 the Fusion Working Group met in July 1984 and January 1985.

Three sub-panels were established to examine long-term perspectives, short and medium-term common problems in physics, technology and reactor concept improvements, and administrative obstacles to effective international collaboration. Their reports were discussed and their conclusions provide the basis of further activities.

Outlook:

Joint planning and collaboration on major fusion research facilities will be pursued in order to avoid duplication and to optimize the utilization of resources in the spirit of Article 22 of the Report of the "Technology, Growth and Employment" Working Group to the London Summit that urges cost effectiveness in this area of fundamental research. In the same spirit collaborative activities will be undertaken in specific areas of physics, reactor concept improvement and technology. Such collaborative activities Presuppose that Summit Members will continue to support their individual programmes at adequate levels. Progress Reports will be submitted within a year.

It is hoped that a Summit endorsement of an indepth review of administrative obstacles to effective international collaboration in science and technology will lead to coordinated action to eliminate them or mitigate their negative impact.

ACTIVITIES

BRUSSELS, BELGIUM

JULY 1984

Controlled Thermonuclear Fusion Agenda

Opening Statements
  A. W. Trivelpiece, United States
  P. Fasella, European Communities

Intermediate Term Program Strategies
  M. Wada, Japan
  D. Palumbo, European Communities
  J. F. Clarke, United States

Charges to Subpanels

Controlled Thermonuclear Fusion Participants

CONTROLLED THERMONUCLEAR FUSION AGENDA

Brussels, 5 and 6 July 1984

THURSDAY 5 JULY

I. OPENING

1.1 Introductory remarks

- Prof. P. FASELLA, host Co-leader and General Director for Science, Research and Development, Commission of the European Communities.
- Dr. A. TRIVELPIECE, Co-Leader and Director, Office of Energy Research, United States Department of Energy.
- Other introductory statements.

1.2 Adoption of the agenda.

II. INTERMEDIATE TERM STRATEGIES

2.1 Presentation of the presently envisaged intermediate term strategies of each programme (Japan, Canada, US, EC).

2.2 General discussion on the presently envisaged intermediate term strategies and possibilities of cooperation.

III. PREPARATION OF A RECOMMENDATION FOR THE 1985 SUMMIT

3.1 Identification of main areas for possible cooperation (e.g.: next steps, technology, alternative lines, physics problems).

FRIDAY 6 JULY

3.2 Drafting of terms of reference for possible working groups on each of the identified areas (if appropriate, by separate drafting groups).

3.3 Adoption of terms of reference, planning of further work, next meetings.

CONTROLLED THERMONUCLEAR FUSION WORKING GROUP MEETING
Brussels, Belgium
July 5 and 6, 1984

A. W. Trivelpiece, Co-Leader
United States

Opening Remarks

At the Versailles Summit meeting, some statements were made regarding the importance of cooperation in science and technology to the world economy. In particular, it was agreed that:

> "Revitalization and growth of the world economy will depend, not only on our own efforts, but also, to a large extent, upon cooperation among our countries and with other countries in the exploitation of scientific and technological development."

It was further agreed to set up a working group of representatives from the seven Summit countries and the European Commission to identify activities that would help attain these objectives. This group made recommendations in a report that was accepted by the Summit countries and reviewed at the Williamsburg Summit.

Several of the conclusions and recommendations of the Summit working group provide the basis for our meeting here in Brussels. Among them:

- "Fundamental scientific research is one source of technological progress in industry and should be given support by governments."
- "Science and technology are a source of national and international strength and can provide immense opportunities for revitalization and growth of the world economy. They should therefore be given consideration in all policy decisions for national development and international cooperation."

They further recommended that the Heads of State and Government "...take science and technology into account in their policy decisions and continue to include the subject on their agenda at future Summit meetings." One of the areas that they recommended be considered for enhanced cooperation is fusion.

The report that they prepared was adopted by the Summit members and subsequently ratified by the Williamsburg Summit process. Following Williamsburg, it became clear that some response to the recommendation of the Working Group was called for. Since the U.S. was the host country and appropriate interest at a high level in government was called for, I invited the Summit countries and the Commission of the European Communities to send a high level political representative of their government to discuss the actions that we might take to be responsive to the instructions that were both explicit and implicit from the Williamsburg Summit.

In particular, we were obliged to prepare a progress report on those activities that we decided to have carried out and to report any progress to the London Summit. Such a report was prepared containing a summary of our first meeting of 29, 30 September 1983.

The conclusions of the September meeting were not many but were significant because of the composition of those drawing the conclusions. The Heads of Delegation reported the conclusions back, not to their scientific community, but to their political leaders. The conclusions were three:

1. The representatives agreed that the fusion research and development programs in progress in the United States, Europe, Canada, and Japan are proceeding well with reasonable expectations of success.

2. Further, they agreed that international cooperation through existing bilateral and multilateral agreements has been excellent over the past 25 years and is particularly desirable for fusion.

3. Early joint planning of future developments is strongly recommended.

A mechanism for the joint planning was left to be set up following the London Summit meeting if the conclusions of this group were endorsed by the leaders. The group felt that any step beyond that of establishing the planning mechanism could not be taken at that time because the exact specifications for a cooperative venture depends upon the results from JET, TFTR, and JT-60.

The deliberations of 29 and 30 September served as the input for the report of the Working Group on Technology, Growth and Employment to the London Summit. In this report there are two items to which I wish to call attention. One of these is Paragraph No. 22 of the report which states:

> "Effective cost sharing is becoming a more important element in the construction of major new facilities. Collaborative projects would benefit if coherent long-range plans for the construction and sharing of facilities in our countries were to be developed."

The second item in this report is the fusion summary page that describes the aim, activities, and outlook for this area. In particular, it says that "...the Working Group recommends that a consensus be sought on the desirable strategy in fusion to facilitate early joint planning to coordinate individual planning." This report was accepted by the London Summit and may well have presaged the last sentence of Paragraph No. 22.

The communique issued after the Summit dealt mostly with economic concerns, but it also took special note of the progress made in the 18 areas of cooperation and "invited" the group to "...pursue further work and to report to a personal representative in time for the next economic Summit."

This is an important opportunity that is not without its risks. Many of the political leaders that I come in contact with state rather categorically that it is ridiculous to even consider duplicating major facilities in several areas of science or technology just for the purpose of scientific competition. So the risk is that unless we develop plans or programs that avoid unnecessary duplication, we may find that needed facilities may not be forthcoming anywhere. The opportunity aspect stems from the fact that the Heads of State of the Summit countries have formally recognized the important role that fusion plays in future economic development, and have asked what kind of collaboration is feasible for major facilities and some of the ancilliary aspects of their operation.

I see our task here in the next two days as one of identifying the charters for several panels that will involve representatives for the Summit countries, or others if appropriate, to do the required work and report back to this group their findings, conclusions, and recommendations that answer the question of the Heads of State. The object is not to solve these problems prior to adjournment, but to be satisfied that the necessary tasks have been commissioned. I would remind you that we should not use this forum to seek solutions to the many minor problems that crop up in the normal course of international cooperation, but rather we should focus our efforts on developing the information that will convince the Heads of State and the legislative bodies of these states that there is a rational plan or process by which fusion can proceed on a worldwide scale without duplication of costly facilities. I believe that it would be foolish to not take full advantage of the opportunity presented by the Summit process. I look forward to lively and constructive discussions on these subjects.

VERSAILLES SUMMIT FOLLOW-UP MEETING FOR FUSION
Brussels, 5 and 6 July 1984

P. Fasella, Co-Leader
European Communities

Opening Remarks

Consensus should not be difficult to reach on the common goal of the fusion programmes of the Summit countries: the development of the necessary scientific and technological data base for the construction of a DEMO i.e. a demonstration fusion reactor including all the components of a fusion power plant but not necessarily optimized from the economic point of view.

The path leading to this goal and the consequent timing are more difficult to define. It is generally accepted that between the JET generation devices and DEMO, an intermediate step is necessary. Whether a single step will also be sufficient will depend mainly on the results of the JET generation devices.

The next step of the EC fusion programme (NET - Next European Torus) is presently conceived as a tokamak-based experimental device aimed at the demonstration of plasma performance at reactor level as well as technological feasibility of fusion. This implies that NET has a strong technological component. This definition of NET and the starting of its construction in 1992 are assumed as working hypotheses in the planning of the EC fusion programme. If such a planning can be implemented, a single step between JET and DEMO might be sufficient.

The EC fusion programme is expected to remain in the front line of fusion R&D during the eighties, thanks to JET and to the other tokamaks presently under construction. It might play a leading role also during the nineties, with the construction and starting of operation of NET.

According to information available in Europe, the US fusion programme appears to be oriented towards the construction of a Burning Core Experiment to be started in 1987-88, with the objective of demonstrating reactor level plasma performance but not technological feasibility of fusion. This seems to imply the construction of another intermediate step between TFTR (JET generation) and DEMO. We think that the Japanese planning provides for the construction of a fusion experimental reactor as a single step between JT 60 (JET generation) and DEMO, and that it is therefore similar to the European working hypothesis. An exchange of more information during the meeting, on the intermediate term plans of the three large programmes (US, Japan, EC) would obviously be very appropriate.

In any case, it appears most likely that each of the three programmes will be confronted sooner or later with the problem of an experimental device including a strong technological component. Since the construction cost of a NET-like device is of the order of 2 billion dollars, the possibility should be continuously discussed to reduce the cost of the overall effort by a pooling of resources either on a few interdependent, complementary and partially sequential machines or possibly on a single comprehensive project. The EC is prepared to play a central role in the development of fusion along the tokamak line.

Whatever the scenario eventually chosen for cooperation on the next step will be, the conditions for its setting up will have to be prepared by years of progressively increasing cooperative activity. It is therefore important to conclude and implement the agreements presently planned on a bilateral basis or within the IEA and to set up close cooperation in particular between the design teams of the next step devices of the three programmes. This will automatically imply better coordination of the programmes both in the physics and in the technology area.

It should be pointed out that in the physics area all the three large programmes are presently confronted with the very serious problem of plasma heating. Cooperation on auxiliary heating systems would be extremely helpful and might turn out to be necessary in order to solve this problem.

In the technology area the preliminary developments required for the construction of the next step constitute a very large amount of work. In several branches the work to be done lends itself particularly well to a sharing of tasks.

In conclusion, a strengthening of cooperation would be appropriate both in a short term perspective, in order to make the solution of present problems easier, and in the longer term in order to prepare the conditions for cooperation on the next step.

The EC member States as well as Sweden and Switzerland will be involved in this process through the EC fusion programme. Canada could bring a valuable additional contribution particularly in some specific areas of fusion technology.

Statement of Japan

Versailles Summit Follow-up Meeting for Fusion
Brussels 5-6 July 1984

M. Wada

There is strong need in Japan for realization of the nuclear fusion as a future energy resource, because of her scarceness in energy resources compared with demand. Today, Japan holds high technological level, being one of the advanced industrialized countries. She has been contributing to the world progress in particular in the high technology fields, and has been expecting to play a significant role in the research and development in the field of the nuclear fusion as well.

The Japanese nuclear fusion research and development has been promoted in a planned and comprehensive manner in accordance with the basic plan established by the Japan Atomic Energy Commission. At the present time, the second phase of the basic plan of the nuclear fusion research and development is being carried out. The plan has been designated as a National project by the commission since 1975. Continuous national support has been given to the project, with increase of the budget for the nuclear fusion R & D by more than an order in magnitude since that time.

The key task of the basic plan is the scientific demonstration for a nuclear fusion reactor. As a facility for this purpose, a break-even plasma test facility, JT-60, is under construction. In addition, vigorous R & D effort has been made also for the alternative lines other than tokamak. The construction of JT-60 is progressing without major difficulties, and approaching now to the final stage, with a schedule of starting experiments in April 1985.

Therefore, at the present time, Japan is concentrating her major effort on the achievement of the break-even plasma conditions with JT-60. However, it is believed that time has come to initiate preparation for a substantial plan of the next phase which will follow the present second phase.

The Japanese long-term program for the development and utilization of nuclear energy, which is the principal policy of the government for atomic energy development in general, was revised in June 1982. In the program, the basic philosophy and direction of the nuclear fusion research and development were described as the demonstration of the technical feasibility of nuclear fusion as a viable energy source, aiming at realization early

21st century. Namely, it stated the major tasks to be the achievement of self-ignition conditions in the latter half of 1990's by constructing an experimental reactor which was currently assumed to be tokamak type, and the research and development for demonstrating the necessary technology and engineering.

Therefore, the substantial plan for the next phase of the nuclear fusion research and development is expected to be developed along those lines. With the commencement of the next phase in the near future, the Japanese nuclear fusion research and development will enter into a new era, aiming at realization early 21st century.

That is a general outline of the present perspective in Japan. On the other hand, in the US TFCX is considered as a follow-on device to TFTR and in Europe, NET as the one after JET. In the proposed program of EC, it is planned that final decision of construction of NET will be made in the beginning of 1990's, through several steps of careful evaluations. In order to arrive that step, various elements of R & D are coordinated. This approach can be an instructive way to promote a big project which involves many technological elements to be developed in due time.

Under such circumstances, where various scenarios can be contemplated as possible approaches, the philosophy and procedure for investigating international cooperation for the next generation machines are to be carefully examined.

In view of the nature that the nuclear fusion research and development should be continued hereafter for a long period of time, at the contemplation of an international cooperation, it is necessary to lay out a realistic cooperative plan, for carrying out it thoroughly and benefitting every participant with its results. In addition, gradual expansion of the cooperation is desirable.

From such viewpoints, let me propose here the following procedures for investigating international cooperation.

(1) First, it should be started with investigation of a comprehensive and long-range development strategy to reach realization of nuclear fusion, by defining the mission and status of the next generation machines in that strategy, and developing a common understanding as to the next generation machines.

(2) Next, it will be required to develop a common understanding as to the R & D items necessary to achieve construction of the next generation machines.

(3) Based on those common understandings, possibility for international cooperation will be investigated, by comparing national programs and extracting appropriate items to be conducted through cooperation. At the investigation of those items for cooperation, it will be reasonable and realistic to start with an investigation of possible roles to be played by the existing devices and facilities in each country, in the process towards the construction of the next generation machines with possible support to be made by other countries for those devices and facilities.

Along the line, several cooperative projects coordinated with national development strategy are already proceeding. For example, Japan has been promoting multilateral or bilateral cooperative projects, such as LCT, Doublet-III, RTNS-II, HFIR/ORR and etc. There are other several cooperations envisaged through IEA, such as those for three large tokamaks, FMIT and alternative lines. The US is also proposing cooperation in the design stage of TFCX.

We believe that starting with investigation of possible cooperation in such realistic projects may be a good approach towards fruitful results.

(4) If the proposed procedures are regarded as adequate and reasonable and are acceptable to each country, setting up a task force to implement the investigation would be an approach worthwhile for consideration.

In concluding my presentation, let me add the following remarks;

First, we believe that implementation of a cooperation between three large tokamaks should be promoted.

Second, we are prepared to respond constructively to the TFCX design activities, by sending our experts in order to support the progress.

Finally, concerning FMIT, the subject is under discussion of the Atomic Energy Commission. However, since an interim experts report was recently submitted to the Commission, emphasizing importance of neutron irradiation experiment in nuclear fusion material development and usefulness of FMIT for that purpose, we are expecting to initiate necessary actions, at submission of the final report by the end of this year.

Versailles Summit Follow-up Meeting for Fusion
Brussels, 5 and 6 July 1984

Presently envisaged intermediate term strategy of the EC fusion programme

D. PALUMBO

Since the beginning of the 70ies the European programme has been centered on the tokamak as the main line. Our general strategy, as recommended by the Beckurts Panel in 1981 is illustrated in Fig. 1.

We recognize that at least one intermediate step between JET and DEMO is necessary. We hope, and this will depend mainly on the results of the JET generation devices, that a single step will also be sufficient. This would be beneficial to the programme, by reducing both delays and expenditure.

With this objective in mind, NET was defined as a tokamak based device with a strong technological component, reaching 3 MW a/m^2 in neutron irradiation.

As shown in Fig. 1 the selection between tokamaks and other magnetic confinement concepts should take place between NET and DEMO.

Our intermediate term strategy is illustrated in Fig. 2. This is our present working hypothesis. In particular the dates must be considered as purely indicative.

At the end of 1987, two important decisions will have to be taken on the basis of JET results with powerful heating: whether to introduce tritium in JET in 1989, and whether to start the detailed design of NET;

Towards the end of 1991, on the basis of the results of deuterium-tritium operation in JET, of the information from the other Tokamaks (the new specialized devices will have been operational for 4 years at that time) and of the progress made in technology, a decision whether to start the construction of NET will have to be made.

If JET does not reach the aim of, for example, sufficient thermonuclear heating, one might decide to improve it so that it may do so. This would introduce a substantial delay in the NET schedule. It might be that JET fails, for example, due to bad scaling laws, or it might be that, even if JET reaches its aims, our general knowledge of tokamak physics, derived from JET and the other tokamaks, remains insufficient to allow extrapolation to a machine which would, with reasonable predictability, meet the physics requirements of NET. In that case, it would be necessary to construct an additional intermediate step which is devoted to physics questions only.

In order to implement this plan the following actions have been started during the present 5-year programme (1982-86) and will be vigorously pursued during the 1985-89 programme recently approved by the Commission and submitted to the European Parliament and to the Council for adoption:

- The NET team has been constituted in March 1983 and is hosted by IPP-Garching. Its present tasks are:
  - to define the basic objectives of NET, outline its essential components and determine the research and development needs for its later construction,
  - to be the focal point and to provide guidance for the current fusion effort, particularly for the technology programme,
  - to provide the technical elements for a decision at the end of 1984 on the future strategy and for the corresponding revision of the programme,
  - to strengthen the European capability for international cooperation on the Next Step,
  - to produce the future European contributions to the INTOR conceptual design as long as this is continued.
- In the physics area, the emphasis will be on heating and impurity problems. This programme will be implemented on the devices which already exist or are under construction as shown in Fig. 3.
- Work was progressively started or intensified in the six branches of fusion technology: Tritium, Superconducting Magnets, Remote Operation, Blanket, Materials, Safety & Environment. This activity will be considerably increased (more than doubled) in the next 5-year programme.
- In the field of confinement systems alternative to tokamaks the activity is concentrated on Stellarators (Garching and on Reversed Field Pinches (mainly Padova).

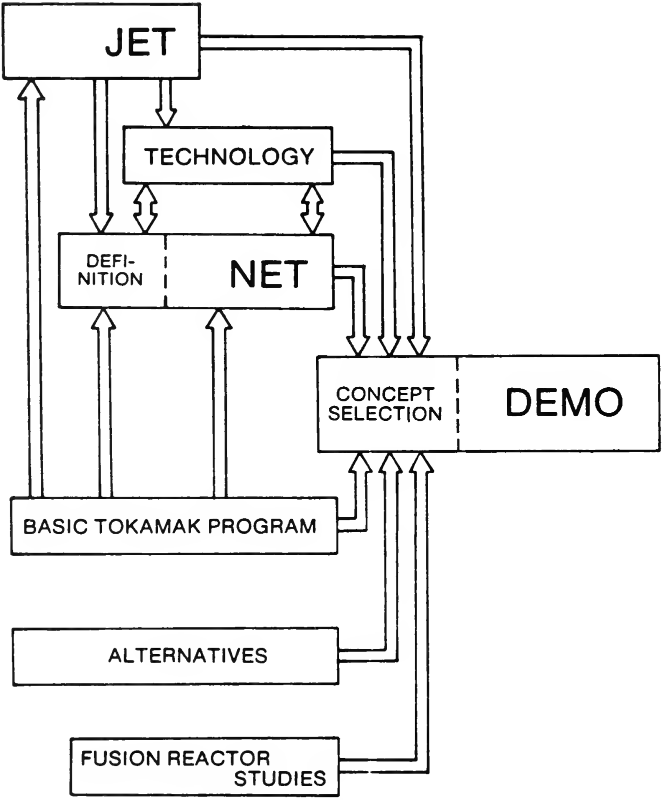
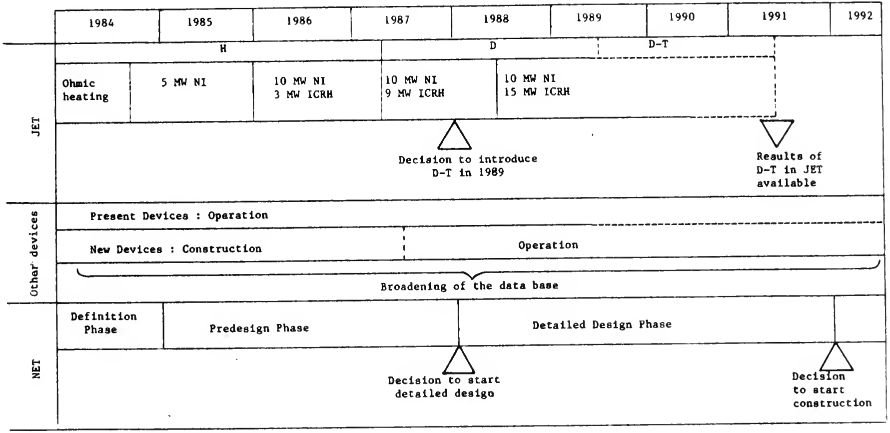


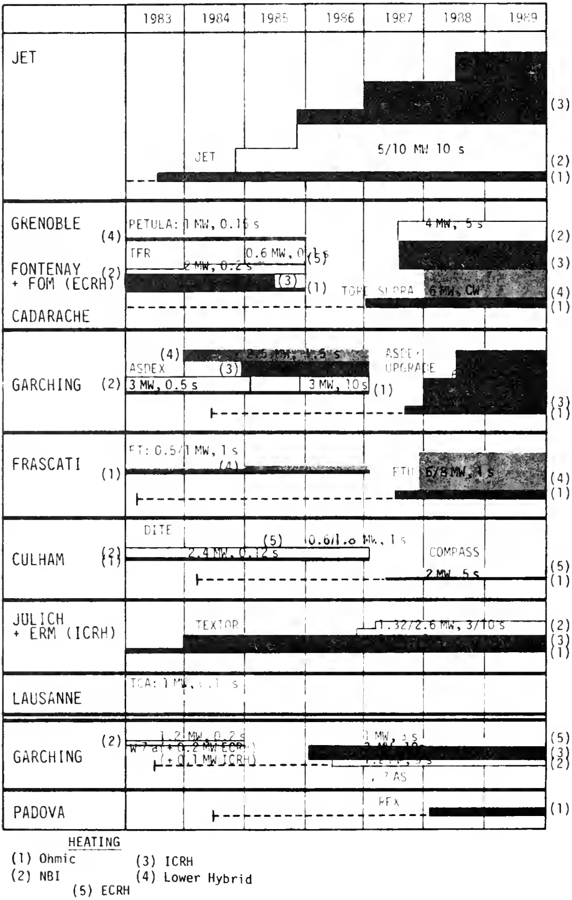
FIG. 1 - **Programme Strategy**

FIG. 2



NI = Neutral Injection
ICRH = Ion Cyclotron Resonance Heating

FIG. 3


1983
1984
1985
1986
1987
1988
1989
JET
JET
5/10 MW 10 s
(3)
(2)
(1)
GRENOBLE
(4)
PETULA: 1 MW, 0.15 s
4 MW, 5 s
FONTENAY
+ FOM (ECRH)
(2)
TFR
0.6 MW, 0.1 s
(5)
2 MW, 0.2 s
(3)
(1)
TORE SUPRA
6 MW, CW
CADARACHE
(2)
(3)
(4)
(1)
GARCHING
(4)
ASDEX
(3)
2.5 MW, 1.5 s
(2)
3 MW, 0.5 s
3 MW, 10 s
(1)
ASDEX UPGRADE
(3)
(1)
FRASCATI
(1)
FT: 0.5/1 MW, 1 s
(4)
FTU
6/8 MW, 1 s
(4)
(1)
CULHAM
(2)
(1)
DITE
(5)
0.6/1.0 MW, 1 s
2.4 MW, 0.12 s
COMPASS
2 MW, 5 s
(5)
(1)
JULICH
+ ERM (ICRH)
TEXTOR
1.32/2.6 MW, 3/10 s
(2)
(3)
(1)
LAUSANNE
TCA: 1 MW, 0.1 s
GARCHING
(2)
1.2 MW, 0.2 s
W 7 a (+ 0.2 MW ECRH)
(+ 0.1 MW ICRH)
1 MW, 3 s
2 MW, 10 s
W 7 AS
(5)
(3)
(2)
PADOVA
RFX
(1)
HEATING
(1) Ohmic
(2) NBI
(3) ICRH
(4) Lower Hybrid
(5) ECRH

PRESENTED BY: JOHN F. CLARKE
UNITED STATES

OVERALL FUSION PROGRAM STRATEGY

OBJECTIVE

CREATE THE BASIS FOR AN ASSESSMENT OF THE ECONOMIC POTENTIAL OF FUSION

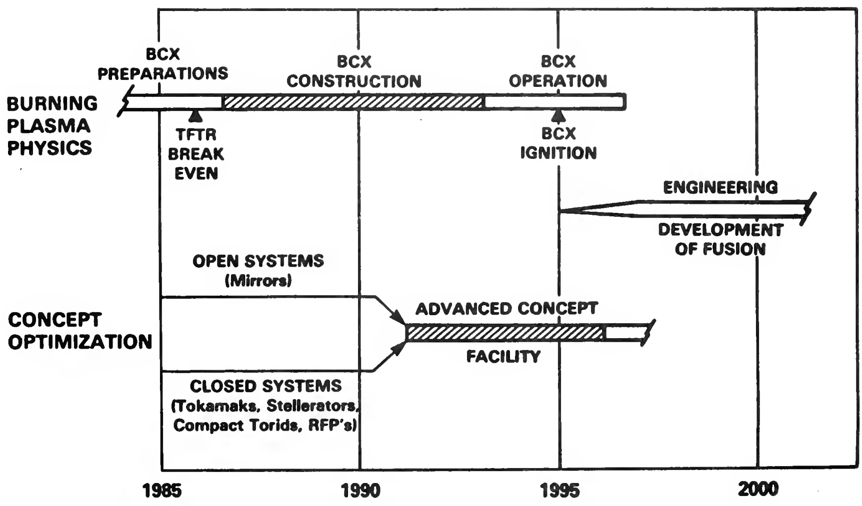
PRINCIPAL TASKS

1. DEMONSTRATE THE SCIENTIFIC REALITY OF FUSION REACTOR CORE
   - ACHIEVE IGNITED PLASMA REGIME
   - MAINTAIN LONG BURN
   - DEVELOP REACTOR-RELEVANT TECHNOLOGY
2. IDENTIFY OPTIMAL, COST EFFECTIVE FUSION-REACTOR APPROACH
   - SIMPLIFY PLASMA CONFIGURATION
   - REDUCE AUXILIARY SYSTEMS
   - ENHANCE PLANT EFFICIENCY

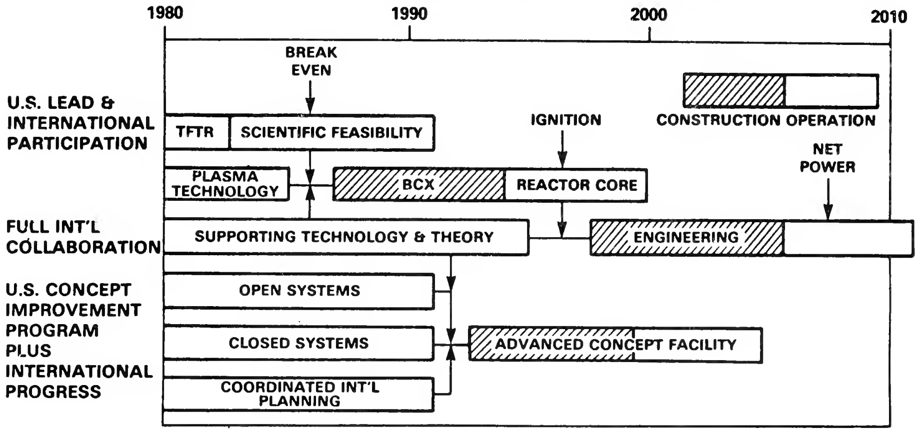
COMMENT

TASKS 1 AND 2 HAVE EQUAL STATUS: NEITHER ONE ALONE ACCOMPLISHES THE OBJECTIVE

FUSION PROGRAM STRATEGY



FUSION PROGRAM STRATEGY



SUMMIT WORKING GROUP ON CONTROLLED THERMONUCLEAR FUSION

Brussels, Belgium
July 5 and 6, 1984

CHARGES TO SUBPANELS

PREAMBLE

The Economic Summit leaders endorsed the report of the Working Group on Technology, Growth and Employment presented to them at their London meeting of June 1984. In the Communique, the leaders invited the Working Group to pursue further work and to report to personal representatives in time for the next Economic Summit.

New sources of energy will be required in the next century. Magnetic fusion is one potential source of energy. It requires that its scientific and technical feasibility be established as soon as realistically possible. The rapid progress in fusion research gives great promise that this can be done with greater effectiveness and efficiency if Summit countries' resources are used cooperatively.

To facilitate the necessary development of fusion on an international basis, attention must be given to improved coordination in both the near and long term. Two Subpanels have been established to identify opportunities for further collaboration. The first will address planning and collaboration on the required major new fusion research facilities. The second will address near-term collaboration in ongoing physics and technology activities. Administrative issues will be addressed in common with the efforts of the Summit Working Group on High Energy Physics. Each Head of Delegation shall appoint an individual to take responsibility to ensure that the required tasks are accomplished and coordinated.

The fusion programs of the Summit Nations are now aimed at establishing the scientific base for fusion and at laying the technological foundation for future developments. These developments require major new facilities both to establish technological feasibility with a burning plasma and to demonstrate a fusion reactor concept. In each of the three large fusion programs developed in Summit Nations some of these new large facilities are under study, although no final decisions have been made. Paragraph No. 22 of the 1984 Report of the Working Group on Technology, Growth and Employment to the London Summit Nations states that:

> "Effective cost sharing is becoming a more important element in the construction of major new facilities. Collaborative projects would benefit if coherent long-term plans for the construction and sharing of facilities in our countries were to be developed."

In this spirit, the Subpanels are charged as follows:

Subpanel for Planning and Collaboration on Major New Fusion Research Facilities (EC and USA Co-leaders)

In consideration of Paragraph No. 22 of the 1984 Report mentioned above, the Subpanel shall initiate the process of identifying the nature and the timing of the facilities required to establish the feasibility of fusion, taking account of the existing national and regional facilities and activities. The Subpanel shall attempt to identify potential opportunities for sharing of responsibility during further planning and in preparation for future development.

Subpanel for Near-term Fusion Physics and Technology

The activities in near-term fusion physics and technology divide naturally into Physics, Technology, and Reactor Concept Improvements. The terms of reference and charges for each Subgroup are the following:

(1) Physics. (Examples: collaborative experiments, diagnostics, heating, codes, etc.) (Dr. P. Fasella, European Communities, Leader)

This is the area in which international collaboration in fusion is most active. Examples range from exchange of ideas and personnel to joint experiments on common facilities. A substantial increase of collaboration on fusion physics appears to be feasible in the future, leading to benefits for all participants.

Charge: This Subpanel should identify key physics areas where increased collaboration would be most beneficial, both on present and planned facilities.

(2) Technology. (Examples: magnets, tritium, materials, blankets, etc.). (Dr. M. Wada, Japan, Leader)

We note that technology development is an important area where there is potential for increased international collaboration in fusion. Such collaborations will be particularly beneficial when the activities are focussed on the technology requirements and/or components of existing and planned facilities.

Charge: The Subpanel should identify key technology areas where increased international collaboration would be beneficial and minimize duplication taking present national plans for fusion energy development into account.

(3) Reactor Concept Improvements. (Examples: Current drive in tokamaks, mirrors, stellarators, RFP's, etc.) (Dr. A. Trivelpiece, USA, Leader)

Research on improved plasma confinement concepts, both improved versions of the tokamak and alternative geometries, has resulted in important advances in physics understanding, as well as the development of approaches that show significant promise of an improved reactor product. To a considerable extent, these programs are already conducted in a cooperative and nonduplicative manner with different emphases in different countries and bilateral agreements where appropriate.

Charge: This Subpanel should identify other opportunities to optimize this endeavor within the limits of resources.

Collaboration between programs can be implemented through different mechanisms: complementarity in development, joint construction or operation of facilities, cooperative experiments using facilities in other nations, exchange of information or tools.

For each scientific or technical item identified for possible collaboration, please suggest the appropriate class of collaboration.

Possible Examples:

- Complementarity: alternative approaches (mirrors, stellarators, RFP, ...) development of advanced diagnostics, ceramics for blankets, ...
- Joint construction or operation of facilities: FMIT, LCT, ALT II, negative ions, energy recovery in neutral injection, ...
- Cooperative experiments using facilities in other nations: steel irradiation data, ...
- Exchange of information or tools: codes, physics data, ...

Subpanel on Administrative Problems Affecting Fusion Cooperation
(Professor P. Fasella, European Communities, Leader)

International cooperation in Controlled Thermonuclear Fusion Research would benefit from some changes in certain fees and regulations in the areas of customs, data and computer communications, and personnel exchanges. The Working Group on High Energy Physics has established Subpanels to examine the facts and make recommendations in this area of administrative problems.

To avoid duplication of effort, the Fusion Working Group will not establish separate Subpanels, but rather, will support the High Energy Physics effort. Each Head of Delegation of the Summit Working Group on Fusion will appoint one individual to work with the High Energy Physics Subpanel on administrative questions.

Custom practices in some countries require the imposition of levies on equipment imported on a long-term loan basis for scientific research. The duty-free, extended-time transfer of scientific apparatus or components from one nation to another would substantially improve the ability of fusion scientists and engineers to effectively and economically conduct the experiments.

Data Communications are of great importance to furthering the Summit goal of expanding and improving international collaboration in science and technology. There are certain barriers to achieving this goal. Elimination of these barriers would substantially enhance cooperative science and technology progress.

Personnel Exchanges are an integral part of science and technology collaboration. There are some problems associated with visas and work permits for family members that result in hardship and other social disadvantages for visiting scientists and engineers. The ability of scientists and engineers to participate in exchanges consistent with the goals of the Summit process would be improved if the Summit Nations could reduce or remove social and legal barriers that negatively influence long-term personal exchanges.

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CONTROLLED THERMONUCLEAR FUSION PARTICIPANTS
Brussels, 5 and 6 July 1984

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ACTIVITIES

CADARACHE, FRANCE

JANUARY 1985

Proposed Agenda

Report of the Fusion Working Group to the Versailles Summit Working Group on Technology, Growth, and Employment for the May 1985, Bonn Economic Summit

- Report of the Versailles Summit Fusion Working Group's Subpanel for Planning and Collaboration on Major New Fusion Research Facilities
- Final Report, Summit Working Group on Fusion, Subpanel for Near-Term Fusion Physics and Technology, Physics Subgroup
- Report of the Subpanel for Near-Term Physics and Technology Subgroup Technology
- Report of Reactor Concept Improvement Subpanel
- Administrative Obstacles to International Scientific and Technical Cooperation

Controlled Thermonuclear Fusion Participants

Summit, Working Group
on
Controlled Thermonuclear Fusion

Cadarache Meeting, 15-16 January 1985

Proposed Agenda

1. Welcome by host Country - Dr. J. HOROWITZ

2. Adoption of the Agenda - Prof. P. FASELLA, Dr. A. TRIVELPIECE

3. Major new fusion research facilities - Dr. J. CLARKE, Dr. D. PALUMBO

    3.1 Report of the Subpanel
    3.2 Recent considerations on burning plasma studies (eg. Ignitor)
    3.3 Discussion

4. Near-term fusion Physics and Technology

    4.1 Physics Subpanel report - Dr. C. MAISONNIER
    4.2 Discussion
    4.3 Technology Subpanel report - Dr. K. TOMABECHI
    4.4 Discussion
    4.5 Reactor concept improvement - Dr. T.K. FOWLER
    4.6 Discussion

5. Administrative problem report summary - Prof. P. FASELLA, Dr. M. PAILLON

    5.1 Customs report
    5.2 Data communications
    5.3 Personnel exchanges
    5.4 Discussion

6. Drafting of Subpanel conclusions report

7. Drafting of Summary Report for the Bonn Summit meeting.

16 January 1985

Report of the Fusion Working Group to the Versailles Summit Working Group on Technology, Growth and Employment for the May 1985 Bonn Economic Summit

The main objectives of the Fusion research cooperation are:

1) To accelerate world development of a new energy source using practically inexhaustible fuels and possessing potential advantages from an environmental point of view.

2) To avoid unnecessary duplication of costly equipment and installations, and to enhance collaborative exploitation of existing devices.

3) To study the possibility of carrying out joint projects in the medium term.

In order to meet these goals and to be productive and constructive partners in international collaboration, the individual programmes of the Summit Members must continue to be supported at adequate levels.

In July 1984, the Fusion Working Group met in Brussels primarily to develop a response to Article 22 of the Versailles Working Group "Technology, Growth and Employment" report to 1984 London Summit.

> "22. Effective cost sharing is becoming a more important element in the construction of major facilities. Collaborative projects would benefit if coherent long term plans for the construction and sharing of facilities in our countries were to be developed."

At Brussels the Fusion Working Group established three study groups to report on:

1) Planning and Collaboration on Major New Fusion Research Facilities,
2) Near-term Fusion Physics and Technology,
3) Administrative Obstacles to International Scientific and Technical Cooperation.

The Fusion Working Group met again in January 1985 at Cadarache to review the reports of these study groups and to make recommendations based on them as might be appropriate.

The complete reports of the Study Groups are included in the appendix. The conclusions and recommendations of the Fusion Working Group follow hereafter.

1. Planning and Collaboration on Major New Fusion Research Facilities

The Fusion Working Group believes, that taking as a basis:

a) the common goal of bringing to fruition a new energy source using fuels which are practically inexhaustible and which possess potential advantages from an environmental point of view,

b) the existing national and regional programmes and activities,

it is now time to initiate the process of identifying the nature and timing of major facilities required to establish the feasibility fusion.

Useful collaboration will require joint planning activities at an early stage. A prerequisite for this will be mutual understanding of the present activities, planning and strategies of the three major programmes. This can most readily be accomplished by setting up a Working Party composed of technical experts (no more than five experts from each major programme and up to two experts from Canada) recommended to the Fusion Working Group by the Summit Members. The Fusion Working Group will seek nominations of Members to this Technical Working party and will convene it to begin its work as soon as the membership is complete with the following terms of reference:

The objective of the Working Party is to improve the transfer of information among the programmes in order to further the establishment of a scientific and a technical consensus on the nature of required future facilities in fusion. The Working Party should review the current options being developed for programmes to resolve the four technical problem areas of burning plasma physics, concept improvement, fusion blanket technology and fusion materials placing emphasis on burning plasma as a first stage.

The Working Party should examine the technical options for future facilities which are being considered by Summit Members. The purpose should be to provide collaborative options that minimize the cost of future fusion development on an international basis. It should also seek to recommend new joint planning activities to develop these options. It should present its conclusions to the Fusion Working Group. Its first report should be ready by December 1, 1985.

Meetings should be held in Europe, North America and Japan, if possible in conjunction with other international meetings, as appropriate, in order to minimize travelling time. Administrative and secretarial assistance should be provided by the host programme.

The input from the Working Party should allow the Fusion Working Group to promote effective cost-sharing in the spirit of Article 22 of the Report of the Technology, Growth and Employment Working Group to the London Economic Summit (1984).

2. NEAR-TERM FUSION PHYSICS AND TECHNOLOGY

2.1 PHYSICS

The physics of high temperature plasmas is still developing and there are many open questions on stability, equilibrium, heating, etc. that need to be addressed. In that regard, there are certain studies involving unique experimental facilities that would benefit from appropriate collaboration. Advanced diagnostics instrumentation and detectors should be designed and shared whenever there is a cost effective advantage. Computer codes and theoretical modelling studies of complex plasma phenomena should be developed in such a way as to avoid duplication of effort and to speed up the process of understanding.

- IEA Agreement on Textor (in force):
  Within it, the realization of the advanced pump limiter ALT II is recommended.

- IEA Agreement on Asdex and Asdex-Upgrade (in preparation):
  It is recommended to sign it as soon as possible.

- IEA Agreement on Cooperation between large Tokamaks (in preparation):
  It is recommended to sign it as soon as possible. It should include provision for development of diagnostics for the active phase of operation.

- Pellet injection:
  A workshop should be organized soon under US leadership to define the needs in this new field and to propose a collaborative strategy for relevant technical developments.

- Neutral beam heating:
  A workshop should be organized soon under European leadership to define the possible future needs in two fields:
    - energy recovery
    - negative ions

  and to propose a collaborative strategy for relevant developments at MW level.

- Computer codes:
  A workshop should be organized soon under Japanese leadership to propose
    - splitting of voluminous codes in specialized packages to be designed by various partners and used by all,
    - development of plasma modelling and comparison of code analysis,
    - possibly the establishment of international data links.

2.2. TECHNOLOGY

The Working Group found that, although extensive activities are being carried out in each country and effective international collaborations are going on, the activities in general in this field are still at the early stage of development and need to be enhanced.

1. The Working Group recommends increased international collaboration in the following areas:

    i) Fusion Materials

    The existing Agreement on Fusion Materials should be pursued and enhanced. Further investigation on the overall development programme should immediately be made within the IEA framework, taking into account the nature of materials development and the means of development.

    ii) Superconducting Magnets

    The existing collaboration should be pursued and expanded, possibly including high current conductors and pulsed superconducting magnets.

2. The Working Group strongly recommends that the following areas be explored for international collaboration:

    i) Plasma Material Interactions and High Heat Flux Experiments.

    ii) Fusion Blanket Technology and Tritium Breeding Issues.

    iii) Tritium Fuel Cycles.

    These explorations could begin in the form of workshops possibly under the existing IEA or bilateral agreements as appropriate.

2.3. REACTOR CONCEPT IMPROVEMENT

The Fusion Working Group considered research on Tokamak improvements, open systems (mirrors), and alternative and supporting systems (stellarator/heliotron, reverse field pinch (RFP), bumpy toroid programme (BTP), compact toroids).

1. It was noted that there is already a considerable degree of international cooperation in these areas through both formal and informal mechanisms.

2. It was recommended that cooperation be also strengthened by implementing the following formal agreements as soon as possible:

   - IEA Stellarator/Heliotron Agreement,

   - IEA RFP Agreement, which should be extended to include major new devices such as RFX.

   Japan noted that it was not now in position to join in the Stellarator agreement, but supported an early action by the US and EC.

3. It was noted that three mechanisms have aided the optimization of world resources in the past:

   - workshops to exchange information and plans;

   - personnel exchanges between countries;

   - selected input from foreign experts in technical reviews of national programmes.

   It was recommended that these practices be continued and extended as appropriate.

3. ADMINISTRATIVE OBSTACLES TO INTERNATIONAL SCIENTIFIC AND TECHNICAL COOPERATION

It is clear that the removal of certain administrative obstacles would greatly improve and facilitate international cooperation in several areas of science and technology. The Working Group believes that because enhanced international collaboration implies cost sharing and cross participation in the construction and exploitation of regional devices, new administrative procedures are imperative. Many of the present procedures are serious obstacles to effective cooperation.

More specifically, the Fusion Working Group recommends that attention should be given to the following questions:

a) Cross participation in projects through the provision of scientific equipment and components for major facilities is currently hampered by the fact that tariff and tax exemptions are only provided for short durations that are not compatible with the timeframe of the collaboration, which may last for more than 10 years.

b) The exchange of scientific and technical staff is an important factor in international collaboration. Increased collaboration can become a reality only if the responsible authorities create conditions suitable for the easy exchange of scientific staff.

There are several such conditions, notably:

- to simplify the administrative admission formalities in the host country;
- to facilitate integration of the research worker and his family in the host country;
- to guarantee adequate social coverage.

c) Data transmission is an important aspect of the work of the Fusion Community. The acceptance of cross participation in facilities, which are widely separated geographically, relies heavily on inexpensive and efficient data transmission. Two aspects have been singled out by the Working Group for urgent consideration within the Versailles Working Group "Technology, Growth and Employment" framework:

- the review of the charging policy for scientific data transmission across borders,
- the promotion of effective data communication standards in order to ensure compatibility.

The Working Group recommends to the Versailles Working Group "Technology, Growth and Employment" that a study be conducted on this subject subsequent to the Bonn Summit and that a report on the steps that might be taken to improve conditions related to the above mentioned administrative impediments to effective cooperation be submitted to the subsequent Economic Summit.

Report of the Versailles Summit Fusion Working Group's Subpanel for Planning and Collaboration on Major New Fusion Research Facilities

The Subpanel met in London on September 17, 1984. The Subpanel was chartered to initiate the process of identifying the nature and timing of the facilities required to establish the feasibility of fusion, taking account of the existing national and regional facilities and activities. The Subpanel was also "to attempt to identify potential opportunities for sharing of responsibility during further planning and in preparation for future development." The Subpanel began its deliberations by considering program objectives, major milestones and technical issues. The Subpanel reconfirmed that the common goal of the fusion programs was as stated in the 1982 report of the Working Group on Technology, Growth and Employment, namely, "to bring to fruition a new energy source using fuels which are practically inexhaustible and which possess potential advantages from an environmental point of view." On the basis of the technical progress reported at the IAEA conference on controlled fusion being held simultaneously in London, the Subpanel members were pleased to note that there was continued advance toward the common goal.

The Subpanel also considered as an essential intermediate objective to establish the scientific and technical data bases upon which decisions could be built to proceed with the planning of a power producing demo reactor. To reach this objective, the programs must all address major technical issues in the areas of burning plasma physics, concept improvement, blanket technology including energy recovery technology, and high neutron flux materials development. This will require large facilities. Each of the programs is working on its own approach to identify such facilities, especially the next major facility to produce a burning plasma and to test technological feasibility, and to complete the data bases required for decisions on such facilities. The Subpanel found there was a complementarity of approaches being explored now by the programs. Given the extent of the technical work already under way to support future steps, these decisions would certainly come after the next few Summit meetings. This timing should be consistent with improved coordination in international planning for such facilities. The Subpanel believed that useful collaboration would require joint planning activities at an early stage. The Subpanel judged that an essential element of this improved coordination of planning would be close interaction on the scientific and technical level in order to foster the development of an international consensus on the nature and timing of the facilities required to explore the remaining issues in fusion.

On this basis, the Subpanel decided to recommend to the FWG the establishment of a technical working party to prepare the groundwork for further collaboration on major new facilities, emphasizing the physics and technology of burning plasma as a first stage. The recommended technical working party would be composed of three to five experts of each major program and one or two experts from Canada. The charter would be as follows:

> Charter for the Major New Fusion Facilities Technical Working Party
>
> The objectives are these: To recommend ways to improve transfer of information among programs to further the establishment of a scientific and technical consensus on the nature of required future facilities. To review jointly the current planning and design activities for the purpose of defining potential, common, large facilities required for the resolution of the principal scientific and technological issues in the areas of burning plasma physics, concept improvement, blanket technology including energy recovery technology, and high neutron fluence materials development, and to ascertain those elements with common development requirements and recommend to the FWG appropriate common studies to establish the basis for future collaboration. The technical working party will meet periodically to ensure common understanding of the individual approaches including design and program plans covering the next ten to fifteen years. The working party will continue its activities throughout the process of defining the minimum number of new major facility steps. This will strengthen the early joint planning for such major fusion facilities. The working party shall report only to the FWG.

The Subpanel also noted that because of the time required to develop collaboration on major new facilities, it was especially important to take those near-term steps being explored by the subgroups in Subpanel 2. The Subpanel thus endorsed the work of Subpanel 2 as a means of building working collaboration on current activities thereby strengthening the infrastructure to support collaboration on future large facilities. With the formulation of the recommendation to the FWG for a "major new fusion facilities technical working party," the Subpanel believed that sufficient preparation for the January meeting of the FWG had been completed and that it need not reconvene before that meeting. The Subpanel recommends to keep in view the total international effort in planning and coordination.

18 December 1984

FINAL REPORT

SUMMIT WORKING GROUP ON FUSION

SUBPANEL FOR NEAR-TERM FUSION PHYSICS AND TECHNOLOGY

PHYSICS SUBGROUP

1. INTRODUCTION

- The strengthening of the bilateral or IEA agreements already existing on near term specific objectives, and the conclusion of new agreements of a similar nature, would be appropriate both in a short term perspective in order to make the solution of present technical and administrative problems easier, and in the longer term in order to prepare the conditions for cooperation on major new facilities. Subpanel 2 has been charged to identify key areas where increased collaboration would be most beneficial, both on present and planned facilities. Subpanel 2 is divided in 3 subgroups: Physics (essentially conventional Tokamaks, heating, diagnostics, codes), Technology, and Reactor Concept Improvements.

- To fulfill its task, the Physics Subgroup, having reviewed the main physics facilities in operation or in construction in the different countries (Appendix 1), has considered:

  o the cooperative actions in progress (paragraph 2);

  o possible cooperative actions which have already been the object of preliminary discussions (paragraph 3);

  and indicated in which specific areas an increased collaboration would be possible and particularly useful (paragraph 4).

- The composition of the Physics subgroup is given in Appendix 2.

2. COOPERATIVE ACTIONS ALREADY IN PROGRESS

2.1 In the frame of the IEA.

- TEXTOR (FRG)

  The implementing agreement on plasma-wall interaction in Textor has been very successful. It led to an effective participation of American, Canadian, Japanese and Swiss physicists in the Textor experiment, accompanied in several cases by transfer of hardware. A second step in the pumped limiter programme ALT II is in an advanced stage of preparation.

2.2 Bilateral cooperative actions

- US/Japan

The cooperation in fusion between USA and Japan entered into a new phase in May 1979 with the signing of the Agreement on cooperation in Energy and Related Fields. The agreement specifically designated fusion as one of the areas of initial emphasis. The coordinating Committee on Fusion Energy is empowered to coordinate, implement and oversee the cooperative activities. The cooperative program now includes seven individual parts: Personnel Exchange, Joint Planning in six areas, Doublet III Cooperation, Joint Institute for Fusion Theory, RTNS-II Cooperation, HFIR/ORR Cooperation, and FNS Cooperation.

- US/Canada

Canada is working closely with the US TFTR program with Canadian experts participating in the design of the Remote Handling Systems for the D-T Burning Phase of TFTR. A defining agreement has been negotiated.

- CEC/Canada

A bilateral Memorandum of Understanding between Canada and the European Community has been negotiated and is being finalized. It covers collaborative exchanges in fusion including confinement physics, plasma heating, tritium technology and remote handling.

- US/UK

The Cockcroft-Libby Exchange of Letters has provided a mechanism for long-term personnel assignments at the DOE and Culham laboratories in the field of fusion.

2.3 Informal

Bilateral cooperation on a more or less informal basis has taken place in the last few years between practically all Fusion Programmes under consideration (Joint Workshops, exchange of staff, even exchange of teams). For instance, exchanges of teams took place between Frascati, Jutphaas and MIT on the Alcator programme, and between Fontenay and Princeton on the ion cyclotron resonance heating programme of PLT.

3. COOPERATIVE ACTIONS UNDER DISCUSSION

3.1 In the frame of the IEA

- ASDEX and ASDEX Upgrade (FRG)

An implementing agreement between the US-DOE and EURATOM is being prepared. Japan has expressed the wish of being kept informed. An exchange of letters of intent between the DOE and IPP confirms the intention of cooperation. This agreement is related to devices possessing a divertor (either "closed" as ASDEX or "open" as ASDEX-Upgrade), which should be used to study the fundamental problem of impurity control, exhaust and refuelling; comparisons with pumped limiters will also be possible.

- Large Tokamak Experiments

Cooperation between the large tokamak programmes during their construction phase has been carried out on an informal basis under the framework of the IEA.

An implementing agreement is under negotiation between the European Atomic Energy Community (EURATOM), the Japanese Atomic Energy Institute (JAERI) and the United States Department of Energy (USDOE). The aim is to enhance the effectiveness and productivity of the research and development of a Tokamak fusion reactor by strengthening the cooperation between the three Large Tokamak Facilities - JET(EURATOM), JT-60(JAERI) and TFTR(USDOE) - and to provide a scientific and technological basis for the development of reactor plasmas; in particular, for the development of devices to follow the Large Tokamak Facilities. The draft agreement covers the exchange of managerial, scientific and technical information, and of equipment, computer codes and personnel.

3.2 Bilateral cooperative actions

- CEC/USA

The CEC and USA are negotiating a bilateral framework agreement for cooperation in fusion.

- CEC/Japan

Cooperation between CEC and Japan in several fields of science and technology, including fusion, is under consideration.

- Canada/Japan

Canada and Japan have made preliminary steps towards drafting a collaboration agreement on fusion between the National Research Council of Canada and JAERI.

4. SUGGESTED AREAS FOR INCREASED COLLABORATION

Key areas in tokamak physics and devices mostly relevant to each of them are listed in Table 1. Those areas in which the Subgroup believes that increased or new cooperation would be particularly appropriate are:

4.1 General performances.

- Pellet injection

Recent results have shown substantial improvements in the energy confinement times in both ohmic and neutral beam heated regimes, when the plasma is refuelled from the inside by pellet injection. Large machines with long pulse operation require both pellet injection velocity higher than what is available and a high repetition rate sustained for long periods. Such a specific technical development will require sizeable efforts and could lead quite naturally to transfer of hardware between laboratories.

- Impurity control, exhaust, refuelling

This important issue will be well covered once the implementing agreement on ASDEX and ASDEX-Upgrade will have been concluded, complementing the TEXTOR agreement already in action. Within the latter, the realization of the advanced pump limiter ALT II is recommended.

4.2 Additional heating.

- Neutral beam heating

Despite progress in RF heating, neutral beam injection remains the reference method for plasma heating in present devices. The reduced efficiency of neutral injection at high particle energy (which is necessary for large devices) can be corrected by two methods:

a) energy recovery of the non-neutralized beam (in the intermediate energy range) and

b) negative ion production and acceleration (in the high energy range).

For practical use, these two methods need to be developed at the megawatt level. This represents a large effort which could profitably be shared between specialized development teams.

4.3 Diagnostics

- Active phase diagnostics

During either DT or DD operation at high neutron fluences the use of conventional diagnostics will encounter difficulties due to activation of the structures, to remote operation, to degradation of component lifetime, etc. ... Also, diagnostics related to alpha-particles will play a major role in the understanding of the physics of the active phase; such measurements are particularly delicate by nature and their interpretation requires a great deal of theoretical and computational effort.

Both the developments of new diagnostics specific of the active operation and the hardening of existing diagnostics will require in the near future substantial efforts which could be divided between interested laboratories. These developments are essential for the exploitation of JET and TFTR; they will also be of use in Tokamak of intermediate size working in Deuterium at high temperature.

4.4 Computer codes

During recent years computer codes have become a powerful tool for describing the behavior of magnetically confined plasmas. The organization of voluminous codes in specialized packages, which could be designed and tested by various partners whereas the full codes could be made available to all, is well suited for international collaboration. The comparison of code analysis and the development of plasma modelling in various physical situations would also benefit from enhanced coordination. A data link to ease this coordination might be a necessary prerequisite.

4.5 Large Tokamak experiments

Cooperation between large Tokamak programmes is an essential issue. It is already in progress on an informal basis. The conclusion of the current negotiations of the IEA Implementing Agreement will give a stronger basis to this cooperation.

4.6 Exchange of information and personnel

Of comparable importance to the formal cooperative actions are the opportunities for the exchange of information and personnel between specific programmes. These activities strengthen working relationships between individual researchers and foster the spirit of cooperation essential to the more substantial cooperative undertakings on major new facilities and projects. The various agreements presently under negotiation will constitute the proper frame for organizing such exchanges.

5. CONCLUDING REMARKS

If implemented, the actions suggested in paragraph 4 together with those already in progress (see paragraph 2) and being planned (see paragraph 3) would establish an efficient collaboration in each of the main domains of tokamak physics and lay a basis of sufficient breadth for a possible future collaboration on new major facilities.

An immediate interaction (for instance through periodic workshops) between the three Next Step groups would certainly contribute significantly to a further identification of physics areas where the rate of progress could be best fostered by international collaboration.

If decisions to strengthen cooperation are taken, technical workshops specific to each of the items identified under 4.1 to 4.5 would have to be organized in order to define concretely the work to be performed.

The Physics Subgroup has the following composition:

Prof. P. Fasella, Leader (CEC)
Dr. Ch. Maisonnier, Acting Leader (CEC)
Dr. R. Bolton (Tokamak de Varennes - Canada)
Dr. R. Tachon (CEA-France)
Dr. G. Grieger (IPP-FRG)
Dr. G. Righetti (ENEA-Italy)
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Dr. M. Yoshikawa (JAERI-Japan)
Dr. R. Sweetman (UKAEA-UK)
Dr. R. Davidson (MIT-USA)
Dr. J. Rawls (GA Technologies - USA)
Dr. R. Bickerton (JET) and Dr. D. Meade (TFTR) have been coopted by the members to allow a better understanding of the possible areas of collaboration between the three large Tokamaks. Dr. Yoshikawa (JT-60) is a member of the Subgroup.

REPORT OF THE SUBPANEL FOR NEAR-TERM PHYSICS AND TECHNOLOGY SUBGROUP TECHNOLOGY

I. Charge of Subgroup

The charge of the subgroup is described by the Summit Working Group on Fusion as follows:

"We note that technology development is an important area where there is potential for increased international collaboration in fusion. Such collaboration will be particularly beneficial when the activities are focused on the technology requirements and/or components of existing and planned facilities.

Charge: The subpanel should identify key areas where increased international collaboration would be beneficial and minimize duplication taking present national plans for fusion energy development into account."

The subgroup has been instructed by the Working Group to consider the near-term fusion technology activities.

II. Findings and Recommendations of Subgroup

The subgroup met on 13th and 18th September 1984 in London to consider the charge. The subgroup came to a conclusion to report the following findings and recommendations, after considering the fusion technology which included such areas as materials, firstwall/blanket/shield, divertor/limiter, remote operations, superconducting magnet, vacuum technology, tritium, instrumentation and control, and heating equipment. The background information used for the discussion is attached as an appendix.

(1) Findings

i) Good international collaborations already exist in fusion technology development. Examples of formalized collaborations are:

Under IAEA:

1. INTOR
2. Nuclear data

Under IEA:

1. LCT
2. Material irradiation in fission reactors
3. TEXTOR - Advanced Limiter Test (ALT-I)

Bilateral (US-Japan):

1. Material irradiation in RTNS-II
2. Material irradiation in fission reactors
3. Blanket experiment in FNS

In addition, well established relations exist between the laboratories worldwide on a more informal basis.

ii) The national activities in fusion technology research and development is essential to provide a sound basis for international collaboration.

iii) International collaboration in fusion technology should be encouraged, particularly for those areas which are not close to commercial application or do not involve specialized and proprietary industrial know-how.

iv) Effective utilization of existing technology-oriented experimental facilities through international collaboration can be helpful in at least two ways. It can help partners avoid the expense of building facilities that are duplicative, and it can save each partner costs through sharing of the full cost of operating existing facilities.

v) International collaboration may be possible even between partners aiming at different approaches to confinement, since many aspects of the required technologies for the partners may be common.

vi) Assessment and preparation of required technology data base for fusion, are important and need international collaboration for exchange of information.

(2) Recommendations

The subgroup recommends increased international collaboration in the following areas:

i) Fusion Materials Experiments and Testing

Experiments and testing of various materials for fusion applications, including materials for structures, insulators, and other applications, are central to the development of an attractive fusion reactor. Thus, a new, powerful source of neutrons is indispensable for fusion technology research and development. Therefore, international collaboration should be pursued on definition and technical realization of such a source.

ii) Plasma - Materials Interactions and High Heat Flux Experiments and Testing

Key test facilities exist for conducting high heat flux experiments and simulations of plasma surface interactions with in-vessel components and the firstwall, but not on a world-wide basis. Therefore, international collaboration in this basic area should be explored.

iii) Fusion Blanket Technology and Tritium Breeding - Issues, Phenomena and Required Experiments

A basic understanding of the critical issues for fusion nuclear technology is being developed but is incomplete. Identification and characterization is needed of fusion nuclear technology issues for which new knowledge is required. Therefore, international collaboration in a joint assessment of the most critical fusion nuclear technology issues is important and is required for future planning. This is especially true with respect to identification of new, required experimental facilities.

International collaboration using existing facilities in several countries, including 14 MeV neutron sources and fission reactors, can be used for experiments on breeding materials, tritium diffusion and recovery, and uncertainties in neutronics methods.

iv) Tritium Fuel Cycle

Tritium handling and processing in the vacuum exhaust system and blanket recovery system are a basic aspect of a DT fusion reactor. Therefore, international collaboration on experiments to develop the data required for fusion reactors should be encouraged.

v) Superconducting Magnets

International collaboration can be helpful in developing high current conductors and pulsed superconducting coils. Such collaboration could be carried out in the context of research and development for future plasma confinement projects.

The subgroup on technology notes that plasma heating and fueling technologies are important areas in which collaborative efforts could be helpful. Future discussions should include these areas; for example, high frequency RF sources and high speed pellet injection.

Appendix I

Participants of Subgroup "Technology"
(13&18 September 1984, London)

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REPORT OF REACTOR CONCEPT IMPROVEMENT SUBPANEL

I. Charge

The purpose of the Subpanel is stated in its charge from the Summit Working Group on Fusion:

> "Research on improved plasma confinement concepts, both improved versions of the tokamak and alternative geometries, has resulted in important advances in physics understanding, as well as the development of approaches that show significant promise of an improved reactor product. To a considerable extent, these programs are already conducted in a cooperative and non-duplicative manner with different emphasis in different countries and bilateral agreements where appropriate."
>
> Charge: This Subpanel should identify other opportunities to optimize this endeavor within the limits of resources."

As part of the Subpanel for Near-Term Fusion Physics and Technology, the focus is on the next 5 years.

II. Scope

The topics assigned to this Subpanel are:

Tokamak Improvements
Open Systems
Alternative and Supporting Systems

Inertial confinement fusion (ICF), though an important part of the fusion programs of several Summit nations, is outside the scope of the Subpanel.

Here Tokamak Improvements refers to those aspects of tokamak research that could ultimately lead to major changes of configuration compared to the large tokamaks of today. Examples are extreme non-circular cross-section, or reliance on rf current drive. Open Systems refers to mirror devices, and Alternative and Supporting Systems refers to toroidal devices other than tokamaks (Stellarator/heliotron, RFP, EBT, Compact Toroids).

III. Background

In parallel with the impressive progress in tokamak development, fusion researchers have continued to explore other magnetic confinement geometries and to improve the tokamak itself. This research has two motivations: (1) to explore geometries that might lead to fusion reactors having qualitatively different features; and (2) to explore new plasma phenomena that contribute to improved understanding of plasma confinement as a whole. Indeed, it is the interplay between these two motivations that has often brought forth our most creative science and invention.

The importance attached to reactor concept improvements is evidenced by their strong support in the national programs. Also, there is already a considerable degree of international cooperation in these areas. The Appendices discuss each concept in more detail.

A. Concepts, Reactor Features

The Concepts covered by the Subpanel are compared to the tokamak in Table I.

The line labelled Reactor Features lists the ways in which these concepts might eventually improve on the present tokamak, which appears to lead to large reactors in the range of 1000 MWe and reactors that are pulsed in time, since the plasma current essential for heat confinement in tokamaks is inductively driven. Thus, two main themes of improvement are: (1) smaller, cheaper reactors (lower power output, smaller dimensions), mainly by increasing the parameter "beta",* and (2) D.C. operation and other engineering simplifications.

Briefly, in Table I, Tokamak Improvements refers to those aspects of tokamak research that address the goals of smaller unit size and D.C. operation; for example, by means of a highly non-circular cross section to increase the beta (more elongated than in the present large experiments) and rf current drive to replace the pulsed inductive current drive in present tokamak experiments. In the Open Systems category, the tandem mirror is a D.C., high-beta system with a linear geometry that simplifies blanket design and may eventually lead to smaller units of lower output power, depending on the length required for confinement. Finally, the category labelled Alternative and Supporting Systems refers to a diverse group of concepts with the common goal of retaining the good heat confinement expected in "closed", or toroidal, systems (and exhibited in tokamaks) while improving the system in other ways. Three examples listed in the table are: (1) stellarators/heliotron, which resemble tokamaks in concept and good plasma confinement performance but do not require current drive or power input to the plasma in order to operate D.C.; (2) the Reversed Field Pinch (RFP), for which high beta and low field may permit the use of

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*Beta is defined as the ratio of plasma pressure to magnetic energy density. Higher beta implies either higher power density or weaker magnetic fields.

ordinary copper coils and the inductive current drive may be sufficient to ignite the plasma by ohmic heating alone; and (3) compact toroids, which seek to combine the geometric simplicity of mirrors with the benefits of toroidal confinement at high beta by means of closed magnetic field patterns generated by the plasma itself. The EBT, discussed in Appendix C, is distinguished by reliance on kinetic effects of energetic electrons to stabilize the plasma.

B. Scientific Contributions, Issues, Status

The second line in Table I lists the Unique Physics Regime to which each of the above lines of research has led. The present tokamak continues to lead the way in attaining the long energy confinement times required to achieve ignition and to explore fully the mechanisms of energy transport across magnetic fields. On the other hand, unique features of the other concepts have frequently led to new phenomena that both enrich our understanding and, in some instances, have anticipated effects that later became important in the tokamak itself or in other concepts. A recent example is the possibility that electrostatic thermal barriers, first utilized in tandem mirrors, may also account for the improved confinement in the so-called H-mode in tokamaks. Other examples are the pioneering work on electron cyclotron heating in the EBT program, and ion cyclotron heating in stellarators/heliotrons.

The third and fourth lines of Table I state the major issues yet to be addressed in each line of research and the present status of the research. As can be seen from the table, the main question for the tokamak, and its near-relative, the stellarator/heliotron, is the ultimate limit on beta. By contrast, high beta has been demonstrated for the tandem mirror, RFP and compact toroids (10 to 20%, 90% for the FRC) but a key question is heat confinement as one scales up from the present experiments of moderate size.

C. Facilities, Goals, Resources

Table II lists by name the larger facilities existing or under construction for each line of research. These facilities and their functions are described in the Appendices, which also list some of the smaller facilities not included in Table II.

Goals for the next 5 years are summarized in line 5 of Table I and the present allocation of resources in line 6. No substantial changes in percentage allocation are expected for the next several years, with appropriate adjustments to accommodate the new facilities listed in Table II. Note that the tokamak allocation includes basic science and technology that benefits all concepts and would be required even if only one concept were pursued. Also, we have not attempted to separate funding for Tokamak Improvements from other tokamak funding.

D. International Cooperation

All of the research lines discussed here have been characterized by extensive interaction between scientists from different countries over a period of years. As a result, each National Program has been planned with the benefit of extensive information concerning the views and plans of other Summit Nations, and also, to a considerable extent, the Soviet Union.

Within the European Community, the national programs of the partner countries are already fully incorporated in the European Fusion Program. In the wider context of other Summit Nations, two highly successful vehicles for interaction have been personnel exchanges, in which scientists work for a period of time in foreign laboratories, and international workshops. In some cases, these exchanges and workshops have arisen on an informal basis in response to the needs of the scientific community. In other instances, they have been facilitated by formal agreements between governments, as in the case of the U.S.-Japan Bilateral Agreement on magnetic fusion research.

Recent workshops are listed in Table III and Personnel Exchanges in Table IV. A third method has been the use of foreign experts to advise National Programs for specific purposes such as the review of proposed new facilities.

The extent and nature of international participation in research on different concepts has varied in different countries depending on their own involvement. Two cases can be distinguished:

(1) Countries actively involved who share results, coordinate plans and divide up tasks where appropriate and practical;

(2) Countries not actively involved who stay abreast of results and trends through workshops and sometimes through limited participation.

In reassessing their interests, from time to time countries have changed the nature of their international involvement accordingly, as when Japan increased its mirror research in the late 1970's and the U.S. its stellarator research in recent years.

IV. Response to the Charge

The Subpanel met during the London IAEA fusion conference 12-19 September 1984 to consider the charge.

A. Recommendations for Early Action

(1) As is described in Section III, the Subpanel found there to be a considerable degree of international cooperation in the areas assigned to us, but in some cases the formal agreements needed to facilitate cooperation are pending approval. The relevant agreements are:

U.S.-Japan Bilateral Agreement	Active
IEA Stellarator/Heliotron Agreement	Pending
IEA RFP Agreement	Pending

We recommend that the pending agreements be implemented as soon as possible, including all necessary procedures regarding patents, expenses for personnel and other necessary administrative matters.

(2) The subpanel notes the necessity to avoid unnecessary duplication of effort in the research areas within our charge in order to optimize the use of world resources. As is discussed in Section III, three methods that have proved effective in the past in dealing with this question are:

(a) Periodic workshops that bring together scientists from all countries engaged in a particular field to discuss their results and future plans (see Table III).

(b) Personnel exchanges between countries in order to maximize the use of existing facilities and the information derived from them to the benefit of all interested countries (see Table IV).

(c) Input from foreign experts in the technical review of proposed new facilities. This both provides useful advice to National programs and enhances the interest of foreign scientists in participating in cooperative research.

We recommend that these methods be continued and extended as appropriate. This would be facilitated by the formal agreements recommended above. As noted in Section III D above, different countries will participate to different degrees depending on their current interest in a given concept.

B. Topics for Further Consideration

The Subpanel also considered longer term questions that will become important by the end of the decade and which may or may not be adequately dealt with by the above recommendations. We believe our recommended actions will lay the groundwork for a more extensive collaborative planning process when it is needed a few years hence.

V. Membership of the Subpanel:

C. Daughney	Canada
U. Finzi	E.E.C.
F. Prevot	France
G. Wolf	F.R.G.
G. Rostagni	Italy
K. Tomabechi	Japan
T. Uchida	Japan
C. Yamanaka	Japan
H. A. Bodin	U.K.
T. K. Fowler, Chairman	U.S.A.
R. K. Linford	U.S.A.
J. F. Lyon	U.S.A.
P. H. Rutherford	U.S.A.

TABLE 1. TYPES OF MAGNETIC FUSION DEVICES

	Tokamak	Tokamak improvements	Open systems: Tandem mirror	Alternative and supporting systems		
				Stellarator/Heliotron	RFP	Compact toroids (Spheromak, FRC)
1. Reactor features	Toroidal, pulsed	Reduced unit size (lower power), possibly D.C.	Reduced unit size (lower power), D.C., simpler blanket	Ignited, D.C., low recirculating power	Copper coils, ohmic ignition	Much smaller, simpler blanket
2. Unique physics regime	Long confinement time	Higher beta	Linear geometry, electrostatic potentials	Current-free torus, electrostatic potentials, and 2nd stability regime	Equal poloidal and toroidal magnetic fields	No external toroidal field
3. Major question	Beta limit	Beta limit	Heat confinement	Beta limit	Heat confinement	Heat confinement
4. Status	$n\tau_E = 6 \times 10^{13} cm^{-3}$ s (JET) T_i = 1 keV Beta = 4.5% (DIII)	First tests	$n\tau_E = 2 \times 10^{10} cm^{-3}$ s T_i = 2 keV Beta = 6-15%	$n\tau_E = 3 \times 10^{12} cm^{-3}$ s T_i = 1 keV Beta = 2%	$n\tau_E = 10^{11} cm^{-3}$ s T_i = 0.4 keV Beta = 20%	Early phase-- $n\tau_E = 4 \times 10^{11} cm^{-3}$ s T_i = 0.1 keV Beta = 90% (FRX-C)
5. Goals by or before 1990	Almost reactor parameters, significant DT burn	Being formulated	Almost reactor parameters	$n\tau_E = 10^{13} cm^{-3}$ s Beta = 5 - 10% T_i = 3-5 keV Steady state	Confinement physics at higher current (2 MA)	Being formulated
6. % of Summit Nations Research effort	80% Includes supporting basic science and Technology*		10%	5%	5%	
7. Summit Nations involved	All	All-strong U.S. interest	U.S., Japan	U.S., Japan, F.R.G.	U.S., Italy, U.K., Japan	U.S., Japan

*The tokamak allocation includes about 15% of effort on supporting basic science and technology that would be required whether or not other concepts were pursued.

TABLE II. FACILITIES EXISTING OR UNDER CONSTRUCTION

Facilities listed are the larger ones in a given field in a given country. Other facilities as well as those listed are discussed in the Appendices.

	Existing or under Construction (with year operational)			
	U.S.	Japan	EC Summit Nations	Canada
Tokamak improvements*	PBX	JFT-2M JIPP-TIIU WT-III (85) TRIAM-IM (87)	Tore Supra(87)(France) Compass(86)(UK)	Varennes Tokamak (85)
Open systems: tandem mirror	MFTF-B (88) TMX-U TARA	GAMMA 10 RFCXX		
Alternative and supporting systems:				
Stellarator/Heliotron	ATF (86)	Heliotron E	W VII-A (FRG) W VII-AS (86)	
RFP	ZT-40 M OHTE	TPE Series REPUTE-1 STP-III M	HBTX-1A (UK) ETA BETA II (Italy) RFX (89) (Italy, UK)	
Compact Toroids	FRX-C S-1	CTCC-1, OCT, NUCTE		

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*Tokamak facilities are listed here whose primary mission is to study magnetic configurations or modes of plasma operation that represent major changes in direction compared to the larger tokamaks of today, such as TFTR, JET and JT-60. Avenues of improvement that follow more directly from the latter devices are studied in other facilities and programs covered by the Physics Subpanel (e.g., moderate D shape, poloidal divertor, advanced limiters, advanced RF heating systems).

TABLE III. EXISTING WORKSHOPS

Concept	Agreement	Frequency	Name, Participants
Tokamak Improvements	Included in overall tokamak program considered by Physics Subpanel		
Open Systems:			
Tandem Mirror	U.S.-Japan bilateral	Annual	U.S., Japan
Alternative and supporting systems:			
Stellarator/Heliotron	Informal	Biennial	International Stell. Workshop, EC, Japan, U.S., and U.S.S.R.
	U.S.-Japan bilateral	Biannual	U.S., Japan
RFP	U.S.-Japan bilateral	Annual	U.S., Japan
	Informal	Biennial	U.S., Japan, EC
Compact Toroids	U.S.-Japan bilateral	Annual	Joint U.S.- Japan CT Workshop
	Informal	Annual	U.S. CT Symposium open to international participants
EBT	U.S.-Japan bilateral	Annual	U.S., Japan

TABLE IV. PERSONNEL EXCHANGES SINCE 1980

Concept	Agreement	Participating Laboratories
Tokamak Improvements:	Included in overall tokamak exchange programs considered by Physics Subpanel	
Open systems:		
Tandem Mirror	U.S.-Japan bilateral	LLNL, U. Tsukuba, MIT, Nagoya, U. Wisconsin
Alternative and Supporting Systems:		
Stellarator/Heliotron	U.S.-Japan bilateral	Kyoto U., ORNL, IFS, LANL, MIT, U. Wisconsin, PPPL
	Informal	IPP Garching, U. Wisconsin ORNL, PPPL, NYU
RFP	U.S.-Japan bilateral	ETL, LANL
	Informal	ETL, Culham, U. Padova, LANL
Compact Toroids	U.S.-Japan bilateral	Osaka U., Nihon U., Hiroshima U., IPP Nagoya, PPPL, LANL, MSNW, Cornell, U. Maryland, U. Washington
	Informal	U. Heidelberg, U. Maryland
EBT	U.S.-Japan bilateral	ORNL, Nagoya

ADMINISTRATIVE OBSTACLES TO INTERNATIONAL SCIENTIFIC AND TECHNICAL COOPERATION

International cooperation in scientific research and technological development must be considered increasingly as a fundamental component of world economic growth and for that reason deserves special attention from the highest authorities.

Although in most sectors the need to cooperate arises spontaneously between research workers, the development of cooperation, on the other hand, requires the presence of optimum conditions which, in most cases, only governmental authorities are capable of creating.

This is particularly true at administrative level, where numerous obstacles hinder; in particular, freedom of trade in scientific and technical equipment and instruments and exchanges of research personnel, both research workers and technicians, or of scientific and technical information. The national and international regulations, most of them laid down several decades ago, are no longer in keeping with modern technological development and, in the present case, form barriers that should be removed or at least lowered in order to make possible and encourage expansion in international scientific and technical cooperation.

The working parties on High Energy Physics and controlled Thermonuclear Fusion set up after the summit meeting of Heads of State and Government held in Williamsburg, USA, in May 1983 considered that these obstacles should be especially examined in order to determine and to suggest ways and means of by-passing them.

This report is the result of that examination with respect to the two areas concerned.

1. Transfer in scientific and technical equipment and instruments

1.1 Present situation

The conditions governing the international transfer of scientific and technical equipment and instruments vary from one country to another and depend as a general rule on the duration of the transfer, the type of equipment involved and its intended use.

In most of the countries[1] which participated in the Summit, temporary importation is a relatively simple matter, but the periods of validity are limited to a maximum of two or three years, which is incompatible in certain cases with the time required to carry out complex scientific experiments. Such importation generally enjoys total or partial exemption from taxes or if a declaration has been made to the effect that the item in question is to be re-exported (the case in Japan). The formalities to be completed in order to obtain such exemption are sometimes quite complex, and should normally take only a relatively short time (say a week), but in complex cases may take longer. However, it requires quite a complex administration and in many cases it is totally impossible to give evidence of identity with respect to each instrument after the completion of the "temporary" use. Here again the existing rules are not at all in keeping with the complexity of international HEP-cooperation.

Permanent importation of scientific and technical equipment is generally subject to the rules of the Florence Convention (1952). In the case of most of the countries which participated in the Summit, specialized scientific equipment can be imported free of tax provided that it is to be used by public research bodies or bodies recognized as such, for non-commercial purposes and that equipment of equivalent scientific value is is not currently produced in the importing country (or in the case of the EEC Member States, in the EC). Depending on the country, components of such equipment may not enjoy the same conditions, which can lead to difficulty where repairs have to be carried out (the case in the USA and Japan).

Exportation of such scientific and technical equipment and instruments is not, as a general rule, subject to special restrictions. It should, however, be noted that the equipment in question often falls within the category of strategic and high-technology products, particularly in the two areas in question, trade in which is at present strictly supervised (particularly in the USA and Canada); where equipment of this type is concerned, restrictions are encountered which necessitate cumbersome formalities that may last for several months.

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[1] The word Country has been used for simplicity but it should be taken to mean customs territory possibly made of several countries (e.g. EEC).

1.2 Existing forms of international cooperation

The case of CERN (Centre Europeen de Recherche Nucleaire - European Nuclear Research Centre) in the field of High-Energy Physics and that of JET (Joint European Torus) in the field of fusion provide interesting examples with regard to trade in scientific and technical equipment and instruments between several countries.

The European Economic Community possesses a Community Regulation dated 28 March 1983[2] relating to the duty-free admission of scientific instruments or apparatus intended "for either public establishments principally engaged in education or scientific research and those departments of public establishments which are principally engaged in education or scientific research" on condition that they have been approved by the competent authorities of the Member States to receive such articles duty-free and "to the extent that instruments or apparatus of equivalent scientific value are not being manufactured in the Community". The regulation requires the European Commission to deal with applications within three months, but pending decision, the competent authority may authorize importation of the instrument or apparatus which is the subject of the application. It has to be noted, however, that the Community regulations give very sophisticated definitions of "a scientific instrument or apparatus" and that these definitions are interpreted very restrictively by the authorities, so that the practical importance of this exception is at present not very great in international HEP.

Scientific equipments or apparatus imported in this way into the Community from other countries are, as a general rule, subject to value added tax; derogations from that rule may, however, be permitted on the basis of bilateral agreement, each case being dealt with individually.

At all events, scientific and technical equipment and instruments sent as gifts, in token of friendship or goodwill "by an official body, public authority or group carrying on an activity in the public interest which is located in a country other than the Member State of importation, to an official body, public authority or group carrying on an activity in the public interest which is located in the Member State of importation and approved by the competent authorities to receive such goods exempt from tax" are exempt from VAT (Council Directive 83/181/EEC of 28 March 1983). Discussions are under way with a view to extending this exemption to equipment and instruments benefitting from the temporary admission system (see proposal for the 17th Council Directive, in respect of which the European Parliament has already expressed a favorable opinion).

As regards CERN, it is exempt, as an intergovernmental organization, from the payment of customs duties and taxes, and it benefits from preferential customs procedures. It thus directly imports (into Switzerland or France) equipment for its own use in accordance with the rules governing its special status. This includes the experimental equipment which remains the property of institutes that cooperate with

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[2] O.J. L 105, April 4, 1983 83/918/EEC.

CERN; in this case, temporary importation is not required. CERN also exports directly (from Switzerland or France) whatever the reason for the exportation may be. Apart from the two host States, CERN has obtained preferential agreements concerning the temporary importation of equipment that belongs to it into the United Kingdom and Italy.

For JET, an agreement has been established between this common enterprise and the United Kingdom which gives it advantages equal to these of CERN.

1.3 Possible improvements

The cases of CERN and JET are examples of potential improvements to the system currently in force. Among possible solutions, consideration can ben given to taking steps at ministerial level to accord a special status to scientific and technical equipment and instruments which would enable them, within the framework of intergovernmental agreements governing the projects that resulted from the Versailles Summit, to be moved freely between the laboratories participating in the "Controlled Thermonuclear Fusion" and "High Energy Physics" projects. Awaiting this solution the following measures should be taken:

- Extension of maximum time for temporary use to 10 years,
- Granting of status of "scientific equipment" for all equipment exclusively used in HEP research,
- Facilitation of procedures to give evidence of identity after temporary use.

It should also be noted that a draft European agreement aimed at facilitating the movement of scientific research equipment between the Member States of the Council of Europe is being studied and that, in this regard, the Ministerial Conference of 17 September 1984 recommended that consideration should be given to whether such an agreement would be of advantage. The agreement will be based on the application of Article 13 of the Customs Convention, itself based on the Florence Convention relating to the importation of scientific equipment, under which minimum facilities are provided for. The negotiation of this new agreement, however, will have to be conducted so as to ensure that it does not hinder application of greater facilities that certain contracting parties grant or might grant, either by means of unilateral provisions or under bilateral or multilateral agreements of the same type as those previously mentioned. (As regards this point, reference may be made, in particular, to the EC Council Directives already being implemented or at the stage of preparation). Subsequently, consideration could be given to extending such an agreement to non-European countries, and in particular to the countries which participated in the Summit.

It will be the task of TGE working group to make a statement upon the practicalities of setting up and operating such an agreement of Conventions.

2. Exchanges of scientific and technical staff

2.1 Present situation

The mobility of research workers has for several years been a matter of concern to those responsible for national scientific and technological policies, at least in Europe. Many studies have been conducted (Council of Europe, EEC, European Science Foundation) and the conclusions are relatively unanimous: such mobility can become a reality only if the responsible authorities create conditions suitable for the free exchange of scientific staff.

There are three such conditions:

- to simplify the administrative admission formalities in the host country (as regards both the research worker and his family) (visas);
- to facilitate integration of the research worker and his family in the host country (accommodation, motor car, work permit for the spouse, children's education);
- to guarantee social coverage equivalent to that in the country of origin (social security, pension rights, return to the country of origin).

2.1.1) Administrative formalities

These formalities are relatively simple in most cases.

Temporary visas can generally be granted and even extended (sometimes, however, with a certain amount of difficulty in this regard in the USA), without major problems in particular if the research workers are covered by a diplomatic agreement or an alliance treaty, if responsibility for them is accepted by international companies or organizations (the case in the USA), or if they can show that they are engaged in highly intellectual activities in the arts or sciences (the case in Japan). The families of the research workers generally enjoy the same facilities. It should, however, be noted that, in certain cases, the research workers and their families lose their citizenship rights both in the host country and in the country of origin.

2.1.2) Integration in the host country

The problems of integration in the host country depend to a large extent on the host laboratory and on its administrative services. In certain cases, the formalities are simplified by bilateral agreements that exist between laboratories (the case in Canada and Italy). In most cases, however, the research workers and their families are subject to the normal rules of the host country.

The conditions relating to accommodation vary considerably from one State to another and even from one town to another; certain research centres possess accommodation in which the families may stay temporarily; but, in most cases, the research worker is obliged to find accommodation for himself. Likewise, as regards driving licenses, road taxes and vehicle registration, the research worker is obliged to complete the normal formalities with which every foreigner arriving in a new country has to cope, even if the visit is for a limited period.

As regards the spouse's work permit, obtaining one is generally a lengthy and difficult process (except within the EEC in the case of nationals of its Member States). Many problems also arise, particularly during short-term stays, with regard to children's education[3], since mother-tongue instruction is not available and there is no point in the children's acquiring diplomas which are not recognized in their country of origin.

2.1.3) Social coverage

Where social coverage is concerned, although the social-security rules of the host country are generally applicable to a guest research worker and his family, it is mainly the country of origin which is responsible for facilitating that person's return to his mother country so that the period he spent abroad does not adversely affect his career prospects and his pension rights. Generally speaking, a research worker who works for some time in a foreign laboratory does not contribute to the national pension and social security systems of its own country while he is abroad and thus loses his social entitlements unless this question is specifically draft with in bilateral totalization agreements or in multilateral agreements (the case of EEC member states). If he returns to his original employment, he could also lose his right to promote and his career prospects suffer in consequence.

2.2. Existing forms of international cooperation

The situation at CERN is sufficiently typical to be referred to here as an example in this respect. Almost half the scientific and technical personnel are from foreign laboratories and stay in Geneva for periods of varying length. Most of these research workers are seconded provisionally from their home laboratories and administrative responsibility for some of them is assumed by CERN, but most of them remain administratively attached to their original laboratories; the problem of their status is thus minimized to a large extent and, after their stay at CERN, the research workers resume work in their home laboratories and their careers generally suffer no adverse effects as a result of their temporary secondment.

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[3] At the European level (JET in particular) this question has been solved by creating European schools with a special status.

In all cases in which a residence permit is issued (activity on behalf of CERN must account for at least 50% of the holder's time), the research worker can be accompanied by his family. In the case of certain persons who are nationals of countries which are not members of CERN, a visa may be necessary to enable them to enter Swiss or French territory, but this requirement gives rise to only a few minor problems.

There is generally no difficulty in obtaining a work permit for spouses, but the situation on the labour market in the Geneva area is relatively depressed at present.

Where children's education is concerned, things are made easier by the international setting of Geneva, but problems do exist in respect of recognition of diplomas. Difficulty is also encountered with regard to accommodation, since the number of apartments available in Geneva is relatively small, but CERN rents some apartments which it can place at the disposal of new arrivals for a limited period.

Within the European Community, moreover, the administrative formalities are simplified, since the question of visas and work permits does not arise. It may, of course, arise in the case of research workers who are nationals of non-Community countries[4].

The problems that remain to be solved are those of the research worker's status and of the conditions under which he returns to his country of origin; no uniform status exists and there is no framework agreement between the Member States of the Community to settle these questions, which consequently are dealt with under bilateral or multilateral agreements between the parties concerned. This is the case, in particular, with the agreement on the promotion and mobility of staff in the field of Thermonuclear Fusion, concluded by all the European States which are participating in that programme and the European Community. Under that agreement, each party to it is prepared to receive staff seconded from the other parties for the purpose of participating in implementation of the joint project, and the Commission of the European Communities assumes responsibility for expenditure arising from the secondment of such staff (travelling, allowances, etc...). The contract of employment between the seconded staff and their original employers remains in force throughout the period of secondment; likewise, the original employer ensures that the social coverage of his seconded staff continues. The host organization places its equipment, social services and other facilities at the disposal of the seconded staff.

It should also be noted that the European Economic Community proposed, in the context of its activities for the purpose of stimulating cooperation and scientific and technical exchanges at European level,

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[4] This is not the case for JET, third countries (Switzerland, Sweden) having the same advantages as Community Member States.

that it support a number of ancillary measures intended to contribute to promoting the mobility of scientific personnel within the Community (transport, career, information, etc...).

2.3 Proposed solutions

From the examples referred to above, it can be seen that one of the best ways of setting up a satisfactory system of mobility for research workers [5], without creating problems concerning subsequent employment, is to base the system on secondment from a research institute or body in the country of origin to a research institute or body in the host country. In this connection, the agreement between the European countries on the joint programme on Controlled Thermonuclear Fusion could form a basis on which an international agreement between the countries which participated in the Summit could be concluded. That same agreement could provide that the secondment expenditure would be shared between the research worker's home laboratory and the host body, and that the latter would undertake to facilitate the integration of the seconded research worker and his family by placing accommodation at his disposal, even if only for a limited period.

Other problems such as those connected with taxes, children's education, equivalence of diplomas and work permits for spouses require lengthy and difficult negotiations before they can be solved, and such negotiations could be initiated forthwith. It should be noted in this regard that the Council of Europe was assigned by the Ministerial Conference of 17 September 1984 the task of examining, in accordance with normal procedures and in cooperation with the competent national authorities, measures to improve the mobility of research workers in Europe. This could lead to measures that might be taken within the broader framework of Summit cooperation.

While such measures are awaited it would in any case be useful to inform potentially mobil researchers of their rights, and the facilities offered by the various laboratories collaborating in the HEP and Fusion fields.

It will be also the task of TGE working group to give its opinion upon the practicalities of setting up and operating such an agreement or convention.

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[5] In this document we have referred to the case of experienced research workers; the mobility of young research workers, particularly during their first employment, gives rise to different problems and should doubtless be examined in greater detail.

3. Exchange of scientific and technical data[6]

3.1. Present situation

The present situation in Europe is described in the ECFA (European Committee for Future Accelerators) Report ECFA/83/75 and references to a more detailed description of the requirements can be found there. The modes of communication which are needed include:

- The transmission of text either as electronic mail or long documents
- The transmission of program files to ensure software standardization, with updating, on a project
- Remote terminal access and remote job submission to certain computer facilities
- The transmission of technical data in graphical form
- The transmission of data from experiments. This is of particular importance for fault diagnosis during the data-taking phase of an experiment
- Tele-conferencing. The efficient management of large collaborative enterprises requires frequent exchange of information and views leading to decisions on policy and design.

The HEP community undertakes its research in international collaborations which span the continents. European groups make extensive use of the facilities in North America such as SLAC (near San Francisco) and Fermilab (near Chicago). Groups from Canada, Japan and the US (and other nations) participate in experiments undertaken at the European Laboratories, such as CERN and DESY. The greater distances separating those involved in the large intercontinental collaborations characteristic of High Energy Physics make good communication facilities essential.

The exchange of scientific and technical information in high technology sectors such as Controlled Thermonuclear Fusion or High-Energy Physics is, like trade in scientific and technical equipment or the mobility of research workers, a prerequisite for the success of research in these fields. The removal of obstacles to such an exchange, however, depends on the preparedness of the parties concerned to communicate information which, in certain cases, can be of commercial value or can be the subject of important scientific communications.

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[6] The term "scientific and technical data" means solely the raw results of scientific and technical experiments and never the communications and publications that result from such experiments. The dissemination of knowledge by those means gives rise to another, more general, problem which is not dealt with in this report.

Apart from that prerequisite, there are still many obstacles, whether at technical level, in view of the large number of data to be transmitted and the difficulties associated with the interconnection of communications networks, at economic level, in view of the rates charged by the companies responsible for transmission, or even at political level, in view of the fact that it is high technologies that are involved here and certain information may be covered by military or industrial secrecy.

3.1.1) Technical obstacles

Intensive use of information technologies for the transmission and processing of scientific and technical data has been an important step in the rise of scientific research and, in sectors such as High Energy Physics or Controlled Thermonuclear Fusion, these technologies are an indispensable instrument without which progress would be impossible.

In the case of High Energy Physics, telecommunications networks making use of private or public cables at present offer only limited possibilities with regard to transmission speeds (9 600 bits/sec) and there are very few intercontinental lines. In the near future (1 1/2 years), it seems that six to eight lines between Europe and the USA and one line between Japan and the USA, all restricted to 9 600 bits/sec, would be necessary in order to meet the physicists' requirements.

In two or three years, it will doubtless be necessary to set up two lines capable of transmitting at the rate of 56 kbits/sec lines and to add eight to ten lines between Europe and the USA and one line between Japan and the USA (all capable of transmitting 9 600 bits/sec). Subsequently, most of the 9 600 bits/sec lines would have to be converted to 56 kbits/sec. For the time being, there seems to be no urgent need to set up 1 Mbits/sec links; nonetheless, in view of the forecasts made by the High Energy Physics laboratories for the end of the decade, it can be estimated that the largest countries might need one hour per day at 2 Mbits/sec via satellite.

Two-way communications across the North Atlantic and the North Pacific could also turn out to be necessary.

The technical obstacle does not arise so much from the available capacity or number of lines, since technical knowledge and resources are such that industry should be able to cope with the requirements sketched out above, as from the compatibility and interconnection of existing networks; the most difficult problem to overcome is probably the absence of a complete set of international standards in this field, both with regard to the interface of means of telecommunication and to the software used. In particular, the network access protocols would have to be standardized or at least harmonized.

The ESPIRIT programme, put in hand within the framework of the EEC, should make it possible to solve some of these problems in the short term, particularly those which concern compatibility of equipment and software in the different European countries[7]. The question will arise once again in the case of exchanges between European, American and Japanese laboratories. An experiment on the on-line transmission of data via a commercial telephone cable is, however, under way as a cooperative project undertaken by Fermilab and the University of Tsukuba.

The purpose of a further experiment will be to link via satellite the data base of the Information Centre of the Nagoya Plasma-Physics Institute with an equivalent data base in the USA. It will be noted on this point that the potential of satellite transmission is very high and should provide increasingly better and cheaper means of communication. Encouragement should be given at this time to exploring the ways by which the scientific community can take advantage of the new economies brought about by these new technologies and, therefore, the broadest set of potential options should be reflected in the planning.

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[7] It should also be noted that the Commission of the European Communities intends to implement a large-scale programme of action for the balanced development at European level of the telecommunication sector, the objective of which, inter alia, is to place at the users' disposal, under the best possible cost and time conditions, the equipment and services most likely to meet their future requirements.

3.1.2) Economical Obstacles

Making use of public data transmission networks, as things stand at present, is often the only solution available to laboratories and research bodies that wish to exchange information.

In particular, where High Energy Physics is concerned: "in France, there is a lot of networking activity in the laboratories of the Paris region, from where previously installed permanent connections exist to different locations in France and to CERN; there is also a permanent connection between Annecy and CERN. In Germany, it may be noted that an important new project has been started under the name DFN (Deutsches Forschungsnetz) with the aim of providing high-level services over the DATEX-P public network. In Italy, there does not exist yet a public data network; various laboratories of the INFN (Istituto Nazionale di Fisica Nucleare) are linked by a private DECNET network, which has a connection to CERNET. In Switzerland, the public network is fairly new and is still missing some international connections. In the United Kingdom, besides the public PSS network, there exists a very important private network operated by the Computer Board, JANET (Joint Academic Network); it is derived from the network previously operated by the Science and Engineering Research Council, SERCNET; JANET is connected to PSS and to some computers at CERN. There is also a permanent connection between the Rutherford Appleton Laboratory and the DESY Laboratory.

The possibility of connection to American networks, including ARPANET, BITNET, TELENET and TYMNET, has been surveyed. Apart from what is offered by most of the European public networks, i.e., essentially access to TELENET and TYMNET with gateways to other networks, some more information is available on a direct connection between ARPANET and SERCNET and on CSNET, a new project of the American National Science Foundation.

Connections also exist between the European networks and DATAPAC (Canada) and VENUS-P (Japan). Contacts are being established with the HEP groups in these countries".[8]

In the field of Controlled Thermonuclear Fusion, laboratories and research centres make use in most cases of the same public networks, but it has been noted that the private links between research centres are less developed than in the case of High Energy Physics. This is probably due to the fact that, in this field, on-line data processing is not required to the same extent.

This use of public data transmission networks, in view of the rates charged by the PTTs, gives rise to considerable expenditure, particularly in the case of High Energy Physics. In this regard, it would doubtless be advisable to activate negotiations with the PTTs

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[8] ECFA/83/75, September 1983.

in order to obtain preferential rates or the allocation of special lines. With regard, in particular, to international links, it would be necessary, on the one hand, for the PTTs to charge rates comparable to those applicable at national level and, on the other hand, for them to authorize free interconnection of the networks reserved for scientific and technical users. It should be noted that several studies have been undertaken within the European framework with a view to defining the characteristics of a high-speed European network in cooperation either with private firms or with the PTT administration. Pending completion of such projects, the interconnection of all the X 25 national networks would be of primary importance.

3.1.3) Political obstacles

The political obstacles are real, but probably less difficult to surmount, particularly in the field of High Energy Physics, where the results are hardly likely to be covered by military or industrial secrecy. Where Fusion is concerned, closed scientific and technical cooperation derives from a declared political will to ensure that participants exchange the most important scientific and technical information relating to this sector. (In this connection, if an agreement between the countries which participated in the Summit is to be concluded in this field, it would be advisable to incorporate in it a clause concerning the dissemination of results).

3.2 Requirements for the coming decade:

On bandwidth:

1. The HEP community in Europe requires in two or three years access to public data networks at medium (56 Kbps) and, by the end of the decade, high (IMbps) bandwidths with international links able to operate at the high bandwidth.

2. The average total international traffic generated at medium bandwidths is 250 K bits/second during the working week. The high bandwidth traffic could reach 2 Megabits/second at the end of the decade when new accelerators are in full operation in Europe and the US.

Technical barriers:

3. It is essential that rapid agreement is reached on ISO standards for communications.

4. Manufacturers must be strongly encouraged to support these standards as they are agreed, by setting public sector procurement requirements, if necessary.

Cost factors:

5. An "academic discount" should be given for the use of computer communication services by the academic community.

6. International tariffs should be set at a level much closer to those for national services.

PTT factors:

7. Full international interconnection of all national public data networks is essential.

8. Until recommendations (1) and (6), in particular, are satisfied, the interconnection of international leased lines for academic use should be permitted without restriction or additional charge.

4. Conclusions

It is clear that the removal of certain administrative obstacles would greatly improve and facilitate international cooperation in several areas of science and technology. Because enhanced international collaboration implies cost sharing and cross participation in the construction and exploitation of regional devices, new administrative procedures are imperative, many of the present procedures being serious obstacles to effective cooperation.

More specifically, the HEP and Fusion Working Groups having examined this report at their Cadarache meeting on January 13 to 16 and recommend that attention should be given to the following questions:

a) Cross participation in projects through the provision of scientific equipment and components for major facilities is currently hampered by the fact that tariff and tax exemptions are only provided for short durations that are not compatible with the timeframe of the collaboration, which may last for more than 10 years.

b) The exchange of scientific and technical staff is an important factor in international collaboration. Increased collaboration can become a reality only if the responsible authorities create conditions suitable for the easy exchange of scientific staff.

There are several such conditions, notably:

- to simplify the administrative admission formalities in the host country;
- to facilitate integration of the research worker and his family in the host country;
- to guarantee adequate social coverage.

c) Data transmission is an important aspect of the work of the HEP and Fusion Communities. The acceptance of cross participation in facilities, which are widely separated geographically, relies heavily on inexpensive and efficient data transmission. Two aspects have been singled out for urgent consideration within the Versailles Working Group "Technology, Growth and Employment" framework:

- the review of the charging policy for scientific data transmission across borders;
- the promotion of effective data communication standards in order to ensure compatibility.

The Working Groups recommend to the Versailles Working Group "Technology, Growth and Employment" that a study be conducted on this subject subsequent to the Bonn Summit and that a report on the steps that might be taken to improve conditions related to the above mentioned administrative impediments to effective cooperation be submitted to the subsequent Economic Summit.

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APPENDICES

APPENDIX A

Excerpt from "Declaration of the Seven Heads of State and Government and Representatives of the European Communities"

June 1982

Excerpt from "Declaration of the Seven Heads of State and Government and Representatives of the European Communities"

Revitalization and growth of the world economy will depend not only on our own effort but also to a large extent upon cooperation among our countries and with other countries in the exploitation of scientific and technological development. We have to exploit the immense opportunities presented by the new technologies, particularly for creating new employment. We need to remove barriers to, and to promote, the development of and trade in new technologies both in the public sector and in the private sector. Our countries will need to train men and women in the new technologies and to create the economic, social and cultural conditions which allow these technologies to develop and flourish. We have considered the report presented to us on these issues by the President of the French Republic. In this context we have decided to set up promptly a working group of representatives of our governments and of the European Community to develop, in close consultation with the appropriate international institutions, especially the OECD, proposals to give help to attain these objectives. This group will be asked to submit its report to us by 31 December 1982. The conclusion of the report and the resulting action will be considered at the next economic Summit to be held in 1983 in the United States of America.

APPENDIX B

Excerpt from the Report of the London Summit of the Working Group on Technology, Growth, and Employment

Progress in the 18 Areas for Co-operation

The Working Group has noted with pleasure the growth of international collaboration in the 18 different areas for co-operation identified in its report to the Williamsburg Summit of 1983. Developing effective international collaboration takes time but nonetheless, significant progress has been made in many areas in one or more of the following respects:

a. the establishment of effective and informal international networks between research institutes in specified fields of science and technology;

b. the identification and initiation of collaborative research activities within the chosen areas for co-operation;

c. the involvement of countries outside the Economic Summit grouping and of relevant international science and technological organizations.

Individual progress reports are attached in the Annex, but there are a number of general observations which can be made.

The nature of the agreed international co-operation differs between the areas. In several, the working groups have agreed the basis on which they will continue to exchange information arising from existing national programmes. In some, this had led to the inauguration of regular seminars and meetings to discuss research results. In others, the groups have tried to identify a framework for research within which new national projects can be planned, which will mean those projects will produce results which are comparable across national boundaries.

In both these types of collaboration, close bilateral and multi-lateral relationships have developed between research institutes, which hold out the prospect of genuine joint projects in the course of future collaboration.

In certain other topic areas, notably those where there has been already a good deal of international co-operation through existing institutions (for example remote sensing from space, biological sciences), the setting up of the working groups has created the opportunity to review the effectiveness of current collaborative machinery and to identify ways forward. The aim has been to assist the planning of programmes within existing networks of collaboration.

Effective cost sharing is becoming a more important element in the construction of major new facilities. Collaborative projects would benefit if coherent long term plan for the construction and sharing of facilities in our countries were to be developed.

Where appropriate, non-Summit countries have participated in seminars, and other project activities. The scope for the involvement of non-Summit countries or other scientific and technological organizations is, of course, different in each of the chosen areas for co-operation. The Working Group has reaffirmed that the principal criterion for such involvement must be the benefit that co-operation in a chosen area might acquire by this participation.

In sum, the activities stimulated by the Technology, Growth and Employment initiative have both improved the climate of international co-operation and helped to focus national science and technology discussions. In this way, they have strengthened the links between national and international science and technology.

In looking to the future, the Working Group is firmly of the view that a failure to take up opportunities for international collaboration may be just as prejudicial to the introduction of new technologies and hence to economic growth as the obstacles referred to earlier in the report.

Progress Report to the London Summit

Area for Collaboration	Controlled Thermonuclear Fusion
Lead Countries	USA, European Communities
Participants	Canada, France, FRG, Italy, Japan, UK
Observers	--
Invited International Organizations	--

AIMS

1. Accelerate world development of a new energy source using practically inexhaustible fuels and possessing potential advantages from an environmental point of view.

2. To avoid duplication of costly equipment and installations.

3. To study the possibility of carrying out joint projects in the medium term.

ACTIVITIES

The working group reviewed the present status of the fusion programs of the Summit countries and their associated international activities. The three major programs are those of the USA, Japan and a joint program within the European fusion community. Recognizing that the remaining efforts to develop fusion into a new energy source will require considerable time and expense, the Working Group recommends that a consensus be sought on the desirable strategy in fusion in order to facilitate early joint planning to coordinate individual programs.

OUTLOOK

The next step following the London Summit is to establish a process to reach such consensus on the minimum number of objectives and machines that are required on scientific and technological grounds to research the ultimate goal.

The next step will begin at the next meeting of the Working Group scheduled for July 1984.

APPENDIX C

Excerpt from the Communique of the London Economic Summit

June 9, 1984

"We, the heads of state or government of seven major industrialized countries and the President of the Commission of the European Communities, have gathered in London from 7 to 9 June 1984 at the invitation of the Right Honorable Margaret Thatcher, the Prime Minister of the United Kingdom, for the 10th annual economic summit.

[2]

"The primary purpose of these meetings is to enable heads of state or government to come together to discuss economic problems, prospects and opportunities for our countries and for the world. We have been able to achieve not only closer understanding of each other's positions and views but also a large measure of agreement on the basic objectives of our respective policies.

[13]

"We welcome the further report of the working group on technology, growth and employment created by the Versailles economic summit and the progress made in the 18 areas of cooperation and invite the group to pursue further work and to report to personal representatives in time for the next economic summit. We also welcome the invitation of the Italian Government to an international conference to be held in Italy in 1985 on the theme of technological innovation and the creation of new jobs."

APPENDIX D

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Cooperation and Competition on the Path to Fusion Energy

A Report Prepared by the
Committee on International Cooperation in Magnetic Fusion
Energy Engineering Board
Commission on Engineering and Technical Systems
National Research Council

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

Because the magnetic fusion process holds unique promise as a long-term energy source or as a source of neutrons, efforts have persisted for many years to solve its challenging scientific and engineering problems. Major programs have been undertaken in the United States, Europe, Japan, and the Soviet Union. As the size and complexity of the experimental devices have grown, international cooperation has occurred in order to produce earlier results, to share risk, to minimize investment, or to acquire skills. Faced with even more demanding future program requirements, officials of the U.S. Department of Energy are considering whether greater levels of international cooperation offer benefits. The Committee on International Cooperation in Magnetic Fusion was appointed by the Commission on Engineering and Technical Systems of the National Research Council to address this question for the Department of Energy. The committee functioned under the guidance of the Energy Engineering Board of the Commission.

The purpose of the study is to recommend a worthwhile course of action in international cooperation, as measured by the criteria of acceptable policy, technical merit, and practical workability.

New and substantial undertakings in international cooperation will depend in a complex and interrelated way on the perceptions of persons at the technical, political, and industrial levels. Accordingly, the committee obtained the viewpoints of such persons by conducting two workshops in the United States and by meeting with officials in the European Community and in Japan. During these meetings, instances of international cooperation in both fusion and other technologies were examined for the lessons they might contain. Various incentives and constraints to cooperation exist, which, taken together, will determine the policies of each of the three main free-world programs. There are also many technical needs and opportunities, ranging from minor participation in supporting experiments to joint investment in costly facilities for generic technology development and the sequencing, or indeed the collaborative construction and operation, of a series of major experimental fusion devices. There are also many types of agreement and details of implementation that may be devised or adapted to carry out cooperation toward joint objectives. All these considerations are discussed here.

No attempt has been made to pass judgment on the various technical approaches being undertaken. However, we have tried diligently to reflect accurately the attitudes and concerns expressed during our meeting and visits.

In looking back over our work, I believe that we have established the need for the United States to articulate its goals, programs, schedules, and commitment more clearly as a prerequisite for the negotiation of cooperative activities. I believe also that we have set forth a number of conditions that should be satisfied in cooperation. And I believe that we have recommended useful initiatives for the Department of Energy to consider as it pursues the topic.

John F. Clarke and Michael Roberts, of the Office of Fusion Energy, have lent their encouragement and substantive support throughout our study. The many individuals listed in the Appendixes, who participated in our domestic workshops and in our meetings abroad, thoughtfully and graciously supplied the substance of our work. My fellow members of the committee gave of their enthusiasm, their time, and their insights. Finally, we were ably supported by the staff of the Energy Engineering Board, led by Dennis F. Miller, its Executive Director, who was largely responsible for initiating the study. John M. Richardson, Study Director, provided day-to-day guidance and support. The cheerful and ready efforts of Cheryl A. Woodward in the full range of administrative matters was valued by all who worked with her. All these contributions I acknowledge with sincere thanks.

Joseph G. Gavin, Jr., Chairman
Committee on International Cooperation
in Magnetic Fusion

CONTENTS

SUMMARY

The United States, the European Community, and Japan are actively considering whether worthwhile advantages lie in increased cooperation among their respective programs of research and development in magnetically confined fusion. To help answer that question for the United States, this report examines why cooperation is a policy option, what might be done, and how.

LIST OF CONCLUSIONS AND RECOMMENDATIONS

For convenient reference the conclusions and recommendations of the study are collected together in this section apart from the arguments that lead up to them. The various supporting arguments are briefly developed at later points in the Summary, whereupon the conclusion or recommendation is stated anew.

The most important inferences from the many facts and viewpoints examined by the committee may be expressed in six specific conclusions:

- On balance, there are substantial potential benefits of large-scale international collaboration in the development of fusion energy.
- A window in time for large-scale international collaboration is now open.
- Large-scale international collaboration can be achieved, but not quickly.
- International collaboration will require stable international commitments.
- There is a host of considerations that must be resolved in the implementation, but these appear workable.
- Past cooperation provides a sound basis for future efforts.

Consideration of the above points in the broader context of the status and prospects for magnetic fusion development led the committee to an overall conclusion:

- For the United States in the years ahead, a program including increased international collaboration is preferable to a predominantly domestic program, which would have to command substantial additional resources for the competitive pursuit of fusion energy development or run the risk of forfeiture of equality with other world programs.

Having concluded that large-scale international collaboration is the preferable course, the committee makes two recommendations for getting started:

- The first priority should be the establishment of a clear set of policies and objectives and a considered program plan for future U.S. fusion activities.

- Having carried out the preceding recommendation, the United States should take the lead in consulting with prospective partners to initiate a joint planning effort aimed at large-scale collaboration.

THE WORLD'S MAJOR MAGNETIC FUSION PROGRAMS

Major magnetic fusion programs are conducted in four areas of the world--the United States, the European Community (EC), Japan, and the Soviet Union. The four magnetic fusion programs are of comparable magnitude and are at a comparable stage of development. In each of these programs a "scientific feasibility" experiment based on the most advanced magnetic confinement concept--the tokamak--either has recently started operation (in the United States and the EC) or will start operation within the next one or two years (in Japan and the USSR, respectively). Smaller fusion programs are carried out in several other countries.

Broadly speaking, the near-term technical objectives of program planners in the four programs are similar: (1) to maintain a vigorous scientific base program, (2) to initiate a major next-step tokamak experiment, (3) to continue to develop the less mature alternative magnetic confinement concepts, and (4) to expand the fusion technology development program. Pursuit of these objectives is financially constrained, to varying degrees, in each of the four programs.

The physics of laboratory plasmas near fusion conditions is primarily an experimental science today. World leadership in fusion generally resides in that country possessing the experimental facilities with the greatest capability to explore the frontiers of plasma physics.

The United States

The United States has a strong experimental tokamak program that has established many of the world record plasma physics parameters. Two of these experiments, Tokamak Fusion Test Reactor (TFTR) and Doublet III D, should continue to extend the knowledge of plasma physics for the next five years or so. The United States also has the leading experimental program in the tandem mirror confinement concept, which is the most advanced alternative concept. Smaller programs are going forward in other, less advanced alternative confinement concepts, for example, stellarator, reversed-field pinch, and compact toroid. The United States has a strong program in basic fusion science and has the broadest and longest-established fusion technology program. For the past decade the United States has been the overall world leader in magnetic fusion, although upon occasion other programs have led in particular areas.

The European Community

The EC program is perceived by its participants to be on the threshold of assuming world leadership in fusion on the basis of a new generation of tokamak experiments, (commonly known by their acronyms as JET, TORE SUPRA, ASDEX-U, and FTU), that will be operating over the next decade. This view is shared by many in the United States. The EC program managers believe that they should maintain their progress toward leadership by constructing a major new tokamak experiment, Next European Torus (NET), to operate in the mid to late 1990s. NET has physics objectives of achieving an ignited plasma and a long-burn pulse and, in addition, ambitious technological objectives. Planning and preconceptual design work for NET has been authorized by the Council of Ministers of the European Community and initiated at the technical level; decisions as to whether to proceed to engineering design and to construction are scheduled for 1988 and 1992, respectively. The EC has programs in the less advanced stellarator and reversed-field pinch alternative concepts. Fusion technology programs are expanding in support of the NET activity. The EC fusion program is carried out in the various national fusion laboratories of its member countries and is partly funded directly by each nation and partly funded by the EC, with only minor participation by European universities.

Japan

The Japanese fusion program is relatively newer than the other three major programs, but it is moving rapidly toward full parity. The program of the Japanese Atomic Energy Research Institute (JAERI), under the Science and Technology Agency, concentrates on the tokamak and on fusion technology. The JT-60 tokamak, which will begin operation within one year, will have confinement capabilities comparable to those of TFTR, although JT-60 is not designed for deuterium-tritium operation. Conceptual design studies are in progress for a new major tokamak experiment, Fusion Experimental Reactor (FER), to operate in the mid to late 1990s. FER would have objectives similar to those of NET. The fusion technology program is comparable in strength to the U.S. program, although not so broad. The university fusion program, under the Ministry of Education, Science and Culture, has funding comparable to the JAERI base program and conducts basic scientific and technological research that appears even broader than either the EC or U.S. programs. This program investigates several confinement concepts, including tokamak, tandem mirror, stellarator, reversed-field pinch, compact toroid, and bumpy torus. The reversed-field pinch is also being developed under a small program of the Ministry of International Trade and Industry. Of special note is the role of Japanese industry in designing and supplying complete systems to the fusion program; in this respect industrial involvement in Japan is greater than it is in the EC and U.S. programs.

The Soviet Union

The committee did not look into the fusion program of the Soviet Union. However, it is known that the USSR program is advanced to a level comparable with that of the other three major programs. The USSR program has historically been characterized by strong scientific insight. Past cooperation with the USSR has been technically fruitful and could beneficially be expanded from the rather modest current levels if U.S. policy constraints change. Circumstances may change sufficiently in the future to make renewed scientific cooperation with the USSR desirable from the policy viewpoint of each country, in which case fusion would be a suitable vehicle.

Implications for Cooperation

Three points made in the foregoing discussion have important implications for increased world cooperation: (1) the programs are at a comparable stage of development, (2) their near- to intermediate-term objectives are similar enough to provide a technical basis for a major expansion of cooperation in the future, and (3) maintaining enough strength to meet national needs will surely be a concern of each program.

PRIOR AND CURRENT COOPERATION

An open and informal exchange of scientific information through publications, meetings, and laboratory visits has existed among the United States, Western Europe, Japan, and the USSR since 1958, when the subject of magnetic fusion was declassified. The U.S. exchange with Western Europe has been the most extensive, probably because of cultural and political similarities.

A formal bilateral agreement with Japan has covered many cooperative activities over the past few years. For example, Japan is contributing approximately $70 million over a five-year period to upgrade the Doublet III tokamak experiment and about $2 million per year to the operation of the Rotating Target Neutron Source II in the United States, as well as sending experimental teams to work on those facilities. In addition, there has been extensive exchange of personnel on other projects and on joint planning activities.

There exist formal multilateral agreements among the United States, Japan, and the EC for several cooperative activities under the aegis of the International Energy Agency (IEA).

The United States, Japan, the EC, and USSR, under the International Atomic Energy Agency (IAEA), are cooperating in the International Tokamak Reactor (commonly known by its acronym INTOR) Workshop on conceptual design of a possible next-step tokamak experiment.

The United States and USSR have exchanged personnel and visiting delegations of scientists under formal agreements dating from the 1973 Nixon-Brezhnev accord.

Previous cooperative undertakings in fusion have been substantial and generally successful. The participants generally believe that they benefited from the cooperation. The technical and program leaders in the U.S., EC, Japanese, and USSR fusion programs have come to know and respect each other through many years of open professional and social contact. This rapport provides an unusual and unique basis to build upon in negotiating and carrying out cooperative activities.

This background is important enough to the issue that it should be expressed as a conclusion:

- Past cooperation provides a sound basis for future efforts.

TECHNICAL OPPORTUNITIES FOR INCREASED COOPERATION

As the major fusion programs progress toward larger experiments and expanded technology development, there will be opportunities for increased benefit through enhanced international cooperation. In the following discussion, the term "cooperation" is used as a general one, in the sense of acting with others for mutual benefit on either a small or a large scale. The term "collaboration" is used more specifically to imply working actively together as approximately equal partners in sizeable enterprises.

Major Next-Step Tokamak Experiments

The EC and Japan are planning experiments (NET and FER) with ambitious physics and technology objectives. These experiments are intended to be initiated at the end of the 1980s, after the essential results from TFTR, JET, and JT-60 are available, and to be operational at the end of the 1990s.

If the United States initiates a next-step tokamak project within the next several years, then the Japanese and Europeans could be invited to participate in a U.S. project. The Japanese and Europeans might be interested in providing components for the project if those components incorporated technologies that were relevant to their subsequent FER and NET experiments.

On the other hand, if a next-step tokamak project is to be delayed beyond the next several years, the United States should explore the possibility of joining with Japan and the EC, on a roughly equal basis, in an international project to plan, design, construct, and operate an experiment with objectives similar to those of FER and NET. The participation could be staged, with decisions on continuation made at the end of each stage.

The physics of tokamaks can be also advanced by experiments on intermediate-level devices with special characteristics, such as TEXTOR, ASDEX-U, and TORE SUPRA. Experiments like these offer technical opportunities for useful international cooperation, in preparation for collaboration on the larger devices.

Fusion Technology

The United States should explore the possibility of joining with Japan and the EC in a three-way effort to identify what information and what new fusion technology facilities will be needed and when, specify the design requirements and experimental programs for such facilities, and identify how the cost and responsibility for constructing and operating these facilities might be distributed equitably among the parties. Agreements among the three parties to participate in a national test facility project of one of them could then be worked out on a case-by-case basis.

Alternative Confinement Concepts

The United States is developing the tandem mirror, stellarator, reversed-field pinch, and compact toroid concepts and is investigating other possibilities at a lower level of effort. Japan is developing the same four concepts, and Europe is developing the stellarator and reversed-field pinch. The development of each concept proceeds through a sequence of steps from small "exploratory" experiments through "intermediate" experiments to larger "scientific feasibility" experiments. In recent years the United States has retreated somewhat from this procedure, making it more difficult for a concept to advance to the next step or even to continue.

The United States should consult with Japan and the EC on cooperation in the development of alternative concepts. This cooperation could take two forms: (1) coordination in specifying the design parameters and experimental programs for intermediate experiments in each country so as to enhance their complementarity and (2) distribution of the responsibility among the three parties for constructing and operating scientific feasibility experiments as national projects in which the other party or parties would participate as junior partner(s).

INCENTIVES FOR AN INCREASED LEVEL OF INTERNATIONAL COOPERATION

The U.S. program has benefited from the the prior international cooperation described above in two quite different ways: resources were available to support effort beyond what could be supported in the United States alone, and novel and unique foreign contributions have influenced the U.S. program technically. One example of financial benefit is the Japanese contribution to the U.S. Doublet III tokamak, which allowed the additional heating equipment to be installed that led to the achievement of record plasma parameters. A prime example of technical benefit is found in the invention of the tokamak confinement concept in the USSR. As a consequence, all four major programs have advanced more rapidly and with better direction than would have been the case without cooperation. Similar benefits may reasonably be expected from future cooperation.

Greatly increased resources are required to maintain the breadth and depth of the national fusion programs while moving forward to explore a burning plasma in a major next-step experiment and to develop fusion technology. There seems to be an increasing body of opinion among responsible leaders in government and in the fusion programs in the United States, the EC, Japan, and the USSR that a cooperative international pooling of national resources may be required in the present economic environment. Such pooling would allow sharing of the increase in costs otherwise required of each separate program. The JET project is a good example of how national programs can be maintained at the same time that national resources are pooled for an international project.

Controlled fusion is the subject of one of the working groups established in 1982 by decision of the Heads of State and Government at the Versailles meeting of the Summit of Industrialized Nations. The Heads of State have subsequently endorsed the activities of the working groups. The fusion working group has identified the importance and magnitude of the effort of developing fusion and has concluded that a substantial increase in international cooperation is justified.

The extent to which any national or multinational fusion program will be willing to rely on international cooperation rather than its own strength and direction is a policy issue, the resolution of which may place constraints upon such cooperation.

Thus the main incentives for increased international cooperation are the expectation of enhanced technical results, probable cumulative savings--through sharing of costs and risks--in human and financial resources compared to those required by a separate program, and long-run merit as seen at the heads-of-state level. The main hesitancy will center on the possibility of weakening the individual programs, but conditions can be set to maintain the desired vigor. For these reasons, we come to the following conclusion:

- On balance, there are substantial potential benefits of large-scale international collaboration in the development of fusion energy.

FACTORS AFFECTING THE IMPLEMENTATION OF INTERNATIONAL COOPERATION

There are many technical, political, institutional, and other factors that define the context within which the possibilities for increased levels of international cooperation in fusion must be explored. Some of these factors are favorable and some tend to be constraining.

Fusion power plants are at least a few decades from commercialization. This time horizon provides a unique opportunity for cooperation over the next decade or two with little compromise of the competitive position that national industries might seek to create in a commercial fusion market of the future. As that time approaches, it should be possible to accommodate proprietary objectives by an orderly disengagement or by other measures commonly employed in today's technological industries.

The points made previously concerning the approximate parity in the status of the world programs, their similarity in objectives, the gathering momentum of the EC and Japanese programs, the existence of technical needs and opportunities, political and administrative receptivity, and the absence of near-term competition in the commercialization of fusion support the following conclusion:

- A window in time for large-scale collaboration is now open.

The EC and Japanese fusion program plans have been developed in detail for the next few years and resource commitments have been made accordingly. Furthermore, any major collaboration must meet the requirements of the separate national programs and therefore must be preceeded by substantial joint planning. Thus, international collaboration cannot be expected to produce any substantial annual cost savings from current levels over the next few years, although cumulative savings over the long run, in the sense described above, may be expected.

Broader U.S. policy considerations may be at odds with technical opportunities for cooperation. The USSR has proposed joint international construction of the next-step tokamak experiment, yet it is unlikely that U.S.-USSR collaboration is possible in the current circumstances. Japan is willing to discuss further major collaboration, but in the United States there exists a political sensitivity to Japan on economic grounds. On the other hand, the Europeans, with whom collaboration would be the least controversial, show little interest.

These points are related to the following conclusion:

- <u>Large-scale international collaboration can be achieved, but not quickly</u>.

Despite the Magnetic Fusion Energy Engineering Act of 1980, the U.S. government is perceived in some quarters as lacking a firm commitment and a realistic plan to develop fusion. A clear policy statement on the goals of the U.S. fusion program and a corresponding plan to meet those goals not only would be helpful for evaluating proposed major international cooperative projects but also would improve perceptions of the U.S. commitment. By contrast, it would be a mistake simply to increase emphasis on international cooperation to compensate for less than a full commitment.

The programmatic and technical decision-making process is quite different in the United States, the EC, and Japan. In the United States, major programmatic and technical decisions can be taken by highly placed individuals or small groups, whereas in Japan such decisions are taken only after lengthy review and discussion at lower echelons lead to a consensus. In Europe such decisions are taken only after numerous committee reviews. These styles lead to flexible, and occasionally even erratic, evolution in U.S. policies and programs and to deliberate, and occasionally even cumbersome, evolution in EC and Japanese policies and programs. Accommodation of these different styles of decision making is necessary for large-scale cooperation.

The United States is also perceived in some quarters as an "unreliable partner" based on previous experiences in space science, synthetic fuels, and fusion itself. The annual funding appropriation process makes it difficult for the United States to commit to multiyear projects without the possibility of facing a choice later of either going back on the commitment or sacrificing other elements of the fusion program. Requesting explicit budget items for international projects, after clear identification of the obligations implied for subsequent years, may ease the problem. Nevertheless the process makes an investment in a multiyear project appear as a high-risk venture to potential foreign collaborators, as well as to leaders of the U.S. fusion program. As a result, a formal and binding instrument might be necessary to assure potential collaborators on a major project that the United States would fulfill its part of the agreement.

All the above factors are embodied in the following conclusion:

o International collaboration will require stable international commitments.

Technology transfer arises as an issue and a possible constraint in three areas: national security, protection of U.S. industry, and loss of advantage to foreign participants from technology developed by them because of provisions of the U.S. Freedom of Information Act mandating wide access to information held by U.S. government agencies. However, technology transfer does not seem to be a major concern at this time because of the remoteness of significant military or commercial applications of magnetic fusion.

There are numerous institutional choices for implementation of international cooperative arrangements. Treaties constitute the most binding commitments of the U.S. government but are the most difficult agreements to conclude. Intergovernmental agreements are much easier to put into place because they can be negotiated at lower governmental levels.

Existing international organizations, such as IAEA and IEA, offer auspices under which more extensive international cooperation could be carried out without the necessity of new implementing agreements. An expansion of cooperative activities under these agencies is reasonable. Neither of these agencies or other existing international organizations would be suitable as sponsors for a major international project because they function primarily as coordinators and administrators, not as managers, and because they have their own priorities. However, an existing international organization may provide a framework for initiating a project, as was the case with the European Organization for Nuclear Research (commonly known by its original French acronym CERN).

For fusion the most relevant example of a major international project is JET. The project was set up as a Joint Undertaking by the Member States of the European Community in 1978 under provisions of the 1957 Treaty of Rome, which established the European Community.

More generally, a joint international project is complicated, but it can work if it is carefully planned and skillfully executed. Organizations must be created to deal successfully with technical direction, administration, liability, and relationships with local and national host governments. Mechanisms must be adopted for site selection, the capture of perceived commercial value, the ownership and sharing of intellectual property, and policy with respect to licensing technology to nonparticipants. The equitable participation of national industry must be accommodated, and technology transfer will have to be suitably controlled in instances that affect national security. Standards for safety and radiation will have to be harmonized, and subtle changes in the roles and missions of established domestic institutions will have to be faced.

The foregoing points all support the following conclusion:

- There is a host of considerations that must be resolved in implementation, but these appear workable.

OVERALL CONCLUSION AND RECOMMENDATIONS

Three widely separated courses seem to be open to the United States on the path to fusion energy: (1) to make the commitment to become the all-out competitive leader in all its aspects, (2) to engage in large-scale international collaboration, or (3) to withdraw with the intent of purchasing the developed technology from others in the future. In actuality, the extreme first and third courses would not likely be so sharply drawn. Degrees of competitiveness, ranging from preeminence down to simple parity with others could be defined. Degrees of withdrawal, from slight to serious forfeiture of equality could be contemplated. Although the committee did not formally analyze the situation in this context, it still forms a useful setting for an overall conclusion, derivable from some of the individual ones stated earlier:

- For the United States at this time, large-scale international collaboration is preferable to a mainly domestic program, which would have to command substantial additional resources for the competitive pursuit of fusion energy development or run the risk of forfeiture of equality with other world programs.

Given this overall conclusion, two major recommendations follow:

- The first priority should be the establishment of a clear set of policies and objectives and a considered program plan for future U.S. fusion activities.

Such a position is necessary as the basis for discussions with potential partners and for any long-range commitments that ensue. Concrete near-term and intermediate objectives and a schedule for their attainment would be appropriate elements of the program plan.

The Department of Energy should formulate the position for the review and approval of the Administration and the Congress.

- Having carried out the preceeding recommendation, the United States should take the lead in consulting with prospective partners to initiate a joint planning effort aimed at large-scale collaboration.

This joint planning activity would have to involve groups at the program leadership level and at the technical leadership level, in appropriate roles, and would have to be a continuing activity over many years. Quite plainly, an opportunity is open for leadership of a cooperative approach to a new technology of global significance.

1

INTRODUCTION

The United States, the European Community (EC), Japan, and the Soviet Union are all vigorously pursuing magnetic fusion as a preeminent scientific challenge and an energy source of tremendous potential benefit. The U.S., EC, and Japanese programs are each being conducted at the level of several hundreds of millions of dollars per year. The next stage of development will require sharply increased effort, and power-producing test or demonstration reactors after that will call for investments of billions of dollars. These demands, if placed on each program, will strain the available human and material resources, with the possible consequences of delayed results, limited scope, and greater risk. Given these prospects, in combination with the history of prior successful international cooperation on a more modest scale, might a significantly greater level of cooperation bring a number of worthwhile returns?

FUSION ENERGY AND THE QUESTION OF GREATER COOPERATION

Magnetic fusion refers to the large-scale production of nuclear reactions involving the lighter elements, using magnetic fields to attain the necessary density and duration of confinement of the reacting nuclei as components of a fully ionized gas, called a plasma. Magnetic fusion research began some 30 years ago with independent classified programs in the United States, the USSR, and the United Kingdom. In 1958 these programs were declassified and an era of information and personnel exchange began. In the intervening years separate programs in the United States, the EC, Japan, and the USSR have grown to their current substantial status.

The Path to Fusion Energy

The United States, the EC, Japan, and the USSR are each committed to pursue fusion as a potential element in their energy futures, although the degree of the commitment differs. It is not possible, however, to proceed forthwith toward the objective of widespread availability of fusion energy in the same way one might proceed directly toward the design, construction, and deployment of a new aircraft. The reason is that much of the necessary science and technology has yet to be developed. (See Conn, 1983.)

The technical path to fusion requires showing its scientific feasibility through convincing theory and substantiating experiments that the laws of nature will allow more energy to be produced from the plasma than is necessary to supply to it to induce the fusion reactions. Next, engineering feasibiity must be established through the choice of a suitable design concept for a reactor and the development of advanced technologies necessary for the production and extraction of useful amounts of power. In actuality, significant overlap exists between the two feasibility conditions, so that the terms are really more useful as simplifying concepts than as distinct developmental stages. A demonstration of power production on a commercial scale will probably be considered necessary to convince users that some form of commercialization is possible. Finally, attainment of economic viability in comparison with alternate technologies for generation of power will be required. Currently, investigations are at the stage where scientific feasibility is expected to be shown within a few years.

The strength of the commitment to fusion energy in the several world programs varies because of varied national circumstances. Japan, for example, has few indigenous energy sources and has decided to explore both fusion energy and fission breeder reactors to meet its forseeable needs. The EC must similarly explore alternative technologies, although its energy needs are neither so immediate nor so acute as those of Japan. The United States, currently enjoying greater reserves of coal and uranium, probably feels the least urgency about fusion. The USSR has its own objectives for a substantial program in magnetic fusion energy. This report is concerned with the programs of the EC and Japan as the most likely candidates for cooperation, and it has comparatively little to say about the USSR program.

The four world programs are certainly competitive in the technical sense with both implicit and explicit rivalry for technical accomplishment. The current stakes are the natural ones of professional recognition and national accomplishment. There seem to be no prominent overtones of any national race to arrive first at some sharply defined fusion goal, such as there was with respect to a moon landing or such as there is with respect to the development of a supercomputer of a specified speed.

Structure of the Question

In principle it would be logical first to examine the technical program substance for cooperative opportunities, then to examine the advantages and disadvantages of particular candidate projects, and lastly to examine various kinds of agreements capable of reaching the desired ends. In practice, however, both the incentives for cooperating and the constraints thereon will feed into the policies governing cooperation. Accordingly, the nature of these incentives and constraints, as they appear to all of the cooperating parties, is of first concern, assuming for the moment that there are ample technical opportunities for cooperation and that there are also ample ways to agree how to carry it out.

One important incentive is achieving needed program results sooner or more completely through joint efforts than is possible by any single partner without cooperation. Another incentive is expanding, and capturing, long-term economic benefits from eventual commercial application of fusion to a greater extent than might be realized from a separate program. Saving research and development costs is often mentioned as an incentive, a feature of particular interest to finance ministries and to officials who must allocate resources over the whole range of competing national needs. Similarly, diversity of technical approach can spread the risks, with possible avoidance of costs. Political objectives, such as the strengthening of economic alliances, have been served in the past by cooperation in fusion and may provide future incentives. Another incentive to cooperation is to broaden the base of interest in fusion. A broader base of interest may help electric utilities, as potential users, to arrive at decisions regarding their own role and may, in addition, involve more manufacturers as suppliers of both experimental and commercial equipment. Public awareness of the technology may also be enhanced, a necessary condition, at least, for eventual public acceptance.

The foregoing incentives for cooperation are overlaid with constraining policy objectives. Each country will have some preconceptions as to the proper degree of its national program strength and independence. Other policy objectives will be to attain national prestige through technical leadership and to avoid the impairment of national security through, say, undesirable technology transfer.

The technical needs and opportunities for cooperation fall into three categories: basic information in plasma science; fusion technology, including engineering component development; and construction and operation of major experimental facilities. The modes of technical cooperation may be conveniently divided into five categories: exchanges of information at meetings and workshops, exchanges of personnel at research facilities, joint planning for effective collaboration on and increasing the complementarity of new facilities, joint programs on unique national facilities, and the joint undertaking of all aspects of major facilities.*

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*In this report the term "cooperation" is used in the general sense of acting with others on either a small or a large scale. Where the more specific sense of working actively together as approximately equal partners in sizeable enterprises is intended, the term "collaboration" is used.

Agreements for implementation of cooperative projects must deal satisfactorily with a number of factors that bear on policy objectives, mutuality of purpose, and conditions for working together. The principal factors are timing, compatibility of goals, stability in the partnership, technology transfer, flow of funds among partners, equitable distribution of the benefits of cooperation, suitability of institutional framework, and workability of the arrangments for project management.

It is in these terms that the report discusses whether greater cooperation is desirable and, if so, what might be undertaken and how.

THE WORK OF THE COMMITTEE

The main task set for the committee was to recommend, for the consideration of the U.S. Department of Energy (DOE), courses of action for international cooperation, analyzed with regard to technical need, relevant national policies, workability, long-term implications, and other criteria of suitability. (See Appendix A for a fuller description of the Scope of Work.) It was expected that the committee would not advise on the content of particular technical projects and programs but would merely identify topics as candidates for cooperative program definition. However, as the committee approached its task, it soon perceived a lack of complete world readiness for large-scale cooperation. Hence the problem of the committee was more one of finding ways to move toward that readiness than of straightforwardly analyzing technical proposals in terms of well established criteria.

Committee Inquiries

The first step of the committee was to explore in some depth viewpoints within the United States in order to fill out the structure of the problem described in the preceding section. Thus, two workshops were conducted to gather domestic views. It was thought impossible to separate cleanly the technical, policy, and organizational aspects of the question so that these might be dealt with in different workshops. Consequently, all three aspects were treated together. Two workshops, covering the same ground but with different participants, were conducted in order to reap a diversity of viewpoints and to ascertain those viewpoints that both groups agreed on. These workshops solicited prepared inputs over a wide range of experience. We heard from management levels of the fusion program of DOE and from the various parts of the technical fusion community itself. We heard from other parts of U.S. government--in particular, from the Department of Defense, the Department of State, and from Congressional staff. We heard individuals who had lived through prior examples of international cooperation in fusion as well as other technologies quite unrelated to fusion. Individuals with experience in the later stages of commercial development of technologies, such as jet engines, computers, and semiconductors, gave us the benefit of their experience. We also obtained the viewpoints of individuals from electric utilities as ultimate users of fusion technology and from the financial community as a source of investment in commercial fusion. Finally, we sought the ideas of those experienced in diplomacy and international law, such as negotiators of the Treaty of the Peaceful Uses of Outer Space and the Law of the Sea.

Of course, it was essential to make first hand contact with scientists and policy level officials in Japan and in countries of the EC. Accordingly, committee members traveled to Japan and to Western Europe to address many of the subjects covered in the domestic workshops, although necessarily in less depth. The travelers attempted to discover compatibility of the various national goals, or the lack thereof. Foreign officials were asked about the intended development of the role of their domestic industry; and their attitudes were sought on cooperation with the United States, which in the last analysis, may determine the response to any U.S. initiatives.

These meetings also inquired into the technical needs and opportunities for cooperation at several levels of effort: modest scientific exchange, organized cooperative planning and study, plasma physics experimentation, large technology test facilities, and major experimental fusion facilities.

The discussions also covered the types of agreements, organizations, and management arrangements that might be adapted to implement cooperative efforts. On the trips, the group examined the characteristics of successful efforts at cooperation, such as the Doublet III experiment, jointly funded by Japan and the United States; the Rotating Target Neutron Source II experiment, similarily conducted; the studies on the German TEXTOR tokamak of impurity control and physics of the plasma edge, under the auspices of the International Energy Agency; and the Joint European Torus, an example of successful resolution of divergent national and cultural interests. The group heard also about other projects such as the Large Coil Test Facility, which has been troubled by scheduling delays, and the Fusion Materials Irradiation Test Facility, for which the United States has not yet been able to conclude an agreement on joint participation.

Organization of the Report

In the remainder of the report, Chapter 2 deals with the incentives and constraints that constitute the policies governing international cooperation and from which will flow the criteria for judging international cooperative initiatives. Chapter 3 discusses the technical needs and opportunities from which the substance of cooperation may be drawn. Chapter 4 examines factors affecting agreement on and implementation of cooperation. Finally, Chapter 5 contains our conclusions and our recommendations for the near future together with the rationale supporting them. Several appendixes, providing more detail on topics discussed in the main body of the report, are included.

2

INCENTIVES AND CONSTRAINTS

International cooperation is an amiably received proposition throughout the fusion community, being widely perceived as a way to broaden the bases and relieve financial strains of national fusion programs. Yet to arrive at sound recommendations about whether to extend international cooperation, one must examine the incentives and constraints, especially those that arise from broader policies. One must also examine the perception of these factors by the various groups concerned with cooperation. Finally, one must weigh the expected consequences, even though these cannot be known with certainty.

INCENTIVES AND CONSTRAINTS AT THE POLICY LEVEL

Incentives

There are a number of incentives, consistent with broad policy goals, that the conventional wisdom widely accepts in a general sense (Rycroft, 1983). Nevertheless, when one goes from the general incentives to specific programs and project details, some reluctance toward international cooperation seems to appear.

Achieving Program Results

International cooperation makes possible a much broader and more diverse program in pursuit of its fusion goals than could be supported by any single nation within presently anticipated budget limits. The information flow available to a national program is thereby increased and broadened; there are more people working in more areas and generating more new ideas and ways of attacking problems; and the chances of generating step advances in the science and technology of fusion--the breakthroughs or lucky accidents that both enliven and accelerate progress in research areas--are usefully increased.

The sharing of scientific and technical information through international cooperation reduces national program risks and improves program opportunities. All research and development efforts have elements of risk through the pursuit of scientific or technological directions that subsequently prove unfruitful. Access to the broadest possible information base improves the chances of avoiding unfruitful ventures and of recognizing opportunities for progress.

Moreover, through the sharing of test facilities and projects for materials and technology development, needed technological results may well be acquired sooner and in greater depth than otherwise.

There is also the point noted by Rose (1982) that in the past capable people have come into the fusion field who might very well not have done so had the activity not offered the opportunity for international contacts. Inasmuch as fusion research and development efforts are likely to have to continue for a good number of years into the future and that the long-term vigor and viability of such programs will depend substantially on the scientific and managerial abilities of the program leaders, the broader, more diverse, and more comprehensive programs made possible by international cooperation should be an important element in attracting the most capable people to the field. The point is a far from trivial one in planning for the very long-term kind of effort that fusion power will surely require.

Expanding Economic Benefits

Rose (1982) also observes that international cooperation in fusion has been a very positive-sum game to date. Programs of all the participants have advanced more rapidly and with better direction than would have been the case without the cooperation (U.S. General Accounting Office, 1984). It is reasonable to expect that this quality, of yielding substantially more program benefits than the funds and effort invested, should be a feature of international cooperation for some years to come. Because everyone gains from the collaboration and the whole amounts to more than the sum of the contributed parts, it should be less important that supplies and equipment contracts in a collaborative effort be distributed with great precision according to the contributions of the collaborators.

The long-term economic benefits that will flow from the full commercialization of fusion through any particular national program are expected to be great, although their exact nature and magnitude cannot be foreseen with certainty. Cooperative programs, through their greater technological diversification, may be able to expand both the scope and the scale of the benefits ultimately available to each participant. The equitable capture of these benefits, of course, will have to be possible under whatever cooperative arrangements are undertaken.

Saving Costs of National Programs

As fusion research and development moves towards large machines and supporting facilities, it becomes highly expensive and difficult for any single nation to support a comprehensive program. International cooperation and the sharing of some costs, including the joint construction and use of expensive installations for which only a single facility of a given type is considered necessary and sufficient, offer relief from national budgetary limitations.

Unnecessary duplication of effort is avoided by the distribution among the members of an international cooperative effort of those tasks that can be shared. Some duplication of effort is inevitable to satisfy the interests of national partners in acquiring "hands-on" experience, but international cooperation can substantially reduce the overall level of duplication and thereby improve the efficiency of use of everyone's limited funds.

Serving Political Objectives

There is a more recent incentive that has considerable meaning for government program managers and staffs. Controlled nuclear fusion is the subject of one of the working groups set up, in the summer of 1982 by decision of the Heads of State and Government at the Versailles meeting of the Summit of Industrialized Nations, to serve the larger political objective of technological cooperation among certain industrialized countries (Science, 1983). In June 1984, the leaders of Canada, Italy, France, the United Kingdom, Japan, West Germany, the United States, and the European Community (EC) endorsed the activities of the working groups in exploring plans for closer collaboration in science and technology in the industrial nations (Science, 1984). The working group considering fusion, in which the United States participates, noted the long-range importance of the technology and the magnitude of human and financial efforts needed and concluded that a substantial increase in the level of international collaboration is justified. Endorsement at the head-of-state level for international cooperation in fusion, even couched in the most general terms, is a powerful influence in determining the attitudes with which government staff and negotiators approach the subject.

From time to time technological topics have been selected to serve, in whole or in part, broader political objectives, such as strengthening alliances, creating good will, or augmenting a particular negotiation. Examples are the United States-Japan space launch agreement, the proposal for an international telecommunications satellite consortium, and the provision of desalinization technology to Middle East countries. Indeed, the EC points with pride to its magnetic fusion program as a successful example of its political goals for European cooperation in large-scale research and development. Other political objectives may arise that can be served by international cooperation in magnetic fusion and will thus provide incentives.

Broadening Constituencies

International cooperation can improve public, political, and electric utility confidence in and acceptance of fusion as an eventual power source. Stability of the fusion programs of the participants is another benefit. Indeed, cooperation will demonstrate a wide agreement among different peoples and different points of national view that practical fusion power sources can be developed and that--on cost, resource, and environmental grounds--fusion power may be at least as acceptable as other alternatives if not superior. Cooperation will also create a sense that not to go forward with fusion is to be left at a disadvantage in the future.

The Member States of the EC, together with three other nations, namely, Sweden, Switzerland, and Spain, have long since recognized the weight of the incentives over the constraints for international cooperation in fusion. These nations have formed a comprehensive and sound research and development program that has produced the leading tokamak, Joint European Torus (JET), as well as early planning efforts for a subsequent large machine. Further levels of international cooperation, between the United States, the EC, and Japan can and may respond to the same incentives, although with different arrangements to deal with the differing constraints and limitations.

Constraints

Just as there are incentives that are widely accepted in the fusion community, so there are some constraints and disincentives under existing policies that are also recognized at a general level. Like the incentives, the general constraints tend to weaken in the face of detailed consideration and negotiation on specific cooperative enterprises. So, in the regime of details and specific projects, just as the incentives appear less clear and forceful, so the constraints become less important as particular ways of dealing with each one are sought and developed.

Maintaining National Program Strength

There is reluctance for national programs to give up any significant part, scientific or technological, of what is seen as the main line of advance toward an eventual fusion power plant. This reluctance is, in part, national preparation to satisfy domestic energy needs and, in part, national protectiveness for domestic industries and for a competitive position as an eventual supplier of fusion plant equipment. This policy constraint gives rise to the question of technology transfer in the implementation of cooperative programs.

If it is true that national research and development budgets are tight and that international cooperation is seen as a way to share costs and maintain comprehensive programs, then it is also true that the funds available for international cooperation are not unlimited. And the funds that are contributed from national programs to international cooperation will be, at least in part, at the sacrifice of some elements of the national programs.

Preserving National Program Prestige

There is a similar reluctance to give up national prestige that comes from successful technical and professional competition. It is a natural instinct of project managers, laboratory directors, and government program officers to seek to maintain and extend world leadership. These instincts are reinforced by the prospect that national objectives may be in some sense endangered by giving up certain program management authority. However, there can be no international cooperation without some financial cost and some surrendering of national control to the joint enterprise.

Safeguarding National Security

A policy constraint that must be taken into account is to avoid impairment of national security through disclosure of militarily useful technology to potential adversaries. The degree of constraint will depend principally on the way that the question of technology transfer is perceived and handled in the implementation. The committee does not suggest that national security imposes serious limitations on international cooperation in fusion with the Western countries; rather, the topic is included here for completeness and is discussed more fully in the chapter on implementation.

PERCEPTIONS OF INCENTIVES AND CONSTRAINTS BY VARIOUS U.S. GROUPS

There are diverse perceptions of the incentives and constraints for international cooperation in fusion among the senior technical leaders in the U.S. program, government program administrators, high-ranking administration officials, Congressional oversight and appropriation committees, manufacturing industries as suppliers, and electric utilities as users. (See Appendix B.)

Technical Leaders

The technical community in the U.S. fusion area, at least as represented by the consensus of the Magnetic Fusion Advisory Committee (MFAC), strongly supports international cooperation on a general basis. MFAC made the following declaration:

> The U.S. fusion program and the development of fusion on a worldwide basis have benefited significantly from the active exchange of information and ideas. International cooperation in fusion reseach should continue to receive strong emphasis in the U.S. program. The planning of national fusion facilities and programs has been guided to considerable extent by a policy of avoiding international duplication and instead addressing complementary technical issues. This policy is both cost-effective and conducive to rapid technical development. It encourages broader coverage of options in the area of alternate concepts and allows larger steps to be taken in the main-line approaches within existing budgetary constraints.
>
> --Magnetic Fusion Advisory Committee, 1983

MFAC goes on to note that within each confinement approach, U.S. effort has been largely complementary to activities in other nations. For example, each of the four large tokamak projects that were undertaken in the mid 1970s--Tokamak Fusion Test Reactor (TFTR) in the United States, JET in Europe, JT-60 in Japan, and T-15 in the Soviet Union--has a distinct set of characteristics and objectives. The MFAC report continues:

> While maximum effective use should be made of research facilities abroad, to supplement U.S. capabilities, the overall priorities of the U.S. program should continue to emphasize the most promising reactor approaches. The international fusion effort will benefit from increased consultation in program planning and from the initiation of coordinated--or even jointly supported--research projects.

The thrust of MFAC's recommended U.S. program and strategy for the coming years, however, has a central theme of "going it alone" with regard to major new steps. The MFAC recommendations have been for maintenance and continuation of the U.S. base program in magnetic fusion and for early initiation of a major new facility, the Tokamak Fusion Core Experiment (TFCX), with an increase in the U.S. fusion budget ramping up over several years to a new level 25 to 40 percent above the present one in constant dollars. Present international cooperative ventures would presumably be continued and opportunity sought for additional exchanges, at least on an information sharing basis; but there is no suggestion in the MFAC plan of more ambitious collaborative ventures.

One can sympathize with program technical leaders who would much prefer to be fully supported by the U.S. domestic budget in a comprehensive research and development program including major new machines at appropriate intervals. That prospect is certainly a more pleasant one than contemplating heavy cuts in the base program in order to provide funds for a major new machine within current budget limits, or surrendering substantial elements of technology and of management control in the next major machine to international partners in a joint venture, or, most likely, both. If the increased funding can be obtained, then the MFAC recommendations certainly lead to a very strong U.S. position in fusion and are probably the actions of choice. However, if U.S. fusion program budget levels are to remain at current levels, or to diminish slightly as suggested by recent Congressional actions on the FY 1985 budget, then the options appear to be to reduce the base program substantially to accomodate TFCX (or other major next-step tokamak), to maintain the base program and delay indefinitely TFCX, or to seek substantial international collaboration on the next major tokamak together with some base program cuts.

Program Administrators

The views of U.S. government program administrators on international cooperation in fusion are consolidated into the Comprehensive Program Management Plan (CPMP) for magnetic fusion, prepared by the U.S. Department of Energy (1983). The CPMP states current U.S. policy with respect to leadership in magnetic fusion in the following terms:

> The Department's intent is to maintain a leadership role for the United States in the area of magnetic fusion energy research and development.

The term, "a leadership role," pointedly indicates that the United States is to be among the leaders and lead in some areas but not others, rather than to move agressively into the world leadership position in magnetic fusion--a position it has had at times in the past. At least one implication of this policy for the prospects of increased international cooperation, particularly for cooperation in major next-generation machines, comes to mind: other nations may be less enthusiastic about entering arrangements with a program that is, at best, even with their own.

The current U.S. policy on international cooperation is stated in the following terms in the CPMP:

> The Department intends to maintain this position [of leadership] in the two major confinement concepts and in the development of critical technologies. We recognize that progress can best be made through a carefully formulated and managed policy of close international cooperation to share specific tasks.

This statement suggests an affirmative policy toward international cooperation, but on a selective basis and with close controls on project scope and activities and on technology aspects to be shared. The phrase "to share specific tasks" was understood to mean that the United States would attempt to retain all essential technologies within the U.S. program. The implications for international cooperation are that hard bargaining as to technical and fiscal contributions and as to the sharing of results will be involved in arranging any joint projects.

The current goal of the U.S. program is stated as follows in the CPMP:

> ...to develop the scientific and technological information required to design and construct magnetic fusion power systems.

This overall objective of the program is more limited than the visions of some years ago and reflects current budget constraints. The CPMP does not contemplate a prototype power plant in the U.S. program and may leave a substantial gap between the government program and any serious attempt at commercial use of the technology. In particular, the CPMP leaves to potential commercial users the development of an industrial base for the fabrication and construction of fusion power plants. Since at least one and perhaps all of the major foreign magnetic fusion programs seem directed toward an eventual goal of controlling and marketing fusion plant technology, there may be significant problems of compatability in basic goals in agreeing on international joint ventures.

The CPMP does call for a large machine, the Engineering Test Reactor (ETR), to be built in the late 1980s, but recent budgetary constraints caused planning at the technical level to be directed towards a less ambitious next step, TFCX. TFCX embodies the physics of ETR but little of the technological and engineering testing features. During the writing of this report this goal has been set aside, and a revised plan is not yet available. The Japanese, EC, and Soviet program plans in magnetic fusion continue to contemplate an engineering test reactors* of roughly similar objectives. Decisions would be taken in the late 1980s or early 1990s and, if favorable, the machines could be ready by the late 1990s. These machines in the foreign programs would then be followed by demonstration reactors.

U.S. government program administrators recognize the potential benefits of international cooperation on a wide scale and, faced with the realties of current budget levels, look to it as an essential part of a successful fusion program. Situated precariously between would-be budget cutters at some levels in the administration and in the Congress and would-be budget raisers in the technical community, the government program administrators' task is to develop a consensus on a reasonable program that balances the dual needs to maintain a strong base program and to move ahead with the next major machine, includes

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*Designated as Fusion Engineering Reactor (FER) in Japan, Next European Torus (NET) in the EC, and OTR in the USSR.

substantial international cooperation, and operates at realistic budget levels--an admirable but difficult task.

Administration Officials

The fusion-related views of high-level U.S. administration officials seem concentrated on program cost matters. Budget officials are unenthusiastic about significant new commitments to large projects, or to increases in base programs either. The President's Science Advisor has talked of a "balanced fusion program," which is to advance with due deliberation, obtaining a maximum of information available from each step and taking full advantage of progress in other technical fields and in other countries. International cooperation would be judged in both quarters, one expects, on its promise to reduce overall U.S. fusion program costs or at least help to hold them level.

Congressional Committees

The Congressional authorization committees tend to be fusion program supporters and inclined toward a comprehensive U.S. program including new machines. The appropriation committees are mainly interested in accomplishments in relation to costs. Recent actions on the fusion budget for fiscal year 1985 were accompanied by questions on the readiness of the U.S. program to advance from a scientifically oriented program to an applications oriented program so soon. In particular, there was a concern that funding the planning for TFCX before full results were available from TFTR might be tantamount to a premature choice of a particular reactor concept. Thus, along with cutting the fusion budget, the appropriation committees admonished the Department of Energy not to damage the base program in favor of TFCX or other new machines.

In general, it may be expected that the Congressional committees will act positively and decisively only when there is consensus on goals, objectives, and program content and when the costs of these are commensurate with probable benefits.

Industry Executives

Apart from those of a few specific firms, executives of the manufacturing industries as suppliers and the electric utilities as users of eventual fusion power systems evince polite interest in the whole subject, including international cooperation, and not much more, principally because the commercial aspects of fusion are so far in the future. There is not much business to be done in fusion for the present; and what there is involves difficult technologies to which American manufacturers seem reluctant to accord matching priority, talent, and energy.

EUROPEAN AND JAPANESE PERCEPTIONS OF INCENTIVES AND CONSTRAINTS

These impressions are culled from the visits of the committee to Japan and the EC to talk to fusion program leaders there. Summaries of these trips appear as Appendixes C and D.

In general, the Europeans and the Japanese seem affected by the general incentives and constraints for international cooperation in much the same way that Americans are. There is some feeling that fusion research and development budgets are not unlimited and that international cooperation, as it has in the past, can be an aid to achieving program results. At the moment, the Europeans and the Japanese seem to feel this incentive less strongly than the Americans. Some other observations indicating European and Japanese perceptions of the incentives and constraints of international cooperation are noted below.

European Perceptions

For a number of Europeans, the perceived need for fusion was not especially strong in view of other energy sources and supplies. Fusion work was classed mainly as an "insurance policy." While the long-term economic benefits from fusion were thought by the Europeans to be great, those benefits cannot be estimated accurately at present. There is, therefore, in the European view, no quantitative justification for any particular program scope and pace. With any deployment far in the future, fusion development programs must be funded entirely by the public sector. The utilities in Europe wait and watch without investing in fusion.

At the political level in the EC, international collaboration on fusion research and development is considered desirable. Cooperation with both the United States and Japan has been endorsed. However, it was felt that the three world-class programs would have to be brought into better coordination in order to enjoy full cooperation on the next large step.

The fusion collaboration within the EC and the product of that collaboration, JET, is viewed with much pride. Indeed, there is some expectation by its participants that the EC tokamak may shortly achieve the leading technical position in the world. There is a desire on the part of some EC participants to maintain the self-sufficiency of the EC program and not to broaden the scale of cooperation to the extent that EC unity might be diminished (Commission of the European Communities, 1984a). Thus, preservation of the unity and coherence in the EC program may be an important constraint on any further cooperative planning and may even diminish interest in large-scale collaboration beyond the EC.

Japanese Perceptions

The Japanese appear to have a firmer and more consistent government energy policy than the United States, stemming from their lack of natural resources. They intend to be successful with fission breeder reactors and eventually with fusion. Compared with the United States and the EC, Japan seems to have more direct industrial participation in fusion programs. As for the Japanese utilities, they are more centralized, appear to be more financially sound than in the United States, and are somewhat more involved in the fusion program.

Japanese industry is actively involved as supplier of experimental equipment (Japan Atomic Industrial Forum, 1983). The industry has exhibited interest in acquiring and protecting fusion technology "know-how." Industry representatives of the Japan Atomic Industrial Forum expressed a generally negative attitude on international cooperation, which seemed to be motivated primarily by their desire to establish industrial leadership. They did not appear concerned that financial constraints might reduce the fusion program or stretch out the period over which it is carried out. They also indicated that Japan should not rely on any other country for the development for any technology that is critical. One form of cooperation proposed by the Japanese industrialists was to let Japanese vendors supply components to the U.S. fusion effort, provided that similar technology promised to be useful to the Japanese program as it progressed.

A generally positive attitude about international cooperation was expressed by government ministry officials, by fusion program leaders, and by influential advisors. The incentive seemed in all cases to be concern about current or future Japanese financial constraints. If fusion were near the application stage, there might not be any Japanese interest in international cooperation. However, with the commercial application of fusion decades away and total development costs running into tens of billions of dollars, it is difficult for anyone to be against international cooperation, especially since Japanese funding seems to have leveled off just at is has in the United States. Program administrators see international cooperation as a means of conserving scarce resources. Scientists see cooperation as a means of expanding or accelerating the fusion program. All groups except the industrial one endorsed international cooperation in principle as desirable or necessary for technical progress, risk sharing, and cost sharing.

It was a Japanese view that international cooperation must not impair national programs. Therefore, cooperative efforts will have to be supplementary to the main core of these programs or else, if more extensive, will have to fit well with the national program content. In the case of collaboration on a major project the parties should start with joint formulation of the objectives, schedules, design features, and so forth. This approach would apply when the collaborating partners had approximately equal shares in the venture.

The Japanese summarized a number of desirable principles for international collaboration. These included the following points: no erosion of the national programs, mutual benefit, participation on an equal footing, assurance of continuity in the collaboration, acceleration of the national program of the partners, overlap of program interest, achievement together of what is not achievable separately, full participation in planning from the beginning, and full access by all sectors to the technology developed.

QUESTIONS ABOUT INTERNATIONAL COOPERATION

There are a number of questions about international cooperation that may illuminate useful policy boundaries and criteria for cooperation. The answers to these questions by various groups within the U.S. and by the Europeans and Japanese may very well be somewhat different as suggested in the following discussion.

Will International Cooperation Accelerate Technical Progress and Return on the Technical Investment?

It almost certainly will in the long run. As noted in the discussion of incentives, there may be synergistic effects from international cooperation that multiply the return on investment in assorted ways. These effects are almost certain to work in the future with international cooperation as they have in the past and to be in addition to the more direct and obvious features of allowing a project to go forward in a cooperative effort where it would either not be possible or would be delayed in a single national program. There are matters of timing involved, however. Note, for instance, the concern voiced in both Japan and the EC that discussions about joint ventures in TFCX and in the next Japanese and EC machines, FER and NET, might delay those machines.

Will International Cooperation Allow Us to Cover Technical Ground That We Could Not Otherwise Cover?

Yes, it will, especially in large-scale collaborations, such as JET, by providing access to a technically broader program than we could maintain by ourselves at a constant budget level. The same is true, of course, for other partners in the collaboration.

Will International Cooperation Gain Us a Competitive Edge in Future World Markets?

If international cooperation is continued to the commercialization phase, it probably would not put us ahead of the other major partners in the cooperation. Nor would it give any of the partners any particular edge over us. What international cooperation will do in that case is to keep us well informed in a technological sense and thus help us to maintain a competitive competence among equally competent potential suppliers of future markets.

If international cooperation is continued only through the phases of scientific inquiry and generic technology development, with disengagement of the partners or other common measures for protecting proprietary interests as commercialization approaches, then the cooperation need not limit the competitive advantages that can be sought and attained by any country. However, such scenarios and consequences are not possible to predict. The pace of the commercialization of fusion will probably be deliberate enough that appropriate competitive adjustments can be made along the way.

Will International Cooperation Reduce Our Costs?

The great article of faith is that it will reduce our costs, and that it will reduce everybody else's as well. The faith is held perhaps a bit more strongly among program administrators and finance officials than among technical people. There is a school of thought that thinks an international collaborative project would be more expensive than doing it within a single national program. The International Tokamak Reactor (INTOR) workshop, for instance, was asked, "What are the effects on cost and schedule of undertaking the INTOR project internationally and partitioning the detail design and fabrication of components, so each of the four parties could benefit from the development of all advanced technologies involved?" The consensus was that relative to a national project, such an international project would cost about 70 percent more, require a larger staff by about 15 percent, and would require about two years longer to complete. However, it is not clear that the question was asked in the right way. For instance, it is doubtful that JET, with many partners in the project, is costing 70 percent more than if it were, for example, totally a United Kingdom project. Nevetheless, true or not, if a major new machine is too expensive a project for any single national program, but can be managed financially by two or three collaborating together, then it does not matter if it is 70 percent more expensive because there is no other way to do it. In that case it is a bargain for each of the partners. That fact suggests that the answer to the question is not so much, "Yes, it will reduce our costs," as it is, "No, but it will allow us to maintain a broad program and to take significant steps forward without increasing our costs."

As to the next few years, there is little possibility that cooperation will produce large annual savings because EC and Japanese plans and budgets are committed to projects in train and thus unavailable for major new initiatives that might create significant savings.

Will International Cooperation Smooth the Way Towards Acceptance by Utilities and the Public?

Yes, it will, for reasons given in the general incentives about acceptance. Again this effect works for the other partners in a collaborative effort equally well. There is, of course, no fundamental rule of nature that if everyone is marching in a certain direction, it is the right direction. Nevertheless, there is a strong momentum created by such a movement.

What Portion of the "Critical Path" to Fusion Energy Is the United States Willing to Allocate to Cooperative Ventures?

Initially, only tasks at the margins of the national program will be offered up for cooperation because of the desire to maintain its strength. The same will be true for all the other partners. All will want full access and participation in all critical elements of cooperative projects that are established. That condition does not mean that there cannot be lead partners for particular parts of a machine in a joint enterprise. But it does mean that no single partner will be allowed to go off in his own laboratories and develop some critical piece of the technology without the full access and participation of staff from the other partners. As time progresses, the margins of cooperation can probably be widened as ways of equitably sharing results are developed.

What Degree of Project Management Is the United States Willing to Yield?

After some internal debates, the United States will probably settle for dividing the management authority in a joint project approximately in proportion to investment. The EC and Japan, after similar processes, would probably arrive at the same results. This division would have to apply at levels corresponding to steering committees and on up to boards of directors. Any project that is actually going to be built ought to be headed by a single individual, and that means a single individual of one nationality or another.

RECAPITULATION

To recapitulate, this chapter has identified a number of factors at the level of policy that provide either incentives or constraints for expanded international cooperation in magnetic fusion. The incentives include promise of enhancement of needed technical progress, potential expansion of long-term economic benefits for each participant, possibility of saving cumulative development costs over the long term, achievement of worthwhile political objectives, and broadening of fusion constituencies. Constraints are imposed by policies to preserve the strengths of the various national programs and to seek national prestige through technical leadership in fusion. No major short-term cost savings appear possible because firm plans in the EC and Japan will preclude any large-scale cooperative ventures over the next few years. Even so, taking into account the views of the groups who would be affected by expanded cooperation, the weight of the incentives prevails over the constraints. Thus, on balance, there are substantial potential benefits of large-scale international collaboration in the development of fusion.

3

TECHNICAL NEEDS AND OPPORTUNITIES

Within the worldwide magnetic fusion programs, a significant case can be made for international cooperation on the basis of maximizing the rate of progress by obtaining and sharing scientific and technical information. There is a long tradition of friendly competition and sharing in all basic science research, although as potential applications develop, access to information tends to get more restrictive.

In fusion, from the earliest days, there have been significant cooperative ventures. This chapter examines the broad technical characteristics of the magnetic fusion programs of the United States, the European Community (EC), and Japan to assess whether there are technical needs and opportunities suitable for cooperative efforts. The current status of the programs themselves and the record of past and current cooperation form the basis for identifying types of future possibilities that seem attractive, although it is left to those responsible for program definition to propose particular candidate projects.

Cooperation can take many forms but a reasonably complete listing consists of the following:

- International meetings and conferences.
- Personnel exchanges and joint research involving individuals or small groups.
- Joint planning aimed at coordination of research and maximum use of facilities.
- Joint programs on national facilities.
- Cooperative design, construction, and operation of major facilities.

Technical needs for basic information, technology development, and major experimental facilities are covered in the discussions of the above categories.

STATUS OF THE PROGRAMS

The comparative status of the U.S., EC, and Japanese programs may be seen in broad perspective from Table 1. All are of comparable, although not identical, magnitude as measured by funding rates and personnel levels. The tokamak configuration is one of the mainline elements of the U.S. program and the only mainline element of the EC and Japanese programs. The second mainline effort in the United States is the magnetic mirror configuration. One or more of the alternative confinement concepts, such as the stellarator, reversed-field pinch, compact toroid, and bumpy torus, are being pursued in each program. The development of a number of advanced technologies, necessary for magnetic fusion energy, is being pursued most extensively in the United States and increasingly in the EC and Japan. These technologies include superconducting magnets, plasma heating by radio-frequency energy and energetic particle beams, and methods of safely handling the radioactive isotope tritium. Other technologies include the development of materials able to withstand both surface and bulk effects of a reacting plasma and the investigation of blankets to absorb the energetic neutrons that carry away the energy produced in the reacting plasma and convert it to a useful form. (See National Research Council, 1982, for further discussion of the above topics.)

In the United States, major program efforts are located in the laboratories of the U.S. Department of Energy (DOE), mainly Lawrence Livermore National Laboratory (LLNL), Plasma Physics Laboratory (at Princeton University), Los Alamos National Laboratory, Oak Ridge National Laboratory (ORNL), Argonne National Laboratory, Sandia National Laboratory, and Hanford Engineering Development Laboratory. In addition, the Massachusetts Institute of Technology and other major universities have significant programs. A major DOE-funded tokamak program is also located at GA Technologies, Incorporated, in San Diego, California.

The physics of plasma confinement will be studied using the existing Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory. Plans for a variety of follow-on machines, one of which is called the Tokamak Fusion Core Experiment (TFCX), have been discussed; but there is no commitment at present. Magnetic mirror confinement will be studied by the Mirror Fusion Test Facility (MFTF), under construction at LLNL. The pace of the U.S. program is to be determined by technical results, available resources, and perceived programmatic benefit.

In the EC the major installation, the Joint European Torus (JET), is located near Abingdon, in Oxfordshire, England. Work that is a part of the EC program is also being conducted by the United Kingdom at Culham Laboratory; by the Federal Republic of Germany at Garching, Karlsruhe, and Julich; by France at Fontenay-aux-Roses, Grenoble, and Cadarache; and by Italy at Milan, Frascati, and Padua. Smaller activities are located in the Netherlands, Belgium, Denmark, Sweden, and Switzerland. The European program is managed as an entity by the

TABLE 1. Comparative Status of Magnetic Fusion Programs

Characteristic	United States	European Community	Japan
Approximate funding rate ($ million per year)	440	370	300
Approximate number of professional personnel	2000	1000	1200
Mainline confinement concept(s)	Tokamak, mirror	Tokamak	Tokamak
Existing large machines	TFTR MFTF (under construction)	JET	JT-60
Proposed large machines	TFCX (inactive)	NET	FER
Alternative concepts	Stellarator, reversed-field pinch, compact toroid	Stellarator, reversed-field pinch	Mirror, stellarator, reversed-field pinch, compact toroid, bumpy torus
Technology development	Superconducting magnets, r-f heating, neutral beam injection, materials, tritium, blanket, pellet fueling	Superconducting magnets, r-f heating, neutral beam injection, materials, tritium	Superconducting magnets, r-f heating, neutral beam injection, materials, tritium, blanket
Program direction	Department of Energy	Commission of EC	STA, Monbusho, MITI
Role of universities	Small to medium projects	Small projects	Medium projects
Role of industry	Major supplier of components	Competitive supplier of equipment	Major supplier of components and systems
Principal program participants	National laboratories, universities, specific firms	Joint EC undertakings, national laboratories	National laboratories, universities

Commission of the European Communities, headquartered in Brussels. The work on JET and some smaller scale studies at the Joint Research Center of the EC, at Ispra, Italy, are joint activities of the member countries. (See Commission of the European Communities, 1984b.)

The broad intent of the EC program is to obtain from JET as much information as is possible about a plasma near the reacting level. Discussion and study is currently under way on the design of a machine called the Next European Torus (NET), which will use a deuterium-tritium (D-T) plasma reacting for a duration of more than 100 seconds per observation and which will test reactor-relevant technologies (NET Team, 1984). Finally a demonstration machine is contemplated to prove engineering feasibility.

The main line of the Japanese program is carried out by the Japan Atomic Energy Research Institute (JAERI), under the Science and Technology Agency (STA). It is this organization that is constructing and will operate the large JT-60 tokamak and investigate the associated technology (Japan Atomic Energy Research Institute, 1982). The Ministry of Education, Science and Culture (Monbusho, after its Japanese acronym) conducts a program of basic scientific and technological research in universities (Uchida, 1983). This program has funding comparable to the program of JAERI. The program investigates several confinement concepts including tokamak, tandem mirror, stellarator, reversed-field pinch, compact toroid, and bumpy torus. The Ministry of International Trade and Industry (MITI) is observing progress with interest, but so far MITI is not so heavily involved as the other two agencies. The program is coordinated through an advisory body, the Nuclear Fusion Council, reporting through the Atomic Energy Commission to the Prime Minister's office.

The long-term Japanese plans are to verify, using JT-60, the physics of confinement and the attainability of the necessary conditions of density and temperature in a hydrogen plasma for fusion to occur. Dependent on favorable results, planning is underway for a device called the Fusion Experimental Reactor (FER), to be constructed to study the operation and the technology associated with a fully reacting D-T plasma. Presumably some sort of prototype or demonstration will follow FER, but such plans are not definite at this time.

PRIOR COOPERATION

Research in the early days of fusion was classified, in the mistaken belief that success would come easily and great advantages would accrue to the first country to harness fusion power. The first major open exchange of information came in 1958 at a conference on the peaceful uses of atomic energy in Geneva. Following that conference, more normal kinds of scientific interaction appeared in the fusion community. For example, the United States and the United Kingdom concluded an early agreement (Cockcroft-Libby) for cooperation.

One early example of experimental cooperation was the measurement of the electron temperature in an early Soviet tokamak by a British team. This measurement convinced the community that the tokamak configuration used by the Soviets was successfully improving plasma confinement.

There are also numerous examples of useful collaboration between the USSR and the United States in the area of magnetic mirror devices such as the invention of the "minimum magnetic field" configuration and the tandem mirror. These activities predated the 1973 Nixon-Brezhnev agreement on cooperation in nuclear energy and have continued. The U.S. fusion community went to considerable effort in 1983 to document the technical value of the U.S.-USSR cooperation and justify continuation of the agreement.

Interactions between the United States and the EC have also been extensive although quite informal in the sense of government-to-government agreements. There are, however, numerous instances of joint work and personnel exchanges, which were fruitful scientifically, especially on toroidal confinement systems, among them the stellarator and the reversed-field pinch.

Significant interaction with the Japanese has been more formal, with major activity following the agreement signed in 1979 on cooperation in energy research. Under this umbrella agreement, activity in joint planning, personnel exchanges, joint workshops, and even joint operation of facilities has flourished. These activities are discussed in detail in the following sections on present and future cooperation.

In fusion technology there has always been significant sharing of experimental and diagnostic technologies. In more recent years where specialized technologies such as neutral-beam heating of plasmas developed, there ensued international collaborations very similar to those on the scientific side. Typically the United States has been at the forefront in most of these areas, an exception being the gyrotron microwave source for electron cyclotron resonance heating, invented and developed in the USSR but perfected and made widely available by the U.S. program.

Other than interaction at meetings and personnel exchanges, the majority of technology collaborations has occurred under the auspices of international agencies. The International Atomic Energy Agency (IAEA) sponsors the International Tokamak Reactor (INTOR) study plus numerous meetings, workshops, and the scientific journal, Nuclear Fusion. The International Energy Agency (IEA), which includes the EC, the United States, and Japan but not the USSR, is the vehicle for the Large Coil Task (Haubenreich, 1983), the TEXTOR work, and considerable work in fusion materials.

CURRENT ACTIVITY

Meetings, Workshops, and Personnel Exchanges

International scientific and technical meetings abound in fusion and fusion technology under the sponsorship of numerous groups. Of the international agencies, the IAEA is particularly active. Its meetings and workshops, especially the biennial meeting on fusion, are one of the few vehicles for significant interaction with the Soviets.

Currently bilateral agreements exist, which formalize and balance the flow of people, between the United States and the USSR, and between the United States and Japan. In fact, outside of international meetings, nearly all of the U.S. interaction with Japan and the USSR is handled in a formal way, typically by agreeing once a year to a rather detailed agenda of cooperative activities. Additional interactions take place through normal scientific channels.

One activity that deserves special note is the INTOR workshop, which is a unique form of international cooperation midway between scientific workshop and a joint planning activity. The INTOR activity was originally formed as a consequence of a USSR proposal to look at the technical issues of designing and building the next step beyond the current generation of large tokamaks.

The cooperation involves teams from the United States, Japan, the EC, and the USSR. The mode of operation is national teams working on parallel tasks and meeting two or three times a year for several weeks in Vienna to critically discuss results and to plan future work. The activity was successful in identifying critical issues in both the physics and technology of fusion. Most people believe it is unlikely that the INTOR machine will be built, but a large number of significant insights have come out of the study. The approach is an excellent model for other activities.

Joint Planning

Currently, formal joint planning is restricted to an agreement with Japan. The major components are: (1) the program of the Joint Institute for Fusion Theory, a collaboration between the Institute of Fusion Studies at the University of Texas at Austin and the Institute for Controlled Fusion Theory at Hiroshima University; (2) joint planning in each of the principal science areas, namely, tandem mirror, stellarator, compact toroid, bumpy torus, and the JT-60 and TFTR experiments; and (3) a cooperative planning activity, which is part of a technology exchange, between the Japanese FER design team and U.S. designers.

Informally, a great deal of joint planning, currently being formalized under the IEA, goes on between the United States, Japan, and the EC, primarily to coordinate experimental programs on the large facilities. Coordination also exists between the U.S. and Japanese compact-toroid and bumpy-torus communities and between the U.S., EC, and Japanese reversed-field pinch experiments at Los Alamos, Padua, Culham, and various locations in Japan.

In technology there is growing coordination between the United States and Japan, particularly in material sciences; and cooperation is under discussion in a number of other areas. Most recently, in 1982, initial discussions, which have continued, have been held between workers in the United States and those in the growing EC technology program.

Naturally, the cooperatively operated facilities involve considerable joint planning. In addition, normal scientific interactions involve discussions that tend to coordinate technical programs either to avoid duplication or to verify important experimental or theoretical results.

Joint Programs on National Facilities

There are currently a number of national facilities with joint programs in the fusion program.

TEXTOR is a medium-sized, state-of-the-art tokamak in Julich, Federal Republic of Germany. Because of its excellent vacuum and plasma conditions and precisely defined and controlled plasma boundary, an international program in plasma edge science and plasma surface interactions has developed. The program is sponsored by the IEA; and involves experimental teams from the United States, Japan, and the EC. The facility is operated by the Germans, and the other teams generally build and bring their own experimental hardware. All results are shared so that each partner is spared the need of carrying on an equivalent effort alone.

The Rotating Target Neutron Source II (RTNS-II) is a high intensity dual (4×10^{13} neutrons/second) 14-million electronvolt neutron source at LLNL in the United States. The facility was built for DOE and is operated by LLNL. Because DOE was never financially able to operate both neutron sources, an agreement was reached with Monbusho to fund operation of the second source. Both partners share in the neutrons produced and the overall experimental program is jointly planned. All results are shared.

The Oak Ridge research reactors are funded jointly by the United States and Japan with a jointly planned radiation damage program similar in operation to the one at RTNS-II. Both are part of the U.S.-Japan bilateral agreement.

Finally, the Large Coil Task is an effort, organized under IEA, to operate, in a U.S.-funded central facility at ORNL, six large prototypical tokamak 8-tesla coils built by the partners. Three of the coils were built by U.S. firms and one each by the EC, Switzerland, and Japan. All design information and results are being shared.

Major Facilities

Currently only one major facility is jointly funded and operated. It is the Doublet III (D-III) tokamak at GA Technologies, Incorporated. An independent subagreement under the U.S.-Japan agreement on energy covers the collaboration, which comes under STA.

One of the principal purposes of the agreement was to give a Japanese physics team experience operating a large tokamak prior to the operation of the JT-60 machine in Japan. The cooperation is still active and has resulted in a vigorous and technically valuable program at D-III.

FUTURE COOPERATION

The technical justification and need for cooperation will continue to exist. If, as this committee recommends, more cooperation is to occur, even to the extent of substantial internationalizing of the program, such activities must make technical sense. This section covers some of the areas where cooperation, if increased, could have substantial impact toward improving the technical productivity of fusion. To be avoided, of course, is narrowing the focus of the program too soon or only seeking lowest common denominator solutions.

Meetings, Workshops, and Personnel Exchanges

Meetings, workshops, and personnel exchanges will continue to be of great importance even in a highly coordinated program. A coordinated program would provide increased breadth, so that useful cross fertilization between various concepts and various solutions to technology problems will occur.

In one case of a highly coordinated program, namely that of the EC, there is an efficient and formal mechanism to allow people to work temporarily in another laboratory. A worldwide coordinated program should also make such opportunities more widely available.

Joint Planning

Joint planning as a form of implementation of cooperation is discussed at greater length in the next chapter. It is assumed here that future cooperation will involve significant joint planning.

Potential Joint Projects

The technical success of joint activities up to the present is a major reason that this committee recommends expanded activity in the future. Even though many of the present cooperations were not jointly planned as projects, the program has been jointly planned and technical results have been shared.

At the committee's domestic workshops and in its travels to Japan and Western Europe, many suggestions were made for joint activity consistent with technical needs. The rest of this section outlines the physics and technology areas where the committee feels cooperation is needed and technically justified. In many cases such as tokamak physics, multiple facilities with coordinated programs are required simply because of the amount and variety of information needed. In other areas like radiation damage or plasma surface interactions, one facility, or at most a few, would serve the international needs for data, just as accelerator and central computing facilities do.

In many ways, the EC program is a good model, within a given political framework, for a centrally planned and coordinated program with distributed facilities. A large-scale program coordinated among the United States, the EC, and Japan might adapt a similar model and procedures.

Physics

An obvious candidate for cooperation because of cost, is a large-scale tokamak with significant technology goals. Such a machine is envisioned in each of the programs with very similar goals and mission.

A number of additional tokamak facilities, each with different emphasis, are also needed to supply data in specific parameter regimes or for special purposes with limiter or divertor configurations. A coordinated program would plan activities at existing facilities or initiate new facilities at institutions where appropriate expertise or related facilities already exist.

In the alternative confinement concepts, a coordinated program could carry a greater variety of configurations to the proof-of-principle stage. Even programs with major facilities like the tandem mirror would benefit from coordinated scientific activity in other countries as well as from a joint program on the major facilities.

Technology

There are already a number of good models where joint programs reduce overlap, for example, TEXTOR, RTNS-II, the Oak Ridge reactors, and the Large Coil Test Facility, although this last project is not yet fully operational. Other technology areas which have been mentioned are:

- A large-scale accelerated materials testing facility like the Fusion Materials Irradiation Test, proposed earlier but still lacking agreement.

- Development facilities (cryogenics, background coils, and so forth) for very high field magnet development.
- Neutral-beam and radio-frequency test stands.
- Tritium-handling facilities.
- Blanket-technology facilities.
- Liquid-metal loops and experimental facilities.
- High heat flux test facilities.

Another possible joint project, which has been highly successful in the United States, is a computer facility for large-scale plasma and facility modelling. Such a joint resource would similarly provide benefits to other large-scale world programs.

RECAPITULATION

There is sufficient similarity in the status of development and near- to intermediate-term objectives of the major world fusion programs to provide a technical basis for major international collaboration in the future. A long tradition of cooperation at the level of information and personnel exchange, gradually increasing to the level of joint programs on particular national facilities, shows that past cooperation provides a sound basis for future efforts. Instances of currently successful cooperation give confidence that larger cooperative efforts in the future would also be successful.

All the world programs have need for basic information in the physics of plasmas near fusion conditions; for the development of the numerous technologies necessary for fusion devices; and for the design, construction, and operation of major experimental facilities. Meetings, workshops, and personnel exchanges will continue to disseminate useful information about plasma science and the individual fusion technologies. In addition, larger-scale collaboration on joint projects in reactor-relevant physics and technology would also contribute to the solution of those technological problems. Finally, in designing, building, and using the major experimental facilities, there is ample opportunity for joint planning and joint undertakings.

4

AGREEMENT AND IMPLEMENTATION

The two preceeding chapters argue that incentives for a greater level of international cooperation outweigh the constraints and that there are many technical needs suitable for cooperation. It remains to examine those factors that will shape actual agreements for cooperation. Timing, compatibility of goals among prospective partners, stability in the partnership, and handling of technology transfer certainly rank high in importance. The list must also include net flow of funds from each partner into the cooperative projects, equitable sharing of benefits generated, suitability of the institutional framework, and workability of the actual management arrangements. Successful implementation of cooperative agreements will depend on the skill with which these factors are treated. Prior experience in many international cooperative enterprises shows that success can often be attained.

TIMING

If the time is not appropriate for some aspect of international cooperation, then it is unlikely to occur. There are stages, as national programs of research and development go on, at which particular collaborative efforts would be useful and appropriate. If the opportunities are missed and the programs get out of phase for such collaboration, at least one of the potential collaborators will find the prospect much less attractive.

A favorable opportunity for cooperation exists now because the three major world programs are at a stage of approximate technical parity, they face similar technical and budgetary problems for the next stage of development, competitive commercial rivalries are far in the future, and there is receptivity to cooperation at the political level.

More specifically, the time at which international cooperation on a specific project should be initiated depends upon the extent of the international cooperation. On the one hand, for a national project in which foreign participation is sought at about the 10 percent level, it is probably best for the initiating nation to determine the objectives, cost, schedule, and design parameters of the project, with limited participation of potential partners. The initiating nation would then make a firm commitment to proceed and invite foreign participants to join in planning and executing the experimental program. On the other hand, for an international project in which the participants intend to collaborate as more or less equal partners, it is necessary for all to work together during the early determination of the objectives, cost, schedule, and design parameters of the project.

COMPATIBILITY OF GOALS

Differing levels of definition and detail in national fusion research and development programs can complicate negotiations on specific international cooperative projects. The party with the better defined program starts with the advantage of knowing more precisely where it wants to go and what it needs to obtain from the cooperative effort. The partners with the less well-defined programs are put at disadvantage. Their choice is between accepting an agreement that may not be fully advantageous or delaying the negotiation until they can evolve a suitable level of detail in their own national program plans to match that of the other negotiators.

The stated goals and milestones differ somewhat among the programs of Japan, the European Community (EC), and the United States, being more definite in the first two. Nevertheless, all these programs, to some degree, lack detail as to performance, schedules, and costs. This fact suggests the possibility, at least, of attaining a reasonable compatibiity of goals through program adjustments.

Accordingly, two matters ought to be taken in hand soon by the U.S. Department of Energy (DOE). The first is the assessment of funding realities for the U.S. fusion program for some years to come, bringing the U.S. fusion community to recognize those realities, and the development in the U.S. fusion community of a consensus on the next important development steps to take. Without a generally accepted priority for the next development steps, all the different project proponents are in competition for the same funds. Until some agreement and order is imposed, these various groups of advocates could confuse any efforts at international cooperation rather badly. A key step in this process is an assessment, and the subsequent acceptance of that assessment, as to whether major machines of the future can be financed by the United States alone without crippling its base research and development program. Substantial increases over current budget levels would be necessary to support the major machines. It if is concluded that those funding levels can and will be provided, then the U.S. fusion program will be strong on its own merits; and international cooperation becomes a voluntary matter of accepting foreign staff members and trading information. If the increased funding levels are assessed not to be available, then the fusion community will have to face that reality and come to agreement on other means, presumably international cooperation if that means is available, to progress toward the goal of workable fusion power systems.

The second matter that should go forward soon at the DOE is a more detailed plan for future research and development, particularly emphasizing the major machines and large development facilities that are anticipated to be needed and assigning relative priorities to each major component. Concrete near-term, intermediate, and long-term objectives and schedules for their attainment should be established. Such a plan would be valuable for several reasons. First of all, it would serve as a guide in defining the particular areas where the United States should seek international collaboration. Secondly, the inclusion of such major steps, as acknowledged components of the future U.S. program, would give all parties (including ourselves) a degree of confidence that an international agreement would actually be carried out. Thirdly, the plan would show more clearly whether the current array of basic program work and development projects is correct by placing them in their proper perspective in a hierarchy of needs. Finally, although the point is outside the province of this report, such planning enables a more efficient, better focused research and development effort. The plan, of course, should be displayed to the Administration and the Congress for review and concurrence.

STABILITY IN THE PARTNERSHIP

In order to enter into arrangments for international fusion cooperation, a certain degree of trust will be required among the participants. While trust is an initial prerequisite, the need for it continues from year to year. If it is ever lost, it is a quality extremely difficult to recover. It is important to avoid unilateral actions, perceived lack of support, and personal conflicts. Accordingly, a clear policy statement of the goals of the U.S. fusion program and a firm commitment to meet them would help establish such trust. It would be a mistake for the United States to try to compensate for a less than full commitment to fusion simply by increased emphasis on international cooperation.

In particular, once a medium- to large-sized project has been agreed upon, it is essential that the commitment to it continue during its life. This lifetime, of course, can cover a decade or two, a circumstance that presents a problem in light of the annual budget review process that governments traditionally use. From time to time it is suggested that a project be taken "off budget" and, therefore, be not subject to annual budget changes. This move is never popular with legislators, who by such a process relinquish a certain degree of their jurisdiction. The arrangement is possible, however, where some independent fee, collected from users, provides money for such a fund--such as the automobile and truck taxes for highway funds. It is possible that such a fund could be established by utility users. It is also possible that through rather formal legal instruments, such as treaties, a strong obligation is created to support a project financially. The fact that international obligations exist will in themselves help to produce funding from year to year. However, the risk continues that at a certain time in the project life the budget resources needed will be terminated by one or more countries, leaving the remaining participants to complete the project on their own, a prospect that may not be acceptable or possible. Thus, the international instruments should address this question and, to the extent possible, produce a reliable supply of funds for the program.

Finally, there is the factor implicit in fairly widespread criticism abroad of the United States as a "reliable" partner in long-term research and development efforts. The annual appropriation process in the United States makes it difficult to guarantee continued support of a long-term commitment at the initially agreed-upon levels. Almost all U.S. commitments to projects in the past have been fulfilled, but a few have not, and those are remembered abroad. None of the people in fusion programs abroad visited by the committee suggested that this matter might preclude cooperation with the United States, but they cited reliability in the partnership as of high importance. Accordingly, in new cooperative ventures, all participants should take great care not to give new cause for complaint. The practice of identifying particular international projects explicitly in annual budget requests, clearly identifying the obligations implied for subsequent budget years, is one way to improve stability of funding.

TECHNOLOGY TRANSFER

Fusion technologies have both national security and long-term commercial implications. Therefore, cooperation in fusion impinges on not one, but two, critical technology transfer concerns. For purposes of this discussion technology transfer is considered to be the act of conveying know-how from one country to another. The means of doing so may embrace the export of technical data, equipment, and processes. Successful fusion cooperation could involve all three. U.S. interests are affected by technology transfers in several ways. These include:

(1) the strength of the domestic economy, (2) the competitive position in international markets, and (3) the complexion of political relationships.

Changing Attitudes

Historically, the United States has taken a relatively neutral position until recently on technology transfer, with the exception of transfers to the USSR and transfers of military technology in general. Most U.S. technology has been transferred across international boundaries through private trade and investment. In open international economic systems, it has been assumed that all nations are better off as a result of the transfers that occur. There is a changing perception, however, that one nation's technological gain is another's loss. Over the past several years the balance has shifted toward a more restrictive technology transfer policy and associated export controls, not only with the USSR but with our traditional trading partners as well. This perception complicates the argument based on mutuality of benefits for international cooperation in technical fields.

Technology Transfer with the European Community and Japan

The position of technological leadership held by the United States after World War II has faltered in many areas, and some have alleged an imprudent transfer of technology to our allies as the cause. However, the decline is the result of many factors that include the following:

- Europe and Japan increased their national investment in research and development relative to gross national product; and the United States decreased its relative expenditures from 1965 through 1978, after which they began to rise again. Of course, in absolute terms, such U.S. expenditures considerably exceed those of other countries.
- A greater proportion of all research and development has gone for military purposes in the United States than in Europe and Japan.
- The two-way flow of much technological information, quite beyond the applicability of even the severest export control rationale, is normal and inevitable.
- There has been an increasing demand in the United States for near-term results for research and development expenditures that has inhibited the accumulation of a base for long-term technological applications.

A fundamental tenet of our nation is freedom of communication. While there are recognized risks from the unrestricted flow of ideas and information, historically the benefits of such free flow, in areas where research and development continue to expand, have been much greater than the costs. Moreover, it is desirable to expand U.S. access to foreign technical information, including that available in Europe and Japan.

The foregoing points support our view that restrictions on transfer of fusion technology to EC and Japan are not likely to serve the purpose of maintaining the economic and political strength of the United States either in isolation or in its alliances.

As to actual articles, services, and technical data for magnetic fusion that are subject to export control through licensing, few items will be primarily related to defense. Even the number of products of strategic significance, including so-called dual-use items, is rather small. Examples of the latter are tritium technology, high-power millimeter-wave generators, advanced materials, and advanced robotics for remote maintenance. In potential instances of dual use a detailed examination and determination is made for each specific case. No denials of export licenses in magnetic fusion have yet occurred, but one cannot thereby conclude that no future limitations will arise. Nor is there enough information about the more restrictive trends to conclude that there will be a problem for certain. The matter will have to be faced as it arises, with the expectation of operating within whatever constraints are designed to safeguard the national security.

A second aspect of information and technology transfer works in the other direction. The U.S. Freedom of Information Act provides that, subject to a few specific exemptions, documents in the hands of U.S. government agencies are available upon specific request to members of the public. This circumstance may give pause to foreign partners who may be concerned that information developed in a cooperative venture and considered by them to be held for the sole benefit and use of the partners could be released by the U.S. side into the public domain. This matter is one to which some attention should be paid in the detailed provisions of the governing agreements, inasmuch as it has already surfaced, for example, in cooperation on breeder reactor research.

Recapitulation

To sum up the points made about technology transfer, fusion cooperation with the EC and Japan would be an instance of its advantageous aspects rather than its disadvantageous ones. To introduce constraints either for national security or commercial reasons would be a severe and damaging step backward. The benefits of cooperation, far outweigh the associated technology transfer risks. The United States has much to gain from magnetic fusion cooperation and little technological leadership to lose.

Since the current substantial level of international cooperation and its associated flow of fusion research and development information do not seem to be unduly impeded by these limitations, future ventures in international cooperation presumably can also be arranged without unduly burdening them.

FLOW OF FUNDS BETWEEN PROGRAMS

Another aspect of implementation is the degree to which the funds of one country will be allowed to flow into cooperative projects. For the United States, if the financial contribution is to buy U.S. equipment and services that are contributed to the project overseas, then there ought not to be much difficulty aside from general budgetary constraints. Or, if the overseas project had an arrangement similar to that of the Joint European Torus (JET), with U.S. personnel part of the project staff and with good access to the information developed in the project, then again the only difficulty would be that associated with general budgetary constraints.

On the other hand, if the proposition is to send cash abroad to be spent by others in other countries for the overseas project, then one might expect the U.S. Congress to be reluctant to provide more than modest funds. Officials of the EC and Japan seem likely to take the same position. However as cooperation grows, more liberal attitudes should be encouraged so that funds might flow more easily in both directions with some latitude in the exact balance.

Nevertheless, investments in fusion projects of other countries can sometimes yield needed information and experience for far less money than would be required to produce that information and experience in the national program. The Japanese investment in Doublet III in the United States is a good example.

EQUITABLE SHARING OF BENEFITS

Benefits are of two kinds. The first kind consists of available staff positions in a joint project and amounts of design and equipment fabrication work to be done by contractors. The ancient rule of international collaboration is that one gets back in the form of these benefits a proportion approximately equal to one's share of the total investment.

Benefits of the second kind comprise the information and technological know-how and experience that flow from the project.

To an extent, technological know-how goes with having carried out design and fabrication for the project. These benefits, then, are distributed approximately in proportion to the investment of the partners. Information about how devices work and why they work, including information about technological details, is all carried away in the heads of the scientists and engineers who worked on the project as well as in the formal reports from the project. It is hard to measure and proportion what is in people's heads; and the partners will have to recognize in the beginning that, in terms of information benefit from the project, all partners who have competent staff on hand will share pretty much equally regardless of the individual financial investments.

As to the sharing of benefits, there exists a feeling in the EC that the Liquid Metal Fast Breeder Reactor cooperative program with the United States was unsatisfactory. The U.S. emphasis on trying to quantify an equitable exchange of information was frequently cited as a cause for the limited results of this cooperative effort. There are some indications that a similar emphasis may be inhibiting the creation of the necessary spirit of mutual trust and cooperation in current negotiations of cooperation in magnetic fusion.

Some of the benefits of the second kind will need to be captured through formal rights to intellectual property. However, patent policy and treatment of industrial proprietary information are areas of substantial difference in national style and practice. Before fusion moves to the position of commercial and industrial viability, it would be useful to reconcile the differences and establish those particular rights at an early stage. It may be possible at this moment to provide for cross-licensing and ownership of jointly developed information that would carry into the future. The effect on the motivation of industry as it may be affected by this treatment would need to be carefully analyzed.

INSTITUTIONAL FRAMEWORK

This section deals with some of the institutional options available for implementing international fusion arrangements that may be developed by the United States, the EC, and Japan or any two of the three. In time, international arrangements between nongovernmental organizations should be anticipated. However, currently and for the foreseeable future international fusion arrangements will probably be on a government-to-government basis because the high-risk, high-cost, and long-term nature of the endeavor puts the programs in the public sector.

Participants

Several possibilities exist as to participants in a fusion program, with each possibility having advantages as well as disadvantages.

International Atomic Energy Agency

The International Atomic Energy Agency (IAEA) has established a cooperative fusion program, which generally is considered to have been useful. The difficulty concerns the issue of cooperation between East and West because of current overriding political difficulties. Although this vehicle for near-term international cooperation is not currently viable, it should be kept in mind for the future, given that the attainment of economical fusion power is thought to lie several decades hence. If the political will should change so as to permit cooperation between the East and West on fusion, the IAEA could be an important organization bringing the parties together.

International Energy Agency

The International Energy Agency (IEA) is undertaking research and development projects in the fusion area as evidenced by the following agreements: "Implementing Agreement for a Programme of Research and Development on Plasma Wall Interaction in Textor," August 10, 1977; "Implementing Agreement for a Programme of Research and Development on Superconducting Magnets for Fusion Power," October 6, 1977; and "Implementing Agreement for a Programme of Research and Development on Radiation Damage in Fusion Materials," October 21, 1980. Certain countries interested in fusion such as France do not belong to the IEA, however, so that cooperation using the IEA framework could become more complex. On the other hand, the existence of IEA with its fusion program provides a ready international mechanism.

Bilateral and Multilateral Arrangements

The United States could have a bilateral arrangement with the EC and one with Japan. In addition, Japan and the EC could have a bilateral arrangement. This form has the advantage of direct relations between two parties so that the cooperation and management may be somewhat less complex. On the other hand, a major participant would not be included; and, if additional bilateral arrangments were established, in the end it might be more, rather than less, complex than a multilateral arrangment. The United States and Japan have a bilateral "Agreement on Cooperation in Research and Development in Energy and Related Fields," dated May 2, 1979. In accordance with this agreement, the two countries exchanged notes dated August 24, 1979, establishing an agreement in fusion energy, and have exchanged further notes establishing committees and providing for cooperation in the Doublet III project. In addition, the EC and the United States are currently discussing a bilateral agreement.

The United States, the EC, and Japan could establish a multilateral arrangement that would involve all three groups. This form has the advantage of involving the principal participants in the West concerned with fusion, but it has the disadvantage of being more complex than a bilateral arrangment because of the number of participants.

Degree of Formality

Treaties

In almost all countries a treaty between nations is the most formal and binding agreement that can be established. Under U.S. law a treaty has the equivalent status of the laws enacted by the federal government. A treaty must be signed by the President and ratified by a two-thirds majority of the Senate. Nations consider treaties as important national commitments. Although a nation can abrogate its obligations under a treaty either by terms of the treaty itself or by unilateral action, the step is not taken lightly or often, affecting, as it does, the basic credibility of a nation. Because of the binding commitment contained in it, a treaty involves a greater degree of review than other forms of agreement and, therefore, normally takes substantially longer for its development and approval. On the other hand, once established, a treaty constitutes a mechanism for maintaining a high degree of certainty about the agreed position of the countries.

Heads-of-State Agreements

The Heads of State of seven major western countries and the EC, starting with the Versailles meeting of the Summit of Industrialized Nations and continuing through successive conferences, have endorsed in principle the idea of international arrangements on fusion. These commitments could be further implemented through heads-of-state agreements. However, the seven countries in the Summit include Canada, which has only a minor fusion program. The Summit tends to emphasize separate countries in Europe as opposed to the EC.

Although it is not out of the question that the Heads of State in the Summit could enter into an agreement, an alternative heads-of-state arrangement could be among Japan, the United States, and the EC or between any two of the three. Such an agreement carries the full weight of the government in power, although in the EC it would be necessary to ascertain its exact status. In the United States the agreement would normally be sent to the Congress for its information.

Abrogation of the agreement by a signing head of state would be an unusual, but not an impossible, act. On the other hand, succeeding heads of state could either confirm the previous agreement or disavow it. Even if the political parties change, there tends to be a certain degree of continuity from one government to another on matters that are more technical than political, as fusion would be for the foreseeable future. Thus, an abrogation of such agreement would not normally be expected, but the possibility would be greater than if a treaty were in force.

Ministerial-Level Agreements

A great many of the agreements between governments are negotiated and signed by appropriate ministries. While these agreements carry the full weight of the government's commitment, they are subject to changing governments as well as to the problems associated with funding through an annual budget process--an issue that is a problem with any arrangement.

Informal Government-to-Government Arrangements

Much information and many people can be exchanged without formal agreements. This opportunity results as a matter of policy decisions by governments to allow exchanges for which it is determined, for particular cases, that the best interests of all concerned can be served. These arrangements tend to be ad hoc, depending on case-by-case decisions, and, thus, work with a certain degree of flexibility. These informal arrangments also contain a degree of uncertainty as to whether they will be established or continued.

Scope of Arrangements

Umbrella Arrangement

An umbrella arrangement is usually a desirable instrument in that it establishes general principles and provides for certain activities immediately and authorizes others to be consummated at a later time. Thus, an umbrella agreement, after establishing the essential principles, could contain provisions for an immediate exchange of technology and personnel, authorize the formation of joint planning exercises, and provide for later entry into medium- and long-term projects. The advantage is that not all of the issues for the long term need to be decided; rather, a framework is established under which subsequent arrangments can be handled.

Base Program

It may or may not be possible to separate medium- and large-sized projects from a base program that is more research oriented. However, if such a division is possible, then cooperation on the base program could be established either in an umbrella agreement or in a separate arrangement. A base program should allow for a certain degree of flexibility, after consultation among all participants, since needs and priorities will change.

Medium- to Large-Sized Projects

While it is possible to put medium- and large-sized projects into an umbrella agreement, the latter ones, and possibly all of them, should be in a subsequent arrangement since they will be established over time. The principles under which medium- and large-sized projects are to be handled may be contained in the umbrella arrangement, but the actual details should be contained in a later arrangement. Once a medium- or large-sized project is agreed upon, then a high degree of reliability is required of all particpants; and it is important to develop funding concepts that are viable for the term of the project. Since it is important to maintain these long-term commitments, the funding principles could be established in the umbrella agreement, subject to implementation in the project arrangement.

Joint Planning

Joint planning can proceed informally, reaching whatever consensus is possible and then relying for the residual matters upon decisions by individual nations or groups of nations. The approach would be to exchange information as to the plans all parties are undertaking but to leave all the participants to proceed according to their own particular goals.

On the other hand, joint planning can be more formalized, either in an umbrella agreement or as a subsequent arrangement, with whatever greater degree of binding effect may be agreed. To be effective, a formal joint planning activity would have to have policy guidance from government program leaders and technical direction from leaders in the laboratories. The undertaking should continue over many years.

At the program management level, the program leaders in the United States, the EC, and Japan should meet periodically to discuss and reconcile their respective programs for the development of fusion and to review the recommendations developed by joint planning groups in specific areas.

The joint planning groups should consist of a small number of the technical leaders from the laboratories in the respective areas. These groups should meet periodically to discuss material prepared at home by a broader community of experts and should maintain continuity of participation. Laying the groundwork with the people in the field is crucial because it produces the worker-to-worker trust and confidence central to long-term success. The various programs already enjoy these advantages to a large degree because of the high quality of prior cooperative experience. It is also important that candidate projects for cooperation be proposed and justified by persons at the program level, since they are the best judges of the technical needs.

At present, it would be appropriate to establish two or three groups: fusion technology development; alternative confinement concept development; and, possibly, the next-step tokamak experiment. The first two groups would plan for collaboratively developing fusion technology and alternative confinement concepts, respectively. These tasks would include identification of the required information and facilities and recommendations for equitable sharing of costs, responsibility for construction and operation, and results. Cooperative projects successfully initiated at the smaller scale of plasma physics, alternative confinement concepts, and technology development will lay the basis for the larger-scale collaboration. If the United States does not plan to initiate a major next-step tokamak project within the next year or so, then it would be appropriate to establish a joint planning group for such experiments. This group would recommend objectives, conceptual design, schedule, and cost and would define the required supporting research and development. The International Tokamak Reactor (commonly known by its acronym INTOR) Workshop has shown that such tasks can be performed successfully by an international group.

Technical and Personnel Exchanges

There exist today extensive information and personnel exchanges, although sometimes there are some difficulties and restraints. These exchanges can continue to be handled as they are currently on a rather informal case-by-case basis, or they could be the subject of agreements contained either in umbrella or subsequent arrangements whereby procedures could be clearly established.

The experience of the JET Joint Undertaking has shown that, for exchanges or assignments of personnel for periods of months or years, it is quite important to provide international schools where the children of the staff may maintain the scholastic progress expected of them in their own countries. An equally important matter is to assure that workers may return home to equivalent employment at the end of their tours, without prejudice for having been away. Some Japanese officials expressed the wish that guest workers in Japan would try to enter more into its life and culture than they do now. By contrast, Japanese scientists temporarily working abroad usually make efforts to learn the language and to enroll their children in the schools of the new country even as they try to maintain their native culture.

WORKABILITY OF MANAGEMENT ARRANGEMENTS

Permitting Flexibility and Innovation

When a technology is in its early stages of research and development, it will become clear as results are obtained that new directions should be pursued and changes should be made in the current program. Thus, a process flexible enough to change with new technological information will in the long run make for a viable program rather than one burdened with outmoded concepts or unwise decisions. This feature, however, requires a careful structuring, since flexibility can also be the mechanism that produces unreliable partners. While there should be flexibility to change the priorities and program, it should be within the context of the agreement by the participants as opposed to unilateral action.

Site Selection

A frequent sticking point in large international projects is agreement on the site for substantial facilities. The JET project underwent great difficulty before its site, adjacent to Culham Laboratory, was settled. Keen rivalry for the site of the Next European Torus is already occuring. While site selection would normally occur on a case-by-case basis, it may be possible to spell out in the umbrella agreements the procedures and processes to be used in deciding on the location of facilities.

Partnership Shares

The extent of the participation of each of the partners is another factor subject to balance in establishing a cooperative project. Depending on circumstances, any degree of participation, from a junior role to full equality, may offer acceptable benefits. Obviously, the greater the degree of participation, the greater the voice that partner should have in decisions about the project's objectives, scope, approach, schedules, and cost, and the earlier that voice should be heard.

Practical Matters

A joint international project is complicated, but it can work if it is carefully planned and skillfully executed. Mechanisms must be established for creating an organizational entity and management structure. Procedures must be adopted for procurement, quality assurance, audits, and inspections. The authority of the project director, technical and political oversight mechanisms, national funding contributions, and priorities for operaton of the facility must be established. Policies with respect to national industrial involvement need to be debated and adopted. Legal instruments must define the relationship of the project to national and local governments, provisions for withdrawal, ownership of the facility, provisions for liabilities and insurance against risk, and provision for taxes and duties.

PRIOR EXPERIENCE

There are a number of successful international ventures. There is no model that one can follow except to recognize the complexity of such arrangements and to be willing to undertake the establishment of a system that matches the technology and the program's objectives. If there is any rule in this area, it should be that the institutional arrangements must match the problem.

Joint European Torus

For fusion the most relevant example of a major international project is JET (JET Joint Undertaking, 1982). The project was set up as a Joint Undertaking by the Member States of the European Community in 1978 (Wilson, 1981) under provisions of the 1957 Treaty of Rome, which established the European Community. Establishment of the Joint Undertaking was preceded by the JET Working Group, in 1971 and the JET Design Team, in 1973.

The following aspects of JET management (Commission of the European Communities, undated) are noteworthy:

- The JET Council, assisted by the JET Executive Committee and the JET Scientific Committee, is responsible for the management of the project.
- Each member of the Joint Undertaking is represented on the Council, usually by a individual from the policy level and another from the technical level.
- The Commission of the European Communities is responsible for financial decisions to the extent of its 80-percent contribution to the project.
- National research organizations provide guidance to the JET Council on technical issues.
- The EC Council of Ministers, with the assistance of the Committee of Permanent Representatives, is responsible for political decisions.

European Organization for Nuclear Research

The European Organization for Nuclear Research (CERN) is another successful enterprise. Factors contributing to its success undoubtedly were its freedom from commercial stakes, freedom from military applications of its work, and absence of problems with the transfer of commercially useful technology. Evidently such an organization was the only way that European countries could mount a world-class program in high-energy physics of a stature comparable to that in the United States and to the program that promised to develop in the USSR and Iron Curtain countries. The governance of CERN has been highly successful and serves as a useful example of program and budget stability.

One unforeseen consequence of this large-scale international effort was that corresponding national programs of the member countries gradually diminished in size and impact. This effect may also occur in the EC fusion program as effort becomes concentrated on large devices. However, by that time, there may be less need for auxilliary national activities.

Fission Energy

Successful international cooperation has also occurred in the development of fission energy. Cooperation in this technology has proceeded at three different levels--that of information and personnel exchange, that of medium technology projects, and that of very large projects. The information exchange agreements have been fruitful, but they might have been more fruitful had they not been hindered by the recognized commercial applicability of the best technical information that was developed and by an excessive insistence on a quid pro quo in the exchange of such information.

Cooperation on medium-sized technology projects would have been enhanced if there had been better recognition of the relationship of the research and development that was being performed vis-a-vis its future commercial use and better provision for the capture of those benefits.

The Super-Phenix project, a 1200-megawatt (electric) fast breeder reactor, is an example of a large-scale project that probably could not have been conducted without international cooperation. Super-Phenix is the result of agreements between the French and Italian governments for breeder development signed in 1974 and agreements between the French and Germans in 1976 on three levels: an agreement on breeder development policy between the governments; an agreement on research and development and the "harmonization" of national efforts between the nuclear research agencies; and agreements on commercial development between French, German, and Italian companies.

Several factors seem to underlie the success of the Super-Phenix project (Beckjord, 1984):

- The French provided strong project management and systems engineering on an extensive base of technology.
- The French have majority control, and the other participants are junior partners. Management decision making was clearly drawn from the beginning, with lines of authority established from the utility customer to the reactor developer and designer and to the component manufacturers.
- The commitment of the parties stems from their lack of indigenous fossil fuels and natural uranium, providing an imperative, as they perceive it, to develop breeder technology, which can make far more efficient use of natural uranium than can light water reactors.
- There was a need to pool resources in such a large undertaking.
- The Super-Phenix project developed against a background of other major cooperative efforts in Western Europe--in science, in aerospace and other multi-national business ventures, and in economic union--that served as trail markers.

Space Technology

In space technology the agreement between the United States and Japan as to the availability of space launch facilities is an example of limited international cooperation. The Apollo-Soyuz spacecraft rendezvous in orbit is an example of cooperation instituted by high-level political agreement. The actual conduct of that project illustrated the need for extremely detailed agreement on project management procedures when two countries of vastly different language and culture decide to cooperate. Current efforts of the U.S. National Aeronautics and Space Administration to obtain joint participation in the manned space-station project is another example of large-scale collaboration. This cooperative proposal has not developed far enough to provide any lessons for fusion; however, the space-station effort should be watched carefully for useful ideas.

International Telecommunications Satellite Organization

The International Telecommunications Satellite Organization (INTELSAT) is perhaps the most successful large-scale international venture in an institutional, operational, and commercial sense. Early on, a fundamental decision was made to reject bilateral agreements in favor of the multilateral introduction of satellite communications technology for global use in order to achieve its full benefits. Such a decision had to overcome vested interests in alternative modes of telecommunications, for example, undersea cables. Nevertheless, these obstacles were overcome and a treaty-level agreement was concluded. Leive (1981) has identified a number of factors contributing to the institutional soundness of INTELSAT:

- Phasing of successive agreements to proceed from the less well defined to the more well defined in order to defer hard policy choices until issues had matured and clarified.
- Combining both political and technical interests in the governance of the organization.
- Initial management by a strong national entity as agent for the organization followed by a deliberate shift to more truly international management as the organization matured.
- Allocating financial interests and voting control to member countries in proportion to their use of the INTELSAT system.
- Assuring that the benefits of new technology developed by the organization are available to its member countries for uses outside INTELSAT.

Jet Aircraft Engines

An example of international cooperation relatively far downstream in the life cycle of a technology was provided by the experience of a commercial firm in jet engines. In the experience of this firm, cooperation on a valuable commercial product was increased successively to greater and greater levels. Cooperation proceeded from the level of mere licensing to the levels of coproduction, shared production, and, finally, a joint venture, in which development engineering, manufacture, and marketing were shared. Such an experience may indicate that similar arrangments can be devised to capture the commercial benefits of fusion to the satisfaction of several cooperating entities.

RECAPITULATION

This chapter has examined some of the practical factors affecting the agreement and implementation of increased international cooperation, assuming that a policy favoring cooperation in principle has been adopted and that ample technical substance for such work exists. An opportune window in time for large-scale international collaboration is now open; if the timing were not favorable, even well justified technical initiatives would face resistance. The goals of the three prospective partners in collaboration either overlap enough or retain enough flexibility to initiate serious discussions of prospective joint activities. However, the first priority for the United States should be the establishment of a clear set of policies and objectives and a considered program plan for future fusion activities. Effective negotiations for increased cooperation need to rest on such a firm basis. International collaboration will require stable international commitments to assure the long-term benefits contemplated by the collaboration and to avoid burdening the remaining partners by any reduction in support by one of them. Prior perceptions of unreliability, justified or not, may inhibit collaborative agreement unless overcome. Limitations on technology transfer constitute an external condition, imposed principally to safeguard national security. International collaboration in magnetic fusion would certainly be hindered by restrictive export control, but the outlook is that the regular case-by-case determinations will result in an acceptable situation.

Beyond these points, decisions specific to each case will have to be made about the net flow of funds among the partners; the use of existing institutional frameworks or the establishment of new ones; details of project management; and the capture of intellectual, industrial, and commercial benefits. In short, there is a host of considerations that must be resolved in the implementation, but all of these appear either workable or bearable, as the experience of many prior collaborative undertakings in diverse fields has shown. Consequently, given the intent to collaborate and the technical substance of it, satisfactory agreement and implementation should be achievable.

5

CONCLUSIONS AND RECOMMENDATIONS

In the course of its domestic workshops and its two overseas trips, the committee covered a wide range of topics concerned with international cooperation in the development of controlled, magnetically confined fusion. The study considered "cooperation," in the general sense of acting with others for mutual benefit on either a small or a large scale and "collaboration," in a somewhat more specific sense of working actively together as approximately equal partners in sizeable enterprises.

The various meetings identified three qualitatively different paths to fusion energy that lie open to the United States. The first is to support in a domestic program the full range of research, development, and prototype plant construction efforts that are needed to optimize the chances for successful fusion power generation, seeking all-out competitive advantage with respect to other world programs, simple parity with them, or somewhere in between. The second path is to carry out that sort of full-range program using increased international collaboration, which shares the financial costs and risks among several partners. The third is to accept a less-than-optimum domestic program, carried out at whatever level is affordable, accepting some likelihood that the United States would forfeit a greater or lesser degree of equality with other programs and, at the extreme, might have to purchase the technology from others sometime in the future. The middle path seems to the committee to be the preferable and practical choice. As a result, the United States would not, as on the first path, be mounting a more costly program than the competitive circumstances suggest. Nor would the country, as on the third path, be conducting a program more limited than it need accept. The committee believes, that, in time, potential partners will reach similar conclusions for themselves.

Accordingly, the committee expresses its view as an overall conclusion of the study:

- For the United States in the years ahead, a program including increased international collaboration is preferable to a predominantly domestic program, which would have to command substantial additional resources for the competitive pursuit of fusion energy development or run the risk of forfeiture of equality with other world programs.

This conclusion is supported by several of the more specific ones presented below. The relevant conclusions concern the potential of greater benefits and lower costs (No. 1), the existence of an open window in time that implies feasibility (No. 2), the judgement that difficulties of implementation are either workable or bearable (No. 5), and the sound foundation provided by past cooperation (No. 6).

SPECIFIC CONCLUSIONS

1. On balance, there are substantial potential benefits of large-scale international collaboration in the development of fusion energy.

The benefits to be gained include a sharing of long-term, cumulative costs, diversification of risks, and a pooling of scientific and technical resources so as to enhance the needed results. In addition, both economic and political merit in cooperative efforts has been seen by participants in the Western Economic Summit meetings since 1982.

The factors at risk are mainly those associated with the prestige of the national programs, long-run commercial competitiveness that would follow from national program strength, and the undesired transfer of new technology. It should be possible either to contain these risks, by planning the nature of the collaboration, or to offset them, by realizing other benefits of the collaboration itself. The European Community itself is a current example of the net advantages of international collaboration.

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2. A window in time for large-scale international collaboration is now open.

The United States, the European Community, and Japan have major programs in magnetically confined fusion that are, currently, similar enough in status and objectives to provide a technical and programmatic basis for future major collaboration. On the basis of current planning and commitment either the European Community or Japan could achieve, at some date, a perceived position that would make international collaboration in a bilateral or trilateral mode less attractive to them than it is today. The Japanese have greater motivation to pursue fusion energy because of lack of indigenous energy resources; they are committed to make fusion a success as an energy source. The Japanese will consider collaboration, but only if it fits their independent program. The Western Europeans have already demonstrated collaboration at the international level through the European Community. The European Community attaches less urgency to its fusion program as a result of its anticipation of the fast breeder fission reactor. However, the European Community collaboration in fusion has overcome early obstacles and has generated a firm plan and stable support.

All our recent discussions revealed a desire for equal participation in planning, science, engineering, and management. At a more senior level, the people that we visited understood clearly the budgetary pressures for greater cooperation as well as the pressures of national interest. We found a receptivity to the idea of large-scale international collaboration at both the program leadership and political levels.

If one considers that each of the three major programs--in the United States, the European Community, and Japan--may well include an engineering reactor and a demonstration reactor (although the latter is not considered in the United States to be a government responsibility) as prerequisites to commercialization, there are also ample technical opportunities for large-scale international collaboration.

Finally, proprietary concerns are largely absent now because the programs are mostly conducted by the public sector in recognition of the long time before commercial application is likely.

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3. Large-scale international collaboration can be achieved, but not quickly.

Because both European Community and Japanese planning is detailed and resources are rather firmly committed for the next few years, large-scale collaboration does not appear possible before the late 1980s. Moreover, results from the Joint European Torus and the JT-60 tokamak in Japan, as well as from the Tokamak Fusion Test Reactor, will also become available during this period; and important program choices are awaiting this information.

Furthermore, any major collaboration must meet the requirements of the separate programs of the parties and so must be preceded by a joint planning effort.

Therefore, while major collaboration may offer investment savings, as well as less risk and a superior program, such results can be expected only after a suitable lead time has elapsed for putting the mechanisms into place.

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4. International collaboration will require stable international commitments.

There are a number of nontechnical factors that could inhibit large-scale international collaboration unless overcome. The United States is perceived as being an "unreliable partner" based on previous experiences in space sciences, synthetic fuels, and, to some extent, fusion itself. There are also perceptions of the United States as not having a firm commitment to develop fusion, nor of having a sound development plan. U.S. policy considerations that go beyond fusion may constrain the options for collaboration. The annual funding appropriation process makes a multiyear project appear as a high-risk venture. By contrast, the European Community operates with a five-year budget and program plan revised every third year.

Futhermore, U.S. fusion policy is perceived to change much more frequently than that of either the European Community or Japan. U.S. directions--enunciated by the Magnetic Fusion Engineering Act of 1980, the more recent Comprehensive Program Management Plan of 1983, and the Energy Research Advisory Board recommendations of 1983-1984, together with current debate, which appears not yet to have coalesced into policy--all of these are observed closely by our potential partners and result in confusion abroad. Past programs outside the responsibility of the U.S. Department of Energy have exacerbated this perception of the United States.

There are, however, successful precedents for stable international commitments: the European Organization for Nuclear Research, the International Telecommunications Satellite Organization, and the Joint European Torus (JET) Joint Undertaking. We believe the Joint European Torus experience, especially, provides an illuminating example.

Since substantial benefits from international collaboration would materialize only from a relationship that was sustained over the long term, some form of agreement will be required that gives all partners a high degree of confidence that each will carry out its commitment without creating a burden on the others by withdrawal of participation and support.

* * * * *

5. There is a host of considerations that must be resolved in implementation, but these appear workable.

In pursuing international collaboration as the preferred course of action, the many complexities that are inherent must be recognized and dealt with. Failure to consider the following in a timely fashion can lead to real difficulty:

a. The fragile balance between independence and interdependence.
b. A procedure for site selection for major future devices.
c. The impact of perceived commercial value, as exemplified by current restricted access to fast breeder reactor engineering technology.
d. Ownership or sharing of intellectual property.
e. Policy with respect to licensing technology to nonparticipants.
f. Equitable participation by industry, including consideration of differing tax and subsidy policies.
g. The question of technology transfer in instances where national security is considered to be involved.
h. Acceptance of international standards, particularly for safety and radiation.
i. The impact on established domestic institutions, such as the national laboratories; some changes in roles and missions seem inevitable.

The committee believes, however, that none of these factors represents an insurmountable obstacle. Satisfactory management arrangements internal to the undertaking can probably be devised, and limitations external to it can probably be borne. Each issue may be addressed when it arises.

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6. Past cooperation provides a sound basis for future efforts.

It was clear from the courtesies extended, from the hours of talent invested in the discussions with the committee, and from the open and frank exchange of views that past international relationships in the fusion community have been excellent. A high degree of mutual trust and respect prevails among leaders of the several programs. Furthermore, there is a precedent of generally successful international cooperation on a modest scale in fusion. These precedents include long-standing information and personnel exchanges, the bilateral agreement between Japan and the United States, the trilateral agreements under the International Energy Agency, and the workshops on the International Tokamak Reactor. We believe that this background provides reason to be optimistic about the possibility of successful achievement of the general goals established at the recent Economic Summit meetings of Heads of State.

RECOMMENDATIONS

Having concluded that large-scale international collaboration is the preferable course, the committee makes two recommendations to proceed:

1. The first priority should be the establishment of a clear set of policies and objectives and a considered program plan for future U.S. fusion activities.

Concrete near-term and intermediate objectives and a schedule for their attainment should be established by the U.S. Department of Energy and displayed to the Administration and the Congress for review and concurrence. Such information is a prerequisite for substantive discussions with potential partners as well as the basis for long-range international commitments.

Improved means should be devised for satisfying Congressional oversight and budget control and at the same time providing improved program stability. As a minimum, multiple year contracts and carefully controlled off-budget financing could help.

Inasmuch as large devices are prime candidates for international collaboration, the United States should promptly formulate its position with respect to next-generation tokamak experiments relative to the Next European Torus in the European Community and the Fusion Experimental Reactor in Japan. If the positions overlap, the United States, as part of the recommendation made below, should explore collaboration with the European Community and Japan in all phases of planning, constructing, and operating a next-step tokamak.

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2. Having carried out the preceding recommendation, the United States should take the lead in consulting with prospective partners to initiate a joint planning effort aimed at large-scale collaboration.

The inevitable lead time associated with large-scale collaboration calls for initiatives to be started earlier rather than later.

Initial assumptions should recognize that the program of the United States, as well as those of the European Community and Japan, must start from a self-sufficient base. The planning effort should identify first those areas where the national and regional plans have coincident interests. Successful cooperation on a smaller scale will lend confidence to larger undertakings. Steps that would lead to interdependence must, as a practical matter, come later. These steps may produce a reasonable compatibility of goals for major experimental fusion devices in the period following the completion of various firmly committed, near-term projects.

This activity should be endorsed at political levels and steered by the fusion program leaders in the respective countries, who should meet periodically to reconcile their programs. Subsidiary planning groups, involving technical leaders, should meet periodically to plan cooperative activities. This activity must be a continuing one. The involvement of the technical level is important both to the planning of sound objectives for the project and to the development of a cooperative spirit for its pursuit. It seems self-evident that the United States should not advocate in these meetings what it cannot deliver.

Although the United States, the European Community, or Japan might well take the lead in proposing increased collaboration, the committee believes that, because the United States is currently reexamining its program, the initiatives could be taken with greater ease from this side. There is, here, an opportunity to provide leadership in a uniquely important technology development of global significance as a potential power source, provided that recognition is given to the concept that leadership is possible in a partnership if we are willing to share it.

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APPENDIX A

SCOPE OF WORK*

A [Committee] on International Cooperation in Magnetic Fusion will be established consisting of approximately ten members with broad backgrounds in electrical engineering; plasma physics; fusion technology; fusion reactor design; industrial participation in high-technology projects; energy supply; technology transfer; and the legal, diplomatic, and political aspects of multinational governmental ventures. The [committee] will:

A. Identify the most important issues in international cooperation in magnetic fusion energy, so that they may be addressed in the study.
B. Review and discuss alternative courses of cooperation in view of the scientific, technological, and engineering needs of fusion power, these courses being consistent with the areas of greatest competence of participating countries and with reasonable assumptions about future technological progress and international relationships.
C. Review U.S. goals and objectives for the development of magnetic fusion as they may be phased over time and as they may relate to technological progress, industrial involvement, and selected socioeconomic factors. Compare U.S. goals and objectives with corresponding ones that may be available for the European and Japanese fusion efforts, in order to identify similarities and differences.
D. Identify and characterize long-term implications of various courses of international cooperation with respect to U.S. goals, drawing as necessary on experience with other instances of international scientific and engineering cooperation.
E. Recommend courses of future international cooperation as to technical topics, experimental facilities, extent, duration, and structure, drawing as necessary on prior studies.

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*Excerpted largely from the Notice of Financial Assistance Award from the U.S. Department of Energy to the National Academy of Sciences.

F. Obtain the views of leaders of the U.S. and foreign fusion communities on the matter of benefits already realized from international cooperation in magnetic fusion energy and benefits expected from enlarged cooperation.

G. Provide an interim report on the progress in formulating recomended U.S. courses of action and the underlying reasons; incorporate the results of the whole study into a final report.

The committee will plan and conduct invitational workshops to consider courses of technical cooperation, goals and implications. The workshops will allow full exploration of alternatives while preserving the prerogative of the sponsor to develop U.S. positions.

APPENDIX B

SUMMARY OF DOMESTIC WORKSHOPS

Two domestic workshops were conducted to explore viewpoints within the United States on the opportunities, policies, and arrangements bearing on a qualitatively higher level of international cooperation in the development of magnetic fusion energy. The salient views as expressed by the workshop participants are summarized here. These views were considered, but not necessarily adopted, by the committee in reaching its conclusions. For convenience, each workshop is described separately, in approximate correspondence with its topical sessions.

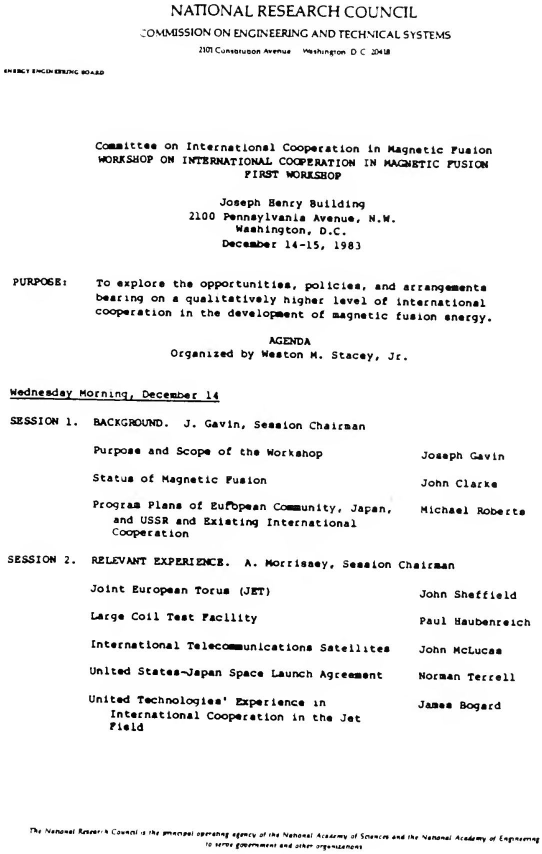
FIRST WORKSHOP

The agenda for the first workshop is shown in Figure 1.

Technical and Programmatic Considerations

In the past the United States has gained substantial technical benefits for its magnetic fusion program from international cooperation. Foreign fusion programs have scientific, technical, and engineering strengths in many areas that are comparable, if not superior, to those of the United States:

- Japan--solid breeding materials, superconducting magnets, materials, neutronics, engineering design.
- European Community (EC)--liquid breeding materials, superconducting magnets, materials, plasma-wall interaction, tokamak physics, stellarator physics, tritium, reversed-field pinch physics, nuclear technology, radio-frequency heating technology.
- Soviet Union--plasma-wall interaction, superconducting magnets, tokamak physics, tandem-mirror physics, radio-frequency heating technology.



NATIONAL RESEARCH COUNCIL
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
2101 Constitution Avenue Washington D C 20418

ENERGY ENGINEERING BOARD

Committee on International Cooperation in Magnetic Fusion
WORKSHOP ON INTERNATIONAL COOPERATION IN MAGNETIC FUSION
FIRST WORKSHOP

Joseph Henry Building
2100 Pennsylvania Avenue, N.W.
Washington, D.C.
December 14-15, 1983

PURPOSE: To explore the opportunities, policies, and arrangements bearing on a qualitatively higher level of international cooperation in the development of magnetic fusion energy.

AGENDA
Organized by Weston M. Stacey, Jr.

Wednesday Morning, December 14

SESSION 1. BACKGROUND. J. Gavin, Session Chairman

Purpose and Scope of the Workshop	Joseph Gavin
Status of Magnetic Fusion	John Clarke
Program Plans of European Community, Japan, and USSR and Existing International Cooperation	Michael Roberts

SESSION 2. RELEVANT EXPERIENCE. A. Morrissey, Session Chairman

Joint European Torus (JET)	John Sheffield
Large Coil Test Facility	Paul Haubenreich
International Telecommunications Satellites	John McLucas
United States-Japan Space Launch Agreement	Norman Terrell
United Technologies' Experience in International Cooperation in the Jet Field	James Bogard

FIGURE 1 Agenda for first workshop.

Wednesday Afternoon, December 14

SESSION 3. TECHNICAL BASIS FOR COOPERATION IN PLASMA PHYSICS, BASIC TECHNOLOGY, AND COMPONENT DEVELOPMENT. R. Borchers, Session Chairman

Possibilities of Further Cooperation in Plasma Physics and Basic Technology	Robert Conn
Large Test Facilities Needed for Component Development	Charles Baker
Panel Discussion on Technical Considerations for Cooperation in Plasma Physics, Basic Technology, and Component Development, Distinguishing Among the Three Major Overseas Programs	Robert Borchers (Panel Chairman), Charles Baker, Harold Furth, Gerald Kulcinski

SESSION 4. TECHNICAL BASIS FOR COOPERATION ON LARGE FUSION PROJECTS. D. Kerr, Session Chairman

Anticipated Large Fusion Projects	John Gilleland
Panel Discusson on Technical Considerations for Cooperation on Large Fusion Projects, Distinguishing Among the Three Major Overseas Programs	Donald Kerr (Panel Chairman), Robert Conn, John Gilleland, Melvin Gottlieb, Norman Terrell

Thursday Morning, December 15

SESSION 5. POLICIES ON INTERNATIONAL COOPERATION. J. Hendrie, Session Chairman

Panel Discusson on the Objectives, Constraints, Long-Term Implications, and Political Acceptability of International Cooperation, Distinguishing Among the Three Major Overseas Programs	Joseph Hendrie, (Panel Chairman), James Bogard, Richard DeLauer, Jack Dugan, Bryan Lawrence, Robert Uhrig

FIGURE 1 Agenda for first workshop (continued).

SESSION 6. IMPLEMENTATION AND ORGANIZATION. M. Muntzing, Session Chairman

Legal Instruments of Agreement for International Cooperation	Susan Kuznick
Organization and Administration of International Projects	George Cunningham
Panel Discussion on the Role of Government and of Industry in International Projects, Distinguishing Among the Three Major Overseas Programs	Manning Muntzing (Panel Chairman), George Cuninngham, Gerald Helman, Susan Kuznick, David Leive, John Moore

Thursday Afternoon, December 15

SESSION 7. SUMMARY. W. Stacey, Session Chairman

Conclusions from Sessions 3-6 with Emphasis on Implications. Discussion.	Robert Borchers, Donald Kerr, Joseph Hendrie, Manning Muntzing

FIGURE 1 Agenda for first workshop (continued).

At the most modest level of cooperation, the free and informal exchange of basic scientific and technological information that now exists is valuable to the U.S. program and should continue to be encouraged. The only government action required is merely to insure that no impediments to free information exchange are created.

Organized cooperative efforts, in which each side pays its own way, should be further encouraged in order to make the most efficient use of available resources worldwide. This category includes the following activities:

- Joint planning of national research programs in specific areas for complementarity--for example, the joint planning of materials research under the International Energy Agency (IEA)--and a sharing of results.
- Joint studies, such as the International Tokamak Reactor (INTOR) under the International Atomic Energy Agency (IAEA), that focus effort on critical technical issues and identify research and development needs.

At the next level, participation of one or more nations in a technology test facility, a component development and test facility, or a plasma physics experiment of another country could reduce the number of such facilities needed worldwide. Examples of each type of facility are, respectively, the Fusion Materials Irradiation Test (FMIT) facility, the Large Coil Test Facility (LCTF), and the TEXTOR tokamak. It would be easier to establish an equitable cost for participation on a case-by-case basis, rather than attempting to establish a comprehensive agreement encompassing many cases. However, an umbrella agreement that provided for the possibility of several individual cases would be appropriate.

The highest level of cooperation, in terms of both degree of international collaboration and complexity of organization, consists of an international project--such as Joint European Torus (JET). Truly international projects are appropriate only for major facilities, such as the suggested Tokamak Fusion Core Experiment (TFCX) or Engineering Test Reactor (ETR), because of the great amount of negotiation that will be required for their establishment.

Examples of International Fusion Cooperation

An open and informal exchange of scientific information through publication, meetings, and visits has existed among the major fusion nations since 1958, when the subject was declassified. The U.S. exchange with Western Europe has been the most extensive.

There is a formal agreement for exchange of personnel for short periods of time with the USSR.

Formal cooperative agreements with Japan exist in several areas: personnel exchange, joint research and development planning in seven areas, joint institutes for fusion theory, Japanese utilization of the Doublet III tokamak experiment for about $10 million per year from Japan, and Japanese utilization of Rotating Target Neutron Source II (RTNS-II) for about $1.8 million per year from Japan.

There is formal cooperation through the IEA under an umbrella agreement in three areas:

- Japan and the EC use the LCTF to test their magnets (Haubenreich, 1983).
- The United States and other countries perform plasma experiments in the TEXTOR tokamak of the Federal Republic of Germany.
- There is coordination of planning for materials research and for research on large tokamaks.

There is formal cooperation with the EC, Japan, and the USSR to focus effort on critical technical issues for next-generation tokamaks and their supporting research and development in the INTOR Workshop.

Policy Considerations

The official goals of the U.S. magnetic fusion program, as embodied in the Comprehensive Program Management Plan (CPMP) (U.S. Department of Energy, 1983), were discussed and were thought to be ambiguous in some respects and to fail to convey a firm commitment to the development of fusion power. There are significant implications of this policy for increased international cooperation:

- The pointed implication of the CPMP objective "to maintain a leadership role" is that the United States has not adopted a national policy to be the leader. Other nations will be much more anxious to cooperate with the leading program than with one that is even with or behind their own.
- The CPMP also states an intention "to maintain this position [of leadership] in the two major confinement concepts...through a carefully formulated and managed policy of close international cooperation to share specific tasks." The implications of this statement are that all essential elements of the mainline effort will be retained within the U.S. program, that the United States will cooperate with other countries only in areas in which they are in a leading position, and that hard bargaining on the part of the United States over equity in technical and financial contributions will be a feature of all negotiations. This is not a posture that is likely to foster a spirit of cooperation.
- The goal of the U.S. program, as stated in the CPMP, "...is to develop scientific and technological information required to design and construct magnetic fusion power systems." This goal

does not contemplate the development of an industrial base for the fabrication of engineering components or the construction of either a demonstration or prototype power reactor; rather, these tasks are left to industrial initiative. Since the other major fusion nations seem to consider the goal of their programs to be the development of fusion power through the demonstration reactor stage, including engineering component development, there is a possibility that this incompatability of goals could inhibit the development of cooperative agreements.

- The Japanese, EC, and USSR program plans in magnetic fusion call for engineering test reactors of roughly similar objectives and characteristics. The devices are designated as Fusion Engineering Reactor (FER) in Japan, Next European Torus (NET) in the EC, and OTR in the USSR. These reactors would be built during the 1990s, followed by a demonstration reactor. The U.S. program plan, as contained in the CPMP, also calls for a similar machine, ETR, to be planned during the later 1980s. However, recent budgetary constraints have caused planning at the technical level, as of the time of the workshop, to be directed towards a less ambitious next step, TFCX, which embodies the physics of ETR but few of the technological and engineering testing features.

A clear policy statement on the goals of the U.S. fusion program and a corresponding firm commitment to meet those goals is a prerequisite for establishing international cooperative projects on a major scale. It was noted that one of the principal reasons for the success of the French Super-Phenix project was a clear national policy that assigned the project high priority, strong technical and industrial support, and adequate financial support. It would be a mistake for the United States to try to compensate for a half-hearted commitment to fusion with increased emphasis on international cooperation.

Broader U.S. policy considerations may be at odds with technical opportunities for cooperation:

- The USSR has officially proposed the design and construction of the next major tokamak experiment on an international basis and has informally expressed a willingness to see this device sited in Western Europe. Administration policy and Congressional inclinations are negative towards cooperation with the Soviet Union now, but this position could be reversed if East-West relations change.
- Japan would probably welcome the opportunity for further cooperation with the United States on engineering component development and major fusion projects. Congress would probably be reluctant to endorse such cooperation because of political sensitivity to Japanese incursions into U.S. markets and the

impact of technology transfer upon U.S. technological leadership.

- The countries of the EC believe that leadership in magnetic fusion research lies in Europe in the near future and are skeptical of the reliability of the United States as a partner because of past experiences; consequently, the EC presently shows little inclination to cooperate on major new projects. On the other hand, cooperation with EC would probably be acceptable to Congress; and the technology transfer issues would be easier to resolve.

The extent of reliance on international cooperation to achieve the objectives of the U.S. magnetic fusion program is a key policy issue. There are two aspects of the issue:

- Should the United States rely on cooperation with programs abroad, where they are or may become available, to carry out technology development or to investigate plasma physics questions in areas that are vital to the mainline U.S. program(s)? The past practice has been not to do so, but rather to encourage foreign program leadership in areas considered less vital. This position is quite probably unsatisfactory from the viewpoints of other countries.
- Should the United States require early joint planning, in the hope of achieving collaboration with programs at home for major new component test facilities and fusion experiments? It seems more likely that foreign collaboration could be established after a firm commitment to go forward with a project had been made by the United States, although there are good reasons to involve prospective partners in early planning.

One compromise on the first point would be to minimize the effects of duplication of effort by phasing related efforts in time among the several partners, rather than asking any partner to forgo an important line of work entirely.

In three policy areas conditions on technology transfer arise in the implementation of cooperative projects: national security, protection of the economic interests of U.S. industry, and preservation of advantage to foreign participants from technology developed by them in the face of provisions of the U.S. Freedom of Information Act mandating public access to such information.

Implementation and Management Considerations

There appear to be many possible methods of implementation of international cooperative arrangements: treaties, Executive agreements, intergovernmental agreements, and bilateral purchase contracts. Treaties establish the most binding commitments of the

U.S. government, but they are the most difficult to establish. Intergovernmental agreements are much easier to put into place because they can be negotiated at lower governmental levels, but they are also much less binding--they can be unilaterally terminated. The credibility of the United States as a "reliable partner" has been damaged by past unilateral terminations in space sciences, synthetic fuels, and even fusion itself.

Existing international organizations offer auspices under which more extensive international cooperation could be carried out without the necessity of new implementing agreements. As previously noted, the IEA is currently serving quite effectively as a mechanism for the participation of several nations in LCTF and TEXTOR. The INTOR workshop under IAEA was also mentioned above. An expansion of such activities under these agencies is reasonable. However, neither IEA nor IAEA, or indeed other existing international organizations, would be suitable as sponsors for a major international project because they all are primarily coordinating, rather than managerial, organizations.

Still, an existing international organization may provide a framework for initiating a project, as was the case with the European Organization for Nuclear Research (CERN). CERN was initiated by an organizing conference in 1951, sponsored by the United Nations Educational, Scientific and Cultural Organization, in an action that was ratified three years later by enough countries to assure 75 percent of the required funding. CERN went on to become a highly successful institution, with international participation in design and construction of large-scale facilities and in performance of experiments.

For fusion the most relevant example of a major international project is JET (JET Joint Undertaking, 1982). The project was set up as a Joint Undertaking by the Member States of the EC in 1978 (Wilson, 1981) under provisions of the 1957 Treaty of Rome, which established the EC. Establishment of the Joint Undertaking was preceded by the JET Working Group in 1971 and the JET Design Team in 1973. Failure in the initial agreement to create a mechanism to decide on the site almost resulted in cancellation of the project in 1977.

The following aspects of JET management (Commission of the European Communities, undated) are noteworthy in that they combine technical and political elements in the decision-making chain:

- The JET Council, assisted by the JET Executive Committee and the JET Scientific Committee, is responsible for the management of the project. The Council meets at least twice a year.
- The Commission of the European Communities is responsible for financial decisions to the extent of its 80-percent contribution to the project.
- National research organizations provide guidance to the JET Council on technical issues.

- The EC Council of Ministers, with the assistance of the Committee of Permanent Representatives, is responsible for political decisions.

The International Telecommunications Satellite Organization (INTELSAT) provides a relevant example of the principle of "phasing in" an international project. Rather than attempting to define a complete set of international agreements at the outset, INTELSAT was established on an interim basis. The agreement specified a time period for a study of the permanent form of the organization but did not set a deadline for the end of the interim arrangements. The permanent INTELSAT agreement, which was concluded six years later, provided for a phased shift from management of its space operations by the United States, as agent, to truly international management.

The following features of INTELSAT management are noteworthy as to the combination of technical and political elelents:

- The Assembly of Parties, which meets every two years, is composed of all nations party to the Agreement and is primarily concerned with issues of concern to the Parties as sovereign states. The principal representation is provided by foreign ministers.
- The Meeting of Signatories, which meets annually, is primarily concerned with financial, technical, and program matters of a general nature. The principal representation is provided by the appropriate technical ministry.
- The Board of Governors, which meets at least four times a year, has responsibility for decisions on the design, development, establishment, operation, and maintenance of the international portions of the system. The principal representation is provided by officials concerned in their home countries with the operation and management of the system.
- Several advisory groups expert in technical, financial, and planning matters assist the Board.

INTELSAT provides an example of finance and control in an international project. Each member's financial interest and voting share on the Board of Governors is strictly proportional to its use of the system, determined on an annual basis; and the member is required to contribute that proportion of the incurred costs.

The LCTF provides an example of finance and control in a national project with international participation. The United States funds, constructs, and operates the facility and pays the costs of its own test coils. The other participants pay for their own test coils. An executive committee, with one representative from each participant, decides on the test program.

The annual appropriation process makes it difficult for the United States to commit to multiyear projects without the possibility of facing a choice later of either reneging or sacrificing other elements of the fusion program.

Another limitation on the implementation of cooperative projects is to be found in conditions on the flow of money between the United States and foreign collaborators. For example, will the United States be willing to contribute money to construct a major facility sited in another country?

Finally, emphasis by the United States on equity and quid pro quo in current negotiations may be inimical to creating a spirit of mutual trust and cooperation.

To sum up, the success of any international cooperation depends upon the extent to which technical considerations and political requirements can be merged. Although previous experience can provide guidance, the appropriate implementation structure must be specifically designed for the project at hand.

SECOND WORKSHOP

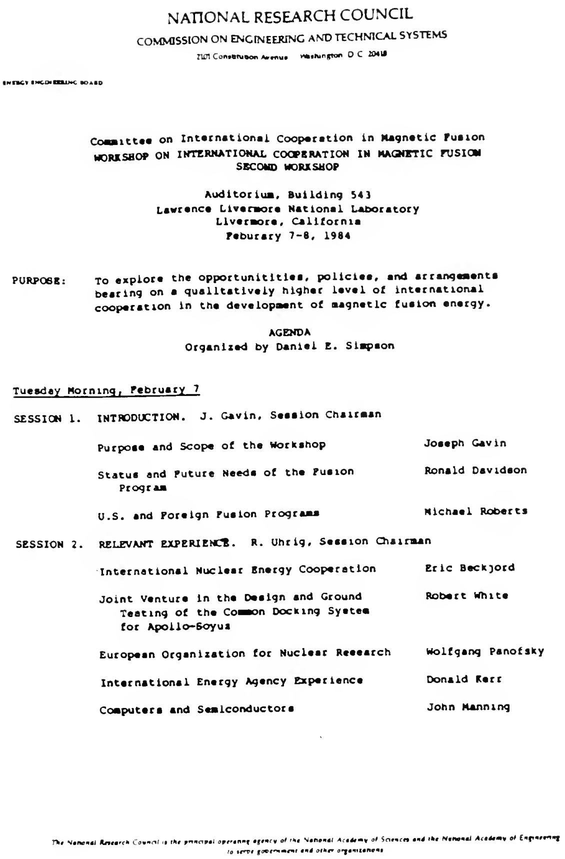
The agenda for the second workshop is given in Figure 2.

Technical and Programmatic Considerations

Fusion is viewed in most quarters as a potential energy resource and therefore as a technology that is important to develop. However, there is not a general recognition of a clearly defined goal of the development program. For example, one participant suggested that the world may pass over the fission breeder and go directly from the light water reactor to fusion; but the fusion program does not take such eventualities into account. Without clearly defined program goals, it becomes hard to use international cooperation as an effective means of reaching them.

Nevertheless, a recent report of the Magnetic Fusion Advisory Committee included the following brief introduction and summary of findings and recommendations with regard to the qualitative benefits of international cooperation in fusion:

> Fusion research and development have been characterized for several decades by active international cooperation and exchange of ideas. The U.S. fusion program has benefited significantly from work in other nations: the most striking example of this is the rapid U.S. development of the tokamak concept, originally investigated in the Soviet Union. Other nations' fusion programs have also benefited from U.S. research activities and concepts: for example, the stellarator approach, originally developed in the United States, is now actively pursued in Europe, Japan, and the Soviet Union. ...The INTOR studies provide an encouraging example of a major multinational advanced design activity....



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ENERGY ENGINEERING BOARD

Committee on International Cooperation in Magnetic Fusion
WORKSHOP ON INTERNATIONAL COOPERATION IN MAGNETIC FUSION
SECOND WORKSHOP

Auditorium, Building 543
Lawrence Livermore National Laboratory
Livermore, California
Feburary 7-8, 1984

PURPOSE: To explore the opportunitities, policies, and arrangements bearing on a qualitatively higher level of international cooperation in the development of magnetic fusion energy.

AGENDA
Organized by Daniel E. Simpson

Tuesday Morning, February 7

SESSION 1.	INTRODUCTION. J. Gavin, Session Chairman	
	Purpose and Scope of the Workshop	Joseph Gavin
	Status and Future Needs of the Fusion Program	Ronald Davidson
	U.S. and Foreign Fusion Programs	Michael Roberts
SESSION 2.	RELEVANT EXPERIENCE. R. Uhrig, Session Chairman	
	International Nuclear Energy Cooperation	Eric Beckjord
	Joint Venture in the Design and Ground Testing of the Common Docking System for Apollo-Soyuz	Robert White
	European Organization for Nuclear Research	Wolfgang Panofsky
	International Energy Agency Experience	Donald Kerr
	Computers and Semiconductors	John Manning

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations

FIGURE 2 Agenda for second workshop.

Tuesday Afternoon, February 7

SESSION 3. FUSION COOPERATION EXPERIENCE. R. Borchers, Session Chairman

Panel on U.S.-International Experience and Lessons Learned in Fusion Cooperation	Panel Chairman: R. Borchers INTOR: W. Stacey Doublet III: J. Gilleland RTNS-II: C. Logan FMIT: L. Trego

SESSION 4. TECHNICAL PROGRAM GOALS AND PERSPECTIVES ON INTERNATIONAL COOPERATION. D. Kerr, Session Chairman

Fusion Energy Potential, Technical Prospects, and Goals	Kenneth Fowler
Panel Discusson on Programmatic Objectives, Technical Needs, and Bases for Cooperation in Plasma Physics, Reactor Design and Technology, Materials, and Engineering	Donald Kerr, (Panel Chairman), Ronald Davidson, Kenneth Fowler, John Sellars, Donald Steiner

Wednesday Morning, February 8

SESSION 5. POLICIES ON INTERNATIONAL COOPERATION. J. Hendrie, Session Chairman

Panel Discussion on National Policy Objectives, Domestic Considerations, Public Interest and Acceptance, and Long-Term Implications of International Fusion Cooperation	Joseph Hendrie, (Panel Chairman), Vincent de Poix, Melvin Gottlieb, Richard Grant, Charles Newstead, Jan Roos, Gerald Tape

SESSION 6. MANAGEMENT AND IMPLEMENTATION. M. Muntzing, Session Chairman

Organization and Implementation of International Cooperative Agreements	Harold Bengelsdorf
Panel Discussion on Government and Industry Roles, Constraints, and Objectives for Implementing Programs of International Cooperation	M. Muntzing, (Panel Chairman), Eric Beckjord, Harold Bengelsdorf, Harvey Brush, Dwain Spencer

FIGURE 2 Agenda for second workshop (continued).

SESSION 7.	**SUMMARY. D. Simpson, Session Chairman**	
	Summary Conclusions and Remarks	Invited Participants
	Fusion Laboratory Tour for Invited Participants	
	Committee Meeting: Key Conclusions and Remarks.	Robert Uhrig, Donald Kerr, Robert Borchers, Joseph Hendrie, Manning Muntzing
	Fusion Laboratory Tour for Committee	

FIGURE 2 Agenda for second workshop (continued).

- The U.S. fusion program and the development of fusion on a worldwide basis have been benefited significantly from the active exchange of information and ideas. International cooperation in fusion research should continue to receive strong emphasis in the U.S. program.
- The planning of national fusion facilities and programs has been guided to a considerable extent by a policy of avoiding international duplication and instead addressing complementary technical issues. This policy is both cost-effective and conducive to rapid technical development. It encourages broader coverage of options in the area of alternate concepts and allows larger steps to be taken in the mainline approaches within existing budgetary constraints.
- While maximum effective use should be made of research facilities abroad, to supplement U.S. capabilities, the overall priorities of the U.S. program should continue to emphasize the most promising reactor approaches.
- The international fusion effort will benefit from increased consultation in program planning and from the initiation of coordinated--or even jointly supported--research projects.

--Magnetic Fusion Advisory Committee, 1983

At the time of the workshop TFCX was identified as the critical near-term project in the U.S. program, which should not be delayed for reasons of international cooperation. A representative of the Office of Fusion Energy, U.S. Department of Energy (DOE), described the proposed TFCX as the "entry into the age of fusion power" but occurring in the "age of budget deficits." He said that the Secretary of Energy appeared sympathetic to TFCX, but required an answer to the basic question: Should this be a national U.S. project or should it be international?

One participant advocated the following direction for the U.S. programs, including major initiatives in both tokamak and mirror fusion:

- The United States should position itself to lead an international effort in the 1990s by proceeding with TFCX.
- The U.S. fusion program should position itself to meet an energy crisis by 1990 by proceeding with TFCX and also a mirror device, complementary to TFCX, to test power-system components.
- The U.S. fusion programs should not rely on international cooperation now, but should be initiating steps toward expanded international cooperation, principally in technology development projects of moderate scope.

A number of workshop panelists emphasized the importance, to U.S. energy needs and technological leadership, of maintaining national control of program scope and direction, with opportunity for international partners to contribute but not to select just the most attractive areas of research and development. No compelling technical reasons for international cooperation were established, in the sense that competence missing in the United States might be joined with such competence existing elsewhere to accomplish what otherwise could not be done. Nevertheless, technology development takes longer than expected and contributions can come from unexpected sources. Hence, fusion hardware development should be internationally coordinated--a step beyond past (successful) information and personnel exchange programs.

It was suggested that national programs might progress by "half-steps," with successive (national) projects "leapfrogging" their foreign predecessors. It was noted that this course is essentially competitive rather than cooperative in that at any particular moment one group will be "ahead."

The following dilemma faces the advocates of specific cooperative projects: on the one hand, the United States should establish its objectives and requirements for an activity before deciding what to offer for international participation; but, on the other hand, potential international partners should be regarded as equals, with full participation in setting cooperative program objectives as well as scope.

Because of the long lead time for major fusion facilities and the commitment of resources to them well in advance, it may be hard to influence the upcoming generation of large tokamaks. Thus it may remain to focus joint planning on the generation after next.

Examples of International Cooperation in Fusion and Other Technologies

A few specific examples of international cooperation in magnetic fusion were described. One, FMIT, was under serious discussion at the time of the workshop but is so far lacking agreement on joint participation. Other projects, already carried out, have been successful. Although these projects encountered difficulties and delays similar to cooperative efforts in other fields, there was general agreement that there were net benefits to the participating partners.

Successful international cooperation in other technologies were also reported. Most of these efforts have been of rather specific scope and purpose, and they include large projects as well as small ones. In most examples, the partners contributed specified tasks and hardware. Some examples, notably CERN, have succeeded when the international partners contributed specified cash payments to the international project. All speakers reported on difficulties and delays in communication and agreement. An international project is more difficult and time-consuming than a purely national effort--one speaker guessed by a factor of two.

Although there may be common themes in these prior examples there is no formula that guarantees success. Nevertheless, we can improve the probability of success by adapting some of their best features and avoiding some of their pitfalls.

International Cooperation in Nuclear Fission

There are three levels where international cooperation in nuclear fission has been undertaken:

Information Exchanges Generally, information exchanges were successful if commercial consideration and licensing information were not involved. Overall, the United States has judged that it got less than it gave in dealing wtih other countries; but the exchanges have proceeded anyhow.

Small- to Medium-Sized Projects Often small or medium projects are part of a larger project that has been "sold" to other nations. These arrangements usually turn out to be beneficial to both parties in that they make more funds available for more work or they cut costs for the individual participants. Even so, the total cost of the project with multinational involvement is generally greater than if only a single nation is involved because of the time required for coordination. The successful programs have involved a clear program definition as well as a clearly defined scope for all the parties involved.

Large Projects Large projects are generally difficult to implement. They need a "lead" country, the classic example being the Super-Phenix, in which France is the lead partner and all other partners play lesser roles. The reason is that consensus management generally does not work in the technical field. The economic impacts on an individual country can be significant. The challenge of such international cooperation on large projects is to develop a strategy that can make the best of opportunities and overcome the difficulties.

The U.S.-USSR Apollo-Soyuz Docking Mission

There is little direct applicability to the fusion program of the international cooperation between the United States and the USSR in the Apollo-Soyuz spacecraft docking mission. The Apollo-Soyuz mission was a symbolic gesture of scientific cooperation to serve political objectives. Each party paid its own way. The overriding consideration was that both parties wanted the mission to succeed and they found a reason, namely, the potential rescue of astronauts, for proceeding. However, the following programatic details involved in this mission may be useful examples for future international cooperative efforts of a highly specific nature:

- The method of operation was documented before the program began.
- The project was managed by a technical project director.
- Each working group was cochaired by joint chairpersons, one from each country.
- Plans for the organization of the project established the documentation standards.
- Interacting Equipment Documents documented the technical requirements and were signed by the joint chairpersons as well as the technical directors, and copies were sent to all official files and all groups.
- Proposed changes were submitted on appropriate forms; there was no bypassing this procedure.
- Material for meetings was sent one month in advance.
- Telecommunications were sent between the parties every two weeks.
- Translations were reverified after each meeting and differences were reconciled.
- The parties agreed to use a common system of units, namely the International System of Units (commonly known by its French acronym SI), with only a couple of specific agreed-upon exceptions.

European Organization for Nuclear Research

The European Organization for Nuclear Research is a successful cooperative scientific organization, but its experience may not be relevant to fusion power development. The sole objective of CERN is the advancement of pure knowledge. There are few patent rights involved, there is no potential military or commercial application, and the transfer of "sensitive" technology usually is not a problem. Even so, along the way CERN has developed a number of tools that have been of economic value. Probably because of its success, CERN has eroded its original "base of the pyramid" concept for high-energy physics in Europe, in which each country was to provide its own "base" program with CERN functioning only as the apex of the pyramid. Instead, CERN attracted the best West European scientists and attracted most of the available money for large accelerator projects in the individual Member States. As a result, CERN's research tools are second to none in the world.

CERN is governed by its Council, which has two representatives from each country--one an administrative or political representative and the other a scientific specialist. The financing of the organization is through a percentage of gross national product of each country, with a cap of 25 percent of CERN's budget on the contributions of any country. The Council gives a stability to the organization, but it constitutes an inertia that is hard to overcome to take advantage of dynamic developing situations. One especially important matter is that there are no preestablished "national rights" for members; that is, no country is guaranteed any particular position for its representative, any specified share of procurements, or any priority as to its projects within CERN.

The programs of CERN, the United States, and the USSR in high-energy physics have generally been complementary, or at least confirmatory in nature. Nevertheless, systematic international planning might have avoided some of the parallelisms, such as the similarity between the Brookhaven and the CERN Alternating Gradient Synchrotrons and the electron-positron storage rings of the Stanford Linear Accelerator Center and the German Electron Synchrotron, DESY. The International Committee on Future Accelerators tends to deal with the "generation-after-next" accelerators because the selection of the next accelerator is too sensitive to deal with in an international committee. In particular, the 20 teraelectronvolt x 20 teraelectronvolt proton-proton collider proposed by the United States may have to become an international project if it is to attract firm commitment.

International Energy Agency

Another example of international cooperation, the International Energy Agency, was formed in 1974 after the oil crisis of that period. The overriding purpose of IEA was to deal with oil shortages through allocations to the various nations. The cooperative research and development program of IEA in energy was initiated to make some of the other activities palatable for the nations involved.

At the present time, IEA is spending about $500 million per year on 40 projects, down from a peak of 50 projects a couple of years ago. The governing board is made up of representatives at the ministerial level from the member countries. The U.S. representative is the Secretary of Energy. The management board is made up of representatives from the research and development establishments of the various member countries. For the United States this representative is the Director of the International Division of the Department of Energy. The Research and Development Committee of IEA, composed mostly of government research and development leaders from the participating nations, decides what research and development projects will be funded.

IEA specifically excludes any research and development in nuclear energy because that is covered by the Nuclear Energy Agency. Projects are carried out by various member countries and often involve bilateral or multilateral agreements among them. IEA serves the role of a research and development broker through the implementation of the IEA agreement. IEA is often involved in topical studies and technological assessment.

The IEA agreements specify the lead organization, and the countries involved in the reports provide a basis for overall management of the projects. The whole organization has fewer than 100 people, and it draws about one third of it support from the United States. IEA has been in operation for a number of years and has a good research and development record. However, the unfortunate experience with the Synthetic Refined Coal-2 project (commonly known as SRC-2) seriously hurt the image of the United States as a reliable partner in IEA work.

International Industrial Cooperation

There are a number of private companies operating internationally with experience that may be relevant as industry becomes more involved in fusion and as fusion ultimately approaches commercialization. International Business Machines Corporation (IBM) is such a company, and some of its policies were explained. IBM has manufacturing facilities and laboratories in 18 countries; each foreign laboratory is under the control of a counterpart U.S. laboratory. The corporation markets and services equipment in most countries of the world and tries to manufacture equipment in the region where it is used. IBM owns patents and leases the rights to these patents to the subsidiary laboratory (for instance, IBM-Japan). The firm also licenses patents to others under certain restricted circumstances. The corporation shares technology at the laboratory level and through publications, but it takes the necessary steps to protect its intellectual property rights. The corporation uses marketing agents (both governmental and nongovernmental) in foreign countries but it retains control of the technology. IBM will withdraw from any country that demands equity in a subsidiary or access to technology as a condition for operation.

Policy Considerations

There was a general acknowledgment that international cooperation in the development of magnetic fusion is certainly desirable and probably necessary. This view arose from a balancing of the probable gains and losses related to the policy considerations brought out in the workshop. However, there was a wide dispersion of views as to how extensive cooperation should be and to what extent it should influence U.S. programs as well as policies. This divergence clearly reflected different evaluations of the balance of gains and losses. For example, one person argued for international cooperation on the smaller steps, although reserving U.S. leadership for TFCX. Another argued that the United States should concentrate on only U.S.-funded projects until a decision point around 1990, when international projects would again be considered. The experts should do more homework and conduct more discussion on specific alternative research and development plans in order to establish a clear strategy and objectives for international cooperation. One cannot make decisions until these points are resolved.

It was proposed that an implementation plan, more specific than the CPMP, is needed to guide the U.S. program. Such a plan would identify the goals and milestones needed to satisfy the national interest. The plan would guide the development of the industrial base for a magnetic fusion power program and would provide the means of evaluating the best opportunities for international cooperation. The plan should have a sound technological basis and should provide a clear statement of U.S. policies in some detail. Questions such as when we should aim to have a viable fusion power capability, what it will replace, and at what cost it is likely to be economical should be covered to the extent practical. One view was that there is no urgency for fusion power plants or fusion-fission hybrid facilities in the early 21st century. Thus, the appropriate research and development pace is consistent with emphasis on an international cooperative programs.

Workshop participants thought that some key decisions on budget and program direction would have to be made soon. For example, at the time of the workshop, proposals for TFCX were being formed. Accordingly, it seemed that decisions were needed on the technical scope of the machine and whether it is to be proposed solely a U.S. project or as a joint venture with others. Then, it seemed necessary to face hard questions of how to accommodate another major fusion machine within prospective budgets. It seemed unlikely that all of the current U.S. work can be continued if TFCX were to be built by the United States alone. Even with some of the costs shared by others, the U.S. part would be a major project.

International cooperation should enlarge the potential benefits; consequently, barriers and difficulties may diminish. Cooperative programs should be developed from open discussions of options for accomplishing mutual objectives. The cooperating parties need to have real contributions to offer and real benefits to obtain.

International collaboration, in the sense of working actively together as approximately equal partners in sizeable enterprises, as distinct from cooperation, in the sense of acting with others for mutual benefit on a small scale, is already vital to some U.S. industry. International cooperation in fusion should continue, with assurance of benefits to U.S. industry. Component and equipment industries should be close to the program because ultimately, the best developed industry will dominate. Program planning should consider how to hold industry attention for the long term. The policy panel of the workshop thought that national industrial policy issues, in connection with both national security and the capture of economic benefits, and technology transfer issues would become increasingly difficult as magnetic fusion development moves toward engineering tests and utilization technology development. U.S. magnetic fusion research, carried out in national laboratories, is as open to foreign businesses as to U.S. firms. This openness does not exist abroad, where much research is considered proprietary. As magnetic fusion work leads toward commercial utilization, foreign firms are likely to have more government support in terms of sales assistance and financing terms than U.S. business, to judge by present practices in the nuclear, electronic, and military equipment fields.

Pressures to collaborate internationally on fusion matters are growing. The key motivating factor concerns finances resulting in cost-sharing concepts being pursued. Such international cooperation should not be deemed a threat to domestic programs but rather a reinforcement of national efforts. It was acknowledged, however, that it is often hard to get commitments for international activities for more than three to four years; but, even if so limited, international cooperation can be helpful to all participants.

The meetings following the Summit of Industrialized Nations at Versailles in 1982 and Williamsburg in 1983 offer an opportunity for international cooperation in magnetic fusion development that may not easily be created again. These meetings, under the thrust of the political initiative from the Heads of State, have determined that the IEA would provide the institutional basis for cooperative fusion program efforts. Specific programs have not yet been discussed, so the time is ripe for presenting initial proposals for cooperation, including joint projects. There was concern in the workshop that uncertainty and argument, in the U.S. fusion community, over the proper next steps might make it difficult to seize the opportunity offered by the Summit initiative.

One speaker held a pessimistic view of fusion as an electric power source. He suggested that the threshold for utility acceptance and use of fusion for power production would be much greater than was the threshold for fission power. Therefore, a much more complete scientific and engineering basis would be necessary to convince utilities to use fusion power. However, this objective could be achieved through international cooperation in science, engineering, safety reviews, and concept selection. Although the speaker thought there was no urgency for fusion power, he concluded that international cooperation would, when the time comes, greatly assist in the process of convincing electric utilities to adopt fusion power. The workshop was also reminded of the need for the eventual public acceptance of fusion and the role of public information about it.

From the point of view of national security, major fusion projects with the USSR are not considered feasible; a joint U.S.-EC-Japan framework may be best.

It was thought not constructive to negotiate too cleverly, to the disadvantage of a partner; such a policy will create a powerful competitor in time.

Implementation and Management Considerations

Various approaches to international cooperation are possible including bilateral, multinational, and international agreements. One possibility is to use the IEA, which is established and has experience behind it, although some of its management concepts may be difficult to work with. Regardless of which approach is used, an essential ingredient is to have strong political support from the nation's leaders to set the tone for international cooperation. This solidarity is hard to achieve in the United States because of different points of view between the Administration and Congress. International cooperation involving the United States must take into account these difficulties and accommodate them so that the United States is not deemed to be an unreliable partner.

Technological developments usually take longer than projected and opinions change as to when major achievements have been reached. Therefore, it is difficult to hold the attention of industry for three to four decades, which may be the time required for fusion technology. This fact makes international cooperation difficult. Nevertheless, the participation of industry is an important aspect of fusion development, both as a matter of policy and in implementation of policy. Industry must determine how it can learn the technology as well as contribute it to the long time frames that are expected.

The relationships between an international board of directors and the project manager are crucial to the success of a project. If both are weak, then the international effort will be a disaster. A strong project manager and a weak board can work together successfully in good times. A strong board and a strong project manager may produce a success but at the same time have conflict potential. In the case of a strong board and a weak manager, the manager will have to go, and quickly. In any case the cooperative project must be managed at the technical level, although policies may be set at the political level.

Overall, the workshop panel members concluded that international cooperation in fusion can work and, in fact, has worked. Panel members encouraged further cooperative efforts. However, it is important to understand the views of potential partners so that agreement is reached through mutual understanding and discussions. For management and implementation of the program to be effective, there are several significant essentials:

- The political process must be reliable and perceived to be so.
- The national scientific community must have something to offer, and it will expect to get something in return.
- Industry must be brought into the process at an early date, and problems such as the current utility structure must be considered from the beginning.

On the assumption that the United States will undertake more international cooperation in fusion, the fusion community should develop some basic priciples for negotiating the agreements. Four points come to mind from the workshop discussions:

- The basic motive is national self-interest, providing and receiving scientific and technical resources in order to achieve an earlier return on the resource expenditure than would otherwise be possible.
- The agreements should provide for a workable system of management and decision making to get the project done on time.
- The effort should call on U.S. industry as well as the fusion research community to the greatest extent possible.
- The agreements should provide for licensing and technology transfer between the partners, such that U.S. industry will have access at a reasonable price to elements of technology provided by partners but not duplicated by U.S. industry under the agreements.

The formulation of a set of negotiating principles would be an appropriate task for a group of key people representing industry, laboratories, and universities to advise the Secretary of Energy. The work of this group should also be made available to the Director of the Office of Science and Technology Policy, officials of the Department of State, and others who will have a voice in what international cooperation is actually proposed and undertaken. The subject is important enough to receive top level attention.

APPENDIX C

SUMMARY OF TRIP TO JAPAN

Five members of the Committee on International Cooperation in Magnetic Fusion, of the Energy Engineering Board of the National Research Council-National Academy of Sciences, visited several magnetic fusion organizations in Japan from April 9-14, 1984. The group consisted of Joseph G. Gavin, Jr., chairman of the committee; Robert R. Borchers, Melvin B. Gottlieb, Weston M. Stacey, Jr., and Robert E. Uhrig, all members of the committee; and Dennis F. Miller and John M. Richardson, of the committee staff.

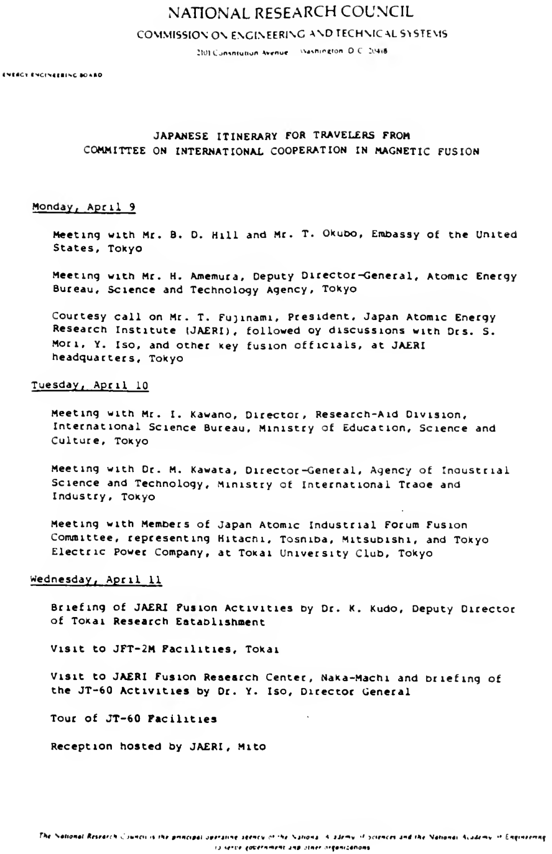
The group met in Tokyo with officials of the Science and Technology Agency; the Ministry of Education, Science and Culture; the Ministry of International Trade and Industry; the Japan Atomic Energy Research Institute; the Japan Atomic Industrial Forum; and the Nuclear Fusion Council of the Atomic Energy Commission. The group also conferred with officials at laboratories of the Japan Atomic Energy Reseach Institute at both Tokai and Naka-Machi, the Electrotechnical Laboratory and University of Tsukuba at Tsukuba, and the Institute of Plasma Physics of Nagoya University at Nagoya. Altogether, about 50 individuals participated in the various meetings.

The itinerary is shown in Figure 1.

PURPOSE AND ROLE

The purpose of the trip was to exchange preliminary views on the advantages and disadvantages of a greater level of international cooperation in magnetic fusion development. The committee wished to explore the technical needs and opportunities for international cooperation, the benefits that might flow to the cooperating countries, and the broad nature of the arrangements under which cooperation might be conducted. The primary goal was to assess the probability of cooperation on the "next big machine" and to find out how such international cooperation might be brought about.

The role of the travelers was to exchange views and to gather information as informally as possible. The committee had no authority to speak or act for the U.S. Government. The function of the committee was purely advisory.



NATIONAL RESEARCH COUNCIL
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
2101 Constitution Avenue Washington, D.C. 20418

ENERGY ENGINEERING BOARD

JAPANESE ITINERARY FOR TRAVELERS FROM COMMITTEE ON INTERNATIONAL COOPERATION IN MAGNETIC FUSION

Monday, April 9

Meeting with Mr. B. D. Hill and Mr. T. Okubo, Embassy of the United States, Tokyo

Meeting with Mr. H. Amemura, Deputy Director-General, Atomic Energy Bureau, Science and Technology Agency, Tokyo

Courtesy call on Mr. T. Fujinami, President, Japan Atomic Energy Research Institute (JAERI), followed by discussions with Drs. S. Mori, Y. Iso, and other key fusion officials, at JAERI headquarters, Tokyo

Tuesday, April 10

Meeting with Mr. I. Kawano, Director, Research-Aid Division, International Science Bureau, Ministry of Education, Science and Culture, Tokyo

Meeting with Dr. M. Kawata, Director-General, Agency of Industrial Science and Technology, Ministry of International Trade and Industry, Tokyo

Meeting with Members of Japan Atomic Industrial Forum Fusion Committee, representing Hitachi, Toshiba, Mitsubishi, and Tokyo Electric Power Company, at Tokai University Club, Tokyo

Wednesday, April 11

Briefing of JAERI Fusion Activities by Dr. K. Kudo, Deputy Director of Tokai Research Establishment

Visit to JFT-2M Facilities, Tokai

Visit to JAERI Fusion Research Center, Naka-Machi and briefing of the JT-60 Activities by Dr. Y. Iso, Director General

Tour of JT-60 Facilities

Reception hosted by JAERI, Mito

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations

FIGURE 3 Japanese itinerary.

Thursday, April 12

Meeting with Dr. M. Sugiura, Chief, Energy Division, Electrotechnical Laboratory, Tsukuba

Courtesy call on Dr. N. Fukuda, President, University of Tsukuba, Tsukuba

Visit to Plasma Research Center, University of Tsukuba, Dr. S. Miyoshi, Director, Tsukuba

Friday, April 13

Meeting with Dr. T. Uchida, Director, Plasma Physics Laboratory, Nagoya University, Nagoya

Saturday, April 14

Meeting with Dr. H. Kakihana (Former Director, Plasma Physics Laboratory, Nagoya University) and Dr. T. Miyajima, Chairman, Nuclear Fusion Council, Japan Atomic Energy Commission, at JAERI Headquarters, Tokyo

FIGURE 3 Japanese itinerary (continued).

SOME BASIC DIFFERENCES BETWEEN JAPAN AND THE UNITED STATES

Japan appeared to have a firmer, more consistent government energy policy deriving from its lack of natural resources. We were told that Japan intends to be successful wtih the light water reactor, the fast breeder reactor, and eventually the fusion reactor. The Japanese approach to the development of fusion contemplates only one device, the Fusion Experimental Reactor (FER), between JT-60 and a fusion power demonstration reactor (DEMO). By contrast, the United States contemplates two steps beyond its Tokamak Fusion Test Reactor (TFTR) before a demonstration reactor. The Japanese seem to have more direct industrial consulation and participation in the fusion program than the United States. Japan's electric utilities are more centralized and appear to be more financially sound than those of the United States. There are also well known basic cultural differences--language, numbers of people involved in decision making, and differences in security requirements.

There is a noteworthy incompatibility between the U.S. and Japanese approaches to large national research programs. The Japanese have an elaborate research coordinating structure within their government that brings to bear all aspects and views of a proposed research program. Decisions are reached by consensus, which involves compromise after all views are expressed. The process is called the "bottom-up" approach to decision making. As a result, there is great difficulty in changing a program, once approved. Rather, the emphasis then shifts to doing the agreed job as well as possible. In contrast, the United States uses a "top-down" approach, in which decisions are made by "top-level advisory committees," government administrators, and Congress with relatively little technical input. The U.S. emphasis is often on diversity of effort with a view to taking advantage of new developments.

This difference in approaches, in our opinion, need not be resolved; but it must be taken into account in all efforts to achieve cooperation wtih the Japanese. Both approaches have merit and every effort should be directed towards bringing the best of each approach to bear in the proposed joint efforts. Perhaps some middle ground between U.S. fluidity and Japanese rigidity would be best. Although it is clear that actual cooperation can come only after agreement at the highest levels, such action is only a necessary condition, not a sufficient one.

The program of university research conducted by the Ministry of Education, Science and Culture (Monbusho, after its Japanese acronym) seems less closely integrated with the program goals of the Japan Atomic Energy Research Institute (JAERI) and the Science and Technology Agency (STA) than the counterpart U.S. programs.

THE FUSION PROGRAM OF JAPAN

Large Facilities

The current Japanese program is based on a 1975 decision to build the tokamak device, JT-60, as a national project carrying the highest priority.

This policy was expanded in 1981 by a recommendation of the Nuclear Fusion Council, which was adopted by the Atomic Energy Commission in 1982. The program called for development work by JAERI under STA, leading toward a tokamak reactor, and basic reseach, including small-scale work on alternate approaches, at the universities and National Laboratories under Monbusho. The dividing lines between the two segments are not entirely clear.

The STA-JAERI program is focussed on developing the tokamak concept to the commercial stage in a sequence of experiments (JT-60 to FER to DEMO) and supporting technology development activities. At present, the primary emphasis in the program is on completion of JT-60 (Japan Atomic Energy Research Institute, 1982). The Naka site of JT-60 will also accommodate the FER. The purpose of FER is not only to demonstrate plasma ignition and burning, but also to provide a facility for testing and demonstrating fusion technology. The current JAERI plan is to construct FER on the Naka site, with a decision in the late 1980s, after JT-60 results are evaluated, to initiate construction. Officials at STA and the Science Council expressed a less firm commitment to FER, noting that the plan was made three years ago in a different financial climate.

The STA-JAERI program accounted in 1981 for over 77 percent of the budget. JT-60 expenditures in 1981 constituted 80 percent of the JAERI expenditures.

The JT-60 is now at about 85-percent completion, with first plasma expected in about one year and completion of the heating systems about a year later. The total cost will be over $1 billion. All components are being thoroughly tested. Expenditures will be high but decreasing during 1985 and 1986, freeing up some funds for the development work scheduled for FER. The cost of FER is anticipated to be about $2 billion plus about $0.7 billion for development.

The general impression of the committee is that the Japanese have a strong and well planned applied research program in nuclear fusion--much stronger than many committee members expected to find. The JT-60 is clearly in the same "generation" as the TFTR at Princeton even though it will operate with hydrogen only. The "on time-within specification" construction of JT-60 is impressive. The back-up test and development facilities lend credibility to the optimism of the Japanese regarding their ability to design, build, and operate their next big test facility, FER.

Small Facilities

The Monbusho university program in basic research is built around a variety of small- to intermediate-scale experiments at several locations (Uchida, 1983). GAMMA-10 tandem mirror at Tsukuba, Heliotron E stellarator at Kyoto, and JIPPT tokamak and NBT bumpy torus at Nagoya are the largest. The Institute of Plasma Physics (IPP) at Nagoya has proposed to build a larger reacting plasma tokomak and is using this proposal as justification for acquiring a new site. Larger tandem mirror, heliotron, and laser fusion experiments have been proposed. It is generally acknowledged that only one of these will be approved because of financial constraints. The Monbusho program on alternative confinement concepts is active and productive. It is anticipated that an intermediate-sized device costing about $200 million will be authorized within the next year or two. Apparently there is a tacit agreement that any new alternate concept magnetic confinement experiment will be located at IPP.

The Monbusho program accounted in 1981 for 22 percent of the budget, about a third of which was allocated to the inertial confinement program at Osaka University. None of these figures includes personnel costs, which are separately funded.

STA also supports a reversed-field pinch experiment at the Electrotechnical Laboratory (ETL). Most of these machines are more recent versions of similar U.S. devices. They benefit signficantly from the U.S. experience, the availability of better instrumentation and computers, and the traditional Japanese attention to detail and quality workmanship. Some of these facilities have supercomputers (Fujitsu Falcom-100, which is comparable to the Cray-1 computer in the United States) available for analysis and data processing.

Particularly noteworthy among the development efforts is the work on superconducting coils conducted at JAERI and ETL.

Cooperation on research at the university and national-laboratory level (generally charcterized as pure science) with unrestricted publication of results and international exchange of scientific information is a democratic tradition that has served both Japan and the United States well over the years. Exchanges of personnel between laboratories (especially postdoctoral fellows) have enhanced this traditional mode of international cooperation. While smaller-scale cooperation of this sort is useful, it was not the main thrust of our visit to Japan.

Key Groups and Attitudes in the Japanese Fusion Effort

JAERI clearly has the intiative in Japan's large-scale fusion development. The Nuclear Fusion Council of the Atomic Energy Commission seems supportive of the JAERI program. STA seems to be the government agency with the greatest responsibility for large-scale fusion.

Monbusho is not closely connected to the mainline effort. Its role in fusion is to support basic science and promising alternative fusion concepts in the universities. Officials at Monbusho disclaimed any responsibility for international collaboration in fusion development. No expansion in collaboration with the United States at the university level is foreseen because of flat budgets. As of April 1, 1984, the Monbusho fusion program was transferred from the Research Aid Division to the Applications Division; this transfer implies that fusion research is firmly established in Monbusho, comparable to other macrosciences, such as space science and high-energy physics. The process by which university fusion research results move toward application and commercialization was not clearly brought out.

The Ministry of International Trade and Industry (MITI) is watching fusion development with interest, but does not yet seem to be a dominant force.

A generally positive attitude about international cooperation was expressed by ministry officials (STA, Monbusho, and MITI), by fusion program leaders (JAERI, ETL, IPP, and University of Tsukuba) and by influential advisors (Nuclear Fusion Council), albeit with different emphasis:

- STA officials seemed to be favorably disposed because of Japanese financial constraints.
- Monbusho officials endorsed the principle but were apparently concerned about the impact on their budget.
- MITI officials were noncommital.
- JAERI leaders were positive, probably because of their awareness of both financial constraints and technical benefits, but emphasized that coooperative activities must fit into their own program.
- IPP leaders were noncommital and were apparently concerned that major cooperation together with a contrained Japanese budget might adversely affect their program.
- Nuclear Fusion Council members indicated that international cooperation must play a larger role than they had previously thought, presumably because of Japanese financial constraints.

The Japan Atomic Industrial Forum (JAIF) represents industry's interests in fusion (Japan Atomic Industrial Forum, 1983). Industry is actively involved as supplier of experimental equipment and exhibited great interest in acquiring and protecting fusion "know-how." Industry representatives of JAIF expressed a generally negative attitude on international cooperation, an attitude which seemed to be motivated primarily by their desire to supply the Japanese effort themselves. This group did not appear to be concerned that Japanese financial constraints may reduce the size of that effort or stretch out the period over which it is distributed. These representatives also indicated that Japan should not rely on anv other country for the development of any technology that is critical. One form of collaboration proposed by JAIF was to let Japanese vendors supply components for U.S. fusion experiments.

A concern about the reliability of the United States as a partner in international collaborative ventures was forcefully expressed by almost all groups. Volatility and instability in U.S. policy and inadequate planning and erratic changes in direction at the fusion program management level were cited as major concerns, under the polite term of "flexibility." It was made clear that the strongest possible implementing agreement, perhaps a treaty, would be necessary if the Japanese were to undertake a major collaboration with the United States.

In discussions with the JAERI program leaders a distinction was drawn between collaboration and cooperation. JAERI officials defined collaboration as each partner contributing about 50 percent (in a bilateral undertaking) and having a proportional voice in the decisions about objectives, design features, and so forth. Alternatively, cooperation was defined as one partner contributing about 10 percent towards the cost of the other partner's experiment in return for the opportunity to make some input to these decisions. Under this view, collaboration on a major project must start with joint formulation of the objectives, schedule, design features, and so forth. Under the other view, one country may appropriately ask another country to cooperate in a project which the former has defined, provided that the latter country is given the opportunity to make input to the final project definition.

The Japanese emphasized that a decision to cooperate on a particular activity must be developed "from the bottom up" in their system. This practice means that the activity must make technical and programmatic sense to everyone involved. As if to illustrate the point, our discussions about international collaboration went much better at the level of working scientists, who knew each other and were comfortable in mutual discussion, than at the level of ministry administrators, who were generally noncommittal.

If nuclear fusion were anywhere near the application stage, we doubt that there would be any Japanese interest at all in cooperating with the United States or anyone else. However, the practical or commercial application of nuclear fusion is decades away, and the total development costs may run into tens of billions of dollars. Under these circumstances it is hard for anyone to be against international cooperation in fusion research, especially since federal funding of nuclear fusion research seems to have stabilized in both the United States and Japan. Program administrators see international cooperation as a means of conserving scarce resources. Scientists see cooperation as a means of expanding or accelerating their program. In the real world, international cooperation may actually slow down a project and increase the total cost beyound what it would have been for one country.

All groups with which we spoke endorsed international collaboration in principle as desirable or necessary for technical progress, risk sharing, and cost sharing. International collaboration is more important to Japan now than it was three years ago. Japan and the United States should think seriously about how to cause collaboration to come about. However, there may be a perception that the United States is interested in collaboration only because it cannot raise the needed funds alone. The converse perception may also be true about Japan. Specific proposals must be examined before specific commitments to international collaboration can be made. There was general agreement among the Japanese that it would be useful to start discussions in the near future regarding possible major cooperative efforts.

Achieving international collaboration will take time. Ideally, discussions would begin in 1985, after JT-60 operating results are available and when a better idea of the post-JT-60 machine has been formulated.

The ultimate commercialization goal need not preclude collaboration at the research and development level. There seemed to be no explicit indication of any national "race" to develop fusion, or strategies to run the race, or concern for the benefits of winning and the penalties of losing.

There seemed to be a preference for bilateral collaboration over multilateral because of the added complexity of the latter. Multilateral collaboration was thought to be harder on a big machine than on a technology test project. However, a case-by-case determination was thought necessary. There is reasonable possibility of planning a big (bilateral) effort with a satisfactory division of tasks. However, careful planning is needed because mistakes will be costly. It will be hard to include the Soviet Union.

COLLABORATION ON MAJOR FUSION PROJECTS

International cooperation must not impair the national programs. Extensive collaborative projects will have to satisfy the national programmatic objectives of the participating nations. Less extensive cooperative programs can be conducted at the margins of the national programs.

For purposes of discussing a specific possibility of collaboration, committee members introduced the subject of the Tokamak Fusion Core Experiment (TFCX), which, at the time of the trip, had been proposed in the United States. There seemed to be more real interest in collaborating on major fusion projects (like TFCX and FER) than on technological test facilities (like large coils, blankets, and tritium processing). The Japanese have set up cooperative programs with both the European Community and the United States that form important components of the Japanese planning. Japanese officials would certainly like to continue and to expand such activities, although there are some problems of implementation. An important area of discussion was whether this cooperation could be extended to collaboration on large devices, a particular example being TFCX. The

JAERI leaders believe that, even at a constant budget level, it might be possible to build FER on a unilateral basis. The FER would be a considerably more ambitious project than TFCX.

The Japanese technical leaders have a uniformly negative view about an experiment with only plasma physics objectives, such as some TFCX options, as an appropriate next-step experiment. They believe that engineering and technology objectives must have a major role in their next-step experiment. The view was expressed by JAERI program leaders that TFCX is seen as a U.S. solution to a U.S. situation--TFTR is operating and there is a need to move ahead towards the next step to maintain momentum, but the budget is constrained. Hence, TFCX, with the promise of early results, was seen as a good U.S. tactic. The Japanese believe that an experiment with more ambitious engineering and technology objectives would be appropriate for international collaboration. The JAERI program leaders made it clear that it would be inappropriate for the United States to ask Japan to collaborate on TFCX in the large-scale sense defined in the preceding section. They left open the possibility of cooperation, implying a more modest undertaking.

A possible joint TFCX-FER program emerged from discussions with JAERI leaders:

- Japan would cooperate with the United States on TFCX by accepting U.S. design and contributing certain Japanese-made components. Japanese interest here is limited to component technologies relevant to FER. JAERI leaders would consider this work as part of their own technology development program. Although the magnitude of the Japanese contribution was not explicitly discussed, there was a distinct impression that a figure of 10 percent or less was meant.
- The United States would reciprocate by cooperating, in the above sense, on FER.
- Japan and the United States would cooperate on their respective technology development programs in support of FER.

The JAERI leaders feel that it would be possible for either side to obtain technical benefit from a collaborative project located in another country, but not without inconvenience. Experience in fabrication could be equitably shared by a balanced procurement program. Construction and operating experience could be obtained by long-term assignment of personnel.

A number of problem areas that would be associated with a collaborative project were identified--patents, different budget mechanisms and fiscal years, difficulty in controlling delays, personnel policies, and so forth.

Cost-sharing on TFCX at any appreciable level might impede the FER and thus delay Japanese progress toward a tokamak reactor unless there were some high-level agreement between Japan and the United States that would increase Japan's budget by the amount needed for its work on TFCX. It was also suggested at one point that international collaboration on TFCX could well convert it to a more ambitious (and more expensive) project.

The idea put forth by the Japanese that their cooperation might take the form of delivering components for the next big U.S. fusion machine, provided that the experience gained would enhance their ability to manufacture components for their next big machine, is a clear advantage for them (and a potential disadvantage for the United States in the long run). This arrangement would allow the Japanese to develop the manufacturing capability that assures that they alone would posess the ability to advance the next generation of machines. In exchange, they would expect to receive the tritium-handling and other technology we have developed. Given the poor U.S. performance on the Large Coil Test Facility (LCTF), this proposal may be the best we can hope for in cooperative efforts.

Officials at MITI noted that collaboration can occur on smaller projects as well. Small-scale collaboration can be a precursor to large-scale.

COOPERATION ON BASIC RESEARCH, TECHNOLOGY, AND ALTERNATIVE CONFINEMENT CONCEPTS

The U.S.-Japan joint agreement for cooperation in fusion appears to be an adequate mechanism for establishing further cooperative activities in basic science and technology and in research on alternative confinement concepts.

One university group would appreciate a recommendation from the committee to increase collaboration at the university level. Cooperation under the joint agreement over the past few years appears, on the whole, to be viewed by the Japanese as successful. However, several complaints arose in the discussions:

- The U.S. centers for some of the activities are located in areas that are difficult to reach and difficult of access because of security requirements (for example, Sandia National Laboratory at Albuquerque and Oak Ridge National Laboratory).
- The United States did not make use of the Japanese bumpy-torus results in its evaulation of the concept.

Japan is engaged in research on a wide range of alternative confinement concepts (tandem mirror, heliotron-stellarator, reversed-field pinch, compact toroid, bumpy torus, and so forth). Cooperative planning of research and evaluation of results seems appropriate.

The Japanese scientists appear to have achieved a significant advance in superconducting magnets. Their progress in the LCTF program, sponsored by the International Energy Agency and administered by Oak Ridge National Laboratory, is impressive. Of the six participants, only the Japanese delivered their superconducting magnet on schedule and thoroughly tested, thereby demonstrating its ability to meet specifications. As of the time of the trip, the German and Swiss coils were just being delivered almost a year late; and the three U.S.-manufactured coils have been a "disaster." The General Electric Company delivered its coil as its "best effort" and then recommended that it be scrapped. The Westinghouse and General Dynamics coils are delayed and are having manufacturing difficulties. With this kind of track record, one wonders that the Japanese would consider cooperating with the United States. Clearly U.S. industry has done an outstanding job on building equipment for the space program--one wonders why it cannot do equally well in the nuclear fusion program.

PROBABLE CONDITIONS ON COLLABORATION

There are several desirable principles for international collaboration:

- No erosion of the strong national programs.
- Mutual benefit.
- Participating on an equal footing.
- Assurance of continuity in the collaboration.
- Acceleration of the national programs of the partners.
- Overlap of program interest.
- Achievement together of what is not achievable separately.
- Full participation in planning right from the beginning; unilateral planning is not acceptable.
- Full access to the technology that is developed.

Cost sharing alone is not a sufficient reason to collaborate. It is not clear what level of cost for a large machine would trigger collaboration, but $1 billion was mentioned.

Japan must acquire fusion technology for its own use. The Japanese investment in collaboration must come back for the benefit of Japanese industry. Patents and know-how must be protected.

JOINT PLANNING

There seemed to be a dilemma in the Japanese position in that one could not discuss near-term candidates for cooperation or collaboration because that planning was already fixed. On the other hand, one could not discuss future candidates because that planning had not yet been done. The attitude was that no joint planning had really been done to date, but that there existed a possibility in the 1985-1988 time period for useful joint planning.

No existing organization, such as the International Energy Agency and the International Atomic Energy Agency, is really suitable to manage international collaboration. A new mechanism is needed, which may come out of the Versailles Summit process.

For managing a large facility, a "lead country" is needed. Putting decisions to "middle-level" bueaucrats is to be avoided; they are reluctant to take initiative.

Our final meeting, with representatives of the Nuclear Fusion Council of the Atomic Energy Commission, was particularly useful. That group was much more positive about fusion than we had been led to expect. The group also seemed positive about cooperation with the United States. In particular, it was said that starting some joint discussion now on TFCX would be good. One working group would be needed to discuss the best concept for TFCX. Another working group would be needed to discuss how to implement collaboration. It was suggested that the TFCX concept be addressed at the forthcoming May 1984 meeting of the U.S.-Japan Joint Coordinating Committee. Japan would participate in the early TFCX planning without any prior commitment to collaborate on construction. U.S. ideas on TFCX would be disclosed by preparing a report available to Japanese scientists. An intention was expressed to convey an interest in Japanese participation in early TFCX planning to an appropriate U.S. program leader.

There was a general consensus that discussions of options should continue on a long-term basis and that any large-scale collaboration would require considerable joint discussions and planning at a technical level as well as a firm commitment at a high level.

Certainly at the subministerial level of the agencies with which we spoke (STA, Monbusho, and MITI) there was an obvious (and well-prepared) reluctance to discuss any alternative that extended beyond the explicit policies expressed in the Atomic Energy Commission planning document of 1982.

SUMMARY IMPRESSIONS

The visiting members of the committee greatly impressed with the Japanese research efforts in nuclear fusion. The committee believes the United States has much to gain from cooperation with Japan. It seems timely to launch a serious well-organized joint planning effort. It is unlikely that any agreement toward future joint effort on a billion-dollar scale will result without such a base.

It is necessary to deal separately with the STA-JAERI complex and the Monbusho-university complex on cooperative or collaborative programs. Major next-step tokamak experiments and technology development are within the purview of the former agencies, while basic research and alternative confinement concept experiments come under the jurisdiction of the latter.

The existing U.S.-Japan cooperative agreement machinery is an adequate mechanism for definition and implementation of cooperation with the Monbusho-university programs.

A new mechanism is needed for definition and implementation of large-scale collaboration on next-step tokamak experiments and the supporting technology development. A workshop, on the model of the International Tokamak Reactor (commonly known as INTOR), might meet periodically to define questions to be answered by each country in the interim between meetings, to discuss these answers, and to draft tentative agreements. Such a workshop could formulate a cooperative or collaborative program, guide its implementation, and monitor its progress. Participants in this workshop should be permanent, so as to establish continuity, and should have the stature and background to address the technical and administrative aspects.

A cooperative and collaborative program of the type suggested by the JAERI leaders would work to the long-term disadvantage of the United States because the Japanese would gain a disproportionate share of the valuable industrial experience relevant to a next-generation machine. However, the suggestion provides a starting point for working out a more favorable program, perhaps involving a collaboration (in the sense defined above) on an engineering test reactor (FER in the case of Japan). There were indications from the JAERI leaders that subsequent U.S. cooperation on a Japanese FER need not be an essential element of the collaboration.

Some attention must be paid to reconciling the Japanese "bottom-up" and the U.S. "top-down" decision-making processes. U.S. fusion program leaders might benefit by adopting, for their own programs, some aspects of the Japanese procedure of developing a consensus among the technical people involved. Such an approach would not only lead to better thought-out programs, but would also lead to a greater compatibility between the U.S. and Japanese technical program objectives. On the other hand, a necessary prerequisite to useful cooperation is agreement between the governments at the very top, which embraces cooperation as national policy.

APPENDIX D

SUMMARY OF TRIP TO EUROPE

Some of the members and staff of the Committee on International Cooperation in Magnetic Fusion, of the Energy Engineering Board of the National Research Council-National Academy of Sciences, met with a number of officials in Europe from May 20-25, 1984. The members were Joseph G. Gavin, Jr., chairman, Robert R. Borchers, Melvin B. Gottlieb, L. Manning Muntzing, and Daniel E. Simpson. In addition Dennis F. Miller and John M. Richardson, of the committee staff, accompanied the group.

Visits were made in Brussels to officials of (1) the Directorate General for Science, Research and Development of the Commission of the European Communities and (2) the U.S. Ambassador to the Commission of the European Communities. The group also met in Bonn with officials of the Federal Ministry for Research and Technology and the Max Planck Institute for Plasma Physics. In Paris the group conferred with officials of (1) the Institute for Basic Research of the Nuclear Studies Center (2) the International Energy Agency, and (3) the Embassy of the United States. The group then visited the Joint European Torus and Culham Laboratory of the United Kingdom Atomic Energy Authority, both near Abingdon, in Oxfordshire, England. Finally the group met with officials of the U.K. Atomic Energy Agency in London. The group interacted with about 40 individuals. The itinerary is given in Figure 1.

PRINCIPAL IMPRESSIONS

Before discussion at somewhat greater length, the principal impressions from the trip may be stated as follows:

- o The need to develop fusion energy is not equally urgent in Japan, the European Community (EC), and the United States, so that the incentives to cooperate are not equally strong.

NATIONAL RESEARCH COUNCIL
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
2101 Constitution Avenue Washington D C 20418

ENERGY ENGINEERING BOARD

EUROPEAN ITINERARY FOR TRAVELERS FROM COMMITTEE ON INTERNATIONAL COOPERATION IN MAGNETIC FUSION

Monday, May 21

Meeting with Prof. D. Palumbo, Directorate General for Science, Research, and Development, Commission of the European Communities, Brussels

Meeting with Honorable George S. Vest, United States Ambassador to the Commission of the European Communities, Brussels

Tuesday, May 22

Meeting with Dr. G. Lehr, Director General, Federal Ministry for Research and Technology, Bonn

Dinner hosted by Dr. K. Pinkau, Scientific Director, Max Planck Institute for Plasma Physics

Wednesday, May 23

Meeting with Dr. J. Horowitz, Director, Institute for Basic Research, Nuclear Studies Center, Fontenay-aux-Roses

Reception hosted by Dr. Thomas J. Wajda, U.S. Mission to the Organisation for Economic Cooperation and Development, and Dr. John P. Boright, Embassy of the United States, Paris

Thursday, May 24

Meeting with Dr. Eric Willis, Director, Office of Energy Research, Development, and Technology Applications, International Energy Agency, Paris

Meeting with Dr. H.-O. Wuster, Director of the Project, Joint European Torus, Abingdon

Dinner hosted by Drs. Wuster and Pease, Oxford

Friday, May 25

Meeting with Dr. R. S Pease, Authority Programme Director for Fusion, Culham Laboratory, U.K. Atomic Energy Authority, Abingdon

Meeting with Mr. G. Stevens, Assistant Secretary, Atomic Energy Division, U. K. Department of Energy, London

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations

FIGURE 4 European itinerary.

- There is no long-run commitment to the integration of the EC and U.S. economies, so that the economic cooperation that impels cooperation in fusion within EC is absent between EC and the United States and in its stead is the ultimate prospect of economic competition.
- The separate stakes in fusion held by the EC, Japan, and the United States may not easily be subordinated to a common effort seeking merely reduced research costs and earlier results.
- Nevertheless, there is a pressure for cooperation from the Versailles Economic Summit and there is receptivity to it at the EC level.
- The preservation of the identity of the EC program will be a likely constraint on wider international cooperation.
- There is technical need and opportunity for cooperation in dovetailing and phasing large, world-class machines; but the desirability of technical diversity and the primacy of indigenous interests may preclude the early consolidation of planned EC, U.S., and Japanese machines into one common effort.
- There is technical need and opportunity for cooperation on alternative concepts and generic technology, but such cooperation will probably be paced more by problems of implementation than by technical urgency.
- The goals of the EC and the U.S. programs have not been articulated explicitly enough to formulate a specific plan for cooperation.
- The United States must deal through EC rather than directly with any Member State.
- The desirability of the United States as a partner is low because of perceived past unreliability in honoring commitments, ungenerous insistence on quid pro quo, efforts to attract financial support from EC, and tendencies to put forward its low priority projects as candidates for cooperation.
- Nevertheless, joint planning for the period from 1988 onward is both possible and welcome.
- Promising institutional forms for large cooperative projects go more toward the Joint European Torus model than toward the International Energy Agency model.

With regard to the fuller discussion that follows, recall that the European program is administered at the level of the Commission of the European Communities. Nevertheless, input to the Commission comes from the various Member States. Views at both levels need to be explored to provide a comprehensive picture. Thus there are often differences of viewpoint at the country level before reconciliation into a single Commission viewpoint.

THE FUSION PROGRAM OF THE EUROPEAN COMMUNITY

In the words of the most recent proposed five-year plan, for 1985-89,

> ...the Community Fusion Program is a long-term cooperative program embracing all the work carried out in the Member States in the field of controlled thermonuclear fusion. It is designed to lead in due course to the joint construction of prototype reactors with a view to their industrial production and marketing (emphasis added).
>
> --Commission of the European Communities, 1984b

The EC program is about two-thirds of the size of the U.S. program, with the tokamak as the dominant approach. The overall program is staffed by about 3500 people, slightly over 1000 of whom are professionals. There is no mirror confinement and little inertial confinement work going on. Alternative confinement schemes being studied are the stellarator and the reversed-field pinch, together representing roughly 10 percent of the program. Almost all of the work is carried out in national laboratories rather than in universities.

Roughly half the support comes from the EC, the other half coming from separate national budgets of Member States.

The flagship of the program is the large Joint European Torus (JET) tokamak (about twice the volume of the Tokamak Fusion Test Reactor), installed adjacent to Culham Laboratory. JET is funded 80 percent by the EC and 20 percent by EC Member States individually. Budgets for the whole EC program are prepared and funded on a five-year basis and are reformulated after three years. The project is staffed by personnel drawn from all the European national laboratories, for example, Culham, Garching (Federal Republic of Germany), Fontenay (France), Frascati (Italy), and Jutphas (Netherlands). JET is now in the early operational phase. Successful completion of the facility represented a major success for European cooperation.

In addition to JET there are three large ($40 million to $100 million) tokamaks being built at Caderache, France (TORE SUPRA); Garching (ASDEX Upgrade); and Frascati (FTU). The TEXTOR device at Julich, Federal Republic of Germany, continues operation. Each of these four tokamaks is expected to stress a different aspect of tokamak physics while at the same time serving to maintain the national capability and national objectives of the participating EC countries.

The EC program is coordinated by the EC staff in Brussels, utilizing a "consultative committee" drawn from all member states. Each national program (or "Association") is managed by a steering committee drawn from both the EC and the particular association.

Future planning is centered on the Next European Torus (NET). The new tokamaks (previously mentioned) will probably go into operation in 1987, and JET is expected to attain operation with tritium in 1989. Assuming favorable results from these experiments, NET might move from conceptual design to detailed engineering design by 1988 and into construction by 1991.

NET conceptual design studies are now under way at Garching with an EC team under the leadership of a former director of the Italian laboratory (NET Team, 1984). NET is viewed currently as an engineering test reactor. The current intent is that NET should provide all the data needed for a real, though perhaps not an economic, power-producing reactor. Other, less ambitious, options will also be studied. These studies have not yet developed to a point where they can be compared with U.S. designs and cost estimates, but such comparisons should be possible beginning later this year.

INCENTIVES AND CONSTRAINTS

Needs for Program Results

An obvious condition for successful international cooperation is that the needs of the participants for program results must be reasonably compatible. A French official noted that both the EC and the U.S. programs lacked clear enough objectives to provide high compatibility. Although the stated goal of the EC program--"construction of prototype reactors with a view to their industrial production and marketing"--seems straightforward, it omits much detail as to performance, schedules, and cost. U.S. goal statements are even less definite.

United Kingdom (U.K.) officials noted that the need for fusion perceived in that country was not strong, since the United Kingdom still exports energy. Fast breeder reactors were thought to be more promising and less costly. The point was made that materials research in connection with the fast breeder reactor is not "open." This remark is interpreted to be an indication of approaching commercial interest. Fusion work is needed mainly as an "insurance policy" and is not to be supported to the detriment of fission research. A German official held similar views. These views imply a descending level of incentive for fusion in Japan, the EC, and the United States and correspondingly different levels of effort.

There was little evidence of any French purpose or objective that will provide an incentive for more than incidental international cooperation in fusion beyond the EC program.

Economic Cooperation and Competition in the Long Term

The long-term economic benefits from fusion are thought to be great, but they certainly cannot be estimated accurately. All three of the world-class programs thus lack quantitative justification for their size and pace. The same long-term feature necessarily puts support for the program in the public sector. The utilities in Europe, as eventual end users, are even more content than those in the United States to watch and wait without investing their own money.

Cooperative efforts on fusion within the EC are driven by the accepted reality of long-run economic cooperation. Thus natural obstacles to fusion cooperation have been overcome. There is faith that the ultimate economic benefits will be captured more or less equitably by all EC participants through normal diffusion within the European economy.

By contrast, there is no natural economic force that compels the EC and the United States to cooperate. The natural long-run competitive relationship will prevail and will make obstacles to fusion cooperation hard to overcome. The same observation holds between the EC and Japan and between the United States and Japan. No mechanism assures that the economic benefits will be captured equitably. More specifically, the fundamentally different treatment of government patent rights in Japan and the United States, for example, remains an unresolved obstacle.

One might expect that the separate stakes in fusion perceived by the EC, Japan, and the United States would tend to persist unaltered and not be easily subordinated to international cooperation.

The Influence of the Versailles Summit

The stated aim of the Summit Working Group in Controlled Thermonuclear Fusion is "to reach a consensus on the desirable strategy in fusion in order to facilitate early joint planning to coordinate individual development programs." Thus, by pushing for a world strategy to which all can agree, the meeting of the Summit of Industrialized Nations at Versailles in 1982, together with subsequent meetings, constitutes an external force toward cooperation. A German official was sympathetic with Summit guidance for joint planning of sequential (or phased) programs in the three world regions. U.K. officials conceded that high costs might compel a high-level mandate for cooperation, say, if the costs of NET reached the neighborhood of $4 billion.

Character of the Program of the European Community

Fusion collaboration within the EC is viewed with much pride as a showpiece of research and development. JET is similarly viewed as the showpiece of fusion. There is significant desire by several of its participants, especially Germany, to maintain the self-sufficiency of the EC program. Germany supports cooperation as much for the psychological benefits of European cooperation as for actual progress in fusion. German officials were not anxious to broaden the scale of cooperation, since EC unity might be diminished and the German contribution might lose relative importance thereby.

A U.K. official had no view, without extensive staff analysis, as to whether the EC program should proceed alone or collaborate with

Japan or the United States. The same official, however, expressed reservations about any attempts to accelerate the EC program.

Thus preservation of the unity and coherence of the EC program, tailored as it has been to fit member-country needs, may be an important constraint on any broader-scale cooperative planning.

European Attitudes

A draft proposal for an EC Council decision (Commission of the European Communities, 1984b) states, "The Commission is convinced that international collaboration on fusion research and development is particularly desirable." At the political level of the Summit of Industrialized Nations, which includes the EC, science advisors to their respective governments have endorsed international scientific cooperation (Science, 1983; Science, 1984). A senior official of the EC fusion program, speaking from a position intermediate between the political and the management level, said that international cooperation should be an essential part of the fusion program, not just an incidental part. This official added that the EC is trying to extend collaboration beyond its frontiers. The motive may be anticipated budget problems associated with the high costs of future large devices. However, the three world-class programs would have to be brought into better coordination in order to enjoy fruitful cooperation on the next large step.

Attitudes in individual Member States differed somewhat from the above sentiments. Germans were largely opposed to large-scale cooperation with the United States, believing that the EC could probably pursue fusion development by itself. They perceived the United States as interested mainly in the one-way flow of cash from the EC to the U.S. program. French officials thought that collaboration was likely only on medium-sized projects and that, if the small-scale cooperation did not work, it would be all the harder to collaborate on large projects. French officials complained about lack of U.S. cooperation on the TORE SUPRA project. A U.K. official expressed his country's reluctance to become enmeshed in another large technology project like the Concorde supersonic transport. Another U.K. official noted that three-way collaboration would have such difficulties with design agreement, siting, procurement, and project management that it might not be workable in practice.

There are limits to large-scale cooperation, as evident in the second report of the so-called Beckurts Committee (Commission of the European Communities, 1984a), recently released. The Beckurts report recommends that expenditures "should be sufficient to keep Europe fully effective, competitive and thus in a strong position to negotiate information exchange and cooperation agreements with other partners." The report further recommends maintaining "a self-consistent European planning, avoiding too much reliance on decisions from other programmes." Overall, however, it would appear that international collaboration is desired by the EC, although the extent and nature still are to be determined.

With regard to international cooperation, there are several different possibilities:

- The EC, Japan, and the United States prefer to place primary reliance on their own programs in a self-sufficient way.
- All three entities prefer to place primary reliance on their own programs, subject, however, to joint planning of scientific and technical developments.
- Two or three of the entities desire to establish international relations that have a high degree of interdependence.

The attitude at the EC level seemed to be that the first possibility is not desired and that they are prepared to proceed at this time with the second, with the remote possibility of moving to the third sometime later if other matters are progressing well.

An International Energy Agency official cautioned that U.S. insistence on strict quid pro quo is counterproductive. The official also advised against completing a U.S. design for its proposed Tokamak Fusion Core Experiment (TFCX) and then asking for international financial support for such a design. This move would repeat the Fusion Materials Irradiation Test (FMIT) mistake.

No serious thought of large-scale collaboration with the USSR was evident.

TECHNICAL NEEDS AND OPPORTUNITIES

EC seems to have a coherent and unified technical program, with JET at the center and with complementary efforts filling gaps without duplication of effort. An extension to world cooperation first requires some consensus on the future world program, then improved collaboration on smaller projects, like FMIT, and then advances to larger projects. International agreements in force, such as TEXTOR, Large Coil Task (LCT), and Radiation Damage in Fusion Materials, lend encouragement to this view.

Large Machines

There was universal EC agreement on the JET to NET to demonstration reactor (DEMO) strategy. NET will be the basis for international cooperation on the next step. The aim of the 1985-1989 EC program is to establish the physics basis for NET, intended to be a burning reactor. Reactor-relevant technology is planned in conjunction with NET, but individuals disagree as to the relative importance of this feature.

German officials favored several world-class machines to provide the technical diversity necessary for achieving optimal solutions for a fusion reactor. German officials also felt that EC must have its own machine to learn the technology of fusion. This view precludes the strategy of a single world machine. By contrast, the Summit Working Group recommends that parties "review the advantages and disadvantages of one single comprehensive project versus several interdependent, complementary, and partially sequential machines."

French officials were cool to the concept of TFCX. They perceived TFCX as more a matter of political expediency to maintain U.S. momentum than a matter of sound scientific investigation. Most of the Europeans believe that (1) the present TFCX designs are not sufficiently ambitious--for example, spending an additional 50 percent would more than double the value of the device--and (2) the insertion into the world scene of a device like TFCX might delay NET, which they regard as more fully committed. A "reasonable" share of TFCX costs (over $100 million) would be extremely difficult for EC to commit. Even to help support FMIT would require the difficult process of requesting supplemental funding. Some of the European reluctance to express any interest in an ignition experiment like TFCX is certainly attributable to their waiting for the performance of JET to be understood better.

Technology Projects

The EC program seems in clear need of access to FMIT or equivalent, as well as other technology development work. However, the EC inclination is not to contribute to the construction costs of FMIT; and no funds are in the 1985-1989 budget for it. One the other hand, one French official did favor finding money for the operation of FMIT.

The opportunity to cooperate on TORE SUPRA is offered to the United States. TORE SUPRA may critically need U.S. support to maintain position in EC.

The future of the International Tokamak Reactor (commonly known as INTOR) study is pending, with U.K. and French officials not persuaded of the merit of further effort.

AGREEMENT AND IMPLEMENTATION

The Unity of the Program of the European Community

The EC program is extremely stable and long-term. It has provided significant benefits that would not have been realized otherwise, such as division of labor, concentration of effort, mobility of personnel, establishment of JET, and significant participation of European industry. These features are valued so much by the Member States that the continuation of the unity of the program will certainly be sought as a feature of wider international cooperation. Furthermore, all member countries would insist that wider cooperation be carried out only via the framework of EC, rather than by direct national agreements.

The national components of the EC program are highly valued now; but in time they may be supplanted by Commission activities only, just as the European Organization for Nuclear Research (commonly known by its original French acronym CERN) supplanted national activities in high-energy physics. Provided the EC member countries remain economically cooperative rather than competitive, this result may be acceptable.

Reliability of the United States as Partner

Officials of EC, IEA, France, Germany, and the United Kingdom stressed reliability, predictability, and avoidance of arbitrariness of style as essential to U.S. partnership in the implementation of cooperation. FMIT and LCT were cited as examples of prior U.S. unreliability in fusion, the Synthetic Refined Coal 2 (commonly known as SRC-2) project in energy, and the International Solar Polar Mission in space exploration. U.K. officials acknowledge a need for flexibility in program content, but opt for rigidity in carrying through projects, once agreed. A way to provide flexibility in programs is to collaborate over a broader base, so that tradeoffs are available. An IEA official advised the United States to stop putting forward its low priority projects for international cooperation.

While granting that some instances of the sort have occurred, one must still entertain the possibility that complaints about the reliability of the United States are being exploited as a bargaining position.

Institutional Suitability

The International Atomic Energy Agency (IAEA) is not a promising institutional home for collaboration because of USSR membership and because of the small scope and relevance of the IAEA fusion program.

The IEA has a record as a suitable institution for medium-sized projects, like LCT, but does not seem to have the infrastructure to manage large-scale collaboration, nor to be likely to acquire it.

A French official noted that, whatever the institutional entity, international agreement lends a project an extra degree of stability, protecting the project against budget fluctuations. The effect may be due to the perceived importance of the existence of an agreement.

The Europeans, by virtue of JET and the overall EC experience, seem better able to cope with the idea of international cooperation in a realistic way. Our discussions did not address how cooperation with the United States could be achieved without political and economic ties similar to those within the EC. No one seemed convinced that United Nations sponsorship or a "world science fund" could succeed. The issue of access to high technology information and know-how, not to mention technology with potential military applications, will need to be faced without an overall political and economic umbrella like the EC. Such matters are not simple even with such an umbrella, as the breeder program demonstrates. Finally the issue of siting a large world-wide, or even a bilateral, endeavor will be an enormous problem.

The Joint European Torus as a Model of Project Management

The governance of JET (Commission of the European Communities, undated) seems to be a successful model, well worth study and imitation for implementation of other large international fusion projects. The undertaking enjoys great stability because of high-level commitments sought and obtained early in the program planning and budgeting process. The Director of the Project has broad authority and responsibility. He reports to and is subject to annual budget and program review by the JET Council. The Executive Subcommittee of the JET Council also approves procurement contract selection over 200,000 European Units of Account (ECU). The Scientific Subcommittee reviews in detail, and approves, the "project development plan." The JET management system has been intact and has worked effectively since project initiation in 1978.

JET does not supersede various national activities, because they are still needed to round out the program. By the time NET is undertaken these programs are expected to have run their courses, and more national activities may not be needed. A U.K. official suggested that NET may require new political agreements and organization beyond JET.

Participation in JET by an additional country, say the United States, would be possible upon approval by the Director of the Project, the JET Council, and the Council of the European Communities.

Joint Planning for Increased Cooperation

The United States might well consider fusion in a larger context of cooperation in science and technology, so as to match the EC science structure better. For example, fusion might be considered along with breeder reactors, space technology, computers, or biotechnology.

It was clearly stated, from JET experience, that joint multilateral effort involves interdependence, requires vigorous debate to produce an agreed program, and should result in a program of considerable stability.

Since the preponderant view is that international cooperation will be necessary but that it will take time and effort to achieve, it is generally agreed that it would be appropriate to start the discussions soon. Discussions should take place at two levels. First, there should be an effort to reach agreement on program goals since the Europeans do not understand current U.S. program goals. Second, there should be joint efforts at a technical level to see if agreement can be reached on the intermediate objectives and the possible timing of the major devices and facilities that would be needed, as well as the critical criteria and decision points that would be involved in the go-ahead decisions.

There are new agreements in preparation that will keep the possibility of cooperation active at medium levels of effort, at least. However, what is lacking now is an international joint planning team to consider concepts for TFCX or equivalent, NET, and the Fusion Experimental Reactor proposed by Japan and how these machines might be modified to give optimum phased advances. German officials thought that joint planning would be feasible only for the period from 1988 onward, since plans until 1988 are rather firm. It was conceded that there is some flexibility in the EC program for NET, through joint planning, to take advantage of whatever physics results might be provided by TFCX. U.K. ministers would countenance some exploration of the possibility of bringing the world-class fusion programs together. A U.K. official noted it was still an open question of whether EC will go forward to NET and DEMO by itself, with only the incidental help of others, or will seek a truly joint undertaking with Japan or the United States. The former course has the advantage of making sure the technology is acquired by the EC, and the latter course has the advantage of probable savings in cost and time.

A JET official noted that an outside country could participate in a large EC project, like NET, say, without participating in all the rest of the EC program. A U.K. official would like to see as much collaboration as possible on smaller projects to gain experience and confidence.

Site selection for NET will remain a difficult issue, as judged by prior insistence to exclude the site of JET and by the competition among Cadarache, Garching, and Ispra as candidate sites.

It seems that, given a strong and well presented U.S. initiative, an international agreement on joint program planning and collaboration at intermediate project sizes could be achieved. However, there would be substantial obstacles, problems, and friction in reaching agreement and in implementation. The question is: Is it worth it?

APPENDIX E

PRINCIPAL PARTICIPANTS IN DOMESTIC WORKSHOPS AND FOREIGN MEETINGS

FIRST WORKSHOP ON INTERNATIONAL COOPERATION IN MAGNETIC FUSION

CHARLES C. BAKER, Argonne National Laboratory, Argonne, Illinois
JAMES R. BOGARD, United Technologies Corporation, East Hampton, Connecticut
JOHN F. CLARKE, U. S. Department of Energy, Washington, D.C.
ROBERT W. CONN, University of California, Los Angeles, California
GEORGE W. CUNNINGHAM, MITRE Corporation, McLean, Virginia
RICHARD D. DELAUER, U. S. Department of Defense, Washington, D.C.
JOHN DUGAN, U. S. House of Representatives, Washington, D.C.
HAROLD P. FURTH, Princeton University, Princeton, New Jersey
JOHN R. GILLELAND, GA Technologies, Incorporated, San Diego, California
PAUL N. HAUBENREICH, Oak Ridge National Laboratory, Oak Ridge, Tennessee
GERALD HELMAN, U. S. Department of State, Washington, D.C.
GERALD L. KULCINSKI, University of Wisconsin, Madison, Wisconsin
SUSAN KUZNICK, U. S. Department of Energy, Washington, D.C.
BRYAN H. LAWRENCE, Dillon-Read, Incorporated, New York, New York
DAVID LEIVE, International Telecommunications Satellite Organization, Washington, D.C.
JOHN L. MCLUCAS, COMSAT World Systems Division, Washington, D.C.
JOHN N. MOORE, University of Virginia, Charlottesville, Virginia
MICHAEL ROBERTS, U. S. Department of Energy, Washington, D.C.
JOHN SHEFFIELD, Oak Ridge National Laboratory, Oak Ridge, Tennessee
NORMAN TERRELL, National Aeronautics and Space Administration, Washington, D.C.

SECOND WORKSHOP ON INTERNATIONAL COOPERATION IN MAGNETIC FUSION

ERIC S. BECKJORD, Argonne National Laboratory, Argonne, Illinois
HAROLD D. BENGELSDORF, International Energy Associates, Washington, D.C.
HARVEY F. BRUSH, Bechtel Group, Incorporated, San Francisco, California

RONALD C. DAVIDSON, Massachusetts Institute of Technology, Cambridge, Massachusetts
VINCENT DE POIX, Teledyne Wah Chang, Albany, Oregon
T. KENNETH FOWLER, Lawrence Livermore National Laboratory, Livermore, California
JOHN R. GILLELAND, GA Technologies, Incorporated, San Diego, California
RICHARD L. GRANT, Boeing Engineering Company Southeast, Incorporated, Oak Ridge, Tennessee
ROBERT A. KRAKOWSKI, Los Alamos National Laboratory, Los Alamos, New Mexico
CLINTON M. LOGAN, Lawrence Livermore National Laboratory, Livermore, California
JOHN D. MANNING, IBM-Americas-Far East Corporation, North Tarrytown, New York
CHARLES NEWSTEAD, U. S. Department of State, Washington, D.C.
WOLFGANG K. H. PANOFSKY, Stanford University, Stanford, California
MICHAEL ROBERTS, U. S. Department of Energy, Washington, D.C.
JAN N. ROOS, TRW, Incorporated, Redondo Beach, California
PAUL RUTHERFORD, Princeton University, Princeton, New Jersey
JOHN A. SELLARS, TRW, Incorporated, Redondo Beach, California
DWAIN F. SPENCER, Electric Power Research Institute, Palo Alto, California
DONALD STEINER, Rensselaer Polytechnic Institute, Troy, New York
GERALD F. TAPE, Associated Universities, Incorporated, Washington, D.C.
C. LAMAR TREGO, Westinghouse Hanford Company, Richland, Washington
ROBERT D. WHITE, NASA Johnson Space Flight Center, Houston, Texas

MEETINGS IN JAPAN

NOBARU AMANO, Japan Atomic Energy Research Institute, Tokyo
H. AMEMURA, Science and Technology Agency, Tokyo
TSUNEO FUJINAMI, Japan Atomic Energy Research Institute, Tokyo
JUNJI FUJITA, Nagoya University, Nagoya
NOBUYUKI FUKUDA, University of Tsukuba, Ibaraki-Ken
HIDEO IKEGAMI, Nagoya University, Nagoya
HIDATAKE KAKIHANA, Atomic Energy Commission, Tokyo
M. KAWAGUCHI, Science and Technology Agency, Tokyo
IWANE KAWANO, Ministry of Education, Science and Culture, Tokyo
MICHIO KAWATA, Ministry of International Trade and Industry, Tokyo
K. KUSAHARA, Ministry of Education, Science and Culture, Tokyo
AKIRA MIYAHARA, Nagoya University, Nagoya
TATUOKI MIYAJIMA, RIKEN Institute of Physical and Chemical Research, Wako-Shi Saitama
S. MIYOSHI, University of Tsukuba, Ibaraki-Ken
SIGERU MORI, Japan Atomic Energy Research Institute, Tokyo
Y. OBATA, Japan Atomic Energy Research Institute, Tokai
JIRO SATO, Ministry of Education, Science and Culture, Tokyo
KOHEI SATO, Electrotechnical Laboratory, Ibaraki

MASARU SUGIURA, Electrotechnical Laboratory, Ibaraki
S. TERASAWA, Hitachi, Limited, Tokyo
YOSHINOSUKE TERASHIMA, Nagoya University, Nagoya
KENICHI TOMABECHI, Japan Atomic Energy Research Institute, Ibaraki-Ken
TAIJIRO UCHIDA, Nagoya University, Nagoya
M. WADA, Science and Technology Agency, Tokyo
KENZO YAMAMOTO, Japan Atomic Industrial Forum, Incorporated, Tokyo
MASAGIO YOSHIKAWA, Japan Atomic Energy Research Institute, Ibaraki-Ken

MEETINGS IN EUROPE

K. H. BECKURTS, Siemens A.G., Munich, Federal Republic of Germany (with Joseph G. Gavin only)
ROY BICKERTSON, JET Joint Undertaking, Abingdon, Oxfordshire, England
JOHN P. BORIGHT, Embassy of the United States of America, Paris, France
F. DIERKENS, UNIPEDE, Brussels, Belgium
P. FASELLA, Commission of the European Communities, Brussels, Belgium
UMBERTO FINZI, Commission of the European Communities, Brussels, Belgium
JULES HOROWITZ, Commissariat a l'Energie Atomique, Gif-sur-Yvette, France
GUNTHER LEHR, Bundesminister fur Forschung und Technologie, Bonn, Federal Republic of Germany
MICK LOMER, Culham Laboratory, Abingdon, Oxfordshire, England
R. S. PEASE, Culham Laboratory, Abingdon, Oxfordshire, England
DONATO PALUMBO, Commission of the European Communities, Brussels, Belgium
KLAUS PINKAU, Max-Planck-Institut fur Plasmaphysik, Garching, Federal Republic of Germany
PAUL REBUT, JET Joint Undertaking, Abingdon, Oxfordshire, England
GEOFFREY H. STEVENS, United Kingdom Department of Energy, London, England
ROLF THEENHAUS, Kernforschungsanlage Julich, Julich, Federal Republic of Germany
GEORGE S. VEST, United States Mission to the Commission of the European Communities, Brussels, Belgium
H.-F. WAGNER, Bundesminister fur Forschung und Technologie, Bonn, Federal Republic of Germany
THOMAS J. WAJDA, United States Mission to the Organisation for Economic Cooperation and Development, Paris, France
ERIC H. WILLIS, International Energy Agency, Paris, France
HANS-OTTO WUSTER, JET Joint Undertaking, Abingdon, Oxfordshire, England

GLOSSARY

ASDEX: Axisymmetric Divertor Experiment, in the Federal Republic of Germany.

CERN: European Organization for Nuclear Research (after its original French acronym).

CPMP: Comprehensive Program Management Plan.

DEMO: Fusion Power Demonstration Reactor.

Divertor: A magnetic field configuration that directs the trajectories of impurity atoms out of the fusion plasma.

DOE: U. S. Department of Energy.

D-III: Doublet III.

D-T: Deuterium-tritium fuel cycle.

EBT: Elmo Bumpy Torus, an alternative fusion reactor concept.

EC: European Community.

Electron cyclotron resonance heating: Technique of radio-frequency plasma heating that puts energy directly into the plasma's electrons.

ECU: European Unit of Account.

ETR: Engineering Test Reactor.

ETL: Electrotechnical Laboratory, Japan.

EURATOM: European Atomic Energy Community.

FED: Fusion Engineering Device.

FER: Fusion Experimental Reactor, Japan.

FMIT: Fusion Materials Irradiation Test.

FTU: Tokamak planned for 1987 operation at Frascati, Italy.

IAEA: International Atomic Energy Agency.

IBM: International Business Machines Corporation.

IEA: International Energy Agency.

Impurities: Atoms heavier than the fusion fuel, the presence of which in the fuel volume can remove by radiation the energy needed to sustain ignition.

INTELSAT: International Telecommunications Satellite Organization.

INTOR: International Tokamak Reactor.

IPP: Institute for Plasma Physics, Nagoya University, Japan.

JAERI: Japan Atomic Energy Research Institute.

JET: Joint European Torus, at the JET Joint Undertaking, near Abindgon, in Oxfordshire, England.

JIPPT: Stellarator hybrid, Japan.

JT-60: Tokamak under construction at the Japan Atomic Energy Research Institute.

LCT: Large Coil Task.

LCTF: Large Coil Test Facility, at the Oak Ridge National Laboratory.

LLNL: Lawrence Livermore National Laboratory.

Magnetic confinement: Any scheme that seeks to isolate a hot (fusion) plasma from its surroundings by using magnetic lines of force to direct the charged particles.

MFAC: Magnetic Fusion Advisory Committee, advisory to the Office of Fusion Energy, U. S. Department of Energy.

MFTF: Mirror Fusion Test Facility, Lawrence Livermore National Laboratory.

MITI: Ministry of International Trade and Industry, Japan.

Monbusho: Ministry of Education, Science and Culture, Japan, after its Japanese acronym.

Neutral-beam injection: Heating of contained plasma toward ignition by injection of beams of energetic (typically greater than 100 thousand electronvolt) neutral atoms, which can cross the magnetic lines of force but which are later ionized in the contained plasma, thus being themselves contained.

NET: Next European Torus.

ORNL: Oak Ridge National Laboratory.

OTR: A next-generation engineering test reactor, USSR.

Plasma: A gas comprising some large fraction of charged particles.

Radio-frequency heating: The application of radio-frequency eletromagnetic power (loosely speaking--microwave power is included under this rubric), which, when in resonance with the gyromagnetic properties of the plasma, can be used to deposit energy in it, thus heating toward ignition.

Reversed-field pinch: An alternative magnetic confinement concept under investigation in several countries.

RTNS-II: Rotating Target Neutron Source II.

STA: Science and Technology Agency, Japan.

Stellarator: A toroidal device (pioneered in the United States) wherein plasma equilibrium and stability are achieved by externally imposed magnetic fields rather than by torodial currents within the plasma, as in the tokamak.

Super-Phenix: A 1200-megawatt (electric) fast breeder reactor, in France.

Tandem mirror: A magnetic containment device in which two mirror machines close the ends of a simple magnetic solenoid.

TEXTOR: A plasma technology experiment built by the Federal Rebublic of Germany.

TFCX: Tokamak Fusion Core Experiment, proposed in the United States.

TFTR: Tokamak Fusion Test Ractor, Plasma Physics Laboratory, Princeton University.

TORE SUPRA: Tokamak being built at Caderache, France.

Tokamak: A magnetic containment device in which the magnetic lines of force are closed on themselves in the shape of a torus, with a large current flowing through the plasma.

Toroidal: The azimuthal direction, about the central axis, within a toroidal containment device.

U.K.: United Kingdom.

BY THE U.S. GENERAL ACCOUNTING OFFICE

Report To The
Honorable Fortney H. Stark, Jr.
House Of Representatives

The Impact Of International Cooperation In DOE's Magnetic Confinement Fusion Program

The U.S. fusion community participates in many cooperative projects with other countries conducting research in fusion energy--a new potential source of virtually unlimited nuclear power. Many of these projects involve routine exchanges of information. Others are pursued under formal agreements that allow U.S. and foreign scientists to participate in research at U.S. and foreign fusion facilities and may involve the contribution of funds and/or equipment.

U.S. fusion energy experts believe that international cooperative efforts benefit all participants and contribute to the advancement of U.S. fusion research objectives. International cooperative efforts, of themselves, do not directly affect the U.S. leadership position in fusion energy. Because fusion energy is in such an early stage of development, it is unlikely that any country could obtain a commercial advantage from information obtained from ongoing international cooperative efforts.

GAO/RCED-84-74
FEBRUARY 17, 1984

UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

RESOURCES, COMMUNITY,
AND ECONOMIC DEVELOPMENT
DIVISION

B-210947

The Honorable Fortney H. Stark, Jr.
House of Representatives

Dear Mr. Stark:

In a July 19, 1982, letter you requested that we address a number of issues relating to fusion energy--a potential new source of virtually unlimited nuclear power. At that time, we were conducting a review of the Department of Energy's (DOE's) implementation of the Magnetic Fusion Energy Engineering Act of 1980 (Public Law No. 96-386) in response to an earlier request from you. After completing the audit work for our April 1983 report,[1] we agreed with your office to focus our efforts on international cooperation in fusion energy development. Specifically, we agreed to address the following questions:

--What is the United States' policy and strategy for international cooperation in fusion energy development?

--What are the different types of fusion international cooperative efforts?

--What is the possible impact of international cooperative efforts on the United States' ability to maintain its world leadership position in fusion energy development?

--What problems have been encountered in international cooperative fusion efforts and how have these been resolved?

--What is industry's role in international cooperative fusion efforts?

To answer these questions, we focused on DOE's plan for fusion development and other relevant documents. We also interviewed cognizant DOE, Department of State, and Office of Science and Technology Policy officials. We also spoke with key national laboratory officials and representatives from the Japanese Embassy and the Commission of the European Communities. Appendix I includes a detailed explanation of our objectives, scope, and methodology.

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[1] Status of DOE's Implementation of the Magnetic Fusion Energy Engineering Act of 1980 (GAO/RCED-83-105, Apr. 29, 1983).

DOE's Office of Fusion Energy directs the U.S. fusion research and development (R&D) program on which over $3.5 billion has been spent from fiscal year 1950 through fiscal year 1983. Throughout the program's history, the United States has participated in international cooperative efforts to enhance fusion R&D. Because of budget constraints, DOE officials expect to increase their participation in international cooperative efforts to further the program. In summary we found that:

--DOE's policy on international cooperation in fusion energy development is to participate in those activities which provide scientific and technical benefits to the U.S. program. DOE's participation in international cooperative activities is coordinated with the Office of Science and Technology Policy of the Executive Office of the President, and the Department of State to ensure that the projects are in conformance with the administration's energy research policy and are politically and diplomatically acceptable. According to DOE officials, all international efforts are designed to contribute to DOE's fusion R&D program but are not considered critical to continued progress in the U.S. fusion program. Where feasible, DOE also strives to reduce the building and operating costs of facilities through international cooperation. To further identify and evaluate international options for the fusion program, such as joint construction projects, DOE has contracted with the National Academy of Sciences for a study of various aspects of international fusion activities.

--U.S. fusion scientists and program officials participate in numerous international cooperative efforts covering a broad spectrum of scientific and technical matters with the other countries conducting major fusion energy research and development programs--Japan, the Soviet Union, and the European Community. Many of these international cooperative efforts involve the routine exchange of information during conferences or through publication in scientific and technical journals. In addition, U.S. personnel periodically visit and participate in research at fusion facilities in other countries and, in turn, host visits of foreign fusion scientists at U.S. research and development facilities. The U.S. program is also involved in three joint projects arranged through formal government-to-government agreements, with Japan. Under those agreements, Japan is contributing about $84 million over a 10-year period to the operation of three research facilities in the United States in exchange for experimental time for Japanese scientists.

--At this time, the United States is generally regarded by U.S. fusion experts as the world leader in fusion energy R&D. This position is in jeopardy as other countries, particularly Japan and the European Community, pursue ambitious national magnetic fusion R&D programs. However, it is the general belief of these experts that all participants benefit from international cooperative efforts. Therefore, international cooperative efforts, of themselves do not directly affect the U.S. leadership position in fusion energy development. These experts also believe that fusion R&D is at such an early stage of development that it is highly unlikely any country could use, to its commercial advantage, information obtained during an ongoing international cooperative effort.

--The U.S. and foreign fusion energy experts we spoke to generally acknowledged that there is excellent cooperation in international cooperative activities between the United States and the other major participants. Problems, such as the timing of the release of research data, have generally been effectively resolved informally among the participants themselves.

--U.S. industry's role in international fusion cooperative projects is limited by cost and risk factors. In the overall U.S. fusion R&D program, the private sector is generally involved only in constructing facilities and fabricating components for DOE. In contrast, Japanese industry plays an active role in planning, designing, constructing, and operating Japan's fusion R&D facilities. This difference may give Japan a significant advantage as fusion energy development approaches commercialization.

Appendix I also contains a brief overview of DOE's fusion program and provides detailed answers to the questions we addressed.

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DOE and the Department of State believe that this report is a fair and accurate discussion of the topic. The views of appropriate officials of each agency and those of the Office of Science and Technology Policy have been incorporated in the report. Their complete comments are included in appendixes II, III and IV. As arranged with your office, we plan to make no further distribution of this report until 7 days after its issuance, unless you make its contents public. At that time, we will send copies to the Secretary of Energy and make copies available to others upon request.

Sincerely yours,

J. Dexter Peach
Director

Contents

ABBREVIATIONS

DOE	Department of Energy
GAO	General Accounting Office
OSTP	Office of Science and Technology Policy
R&D	research and development

INTERNATIONAL COOPERATION IN DOE'S MAGNETIC CONFINEMENT FUSION PROGRAM

By letter dated July 19, 1982, Representative Fortney H. Stark asked us to address a number of issues relating to fusion energy. After completing audit work on an ongoing review of the implementation of the Magnetic Fusion Energy Engineering Act of 1980 (Public Law No. 96-386),[1] we agreed with his office to focus our efforts on international cooperation in fusion energy development. Specifically, we agreed to address the following questions:

--What is the United States' policy and strategy for international cooperative efforts in fusion energy development?

--What are the different types of fusion international cooperative efforts?

--What is the possible impact of international cooperative fusion efforts on the United States' ability to maintain its world leadership position in fusion energy development?

--What problems have been encountered in international cooperative fusion efforts and how have these been resolved?

--What is industry's role in international cooperative fusion efforts?

OBJECTIVES, SCOPE, AND METHODOLOGY

To answer these questions, we interviewed cognizant DOE and national laboratory officials. For example, to obtain information about policy relating to international cooperation, we interviewed officials from the three agencies responsible for establishing this policy--the Department of Energy (DOE), the Department of State, and the Office of Science and Technology Policy (OSTP). In particular, to determine DOE's strategy for international cooperation, we interviewed officials from DOE's Office of International Affairs and the Office of Fusion Energy. In addition, we reviewed DOE's Comprehensive Program Management Plan, which describes DOE's policy and strategy on international cooperation.

To obtain information on (1) the different types of international cooperative efforts and how they relate to DOE fusion program objectives, (2) the impact of international cooperation on the United States' leadership position, and (3) problems encountered, we interviewed program officials and project managers at DOE's Office of Fusion Energy and DOE's main fusion research

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[1] Status of DOE's Implementation of the Magnetic Fusion Energy Engineering Act of 1980 (GAO/RCED-83-105, Apr. 29, 1983).

facilities--the Lawrence Livermore and Oak Ridge National Laboratories, the Princeton University Plasma Physics Laboratory, and the Massachusetts Institute of Technology Plasma Fusion Center. To understand private industry's role, we interviewed officials from Westinghouse, Inc.; Union Carbide; and GA Technologies, Inc.

In addition, we reviewed relevant documentation, including congressional testimony, international cooperation agreements, data on personnel exchanges, and material prepared for a 1981 National Science Foundation workshop on international cooperation in fusion energy development.

Japan, the European Community, and the Soviet Union are the other countries with major fusion programs. The United States participates in cooperative efforts with each of them, as well as with Switzerland, Canada, and China. Personnel exchanges also occur with several other countries. We met with representatives from the Japanese Embassy and the Delegation of the Commission of the European Communities to obtain their views on international cooperative efforts in fusion research and development (R&D).

We conducted our review between May and September 1983 in accordance with generally accepted government auditing standards.

OVERVIEW OF THE U.S. MAGNETIC CONFINEMENT FUSION[2] PROGRAM

The United States, through DOE and its predecessor agencies--the Energy Research and Development Administration and the Atomic Energy Commission--has spent over $3.5 billion on fusion R&D efforts from fiscal year 1950 through fiscal year 1983. DOE's Office of Fusion Energy currently funds and directs the nation's fusion energy program. It also coordinates the R&D efforts of several national laboratories, some industrial participants, and

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[2] Fusion energy is a from of nuclear energy that results when atoms of light chemical elements that have been heated and confined combine to form heavier elements and, in the process, release energy. It is, in effect, the opposite of nuclear fission, which powers today's reactors. During fission, atoms of heavy chemical elements are split, releasing energy. Currently, there are two major approaches to developing fusion energy: magnetic confinement and inertial confinement. Magnetic confinement, the main approach being explored for commercial energy generation, involves the confinement of fusion fuel in magnetic fields, where it is heated to the extreme temperature needed to initiate a fusion reaction. Inertial confinement uses lasers and particle beams to initiate a fusion reaction. This report only addresses the magnetic confinement fusion program. Another DOE program is investigating inertial confinement, primarily for its military applications.

many universities. DOE is concentrating its R&D resources on two mainline concepts--tokamaks and mirrors.[3] The following table identifies the principal tokamak and mirror fusion devices, their locations, and their fiscal year 1984 budgets including funds for both operating expenses and capital modifications.

Tokamaks	Location	1984 Budget (millions)
Tokamak Fusion Test Reactor	Princeton University Plasma Physics Laboratory Princeton, N.J.	$97.9
Doublet-III	GA Technologies, Inc. San Diego, Calif.	32.5
Princeton Large Torus and Poloidal Divertor Experiment	Princeton University Plasma Physics Laboratory, Princeton, N.J.	18.1
Alcator-C	Massachusetts Institute of Technology, Cambridge, Mass.	9.0
Mirrors		
Tandem Mirror Experiment, and its upgrade	Lawrence Livermore National Laboratory, Livermore, Calif.	22.7
Mirror Fusion Test Facility (under (construction)	Lawrence Livermore National Laboratory, Livermore, Calif.	54.8
TARA Tandem Mirror	Massachusetts Institute of Technology, Cambridge, Mass.	7.6

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[3] The two mainline magnetic confinement approaches are categorized as closed and open. Closed magnetic confinement systems are doughnut-shaped devices generally referred to as toroids. There are several kinds of toroidal devices including tokamaks, stellarators, and compact toroids. Because of promising experimental results, tokamaks are the toroidal devices being examined most extensively, both in the United States and in other countries. Open magnetic confinement systems are generally referred to as mirrors. They consist of a long tube with large magnets at each end that reflect back and contain the fusion fuel.

On October 7, 1980, the President signed into law the Magnetic Fusion Energy Engineering Act of 1980 (Public Law 96-386). The act recognized the need to develop an essentially inexhaustible energy resource to offset the impending worldwide scarcity of many exhaustible, conventional energy resources. It established several R&D objectives such as demonstrating the engineering feasibility of magnetic fusion by the early 1990's.

Even though actual funding for fusion R&D has remained relatively high--$466.1 million in fiscal year 1983--the act envisioned funding at $615 million for fiscal year 1983 and $788 million by fiscal year 1988. Past and expected budget constraints have and will cause delays in DOE's fulfilling some of the act's requirements.[4] As budget constraints tighten, and the costs of large, more advanced fusion facilities increase, DOE officials have stated that they will be more dependent on international cooperative efforts to further the nation's fusion program.

POLICY AND STRATEGY FOR INTERNATIONAL COOPERATION IN FUSION ENERGY R&D

U.S. policy on international cooperative efforts in fusion energy research and development is formulated by three agencies: OSTP, the Department of State, and DOE. Participation in international cooperative research projects has to be consistent with administration interests and foreign policy. Administration interests are conveyed to DOE by OSTP and those related to foreign policy by the Department of State. The Department of State helps to ensure that proper diplomatic protocol is followed in negotiating an agreement and that an agreement is consistent with U.S. foreign policy.

DOE's policy on international cooperation in fusion energy development is described in its June 1983 Comprehensive Program Management Plan developed in response to Public Law 96-386. Briefly, that policy is that the United States participate, through the Office of Fusion Energy, in those international cooperative efforts which (1) benefit the overall fusion program and (2) allow the United States to maintain its leadership position in fusion activities. International cooperative efforts are used to complement the U.S. fusion program and, where feasible, reduce program costs by sharing the expense of building and operating selected facilities.

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[4] For further information on the status of DOE's fusion R&D program, see our April 29, 1983, report, Status of DOE's Implementation of the Magnetic Fusion Energy Engineering Act of 1980 (GAO/RCED-83-105).

U.S. participation in a specific international cooperative effort may be motivated by technical or foreign policy considerations. DOE's Office of Fusion Energy routinely identifies opportunities for international cooperation which it perceives will benefit the fusion program technically. For example, in 1983 that office began negotiations with Germany for a joint fusion fuel impurity study when funding for the project was not included in the fiscal year 1983 budget. The Office of Fusion Energy also evaluates inquiries for cooperative efforts from its technical counterparts in other countries. Prior to entering into any agreement, DOE coordinates its plans, through its Office of International Affairs, with the Department of State to ensure that the proposed agreement is in consonance with the United States' overall foreign policy objectives. DOE does not enter into agreements that are diplomatically undesirable.

Occasionally, the Department of State also identifies fusion research opportunities which it perceives as enhancing relationships between participating countries. According to DOE officials, in those cases DOE tries to develop exchange efforts that will contribute to the U.S. program as well as meet diplomatic objectives.

International cooperation--a component of DOE's fusion program strategy

According to DOE officials, international cooperative efforts in the magnetic confinement fusion program have in the past provided valuable experience and information for U.S. fusion scientists. Further, because of the combination of projected high costs for more advanced fusion facilities and anticipated budget constraints, DOE expects international cooperation to assume an increasingly greater role in achieving the program's objectives. However, program officials stated that international cooperative efforts have been, and will continue to be, in areas which contribute to and complement, but are not critical to, continued progress in the U.S. fusion program. For example, the United States has extensive exchange programs with Japan involving peripheral aspects--computer modeling and diagnostics development--of its two mainline magnetic confinement fusion concepts.

The United States also participates in international cooperative exchanges to keep abreast of developments in alternative magnetic confinement fusion concepts. For example, it has informal arrangements with the European Community involving stellarator research activities. (Stellarators are another form of a toroidal fusion device.) The U.S. fusion program began with the stellarator concept in the early 1950's, but experienced many difficulties. The program shifted its emphasis to tokamaks in the late 1960's, after the Soviets achieved dramatic results using them. Now that stellarators are demonstrating renewed promise, U.S.

participation in this research provides U.S. scientists their main source of information on this concept.

An example of DOE's efforts to obtain budgetary relief through the use of international cooperative projects is its ongoing negotiations with potential partners to participate in the construction and operation of a fusion materials irradiation test facility. Fusion R&D facilities are expensive, and this test facility would be no exception; its cost is estimated to be over $100 million. The facility would expose various materials to intense neutron bombardment of the type that will occur in fusion reactors in order to identify those materials best suited for key components of fusion reactors. Although not considered essential at this time by DOE for continued progress on the mainline fusion concepts, it will ultimately be needed to identify the most suitable materials for constructing a prototype reactor.

All of these cooperative efforts serve to enhance the United States' understanding of fusion-related issues. But none, according to DOE officials, is critical to the continued progress of the fusion R&D program. According to DOE officials, without these projects, the U.S. program would still move forward, albeit with perhaps a greater risk of setbacks because of the narrower scope of research activity.

In light of the increasing likelihood of future constrained budgets, and the need for increasingly expensive fusion devices, DOE decided in 1983 to examine its strategy for the future role of international cooperation in the fusion area. Thus, DOE contracted in August 1983 with the National Academy of Sciences to perform a study exploring several aspects of international cooperation. The Academy, through its Committee on International Cooperation in Magnetic Fusion, will

--identify the most important issues in international cooperation in magnetic fusion energy development;

--review and discuss alternative courses of international cooperation, such as joint construction projects;

--review U.S. objectives for fusion energy development, and compare them with European and Japanese objectives to identify similarities and differences; and

--identify the long-term implications of alternative courses of international cooperation, and how they affect U.S. fusion development objectives.

The Academy expects to issue its report in October 1984.

INTERNATIONAL COOPERATIVE EFFORTS AND DOE'S STRATEGY TO ACHIEVE FUSION R&D OBJECTIVES

International cooperative efforts in the U.S. fusion program can be grouped into three broad categories: (1) information exchanges, (2) personnel exchanges, and (3) joint projects involving the transfer of funds or equipment. In the latter, one country contributes funds or equipment to another country's program to build or upgrade a facility in exchange for direct participation in the experimental activities at the facility. Within each of these broad categories, existing U.S. cooperative R&D efforts with the other countries that have major fusion programs cover a broad spectrum of scientific and technical areas.

Information exchanges

U.S. fusion scientists and program managers participate in numerous international cooperative efforts that primarily involve the exchange of information. This exchange often occurs at meetings, such as symposia, conferences, and workshops, or in the publication of information in technical journals. Meetings may vary in scope, both in terms of the material covered and in the number of participants involved. For example, the International Atomic Energy Agency[5] sponsors conferences, such as the biennial conference on fusion energy, which are attended by representatives from a worldwide membership. The conferences cover a variety of topics related to fusion energy research and development. Other meetings are much more focused, and are attended by a limited number of participants. In addition, information exchanges are carried out under International Energy Agency and bi-lateral arrangements.

The International Atomic Energy Agency also sponsors the International Tokamak Reactor workshop, a multinational study to produce an advanced tokamak reactor design. Under this study, the United States, Japan, the European Community, and the Soviet Union have met periodically since 1978 to define the characteristics of the next major tokamak facility. This facility would follow the current generation of large tokamaks such as Princeton's Tokamak Fusion Test Reactor and the Joint European Torus in Britain. Because of the myriad of problems involved in pursuing a large joint R&D construction project of this type, it is unlikely that such a facility will ever be built cooperatively. However, the

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[5] The International Atomic Energy Agency is a United Nations organization that encourages the peaceful uses of atomic energy throughout the world. Its activities include organizing meetings, establishing nuclear activity safety standards, and advising governments on atomic energy programs.

study has been extremely useful in identifying design problems and enhancing the design talents of the participating countries.

Personnel exchanges

International cooperative personnel exchanges generally occur in two forms--visits and assignments. Visits are of short duration, i.e., several days to a few weeks, and involve a short-term admittance to one or more of a host country's facilities. The purpose of visits is to gain familiarity with the host country's fusion activities and facilities, but not to participate in experimental work. Assignments are of longer duration, i.e., several weeks, months, or years, and involve admittance to a single host-country facility. The purpose of assignments is to allow participation in actual experimental work to gain direct experience at a facility. During an assignment, the guest participants become members of the experimental team and engage in all aspects of experimental work, including planning and conducting experiments and analyzing results.

Visits may be arranged at several levels. For example, exchanges may be arranged at the national or university laboratory level, such as between the Princeton University Plasma Physics Laboratory or the Oak Ridge National Laboratory and a similar facility in Japan, Europe, or the Soviet Union. Personnel assignments may also be arranged under an international agreement under the auspices of an international organization such as the International Energy Agency,[6] or under a bi-lateral or multi-lateral international agreement.

Almost all of the personnel exchanges in the fusion program are with the other three major participants in magnetic fusion R&D--Japan, the European Community, and the Soviet Union. The United States has formal exchange agreements with Japan and the Soviet Union. The following table indicates that U.S. personnel exchanges with Japan occur about seven times more frequently than with the Soviet Union. DOE does not have accurate data for exchanges with the European Community because they are carried out on an informal basis.

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[6] The International Energy Agency is part of the Organization for Economic Cooperation and Development. It is an alliance of 21 major oil-importing countries, including the United States, which was formed in November 1974 as part of an effort to reduce dependence on imported oil. It provides the legal framework enabling member countries to participate in international cooperative efforts to construct and conduct experiments at fusion research facilities. The International Energy Agency experiment-oriented activities in fusion complement those of the the International Atomic Energy Agency, whose activities are oriented toward information exchange.

Fusion Personnel Exchanges[a]

Japanese assignment-days[b] in the United States	2,170
U.S. assignment-days[b] in Japan	2,061
Soviet assignment-days[b] in the United States	380
U.S. assignment-days[b] in the U.S.S.R.	253

[a] Exchanges with Japan cover the year April 1983 through March 1984. Exchanges with the Soviet Union took place during calendar year 1983.

[b] "Assignment-days" refers to the total number of days all scientists spend in long-term assignments at all facilities. For example, if two scientists are assigned to a facility for 30 and 40 days respectively, the number of assignment-days is 70.

In the same time period, Japanese scientists will also spend an additional 4,100 days participating in the Doublet-III and Rotating Target Neutron Source joint projects described in the following section. In exchange for Japanese participation in these projects, the U.S. program is receiving about $84 million over 10 years.

Joint projects

Exchanges may also be arranged as joint projects under formal government-to-government bilateral or multilateral agreements. An example is the U.S.-Japanese bilateral agreement involving work on the Doublet-III fusion device located in San Diego, California. While Japan is benefiting from experimental time at this facility, the United States is benefiting from Japan's financial and technical contributions to the project. Under the agreement, Japan is contributing approximately $70 million to the Doublet-III project over a 5-year period. The Japanese funding contributions have allowed Doublet-III to be upgraded for advanced studies and have allowed an acceleration of its experimental timetable.

Another similar joint project is taking place at the Rotating Target Neutron Source facility at the Lawrence Livermore National Laboratory. Under this agreement, Japan is contributing approximately $9 million over a 5-year period in exchange for participation in the experimental work directed toward materials research for fusion reactors.

A third joint project with Japan was negotiated in November 1983. Under that agreement, Japan will contribute $5 million over 5 years to the operation of two fission reactors at the Oak Ridge National Laboratory in exchange for participation in ongoing fusion-related materials experiments at those reactors.

The only other fusion joint project is the Large Coil Project at the Oak Ridge National Laboratory. This project, arranged under the auspices of the International Energy Agency, is a multi-national effort involving the United States, Japan, Switzerland, and the European Community. Under this project, these countries are supplying large superconducting magnets--magnets that become excellent conductors of electricity at very low temperatures--to the Oak Ridge National Laboratory. Experiments are being conducted there to examine the performance of alternative designs in superconducting magnet technology, and to prove magnet design principles and fabrication techniques needed for the next generation of fusion reactors.

IMPACT OF INTERNATIONAL COOPERATIVE EFFORTS ON THE UNITED STATES' ABILITY TO MAINTAIN WORLD LEADERSHIP IN FUSION ENERGY DEVELOPMENT

At this time, the United States is generally regarded by U.S. fusion experts as the world leader in fusion energy development. This position is in jeopardy as other countries pursue ambitious magnetic fusion R&D programs. The fusion experts we talked to, however, do not believe that U.S. participation in international cooperative R&D projects directly affects its leadership position because all countries are benefiting from them, and because the construction of a commercial fusion reactor is so far in the future. Rather, leadership will depend on the United States' future commitments to its program compared with other nations' commitments to their programs.

According to the head of the experimental division at the Princeton University Plasma Physics Laboratory, the United States is the world leader in fusion R&D because it has constructed and is operating a fusion device which most closely approximates a commercial fusion reactor--the Tokamak Fusion Test Reactor at Princeton. However, both Japan and the European Community are constructing larger, more ambitious tokamak devices which will be in operation in the near future.

Leadership in the 1990's will depend on which country makes a commitment to a new, larger, more advanced fusion project to follow the current generation of fusion devices. Both Japan and the European Community are already designing and have definite plans to construct a next-generation fusion device. The United States does not yet have definite plans for such a device.

DOE's Comprehensive Program Management Plan for fusion development cites as one of its objectives the preparation of an engineering development program to follow the anticipated demonstration of the scientific feasibility[7] of fusion energy on Princeton's Tokamak Fusion Test Reactor. One way of implementing the engineering development program would be to construct a large-scale engineering device as the next major fusion reactor. DOE identifies this next reactor in the fusion program as an Engineering Test Reactor, but has not at this time defined its characteristics. This, according to DOE officials is partly due to the program's constrained budget, which has caused delays in developing the information necessary to define the next reactor in the U.S. fusion program.

DOE, national laboratory, and university fusion experts feel that all participants have benefited from international cooperative efforts. These experts also firmly believe that fusion R&D is so far from construction of a commercial reactor that it is unlikely any country could take information obtained in an exchange program and exploit it to its advantage. Therefore, they believe that international cooperative efforts will not directly affect the United States' leadership position. Rather, the degree of commitment and funding given the program in comparison with other countries' national efforts will determine who retains fusion development leadership.

The way in which a country benefits from international fusion projects depends on each participant's area of expertise. The U.S. program, for example, has benefited from exchanges with the Soviet Union because of its expertise in fusion theory. The tokamak confinement concept, currently the lead magnetic confinement fusion concept in the world, was developed by the Soviets and openly shared with scientists from the United States and other countries. Other aspects of the U.S. program have benefited similarly from exchanges of information with the Soviet program. These include exchanges relating to plasma[8] theory, mirror confinement, and compact toroids. Additionally, U.S. fusion experts noted that Soviet theoreticians often offer a totally different perspective and methodology for the solution of fundamental fusion problems.

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[7] Demonstrating scientific feasibility for fusion means simultaneously achieving the temperature and confinement conditions necessary for a fusion reaction to occur and producing as much energy as is needed to sustain it.

[8] Plasma is the name given to the very hot, electrically charged gaseous form of the light chemical elements that combine in the fusion process.

The U.S. program has similarly benefited from cooperative efforts with Japan and the European Community. For example, it has benefited from Japan's financial and technical contributions to the GA Technologies and Lawrence Livermore projects. In addition, cooperation with Japan has provided valuable insight into the role of industry in fusion energy development, and Japan's ability to adapt, and improve upon, technological innovations from the U.S. fusion program. As noted previously, the United States is keeping abreast of advances in stellarators through exchanges with the European Community, as well as with Japan and the Soviet Union.

The foreign programs have also benefited from U.S. participation in international cooperative efforts. At a minimum, the foreign programs have benefited from U.S. technological advances in plasma-heating techniques, materials studies, and the development of the mirror and bumpy torus[9] concepts. Foreign efforts have also benefited from the U.S. program's fundamental advances in tokamak confinement physics.

PROBLEMS ENCOUNTERED

DOE fusion program officials and Japanese and European Community representatives state that there has been excellent cooperation among participants in international fusion R&D efforts. In all cases, once an agreement had been reached, the participants endeavored to adhere to its letter and intent. Any problems encountered after an agreement had been signed have been relatively minor. Problems have generally been resolved informally among the participants.

When preparing an agreement, participants attempt to preclude problems of a substantive nature from occurring. Thus, an agreement should clearly define each participant's rights and responsibilities before it is signed. Agreements, as a rule, establish committees to resolve any substantive problems that may occur.

Negotiation of an agreement can, at times, take more time to complete than is initially expected, for after technical scope of the cooperative efforts has been selected, agreement must still be reached on terms and conditions with respect to the liability of each participant, the treatment of intellectual property, and various procedures for the implementation of the particular program or projects under the agreement. Since the Freedom of Information Act is unique to the United States, the handling of

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[9] Bumpy torus is an alternative magnetic confinement fusion concept. It is a hybrid (tokamak-mirror) device in which short mirror segments are connected in a circular configuration.

information also has to be carefully worked out. International cooperative efforts also require more time to implement than a comparable domestic effort. Not only do the distances involved make communications more difficult but each nation also has its own way of conducting such exchanges. The inherent political importance of these projects also necessarily requires the increased attention of program management.

In the first years of the implementation of the exchanges with the Soviet Union, misunderstandings arose over what each side wanted and expected in an exchange. This problem in communication has been resolved by first reaching agreement in writing on the details of the itinerary of the exchange, subjects to be discussed, personnel to be contacted, procedures for the exchanges of materials or equipment, and so forth. Since this procedure was implemented beginning in late 1979, exchanges with the Soviet Union have been comparable to those with Japan or the European Community.

INDUSTRY'S ROLE

With the exception of GA Technologies, Inc., private industry's role in the U.S. fusion R&D program is primarily that of a supplier to DOE-supported laboratories. Industry constructs facilities and fabricates components which conform to DOE contract specifications. It is not involved to any significant degree in the planning, design, or operation of fusion R&D facilities. The basic reason for this is that fusion R&D remains essentially a high-risk, very expensive scientific endeavor, still far removed from commercialization. According to DOE and industry representatives we talked to, industry does not feel it can undertake such large investments since the return is so distant and uncertain. Consequently, the program is funded by the federal government and conducted primarily at national laboratories and universities.

The participation of GA Technologies, Inc., in the fusion program is unique. While it is a private company, it conducts fusion R&D activities for DOE. The Doublet-III project funded by DOE is located at GA Technologies' facilities at La Jolla, California, and is a major component of DOE's tokamak research effort.

In contrast to the United States, many Japanese companies are significantly involved in Japan's fusion program. Engineers and scientists from Japanese industry participate in the planning, design, construction, and operation of fusion facilities. A recent report to DOE evaluating the United States-Japan fusion energy exchange program[10] states that Japan's institutional framework allows much greater industrial involvement in the Japanese program. The report also states that this difference is

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[10] Collection of Background Information on the U.S.-Japanese Fusion Energy Exchange Program (Apr. 30, 1983).

a concern of U.S. fusion scientists. These scientists cite the Japanese industry's past successes in converting U.S. technological innovations into first-rate "products." The report predicts that the Japanese industry, because of its early involvement in fusion energy development, may eventually become the world supplier of fusion reactors.

DOE, in September 1983, asked its own Magnetic Fusion Advisory Committee to examine the role of industry in the fusion program. The committee, formed by DOE in May 1982, includes fusion experts from industry, academia, and the national laboratories and is charged with advising DOE on fusion development consistent with Public Law 96-386 objectives in a period of budget constraints. DOE expects the report to be completed by May 1984.

Department of Energy
Washington, D.C. 20585

[illegible] 1984

Mr. J. Dexter Peach
Director, Resources, Community and
Economic Development Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Peach:

The Department of Energy (DOE) appreciates the opportunity to review and comment on the GAO draft report entitled "The Impact of International Cooperation on the United States' Magnetic Confinement Fusion Program." The draft report is a fair and accurate discussion of the topic. This view is shared by the Department of State.

Sincerely,

Martha O. Hesse
Assistant Secretary
Management and Administration

Enclosure:
Revised Draft GAO Report

DEPARTMENT OF STATE
Comptroller
Washington, D.C. 20520

13 JAN 1984

Dear Frank:

I am replying to your letter of Decmeber 29, 1983, which forwarded copies of the draft report: "The Impact of International Cooperation on the United States' Magnetic Confinement Fusion Program."

The enclosed comments on this report were prepared in the Bureau of Oceans and International Environmental and Scientific Affairs.

We appreciate having had the opportunity to review and comment on the draft report. If I may be of further assistance, I trust you will let me know.

Sincerely,

Roger
Roger B. Feldman

Enclosure:
As stated.

Mr. Frank C. Conahan,
Director,
National Security and
International Affairs Division,
U.S. General Accounting Office,
Washington, D.C. 20548

GAO REPORT: "THE IMPACT OF INTERNATIONAL COOPERATION ON THE UNITED STATES' MAGNETIC CONFINEMENT FUSION PROGRAM"

We have given you most of the comments contained below orally and understand that they were incorporated in a later version of the study that we have not received. The memo below is for the record.

We find the report generally accurate; its brevity, however, may result in some misleading conclusions. For example singling out the INTOR project of the IAEA as the sole example of information exchanges gives this activity an inappropriate amount of emphasis; information exchanges carried out under IEA or bilateral arrangements are considerably more voluminous.

Specific suggestions that might clarify other portions of the report follow:

Appendix 1, Page 4, para 3, line 6
Insert "those related to foreign policy by" between "and" and "the". This insertion would describe more accurately the role of the Department of State.

Line 6

Eliminate the sentence beginning with "OSTP" and ending with "agreement".

This sentence is inaccurate.

Page 5, para 1, line 13

Insert "in consonance with our overall foreign policy objectives" in place of "diplomatically acceptable."

This change would reflect more accurately the role of the Department of State.

Page 5, para 2, lines 1-3

Insert the word "occasionally" before "The Department..." Eliminate the phrase "desirable for foreign policy reasons will"...

[GAO note: Page references in this appendix were changed to reflect their location in this final report.]

These changes would correct any impression that the Department of State sometimes encourages international fusion agreements for foreign policy benefits alone, State recognizes technical agreement should be based primarily on technical benefits to the participating program Agency.

James L. Malone

James L. Malone
Assistant Secretary
Bureau of Oceans and International
Environmental and Scientific
Affairs

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

January 19, 1984

Dear Mr. Peach:

As requested in your letter of December 29, 1983, we have reviewed the GAO draft report entitled "The Impact of International Cooperation on the United States' Magnetic Confinement Fusion Program."

We basically agree with your description of U.S. policy for international cooperative efforts in fusion energy development and of the effectiveness and impact of existing bilateral programs to advance fusion science. I would like to make two suggestions. The first is a specific addition regarding OSTP's role in energy policy -- on Page 2, in in the third paragraph the second sentence should read, "... to ensure that the projects are in conformance with the Administration's energy research policy, and are politically and diplomatically acceptable." The second suggestion is general and affects several parts of the report. The text mentions that much of the international cooperation in the fusion programs could be considered complementary but not critical to the progress of U.S. programs. I believe the report should also recognize that when the U.S. agrees to participate in international projects, it does so on the basis that they are an integral part of U.S. program planning and that they will contribute to the advancement of U.S. fusion objectives.

If in the future you should draw any conclusions or make any recommendations regarding this study, we would be happy to review and comment once again.

Thank you for providing us the opportunity to review your draft report. Let us know if we can be of further assistance.

Sincerely,

Wallace R. Kornack

Wallace R. Kornack
Assistant Director

Mr. J. Dexter Peach
Director
United States General
Accounting Office
Washington, D.C. 20548

(301624)

INTERNATIONAL SCIENCE AND TECHNOLOGY ACTIVITIES OF "DOMESTIC" DEPARTMENTS AND AGENCIES

E. B. Skolnikoff
Office of Science and Technology Policy
September 13, 1979

The Problem

The international dimension of science and technology, always important, is receiving increasing policy interest, especially with respect to international programs and activities of US Government agencies carried out for purposes that can vary from advancing a research objective to attempts to use science or technology to achieve a political objective. The mixture of such objectives often raises difficult policy, management, and political problems, particularly for agencies whose mandate does not normally or predominantly lie in international areas.

The broader purpose of these international activities is the same as that for the support of science and technology itself -- to contribute to the nation's domestic and international goals. The problems encountered, however, have tended to discourage substantial and fully productive use of US resources, especially with regard to support of international goals, and lead to a need to reexamine the present situation and explore alternative approaches to meeting those problems.

The question to be examined can be simply stated as how to achieve more effective use of science and technology, and in particular of the scientific and technological resources of the US Government, in the service of national interests in the international arena, while maintaining responsible policy and management control.

The operational issues that must be addressed tend to take the form, in the day-to-day policy process, of management and budget questions. Most often they stem from the fact that the agencies with the scientific expertise and resources have historically and politically a domestic orientation. Those agencies concerned primarily with foreign policy and international development must rely heavily on the "domestic" agencies for the conduct of international activities in science and technology and, more generally, for sensitivity to the international dimensions of those fields. The present process for dealing with this multiagency dependence often leads to dissatisfaction with the quality of programs, with the arrangements by which different agences are involved, with the opportunities missed, and with the funding problems encountered. It also fails to reflect both the growing interest in the Executive Branch and the Congress in making better use of international activities in science and technology, and the increasing pressure induced by evolving global issues to involve science and technology more adequately in their solution.

The challenge is to design adequate policy, program and budgetary procedures for international activities extensively involving domestic agencies within a system that has developed with rather sharp demarcations between international and domestic activities.

The goal of efficient management leads to a desire to compartmentalize programs according to their objectives, to ascribe funding to the relevant sources, to compare programs competing for resources within a defined area, and to develop clear criteria for evaluation. These procedures, obviously desirable in themselves, are difficult to follow successfully when applied to international science and technology programs that are often carried out for a mix of policy and scientific objectives with different agencies having differing criteria of choice representing aspects of that mix. How can effective criticria be developed for judging the value of programs, as compared to what other programs? How can subjective foreign policy criteria be weighed against relatively objective scientific criteria? Where is the funding to come from: domestic science budgets, or budgets of a foreign policy agency, or a separate line item in domestic agency budgets? The requirement for funding to come entirely from development agencies may make sense from an abstract management perspective, but may not be commensurate with the mixed purposes of programs, nor the way in practice to develop quality programs or to mazimize effectiveness. Programs funded entirely from sources outside an agency rarely lead to the kind of commitment, leverage within the agency, assignment of permanent positions, or support from the Agency leadership or from the Congress necessary to encourage adequate attention to qaulity or to policy objectives.

These elements of alternative procedures to meet these and other difficulties are suggested in the discussion below. As in any intricate policy area, the subject is sufficiently complex to make it difficult to encompass all aspects in a relatively brief analysis, or to make substantial changes in the program and policy process quickly. Accordingly, the suggestions are made later are proposed as experiments to explore what is realistic and to modify procedures in the light of experience.

Categories of "International Science & Technology"

International science and technology activities cover a wide range with different issues associated with different kinds of programs. In order to examine these issues clearly, it is necessary first to separate activities into several categories, recognizing that there is inevitably some overlap among them.

I. International activities directly supporting US "domestic" R&D objectives

In this category are those programs or activities that arise directly from the R&D goals of the US Government. Examples are:

- -- cooperation with, and occasional support of, foreign scientists or institutions in pursuit of common scientific objectives when justified on competitive scientific grounds;
- -- programs carried out internationally because of the requirements of the subject, such as in oceanography, geophysics, or global climate;
- -- programs to develop new facilities cooperatively for cost-sharing purposes, including research facilities, participation in space projects, Glomar Explorer, and others;
- -- participation in internationally organized research endeavors, such as International Geophysical Year or Global Atmospheric Research Project;
- -- comparative studies or conferences intended to improve US efforts by examination of policies or programs of other countries (e.g., in environmental studies, standards for use of health care technology).

II. International activities carried out for mixed foreign policy and scientific purposes. (NOTE: development purposes -- related to developing country problems -- are considered separately from foreign policy purposes for reasons of clarity, though the separation is somewhat artificial)

In this category are those programs or activities that have an important foreign policy component as part of their motivation. Examples are:

- -- dedicated programs of bilateral cooperation with other countries that are established to serve one or several foreign policy objectives with those countries (the programs with the USSR, Japan, China and France are illustrations. The Chinese program overlaps with the development category as well.):
- -- activities with, or in, other countries which may not be part of a dedicated program with that country, but are at least partially justified by foreign policy interests (e.g., possible desalination projects in the Middle East, involvement of local oceanographic institutions in US expeditions);
- -- application of US science and technology capabilities outside the country for US policy purposes (such as foreign participation in Landsat, or use of US technology abroad for mapping and oil exploration);

- -- programs to encourage expansion of foreign R&D, or refocusing of foreign R&D on objectives the US sees as priority problems (e.g., efforts to stimulate energy-related R&D through the IEA, or some aspects of the Japanese cooperative program).

III. S&T activities designed to serve international development objectives.

This category, closely related to the previous, involves those activities particularly geared to the development objectives of the US and developing countries across the range from the poorest to those now considered "middle-income". The justification for separation from other foreign policy interests is simply the present magnitude and likely future significance of this category to the US. In addition, the different policy and funding structure in the development area makes the issues to be dealt with substantially distinct. Examples are:

- -- programs of cooperation between US agencies, or US-funded institutions and those in LDC's on development problems, sometimes in the context of dedicated bilateral agreements, other times on an individual project basis;
- -- support of R&D in institutions outside the US on development problems;
- -- commitment of R&D resources in the US to work on development problems, varying from full commitment of some resources to partial modification of domestically-oriented programs to make them more relevant to application for development;
- -- application of US S&T capabilities to development needs abroad, such as resource exploration, Landsat imagery, communications technology;
- -- participation in international S&T programs (UN and others) concerned with development.

IV. US R&D for foreign policy objectives

This category, included for completeness, refers to the dedication of R&D resources to serve foreign policy interests, such as military, space, intelligence and similar goals. In one sense, the majority of government-funded R&D in the US is intended to serve the nation's international interests. This, of course, is a general rather than specific relationship.

However, in some specific areas, for example, non-proliferation, there is the possibility of detailed modification of R&D objectives in the light of foreign policy objectives. (Development-related R&D also is an example, but is considered separately.) In practice, the intervention of foreign policy considerations in the R&D process proves to be exceedingly difficult in the US Government and not particularly successful. The issues involved are interesting and challenging, but are not central to this analysis, and will not be considered further here.

Policy, Management Issues

Category I: International activities directly supporting US "domestic" R&D objectives

Key Recommendation: Take steps necessary, starting at the White House to encourage more of an international perspective in Government R&D programs, including assurance of high-level interest, receptivity for development of international aspects of programs, recognition of greater uncertainty necessarily encountered in program evaluation, and willingness to allow limited extra funds for exploratory and higher infrastructure costs.

This category of activities poses the least difficult immediate management issues since the programs presumably must and can compete for funds within agency budgets and objectives. Criteria are clear, or at least no less clear than for R&D in general, and it is evident what programs new proposals are to be compared against.

To the extent there is an issue here, it has to do with the general interest in and encouragement of an international perspective in Government R&D programs. The dominant domestic orientation of the R&D enterprise has historical, commercial, security and prestige roots, that will long preserve that situation. But, it is anomalous in an era in which high-quality R&D capability exists (and is growing) in many countries that share US interests, in which the problems facing these societies are increasingly common and intertwined with those of the US, and in which the costs of R&D increase so as to limit the ability of any one country, even the US, to seek answers entirely on its own, that so little of an international perspective is yet in evidence.

To begin to develop that perspective, to take more advantage of the R&D benefits of international cooperation, and to realize the potential value to the US of an international approach to the problems that loom so large in all societies will not develop naturally. Agencies and particularly the lower levels of R&D management, would have to be sure not only that there is high-level interest in international activities that support their R&D objectives, but also that international programs, if competitive, would be welcomed in their overall program and that the likely greater uncertainties encountered in evaluation of new proposals would be sympathetically taken into account. Some limited funds within agencies for exploration of opportunities, for higher infrastructure costs, and for topping out purposes to add an international dimension to existing projects, would be appropriate.

How to bring about this change of attitude is, of course, not easy or likely to be accomplished overnight. It will involve actions by the White House, OMB, OSTP, and a continuing concern by an appropriate interagency group, perhaps under the Federal Coordinating Committee for Science and Engineering Technology (FCCSET). A strategy for achieving this goal deserves immediate attention.

It is also worthwhile noting not only the difficulty, but also the importance, of making the "domestic" agencies of the US Government conscious of the international framework in which R&D is actually embedded. Not only can US R&D benefit from work in other countries, much more of which is now equal to US R&D in quality, but the results of R&D will affect directly and indirectly people in all countries. They have no voice in setting R&D objectives in the US even though they have an interest in the outcome, nor can any process be imagined in the near future (at least) that could provide such participation.

But, that only emphasizes the desirability of developing over time much greater sensitivitiy in the US to the international nature of the R&D enterprise and to its social effects that are not limited by national borders. The decision processes of the US Government in important respects are suprisingly parochial. The conscious encouragement of greater involvement in the international programs and cooperation of US domestically-oriented agencies in meeting their R&D objects can, in the long run, serve to increase understanding of the international dimensions of everything the US does in science and technology.

Category II: International S&T activities carried out for mixed foreign policy and scientific purposes (excluding those primarily for development objectives).

Key Recommendations:

1. For ongoing international programs funded from regular agency budgets, an experiment is proposed in which the Department of State would rank a limited number of international programs across agencies according to criteria it developed, while agencies include those programs within their own regular rankings. State rankings would be used to adjust the final rankings within an agency for those programs that fall near the cutoff.

2. Some international programs of cooperation, especially in their initial development and implementation phase, require segregated funding. Such funding should be strictly limited, and could be in the Department of State or, more realistically in the NSF, in some cases the ISTC, or as line items in appropriate agencies.

Discussion

There have been several Government studies of this (and the next) category of activities in recent years, with elaboration of the management and policy issues they raise, and various recommendations made. The details of the issues will not be repeated here, but rather an attempt made to provide a framework within which the issues should be debated, and to highlight what appears to be the key problems and choices. Much of the discussion here will also apply to Category III dealing with development-related R&D.

The question is not whether, but how to use S&T in support of international goals. Clearly, international activities in S&T can serve a variety of objectives in addition to domestic R&D goals, including contributing to political and economic interests, attracting high level attention to particular issues, creating advantages for American industry in foreign countries, providing knowledge of scientific and technological progress in other countries, and stimulating work on common or global problems. In any case, Presidents, Secretaries of State, and others have capitalized on the nation's strength in S&T for more than scientific purposes and will continue to want to do so. That is appropriate, for national goals can be served by sensible use of all resources, as long as it is done responsibly and without damage to the primary mission of those resources.

Funding

The most difficult of all the issues, and the ones that are at the heart of the problems of management of international S&T issues are those associated with funding. They are central to the goal of responsible management and deployment of public funds, and central to the ability of the Government to use its resources effectively for a variety of program objectives.

The major problem is that the international programs under consideration cannot be fully competitive with alternative domestic programs (if they were they would raise no special problems, as Category I), and even when they can eventually be so, the advance planning and commitment process required to initiate a formal international or bilateral agreement is not compatible with the normal competitive budget process. Alternative budgetary processes and in some cases segregated funding are unavoidable.

There are several alternative funding mechanisms possible, none of them fully satisfactory nor mutually-exclusive. They include funding of international activities from regular appropriated R&D funds, developing line items within the domestic agencies administered either by the technical divisions or by an international programs office, seeking dedicated funds in the Department of State to be transferred to the operating agencies to fund these activities, or seeking dedicated funds in another agency, such as the NSF or ISTC for transfer as appropriate.

A different technique of one-shot endowment for a "bi-national foundation" is also possible and has been employed in the past, notably in the case of Israel. Each have their advantages and disadvantages. (The establishment of an Executive Office of the President fund is a logical possibility, but is neither realistic or desirable, and will not be considered further.)

Relying on appropriated agency R&D funds has several problems: establishing objective criteria for comparing the foreign policy interest of alternative proposals, determining the weight that should be given to those interests, providing adequate means for representing those interests in the budget process, and absorbing the implicit reduction in funds available for the domestic objectives of the agency (especially acute if funds must be segregated in advance to protect against later rejection). The programs, however, are more likely to be of high quality since the technical people most knowledgeable are those most heavily involved, and the scientific evaluation would be by the normal process.

Developing a separate line item budget within agencies administered by the technical divisions or the international office (or both) avoids the problem of reducing funds for "domestic" R&D objectives (assuming no larger tradeoff), but raises more starkly the problem of justification of funds and effective program evaluation. It can lead to continuation of funding once started simply from the normal inertia of budgets, and can reduce the pressure for scientific justification since the funds are not subject to as rigorous competition. In addition, the international offices, if they asminister the funds, may develop a vested interest in the programs which may not adequately reflect either overall US foreign policy interests or the scientific opportunities. Line items for programs intended to serve, in part, foreign policy interests raise directly the problem of how funds and programs are compared across agency lines, especially since the normal budget process within agencies and with the Congress involves other considerations.

On the other hand, both line items and use of regular R&D funds give the agencies a stake in international activities, force them to have to evaluate, advocate and defend the programs as their own, require attention to use of resources for international purposes, and allow the development of permanent staff commitment as opposed simply to carrying out programs as a "service" to other agencies.

The alternative of establishing funds in the Department of State to support international scientific and technological activities of the agencies has several serious barriers, though it appears attractive in the abstract as a way of forcing projects to compete within a limited fund. One barrier is simply the political reality of expecting State to be able to obtain funds of any scale for this purpose. Another is the separation of the source of funds from the scientific and technological resources, coupled with State's inherent difficulty in identifying adequately the opportunities in science and technology across the Government.

In addition, many activities should not be discrete separate programs, but part of larger efforts. If most international funds had to come from the Department of State, the bureaucratic burden would be enormous and probably intolerable. Moreover, this route is not likely to develop the desired commitment and competence in the agencies.

A fund in the Department of State that would be available for those projects which are of very low interest to an agency and hence motivated almost entirely by foreign policy purposes, or for which unexpectedly rapid commitment of funds is necessary might be more easily justified. It seems unlikely that State could obtain substantial funds from the Congress for this purpose either, and would have the danger that the projects supported would be so political as to make them vulnerable to attack. On the other hand, it it could be done, a small fund of this kind could be useful.

Establishment of dedicated funds in another agency, such as the NSF, has some of the same problems as a State Department fund, except that it has proven more feasible to appropriate money to the NSF for international programs, and NSF's internal competence in science and technology could make it easier to work with the technical programs of other agencies. As is evident from past use of NSF in this way, however, any agency finds it difficult to accommodate substantial funds that, as a matter of course, are only to be justified and spent by others. It also puts NSF in the middle between domestic and international agencies with little stake of its own.

The ISTC is not a suitable candidate for many of the programs in this category because of its focus on development, rather than on more general foreign policy concerns, and because the size of its budget is likely to be too limited. It can provide some resources when dealing with middle income countries, but a broader role would alter its primary purpose. The ISTC can be particularly useful, however, as a source of information and coordination of international science and technological programs to help in the budgetary and management process, which is one of its intended purposes (of which more later).

The bi-national foundation approach has considerable appeal for a limited number of countries as a result of its permanent basis that does not require annual appropriations or detailed oversight. By definition, it is not available for short-term foreign policy purposes though it's existence and successful operation can obviously contribute steadily to relatonships. Its independence is an asset, but by the same token it is external to US departments and agencies and not likely over time to stimulate international interests within those agencies, or see its mission as integration of scientific and technological capacity with US international interests. Finally, its independent status makes program review or modification difficult once a direction is set.

Though all of the alternatives have their strengths and weaknesses, it seems inescapable that for the bulk of international science and technology activities justified in part on foreign policy grounds, it is the resources of the agencies themselves that will have to be relied upon. The other choices are simply not commensurate with the nature and scale of the overall objective and with likely growth in interest, though all mechanisms are, and ought to be, used to some extent.

That will not be enough, however, for the need for planning flexibility, especially for broad programs of cooperation of high political value and White House interest, such as with China and the Soviet Union, dictates a requirement for some segregated funds able to be used for new international initiatives. The amounts should be strictly limited on the assumption that programs once established should move into a competitive process of some kind as rapidly as possible. Under that assumption, the Department of State could be the logical repository of such funds, but more realistically they can reside within the NSF, and/or as line items in the appropriate domestic agency budgets.

Process for managing agency funds

The conclusion that the bulk of the resources must come from the agencies, however, requires coming to grips with the difficulties associated with that route. Primarily, those difficulties have to do with evaluation and choice when a foreign policy motivation is involved. Who is responsible and/or qualified to represent the foreign policy interest? How much should it weigh against scientific evaluation? How can activities with different countries, different fields, different agencies be compared? What can provide the discipline that is required to force hard choices? How objective can foreign policy criteria be in any case?

An argument can be made that almost any S&T interaction with a country of interest is "good." Traditionally, the Department of State has tended to support fairly uncritically international S&T activities of other agencies within broad foreign policy constraints. But that is inadequate, if it ever was otherwise, in a period of growing interest in more effective use of US S&T capacity internationally. Even if funding constraints were not as serious as they are today, responsible use of public funds and resources would require more appropriate discipline.

In thinking about various alternative mechanisms, it is important to realize that the international activities that are actually relevant to this analysis are only those that fall marginally below the cutoff point on an agency's ZBB ranking. That is, proposals above the cutoff will be funded whatever the foreign policy interest. Proposals that fall near the bottom of the ZBB ranking are of little interest to the agency and should proceed only if there is a special foreign policy interest in having them implemented. In that case, external funding is clearly appropriate and, in fact, essential. Only those below but near the cutoff are of interest, for they have reasonable scientific merit and agency engagement.

This logic leads to the following possible approach. The Department of State could, in the budget cycle, attempt a ranking of international S&T programs across departments and agencies according to foreign policy interest. That ranking would be compared with the independent ranking within departments and agencies based on agency criteria. Projects that are marginal on an agency ranking but high on foreign policy ranking would be given an extra boost. Those marginal within the agency but low on foreign policy would be dropped, while those low in agency ranking, but high on foreign policy would proceed only with funding provided by the Department of State or other external source. Those marginal on both scales might deserve further examination.

Such a process may not be feasible for all international S&T activities, especially given the subjectivity of foreign policy criteria, and the staff time and competence that would be required of the Department of State. However, as an experiment, a selected list of programs identified *by the agencies* that require some foreign policy evaluation and are problematic within agency budgets, would produce a manageable first list. There may also be other ways of reducing the task by sampling or grouping of particular target countries, or decentralizing the process in particular cases. Such a procedure would have the virtue of requiring the Department of State to undertake the very difficult task of development of specific criteria that can be used for evaluation. If successful, it would likely lead to upgrading or dropping of some programs that have simply coasted for some years.

This process gives opportunity for a certain amount of "gaming" by agencies as they anticipate which programs will likely be given a boost by State and possibly adjusting their own rankings accordingly. To limit that possibility, it will be important for OMB to be directly involved, especially in the experimental phase.

The "international program office" of agencies would also have to be involved. All too often these offices have inadequate expertise, few ties to the technical divisions, and their own vested interests in the expansion of international programs rather than in critical evaluation and support. There is no simple key to guarantee their effective operation since they suffer the same structural problems within an agency on S&T issues that State does with respect to the technical agencies. Involving them directly in the dual ranking process proposed, however, working both with State and with their own technical divisions, can be a means of bringing about more effective integration and effectiveness.

In considering these proposals, it should also be noted that the structure of OMB is itself relevant to their successful operation. If domestic program funds, even under the restricted conditions noted, are to be used when programs are partially justified by foreign policy considerations, the domestic and international divisions of OMB become directly engaged in negotiation. There must be clear agreement within

OMB of the process and how it will be implemented by the agencies and throughout the budget cycle, if it is to have any chance of working. OMB might consider the same technique of cross-cutting ranking in the final budget process.

Planning, Management and Oversight

Whatever the funding mechanisms used, the need for adequate planning, management and oversight of international S&T activities is critical. Until recently, the planning phase of international activities, especially those origniating from strong foreign policy motivation, tended to be quite weak. Many agreements and programs were undertaken without adequate advance thought with resulting serious problems of implementation, and often raising questions about quality, objectives, and the possibility of "drain" of S&T information.

In the last two years, the need for a different approach has been recognized, with detailed planning carried out under the leadership of OSTP and with the cooperation of OMB as new agreements were contemplated, or existing ones reexamined. The situation is now strikingly improved, as is evident in the Chinese, Japanese, and Mexican S&T agreements, and in the reexamination of the agreements with the USSR.

The need is not only for adequate planning when the President or Secretary of State or other official sees a politically-justified requirement for an S&T agreement. The goal should also be to develop opportunities in which science and technology can contribute to the foreign policy interests of the US. This is much harder to achieve, since it involves greater sensitivitity throughout the Government to those foreign policy interests and of how S&T programs can serve them.

Substantive management and oversight, in turn, is obviously important for any program; it can be more difficult for international S&T activities than many, or at least require some additional management devices, because of the multiagency involvement and the mix of disparate scientific and foreign policy objectives. There is little need here to discuss the details of alternative management and oversight devices. The CISET Committee of the FCCSET ought to be able to establish appropriate process and procedures. Obviously, the activities should be managed with the goal of maximizing both the scientific and policy returns. Hopefully, these are fully congruent, so that the better a project on technical grounds, the more likely it is to serve policy purposes.

In establishing a mechanism to provide oversight for international S&T activities, it is important to keep in mind that the whole may be greater than the sum of the individual programs. That is, even if the scientific interest in a given activity may not have been fully competitive by itself, the sum of international S&T activities may offer considerable long-term scientific interest to the US. The growing involvement, and dependence, on global problems gives the US a considerable stake in developing interest and capacity in research on those problems throughout the world. And, increasingly, the solutions to problems within other countries may be of interest to the US as this country faces new resource and energy constraints, and as scientific and technological competence in other countries grows to match that of the US.

Adequate management and oversight must also provide a means for substantive review, for assisting in whatever evaluation and budgetary process is designed, and for providing a better information base than has been available until now. The ISTC should be able to take on the last-mentioned task, since it will have an overlapping information responsibility with regard to development-related S&T.

Category III: S&T activities designed to serve international development objectives.

Key Recommendation: To allow more effective application of agency scientific and technological resources to problems of development, an experiment is proposed with a small number of agencies to create a line item in agency budgets for programs of interest to the agencies, important to development, but not sufficiently within agency domestic missions to warrant regular funding. These programs would be ranked by the agencies on scientific criteria, and the ISTC would rank all such development-related S&T programs according to development criteria independent of the agency concerned. Only programs scoring high on both rankings would be allowed to proceed.

The ISTC would also provide a more general mechanism able to work across agencies on development-related S&T to provide a focus for planning, for development of programs, and for centralized information and monitoring.

Discussion

The overall question in the development category remains the same: how to achieve effective use of S&T in support of US interests. The key distinguishing aspect, however, from more general foreign policy goals is the explicit commitment of the US Government to assist in development, and in particular to the application of S&T to the problems of development. The latter commitment is made manifest, beyond oft-repeated rhetoric, in the mandate of the new ISTC and in the scientific and technological portions of the AID budget. But AID and the ISTC are in themselves only a small fraction of the scientific and technological resources of the US Government that are or could be relevant to development problems. How can those broader resources be effectively tapped, and how should they relate to the agencies whose mission is development?

There is not, of course, a sharp demarcation between programs of interest to developing countries and those of domestic interest to the US. Some do fall wholly on one side or the other, but often programs have some degree of interest to both. In fact, it is the tendency to ascribe all programs as either of primary benefit to the US or of primary benefit to other countries that creates some of the difficulties of using effectively the capabilities of the domestic agencies.

Management procedures emphasize budgeting by objective, in order to make clear the lines of authority and responsibility, and to simplify comparisons among programs. Thus, programs that are seen as being primarily of benefit to other countries, whatever agency is involved, should be funded from the foreign assistance appropriation, with funds transferred from AID, and in the future ISTC as well, to the agency concerned. This procedure allows a single ZBB process for ranking of programs, and single presentation to the Congress. It minimizes the problems of coordination and appears to ensure efficient use of resources.

If such procedures can be realistically and effectively applied, and can achieve the desired objectives, they are obviously to be preferred. However, it is not always possible or appropriate to compartmentalize in this way. An attempt to force programs into this sharply demarcated mold can have serious costs:

1. Departments and agencies are unlikely (at best) to develop and maintain quality programs if the funding always comes from other agencies. It means a dependence on budgets over which they have no control, an inability to develop regular staff positions and thus a line of advancement, little influence within the agency since the budget does not go through agency processes, no requirement for program commitment on the part of the agency leadership or the relevant Congressional committees, dependence on an external bureaucracy with different goals, and often a limited role in program development on the part of those who will have to carry out the program. Any given program may work well, and there are many examples; but as a way of tapping the S&T resources of the US Government for development purposes, compartmentalization in this way is not a route for sustained quality results.

2. The difficulty of building programs within agencies which depend wholly on outside funds also tends to reinforce the increasingly artificial separation between domestic and international objectives. It makes more difficult the development of sensitivity to possible applications of US R&D in developing countries, and reduces the opportunity to learn from what others are doing. Both sides of that coin are important. Much more of domestically-oriented US R&D is likely to be relevant to developing countries than is generally realized. The most effective way of determining relevance and making the work accessible is not by "information banks," but by involvement of more American scientists and engineers, and of R&D managers in development-related activities. With regard to learning from others, the results of increasingly competent R&D efforts in developing countries especially those with "middle-income" status, are likely to be of growing interest and pertinence to the US. This country no longer dominates the S&T scene as it once did, while at the

same time there is a more evident convergence of problems faced within all countries. Useful knowledge of what is being done elsewhere is best obtained by those concerned with the same issues in this country.

3. Realistically, a policy to obtain government-wide funds for S&T activities from a single appropriation is unlikely to develop adequate funding resources over time commensurate with the opportunities. Certainly, it is unlikely to be a satisfactory route for meeting the President's commitment to increase the total of American funds devoted to assistance for developing countries. Whatever long-range possibilities there may be for ISTC funding, they are unlikely to be large enough to encompass substantial support for programs in the domestic agencies.

4. An attempt to restrict agencies only to those development-related programs that are funded by AID or ISTC does not reflect growing pressure both from within departments and agencies, and from some parts of the Congress, to see more effective application of agency resources to development objectives. The existing situation is already beyond the simple pattern of earlier years; several agencies now have the statutory authority to seek their own funds for development programs. DOE, NASA, NSF, part of HEW and perhaps others have the authority, though with few formal programs. Many agencies are interested however, with pressure likely to grow.

Thus, a preferred management strategy has substantial disadvantages. Is there a satisfactory alternative? The simplest logical alternative is to have separate budgets in agencies for development-related S&T activities. That could avoid the problems of single-source funding, but would have serious costs as well:

1. Greater difficulty of central oversight, planning and rigorous evaluation of individual budgets and programs, and of the overall development-related budget of the government;

2. Danger of independent agency activities overseas, at times with contradictory aims, with inadequate control or coordination;

3. Possibility of allowing narrow programs that may be scientifically justified within a discipline or within an agency but inappropriate from broader development considerations;

4. Questionable statutory authority in some agencies, and uncertain reaction of Congressional or other interest groups.

Both processes have important problems, but those associated with funding from a single appropriation which is the present policy, seem increasingly inadequate to the overall goal. Moreover, single source funding does not have the flexibility that will increasingly be required on the basis of either scale or quality of effort.

The alternative of separate agency budgets has its own pitfalls but, with the exception of the question of statutory authority and Congressional reaction, these are essentially management questions. Is it possible to design a structure and process that would make this alternative work while minimizing the very real inherent problems?

Some elements of a potentially satisfactory structure and process can be suggested, though the details will require more discussion and elaboration. It is proposed that an experiment be conducted with a very limited number of agencies and/or with stringent budgetary constraints, to test the ideas and their acceptability.

Separate agency budgets; a possible process and an experiment

The problem in some respects is easier than implied by the discussion above, for a substantial segment of development-related activities could fall in categories that cause no or few special problems. Some programs are of sufficient interest to the US, or could be seen to be with "encouragement," as to hold their own in the competition for "domestic" resources. For example, research on foot and mouth disease in Mexico is also of clear interest to the US and could easily be justified from regular budgets. An indication of Presidential or White House encouragement would likely lead to more proposed programs of this kind within regular agency budgets.

At the other end of the spectrum are those programs that are of interest to US foreign assistance agencies but of very low interest to the domestic agency in that field. Such programs would have to continue to be supported from the budgets of the foreign assistance agencies as at present.

In between are those activities that cannot be considered to be clearly within missions defined purely domestically, and yet which are of some interest to domestic agencies, are relevant to the capabilties of the agencies, and are pertinent to important development problems. It is for these that a different process needs to be developed if the resources of the domestic agencies are to be more extensively engaged. (Of course, the statutory authority and Congressional approval for a departure from present practices may not be possible for some agencies; that go/no go question will be ignored for the purposes of the discussion, though it obviously may be a complete barrier in some cases.)

The essential problems with separate agency budgets for development-related S&T programs stem from the greater difficulty of management control, including issues of program development, evaluation, funding comparison, implementation, and central oversight. What is required is a mechanism able to work across agencies for program development and continued cognizance, and a budget process that forces rigorous evaluation of programs, comparisons between them, and oversight as a whole.

The major structural change in the Government that offers the possibility of providing the necessary instrument for assistance in these tasks is the creation of the ISTC in the context of a newly centralized foreign assistance agency, the International Development Cooperation Agency (IDCA). Though the ISTC is a subsidiary part of the IDCA, it is intended to have considerable autonomy, and was conceived from the beginning to be able to play something akin to this coordinating and integrating role across the Government for science and technology related to development. In this respect, it can be an important arm for IDCA's and the Development Coordinating Committee's responsibilities. Though the ISTC is not yet in existence, having just been authorized by the Congress for an October 1979 start, it already has been given an assignment by the PRC to survey existing R&D programs of the Government that are of potential interest to developing countries.

The ISTC, within the new IDCA charter and position, offers the capability, at least in prospect, of providing a mechanism able to work across agencies and provide a focus for planning, for development of programs, and for centralized information and monitoring of S&T programs that can meet a portion of the management problems raised by separate agency budgets. In addition, it can play a key role in a modified budget process to enable the rigorous ranking of programs required.

The modified budget process proposed starts with the assumption that the development related programs under consideration will be expected to be of scientific and technological merit and thus competitive on scientific grounds with regular programs. Thus, the agencies would be able to carry out normal scientific and technological evaluation without compromise of standards. Ranking within regular agency programs will be difficult however, since by definition these programs do not fit sufficiently within the domestic missions of the agencies to be compared with those that do. The agencies can be asked as a special exercise, however, to estimate their relative scientific ranking as if they did fall within their mission.

Comparison and ranking of program across agencies on the basis of their perceived importance for development is then necessary as a way of obtaining a Government wide ranking according to development criteria. The ISTC could be charged with this task. It would be a complicated task since it would be ranking its own programs and programs it helped to develop along with others, the opportunities for bureaucratic gaming would be high, and it would to some extent be second guessing the scientific evaluation within the agencies. The purpose, however is to provide a dual ranking of programs across agency lines on both development and scientific criteria that can provide a reasonable basis for rigorous discipline.

Essentially, the ISTC would be responsible for a government-wide S&T budget for development, which would include its own programs, relevant portions of the AID program, and those development related programs of individual agencies not included within domestic missions. The ISTC would have to defend this budget in the annual budget cycle. Individual agencies would of course have to defend their whole budget before OMB, and later the Congress, but would look to the ISTC to certify their submissions of development-related programs.

This process, which has logical consistency in the abstract, would not be easy to implement. To explore the approach, it would be useful to experiment for a year or two with a small number of agencies that already have clear legislative authority in this area, with a relatively small budget authorized, and with emphasis on programs that also have substantial domestic interest so as to reduce risk. Procedures, and criteria could be developed during that time and the whole process monitored and evaluated for its viability.

Another issue is the importance of the internal organization of OMB to the ability to introduce a process such as is described. Though a different problem than in Category II, what is suggested here involves substantial cooperation and joint evaluation in the budget process by the domestic and international arms of OMB. Without a considerable degree of agreement and of understanding of the objectives being sought on the part of the OMB divisions, the process intended to be asked of the agencies simply would not be viable.

OSTP, too, would have to take an active role, especially during the experimental period, to test out the procedures, encourage cooperation of the agencies, resolve bureaucratic disputes, support ISTC, and work closely with OMB to be sure of coincidence of objectives and adequate evaluation.

It should be noted, of course, that the question of statutory authority for agencies to seek funds for other than domestic purposes is not a minor issue, though it has been put aside in this discussion to allow exploration of the issues. Some agencies clearly do have such authority; for others, the situation is hazy; others clearly do not. Obviously, even for those without such authority, it is conceivable to obtain it if it were thought sufficiently important and Congress could be convinced.

Perhaps more to the point is the question of Congressional reaction to agencies seeking line item budgets for programs intended to benefit developing countries (as well as the US). That reaction is not fully predictable, and is likely in fact to vary with the committee, and over time. Various Congressional constituencies have become more interested in seeing "their" agencies become more directly involved in development activities; others resist such a move. On the whole it would appear that the Congress is moving toward greater flexibility and interest. Certainly, Congressional concurrence would be required and, it must be observed, such concurrence is much more likely if it can be convincingly shown that the procedures by which programs will be generated and implemented are rigorous and under full control.

Coda

The proposals made here for enabling the US Government to make more effective use of its scientific and technological resources in support of international goals will not be easy to put in place or maintain. They or some alternative, are important to develop, however, for the present policies and procedures do not permit the application of the nation's capabilities in S&T to international purposes in a manner commensurate either with the opportunities or needs. The future will make even clearer than today the inadequacy of the present situation; the time to begin to experiment with alternatives is clearly at hand.

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OECD

Cooperation in Science & Technology+

Eugene B. Skolnikoff

The Case for Cooperation

Cooperation in science and technology among the OECD nations is not an unusual phenomena. All participate in cooperative programmes to some extent; for some the level and scale of continuing cooperation is substantial.* Are there new conditions, new opportunities, or new needs that justify a re-examination of the subject by ministers in an OECD context?

There does appear to be an excellent case for such a re-examination, though it must be conducted with sober awareness both of the many existing mechanisms for cooperation, some within OECD itself, and the costs as well as benefits of cooperation as seen from a multilateral framework.

The case can be stated succinctly.

The Western industrial countries and Japan all, to varying degrees, require more rapid and effective technological progress and innovation to meet their economic, social and political needs. But, at the same time, the economic situation that serves to create these needs places important budgetary constraints on R&D expenditures, inevitably limiting the projects that can be undertaken within each nation. The high cost of many scientific and technological fields further constrains what each nation can undertake alone.

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* The differential participation of OECD countries is itself a significant fact that may be usefully discussed by Ministers.

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Moreover, the relatively equal scientific and technological competence throughout most OECD countries, with leadership in specific fields scattered among several countries and with no country able to dominate in all fields, means that a given project or field is likely to benefit in quality or rate of progress from contributions that go beyond a single country's resources. In some cases, participation of more than one country is required to attain a critical size necessary for effective attack on the subject. Some fields, of course, by their nature require international cooperation.

To these arguments can be added the attractiveness of cooperation in the light of massive investments required in fields of central, and growing, importance to OECD countries. This is particularly evident in energy-related areas, but also pertinent to the atmosphere, the oceans, and the deep earth, the understanding of all of which will be crucial to future well-being. And some fields which may involve projects of relatively small size, such as waste disposal or urban technologies, may in the aggregate be sufficiently massive in scale as also to raise possibilities for savings and more rapid progress through cooperative approaches.

On the other hand, it must be recognised that the economic situation also leads to greater interest in each country in improving its competitive position. At times, this objective can appear to be in conflict with opportunities for cooperation.

But, as is noted in more detail later, experience now shows that cooperation need not detract from a nation's competitive interests if the projects are carefully formulated with prior agreements on sharing of the results. It is a nation's ability to exploit technology in the market place that is the largest determinant of its competitive position.

To argue that conditions, needs and opportunities have changed sufficiently to make expanded international cooperation in science and technology an important option for OECD countries, does not, of course, of itself justify more cooperation or particular forms of cooperation. The potential costs are real and must be carefully assessed. These "costs" include the inherent difficulties of meshing disparate bureaucracies; the delays often encountered in achieving common decisions among differing political and legal systems; the complications of varying decision processes, priorities and competence of countries; the costs of added international bureaucracy if that is required; the added overall cost (though not the cost to each participant) sometimes resulting from international efforts; the danger of inertia that makes projects hard to start, but even harder to stop once started; the possibilities of continuing drains on national R&D budgets because of international commitments; and the occasional tendency to undertake internationally only those lower priority projects that are not of substantial importance within a country.

These problems of multinational cooperation are real, but the scale of existing cooperation and the evident success of many projects demonstrates that the problems can be dealt with, or at least need not over-balance the benefits that are achievable. In fact, learning how to ameliorate the problems should make succeeding projects easier.

It is also necessary to distinguish among various forms of cooperation - bilateral, trilateral, or those involving numbers of countries; whether nations manage the cooperation themselves or place management in the hands of an international organisation of some kind; whether the cooperation is formal or informal; whether joint work is involved or simply exchange of people or information; and other distinctions. The problems and costs vary markedly depending on the nature of the cooperation.

It should be noticed that the idea that cooperation, any cooperation, is "good" is no longer a serious argument in the technological maturity that characterizes most OECD countries. Proposals for cooperation must be systematically and hard-headedly evaluated as are any other proposals for government activities and expenditures. Having said that, it is also worth saying that the general value of increased interaction and of appreciation of shared goals among OECD countries may well be of growing importance in an era in which disagreements, especially across the Atlantic, are in fact politically serious.

Potential Subject and Nature of Cooperation

It may not be difficult to agree that scientific and technological cooperation needs to be re-examined given the changed situation, but an immediate question is whether there are in fact subjects that could be proposed that are not adequately covered in existing forums or mechanisms. Discussions held in various OECD capitals in preparation of this paper often focussed on this issue.

This task of identification of candidate subjects needs to be carried out by governments, possibly with some OECD assistance, (a particular role for the OECD is proposed and discussed later), in effect asking what programmes internally had to be deferred because of budgetary constraints that might go ahead if the burden could be shared, which might proceed faster if costs and technical resources could be shared with others, which might benefit from the technical competence found in other countries, and which might be duplicative of unknown but likely similar work in other countries.

The exploratory discussions that were held, raised possibilities in several fields that appear to justify further examination. They can only be mentioned as a title here; further elaboration is required in each case. The fact that several candidate fields were tentatively identified for further examination seems to give confidence that concerted attention by governments is likely to identify others, and with greater specificity.

Among the fields of possible interest that were mentioned (which, of course, are not formal proposals by governments) are:

- deep ocean rift exploration; development of research vessels and cooperative programmes;
- ocean margin drilling; cooperative programmes;
- deep geological exploration; development of technology and cooperative programmes;
- mineral extraction technology; development of new technologies;
- public service technologies; comparison of programmes and sharing of development tasks in, for example, waste disposal, urban technologies, transportation;
- regulatory technologies; development of testing technologies, for example for toxic chemical evaluation;
- technologies for developing countries, cooperative R&D or cooperative programmes in specific countries;
- large scientific facilities; joint funding and development of new particle accelerators or large telescopes;
- generic technology centres; institutional cooperation among similar centres in different countries.

Each of these has a particular history, often national programmes of substantial size, and in some cases international experience. It must be kept in mind that the issue is whether the subjects can be more effectively and expeditiously pursued through some form of cooperation, or more intensive cooperation, than they can through present patterns of support.

Several comments about this list, and others that may be considered, must be made.

A. Variety of forms of cooperation

International cooperation not only can vary according to the number of countries involved, (it is assumed here, and is discussed later, that only countries interested in any specific programme would be involved), but also in the form of cooperation. There are three broad categories:

1. joint R&D, involving a specific facility, or assemblage of a single team in one or a small number of places;
2. task-sharing, involving joint planning of R&D and agreement on division of tasks; or
3. exchange of people and information, including exchange of research results and increased interaction of scientists and engineers, and also, possible cooperation in planning and budgetary processes.

Which form of cooperation is appropriate necessarily varies with the subject and its state of development. Clearly, where a single large expensive facility is required, the first cateogry of joint programmes is relevant. In some subjects, such as public service sectors or R&D for developing countries, there may be so little information now of each country's programme that the third category is a necessary first step. The purpose would be simply to identify overlap and duplication as well as opportunities for other forms of cooperation. In such cases that limited degree of cooperation may be sufficient, and already represent a substantial forward step. In some categories, such as special research centres established in each country (e.g. generic technology centres), what may be called for is institutional arrangements for cooperation among national centres. For other subjects, in which there are now substantial programmes in some countries, such as deep ocean exploration, the second category of task-sharing may be justified as a way of making more rapid progress and avoiding duplicative programmes.

It is worth recalling, in passing, that there is growing concern among OECD countries at what appears to be a substantial falling off of the movement of scientists and engineers among OECD countries. If this is so, one important focus of increased cooperation would be to stimulate greater interaction of this kind. The case for that need not be made here, but should be examined in the OECD context.

B. The basic science to industrial technology spectrum

It has become a commonplace to observe that international cooperation works best when dealing with basic science, and tends to be very much more difficult as the subject is closer to the marketplace. By now it should be realised that this rule is an enormous oversimplification. In fact, those fields of basic science requiring large facilities such as new accelerators or new telescopes probably should receive little attention in this Ministerial re-examination. Those are the subjects for which cooperation is relatively established, and which have such well-developed and organised professional communities that there is little concern that opportunities for cooperation will be missed.

On the other hand, it is the applied science and applied technology areas that require large investments, that do not ordinarily have organised professional communities to surface cooperative opportunities, and that often do not receive adequate consideration as candidates for international cooperation because of concern about possible industrial competition.

Experience in recent years with many cooperative programmes in technological areas, including particularly the IEA, has shown that with adequate prior attention to agreements on patents, licences and related issues, these programmes can, in fact, be quite successful. They are not easy, and there certainly have been programmes that have achieved far less than desired. But it is clear now that they can be done well.

Thus, it is in these more applied areas where the greatest opportunities are likely to exist, since they constitute the largest demands on national R&D budgets, and have tended not to receive adequate consideration in the past.

C. Criteria of "Eligibility"

In thinking of eligible candidates for cooperation, the relative criterion is not where a subject falls on the basic research to technology spectrum, but rather what are the subjects for which governments are providing public funds. Presumably, where only private sector industrial support is involved, it is and should be up to industry whether cooperative R&D is justified. There are, of course, many examples of such cooperation. (Even here, there may be occasions when governments want to stimulate or ease the way to industrial cooperation, but these are special cases that need not be of concern here).

Even when public funds are involved, decisions about cooperation in some cases may be more appropriately left to industry, especially if a subject is largely at the commercial exploitation stage.

But, in all other areas of public funding of R&D, it is reasonable for governments to ask whether programmes are or should candidates for greater international collaboration. Criteria for such a decision, some of which are roughly the same as those for government involvement in the first place, would include:

1. Does the subject have a particularly long time frame?
2. Does it involve large investment costs?
3. Will it involve large and perhaps unique facilities for demonstration or pilot plants?
4. Is it stretching the state of the art?

5. Do other countries face similar needs, and perhaps have relevant experience?

6. Does it have some particular international aspect or consequence?

7. Is it one in which exchange of information and personnel takes place naturally, or does such interaction require stimulation?

8. Are there common as well as national benefits to be expected from pooling efforts in the field?

Recognising the important differences among countries in terms of process and funding policies, a review of R&D programmes with these criteria in mind, even without great precision about what constitutes "large" or "long", would undoubtedly result in appreciably more candidates for international cooperation than are now on the international agenda.

Process

The discussion above applies in general to scientific and technological cooperation among OECD countries, without reference to the process by which such cooperation should be considered, how it should come into being, what countries would be involved, or indeed, what the role of the OECD should be. Several guiding principles and process proposals can be spelled out for discussion among the ministers of science, based on prior experience, analysis of that experience, and discussions with several OECD governments. These are:

With regard to attitudes of governments:

1. The fewer the number of countries involved in cooperation, the easier the arrangements. Accordingly, cooperation among two or a very limited number of countries is the easiest to organise, and can be started and led by one country raising the issue bilaterally. However, that requires individual countries to take the initiative in exploration of possible interest among potential partners. That obviously does happen, but it is difficult for a country to make many such initiatives on its own. Thus, by this procedure, there is no assurance that the scope of possibilities outlined above, will be surfaced or surveyed.

2. In general, whenever possible, governments and their technical agencies prefer to operate international cooperative programmes through direct contacts with their counterparts in other governments, without intervention of international organisations.

3. Each country is different in its structure, internal processes, priorities, distribution of scientific and technological resources, and commitments to multinational organisations or existing international cooperative programmes: As a result, the authority for an overall examination within a country for new prospects for cooperation must come from a central point; hence the appropriateness of consideration by the ministers of science.

4. Differences among OECD countries are substantial not only in size and in depth of science and technology programmes, but also in experience with cooperation and attitude towards it. The less advanced countries of OECD present particularly important targets for greater involvement in appropriate ways. The United States presents a different situation, for its experience with detailed international cooperation in civil R&D is actually rather limited, and its budgetary and decision processes are not traditionally geared to the need or opportunities for cooperation with other countries. Hence, one of the goals should be to create a greater capacity in the decision processes of Member countries for consideration of cooperation as a "matter of course".

With regard to OECD:

1. There appears to be general agreement that OECD's function should be primarily as a catalyst or animator, assuming no continuing operational role in specific projects.

2. Accordingly, its role would be to stimulate ideas from governments, serve as a repository of candidate programmes, provide initial staff functions for calling together expert groups, help identify governments interested in participation, and then step aside while those governments develop the programmes on their own.

3. The OECD can have a most important "forcing" or "trigger" function (what one senior official called "international scratching powder"), given the fact that governments do not as a regular matter canvass their activities to identify possible subjects for cooperation, and do not easily take initiatives on their own to develop multilateral cooperation. Thus, in addition to a continuing receptivity for ideas, there would be a periodic, say every three-four years, request to governments for a special effort to explore and propose areas for cooperation.

4. The OECD might also undertake specific studies or seminars in those fields for which national programmes are not widely known, and thus for which prior exchange of national programme information is necessary before cooperation can be usefully considered.

5. The OECD could also usefully study how to lower the barriers to effective cooperation for specific fields or categories of cooperation. In particular, proposals for more effective ways of cooperation in "research planning" would make substantive cooperation much easier. At present the great difficulties inherent in meshing plans where each country operates on its own schedules are often a serious barrier, especially to long-range cooperation.

In this formulation, the primary task of the OECD would be to act as the means for stimulating governments to consider enhanced possibilities for international cooperation in science and technology, and to ease the way for development of specific programmes. It would undertake no operational programmes of its own, and avoid maintaining substantial involvement with programmes once launched. Participating governments must bear the full responsibility for supporting programmes once they have been initiated.

Conclusion

The case for re-examining the scope and opportunities for international scientific and technological cooperation among OECD countries seems a good one in the changed circumstances in which all nations find themselves. The OECD can play a critical catalytic and forcing role in stimulating both that re-examination, and the action that may follow it.

The justification for increased cooperation is primarily economic. However, the political importance to relations among OECD countries can be substantial. Increased cooperation and recognition of common goals can be a significant counterweight to tendencies toward nationalism and weakening solidarity among OECD countries.

Issues for Discussion

1. How can the less developed OECD countries be brought into greater interaction on S&T.

2. How can the different planning schedules, framework, etc. of each country be reconciled? Can there be greater collaboration in the planning of R&D than at present?

3. What are candidate subjects for cooperation deserving examination?

4. Should OECD undertake a study of the barriers to cooperation?

5. What, if any, fields require laying out of national programmes to provide information not now available, and to consider whether cooperation is needed. (e.g. waste disposal).

6. How can the possible conflict between cooperation and competition be reconciled?

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AAAS -- Five-Year Outlook

Science, Technology and International Security *

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In a world substantially altered in this century as a result of the products of research and development, with the elements of security of most nations directly affected, government institutions and policy processes in the U.S. remain heavily domestic in orientation. Contrary to common assumption, this is at least as true for the scientific and technological enterprise as for any other.

There are many detailed issues and needs that are relevant to "Science, Technology and International Security," some of the most important of which are presented in the pages that follow and in the accompanying papers. But a common recurring theme is the parochial nature of U.S. national institutions that makes it peculiarly difficult to come to grips with some of the needs, or to anticipate them in any reasonably orderly way. This is a problem that has plagued U.S. Government attempts to deal with the international implications of R&D, and with international security and technology itself for many years. The problems, and the dangers, now become more pressing as the problems increase in severity and as scientific and technological competence grow in other nations. New measures are needed, yet the issue of excessive domestic orientation is only rarely identified or confronted directly. Without some attempt to deal with this institutional process question, actions to focus on the specific needs discussed below are likely always to remain *ad hoc*, and only rarely commensurate with the full dimension of what is required.

I. Background

The results of the scientific and technological enterprise have been central elements in the restructuring of national societies and international affairs, particularly in the 35 years since the Second World War. The development and application of aircraft, satellite communications, health and sanitation measures, missiles, nuclear weapons, automated production, radio and television, agricultural mechanization and new crop strains, all bear witness to the productivity of R&D and, in their effects, to the profound revolution in human affairs they have brought about or made possible. The pace of change either in the laboratory, or in the effects of the products of the laboratory, shows no sign of slackening.

The effects on international affairs and on the international political system have been heavily conditioned by the differential ability of nations to carry out R&D, or to take advantage of the results of R&D. Two nations have emerged with military power and influence far greater than others largely as a result of their natural endowments and resource base that allow massive exploitation of science and technology. The gradual decay of that dominance, especially in its economic dimension, is already a source of new international relationships, and new problems. The disparity between nations of the North and South in ability to acquire and exploit technology has equally come to be recognized as a major factor in their relative economic status and prospects, and in their increasingly acerbic political relations.

Concurrently, the pace of industrialization of technological societies has greatly intensified the dependency relations among states, so that even the most advanced find themselves critically dependent on others for resources, information, capital, markets, food, and even technology itself.

Traditional geopolitical factors have been altered or expanded by advances in science and technology to include, inter alia, size and number of long-range nuclear missiles, satellite communications and surveillance capability, competence of the educational system, fundamental change in the very significance of major conflict, and, critically, R&D capacity.

The results of R&D have also thrown up new technologies of global scale, creating wholly new issues in international affairs, notably atomic energy and space. And the side effects of technological societies have altered traditional international issues, or created major new ones, such as transborder environmental concerns, stratospheric modification, or ocean exploitation.

Not all of these changes in international affairs are encompassed within a traditional notion of "security." But the web of interactions so characteristic of a technological world in effect make it difficult, and misleading, to attempt to exclude, say, economic concerns of developing countries from the concept of international security. In fact, the broad issues of food, health, resources, energy, population are as legitimately aspects of security as are military issues. Certainly, the progress of developing countries in those areas will be directly relevant not only to their own security, but also to that of the U.S.

Given these effects of science and technology on the international system and on the international security of states, it is interesting to observe that the support for science and technology is primarily a national endeavor in all states, and particularly in the U.S. That is, the decisions about support for R&D, the determination of objectives, the setting within which budgets are considered, the allocations among competing fields or issues, are all taken in a national framework. By itself, that is not surprising since national governments are the dominant source of funding for R&D. This means, however, that international or global needs are not likely to be adequately reflected on the basis of national consideration alone.

This phenomenon is not peculiar to science and technology. A natural result of the nation/state basis of the international system is that decisions, even life and death decisions affecting people in other countries, are often made unilaterally within one nation. Moreover, the apparent worldwide intensification of nationalism in the face of economic difficulty, not least in the U.S., further emphasizes this situation.

However, with regard to science and technology, the parochial nature of the process goes beyond normal constraints of nation-based decision-making and funding. The decentralized nature of public funding for R&D means that R&D is predominantly considered within the context of mission agency budgets. Even for those agencies whose rationale has a basic foreign policy motivation (DOD, DOE), the actual decisions and choices are heavily influenced by domestic pressures and inputs. Some departments or agencies are in fact precluded by their legislative charter from committing resources for anything other than "domestic" problems. All are faced with a budget process in both the Executive and Legislative branches that discourages (usually denies) all departments except foreign policy agencies the right to allocate their own R&D funds for other than U.S.-defined problems.

In the private sector as well, R&D decisions are heavily conditioned by the U.S. market, with American industry still dominantly concerned with U.S. sales, and only gradually adjusting to the growing share of exports in the economy.

The implications of this situation are evident throughout the discussion of specific issues below, and deserve more elaboration subsequently to suggest possible policy or institutional departures that could be undertaken.

Of course, not all needs or issues (or opportunities) are handicapped by this particular institutional problem. What follows is a broader discussion of the issues in the interaction of science, technology and international security that are likely to be central questions over the next five years, and with which science and technology, or U.S. Government policy will have to, or should, cope. Though the focus is on a five-year period, policies cannot sensibly be seen in that short time frame without reference to a much longer time horizon, with long-term objectives explicitly or implicitly in mind. Where relevant, what are in effect assumptions about desirable futures will be spelled out. The final section will be concerned with some of the institution/policy process questions raised by the specific issues.

II. Key Issue Areas

It is tempting to start with national security issues, which appear to be most directly related to the subject. But, as is reflected in the U.S. today, economic issues are likely to receive policy priority in the next few years, with important issues and consequences for international security. In addition, as significant as are the defense issues, they have tended to receive more concentrated attention. Hence, they will appear later in this paper, without denying in any way the fundamental significance of science and technology to security issues and, particularly, to international stability.

A. Economic

1. Competition/Cooperation Among Advanced Industrial Countries

It is not a novel observation that the most serious short-term problem of the U.S. and of other Western industrialized nations is and will continue to be coping with the effects of inflation in a largely stagnating economic situation. Unemployment rates are high in many of the countries (over 9% in the U.K. at the end of 1980), with inflation at the double digit level for several. There are, of course, many causes for the relatively bleak economic outlook, which it would be inappropriate to attempt to analyze in the context of this paper. However, not only does this situation affect the international role that science and technology may play, but some measures individual countries may take for economic purposes will affect the course of science and technology, and some may be designed to limit the international flow of scientific and technological information in the attempt to serve economic goals.

a. Industrial Policy:

It has become almost a fad to talk of the need in the U.S. for an "industrial policy" or for "reindustrialization." Whatever the full connotations of those phrases, several aspects are particularly relevant to

R&D. One is the ability (legal, political and psychological) of the U.S. Government to work cooperatively with individual companies, or with a consortium of companies, to support R&D designed to improve the international competitive position of U.S. industry. Antitrust considerations, among others, have deterred such joint activity in the past.

Two initiatives in the past Administration have shown that the barriers can be overcome, at least for rather fundamental work. The joint research programs on automobile engines with a consortium of auto companies (Cooperatiave Automobile Research Program), and the cooperative program for ocean margin drilling with a group of oil companies have received the advance blessing of the Justice Department. These are now, however, in jeopardy or cancelled, apparently from the conviction that industry should make these investments on its own. The international economic payoffs of closer government/industry R&D cooperation (and the costs of not easing the way) will likely prove to be important enough over the next several years to justify reconsideration of this policy. Whether the Government is involved or not, the advantage for international competitiveness of allowing R&D cooperation among companies in the same industry is likely to lead to interest in modifying antitrust policy legislation. Clearly, such proposals would induce major political controversy.

A related aspect of industrial policy is the tendency of the U.S. to attempt to apply to U.S. companies operating abroad the same rules and constraints that apply inside the country.[1] The essentially adversarial

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[1] Lester Thurow, Zero-Sum Society, Basic Books, New York, 1980.

relation between government and industry in the U.S., whatever its historical justification and merits in spurring competition, serves often to put American companies at a disadvantage abroad when competing with companies that are directly supported and often subsidized by other governments. This is particularly relevant in high-technology industries, as companies in other countries are now able to compete as technological equals for the major new markets that will determine future economic strength. There are obviously many complex and contentious factors that must be addressed in this issue, but they must be addressed. The economic stakes are high.

Of course, the key determinant of America's competitive international technological position is the strength and innovativeness of its high technology industry. Domestic science policy, including support for R&D, tax incentives, regulations, quality and adequacy of the education establishment, and other elements will crucially affect the economic scene in years to come. (The proposed reduction of support for science education is particularly disturbing for that reason.) In addition, specific tax and other policies that bear directly on industry's decisions to carry out R&D abroad or in the U.S. will require examination, though it should not be an automatic conclusion that overseas R&D by American firms is necessarily against the U.S. interest. Depending on the specifics, it can contribute directly to American R&D objectives, can enhance the possibilities for cooperation on large-scale projects (of which more below), and can be an important contributor to knowledge more generally, for the benefit of all.

One of the greatest dangers of the current economic malaise in Western countries, coincident with serious competition from third world countries in specific technology industries and from within industrialized countries (especially Japan), is the possibility of a rise of protectionism to preserve dying or inefficient industries. The causes of the changed status of an industry are likely to be many and varied: increased labor costs relative to other countries; changes in costs of other factors of production, particularly energy and resources; relatively lower productivity; lagging innovation; inadequate structure or industrial organization to make possible effective competition; and others. The political temptations to respond to worsening domestic unemployment and its ancillary effects by preserving and protecting inefficient industries are very large, especially when a certain amount of implicit or informal protectionism is practiced by most countries in one way or another (hidden subsidies, biased regulations).

The economic costs of the emergence of a protectionist spiral among industrialized countries, and the consequent loss of incentives for innovation and support of R&D could be very great. In effect, protectionist measures are an alternative to R&D investment, at relatively low short-term cost and very high long-term cost. It would be a poor bargain, but one likely to be proposed and actively sought by powerful forces in the near-term future.

A particular technological aspect of protectionism has emerged in recent years. That is the concern over export of technology which, it is argued, is tantamount to the export of American jobs as that technology becomes the basis of new competing industries. The argument is that U.S.-developed technology is sold or made available to others at a price that does not adequately reflect the true costs, or the broader effects of the sale on the U.S. It is a disputed issue, not only with regard to the facts but also whether possible cures, most of them protectionist in nature, would be worse than the disease. For example, is the current Government pressure to exclude foreign students and faculty from advanced integrated circuit research facilities at universities a wise policy? It is an issue likely to be more rather than less visible in the future.

Lastly, under the heading of industrial policy must be included the relationship between domestic regulatory policy to protect health and safety, and a nation's international economic position. Already under intense scrutiny, this subject is certain to be the focus of important debate in the next five years. The basic concern is that unequal regulations in different countries can result in substantially different costs of production thereby changing a nation's competitive position. That claim is made now with regard to American environmental and safety regulations that are presumed to have important effects on the U.S. export potential. Equalizing regulations would be one way to deal with the problem when it exists, but that often does not reflect differing conditions in countries, different factors of production, or differing values. Sometimes, regulations can improve competitive position if the costs of compliance are higher in other countries competing in the same market. At times, regulations are simply a disguised trade barrier. Once again, the complexity of the situation does not allow simple judgments or overall generalizations. The positive current account balance of the U.S. in the last months of 1980, in the face of high energy costs and an improving value of the dollar would seem to belie the importance of the negative effects argument, but that does not indicate what the balance might have been in the absence of a regulatory effect. Moreover, the issue is usually cast not only in specific cost terms, but also with regard to the delays, uncertainties and bureaucratic constraints imposed on industry by what is seen as a burgeoning regulatory environment.

The incoming Administration has indicated its intention to address this issue directly. Hopefully, sound data and analysis will underlie any actions taken.

b. Cooperation:

Scientific and technological cooperation among Western technologically-advanced countries is not rare, especially in fundamental scientific research. However, as compared to the scale of investments in R&D and the common goals of Western countries, the number of genuinely cooperative projects is actually quite small, especially at the technological development end of the spectrum. The explanations are easy to find: the difficulties encountered in organizing cooperation, the concern over losing a competitive position, and, most important, the basically domestic orientation of most governments. That makes the meshing of programs, objectives, budgets, and people much more complex than when carried out within one country.

The economic needs and the constraints may now be sufficiently changed as to put the possibilities for cooperation, especially technological cooperation, much higher on the agenda in the coming period. Industrial countries are all in need of technological progress to meet their social, political and economic requirements, at the very time when the economic situation that created these requirements also serves to place severe budgetary constraints on national R&D expenditures.

Today's relatively equal competence in science and technology also means that a given project is likely to benefit in quality or rate of progress from larger application of resources. In some cases, participation by more than one country may be necessary to attain a critical size.

The massive investments required in many fields of central, and growing, importance, especially energy, also make the possibilities of cooperation to reduce the drain on national budgets particularly attractive.

The difficulties, and the costs, of cooperation cannot of course be ignored. For example, the inherent difficulties of meshing disparate bureaucracies; the delays often encountered in reaching common decisions among differing political and legal systems; the complications of varying decision processes, priorities, and competence; the costs of added international bureaucracy; the danger of political inertia that makes projects hard to start, but even harder to stop once started; the possibilities of continuing drain on R&D budgets because of international commitments; and the tendency to undertake internationally only those lower priority projects that are not of priority importance within a country. To this must be added the apparent conflict between cooperation and improving a nation's competitive position.

Successful cooperation also requires reliable partners. The record of the U.S. in taking unilateral decisions to modify or abrogate agreements (most recently the proposal to cancel the coal liquefaction development project with Japan and Germany, and withdraw from the International Institute of Applied Systems Analysis) makes future agreements harder to reach.

These are formidable difficulties, but the potential benefits in the new situation are also formidable. Successful examples of cooperation (e.g., airbus, IEA projects, coal liquefaction until this year) have demonstrated it can be done. Greater willingness of the U.S. bureaucracy to look outside the U.S. and recognize the competence and knowledge available elsewhere, and the greater experience the bureaucracy would attain through making the effort, would be substantial additional benefits of forcing the pace of international cooperation. The forms of cooperation (bilateral, trilateral, OECD) all need to be examined for each case, though the OECD is the logical organization in which to lay the groundwork and establish a framework among Western countries. Increased attention to genuine international technological cooperation ought to be an importance task of the 1980's.

2. North/South Science and Technology Issues

It was noted in the introduction that the differential ability to acquire and exploit technology is a major determinant of the strikingly different economic situation and prospects of nations of the North and South, and one of the prime sources of the political disputes among them. Those very differences in technological capability, however, are potential levers that provide opportunities for constructive assistance and cooperation with high potential payoff for all involved. Can this nation grasp those opportunities, which play to its strongest suit -- its technological strength?[2]

The fate of developing countries in economic, political and military terms in coming years will have a great deal to do with international political

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[2] Another paper in this series (C. Weiss) is devoted exclusively to this subject of science, technology and development.

stability, and with the security of all nations, not the least the U.S. It is a reasonable forecast that international turbulence will be centered in the developing world. That estimate is reflected in U.S. military and foreign policies. It is much less evident in official economic policies, especially as represented by the U.S. commitment to economic assistance, which is scandalously low relative to the commitments of other industrialized countries. Altruism is not a necessary part of the justification for assistance; national self-interest in reasonably orderly and positive economic development ought to dictate a much larger U.S. effort than is presently in evidence (or in prospect).

Whether or not economic assistance to developing countries is high on the U.S. agenda at the moment, there is a substantial probability that it will be forced there through political or economic crises, or national calamities such as widespread drought.

The various reasons for the U.S. indifference and often opposition to foreign assistance cannot be usefully probed here. However, the central nature of technology in development does provide a focus for exploring how to maximize the U.S. role, whatever the aggregate scale of assistance, and for highlighting some of the particular issues within specific fields, such as agriculture and population that need to be confronted.

It should be explicitly stated that underlying this section is the belief that economic growth, reasonable political stability, and a working economic system in a developing country (with important effects on markets for goods, agriculture production, resource availability, and reduction in fertility) can all be advanced by appropriate and substantial external assistance, that all of those are very much in the self-interest of the U.S., and that all are likely to be impeded in the absence of adequate assistance from the U.S. This is not to deny controversy over the growth of economic competition from LDC's, the fact that political stability does not automatically follow growth, or the significance of differences in political objectives. But, it is assumed that U.S. self-interest is better served by steady advancement of developing countries than by its absence.

a. Technology Policy to Developing Countries:

It is no longer necessary to justify the importance of technology in development, and not necessary for this paper to make a relative assessment of technology vs. X. The simple fact is that technology is essential in dealing with the problems of agriculture, health, environment, industrialization, population, energy, and most other aspects of a modernizing society, and is seen (sometimes in exaggerated form) in most developing countries to be essential. The U.S., whatever its relative decline in technological leadership, still is the world's strongest technological nation, with a broad and flexible education and research establishment. The implication is obvious.

The scientific and technological capability of many, perhaps most, developing countries is steadily improving. Nevertheless, the overwhelming majority of R&D is carried out in the developed countries, either for military purposes or for the domestic problems of those countries. Very little, perhaps no more than 5% of global R&D, can be said to be devoted exclusively to problems of development. In a setting in which industrialized nations have such a stake in economic growth and elimination of poverty in the developing world, it makes little sense to devote so little scientific and technological effort to problems that are peculiarly those of LDC's.

Much of this R&D cannot and should not be done in industrialized countries, for practical as well as philosophical and political reasons. To be effective, to work on the right problems, to be sensitive to local needs and preferences, to produce solutions that fit and are likely to be adopted, to keep up with and adapt technology, all require R&D defined and carried out locally. In turn, this implies attention to the building of the scientific and technological infrastructure in LDC's.

But, this does not mean that <u>all</u> R&D relevant to LDC needs must be carried out in LDC's. Many areas of basic research can more effectively be done in existing laboratories; many problems are generic and can be more quickly investigated in experienced laboratories with resources and skills already deployed; many technological problems require general solutions before locally-adapted applications are possible. Perhaps most important is finding ways to commit scientists and engineers in industrialized countries to work on problems of development in a sustained way that allows cumulative benefits and continuous attention. Long-term availability of financial resources is essential, not only to make such commitment possible, but also to make such a commitment respectable in the eyes of disciplinary peers.

Transfer of existing technology to LDC's, all that was thought necessary in the past is not an adequate alternative. Though some will always be useful, the lessons of experience show that such transfer, especially of "public" technologies of health and agriculture, is ineffective or inappropriate without adequate receptors to choose, adapt, finance and develop knowledge to fit local environments and needs. Technology requires adaptation to a unique social, economic, and political as well as technical environment. Also, it tends to change that environment, often quite rapidly, so that mutual adaptation of technology and environment is a continuing and dynamic process.

LDC relations with multinational corporations also require local capability. The bulk of industrial technology is transferred to LDC's through private investment by international firms. To be in a position to work effectively with technologically-advanced companies without losing control of the nature of the resulting development or being exploited economically, presupposes the technological ability to set realistic objectives, negotiate technical contracts, weigh often esoteric choices, and in general be fully aware of technological/economic options.

Thus, a significant and growing indigenous capability in developing countries is required. And, it must embrace basic science as well as technology, for without the insight and self-confidence created by an indigenous scientific community a developing country will lack the ability to control its own technological development.

In short, what is required is both greater allocation of R&D resources to development problems in advanced countries, especially in the U.S., and the building and strengthening of indigenous capability in developing countries.

The ability of the U.S. to date to help in either of these efforts is seriously limited, both because of the low level of resources allocated, and because of the institutional and policy constraints that deter or prevent effective commitment of scientific and technological resources for other than "domestic" purposes. At present, essentially all R&D devoted to problems of

LDC's must come from the foreign assistance budget either spent directly by AID, or through transfer to other U.S. Government departments and agencies. With minor exceptions, departments and agencies are prohibited by their legislative charters or by the budget process that aims to compartmentalize all foreign-oriented expenditures in one budget, from expending any of their own funds for other than domestically-defined objectives. Thus in an overall R&D federal budget well in excess of $30 billion, the total allocated for direct LDC-related objectives is on the order of $100 million or one-third of 1%.[3]

The result is not only very limited in terms of R&D output. It also means that the competence of the U.S. Government's technical agencies is barely tapped on issues to which they could significantly contribute. When all funds come by transfer from other agencies, there is no incentive to build staff or agency commitment, to work on these issues with their Congressional committees and university or industry constituents, or even to know through experience how they can contribute.

The rationale for these legislative restrictions and for budget compartmentalization, stem from the early history of the creation of Cabinet departments and agencies, and from natural management principles of tying program objectives tightly to appropriate funding sources. The trouble is that as the "national interest" has broadened to encompass foreign as well as domestic problems, corresponding reflection in the allocation of resources has not taken place. And, the rigid budget compartmentalization does not take

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[3] "Development Issues," 1981 Annual Report of the Chairman of the Development Coordination Committee, U.S. IDCA.

account of the often mixed purposes (combining technological and development assistance goals) of many possible programs.

The implications of these institutional restraints go farther. Astonishingly, the U.S. has no governmental instrument for cooperation with developing countries, or any countries for that matter, when the purposes of that cooperation cannot be defined either as scientifically competitive with domestic R&D, or as pure assistance for the poorest of countries. That is, in the broad range of situations in which cooperation could serve important U.S. purposes, but cannot be categorized as simple foreign aid or highest quality science, there is no regular means for effecting that cooperation, or providing the U.S. share of its funding. Thus, the U.S. finds itself hamstrung in its capability to respond to those developing countries that have "graduated" from the poorest status. These also happen to be those countries with developing science/technology capability best able to make use of cooperation with the U.S., with the greatest interest in substantive cooperation (often without any transfer of dollars), and in the best position to contribute not only to solving their own problems but also to assist in attacking global problems.

In fact, in recent years, rather substantial efforts at developing bilateral science/technology cooperation with such countries have been undertaken by the U.S. government. Those initiatives have had to be taken primarily at the White House level directly, with substantial problems of planning and follow-through because of the constraints enumerated above. And now, it appears, with the likelihood of pulling back from at least some of the bilateral agreements that have been negotiated.

The opportunities to use America's strength in science and technology in cooperation with other countries to further U.S. objectives (political and economic as well as scientific) are likely to grow in the coming years. The absence of an adequate institution and policy process to plan and fund these programs, and to engage the competence of the American scientific enterprise, both governmental and private, will be an important issue that will have to be confronted.

In 1978, the Administration proposed the creation of a new agency -- The Institute for Scientific and Technological Cooperation (ISTC) -- designed to correct some of these institutional and process deficiencies. The Congress authorized the ISTC, but did not fund it. The problem remains. (Additional discussion will be found in the last section of this paper.)

b. Food and Agriculture:

Some scientific and technological issues within the context of North/South relations stand out in their importance and in the likelihood they will or should be the focus of much greater attention in the next quinquennium in the U.S. One of these is food and agriculture because of its fundamental nature in the development process, and the great concern that increases in agricultural productivity will not keep pace with the growth of population that already includes several hundreds of millions chronically malnourished.[4] It is estimated that food production must increase at least

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[4] Another paper in this series (S. Wittwer) is devoted exclusively to U.S. agriculture in the context of global needs.

3-4% per year if significant improvement is to occur by the end of the century.[5]

The U.S. has a unique role to play both because of its agricultural production which has become the most important buffer for many other countries that must rely on imports, and its R&D capability that has been so important in the past and could be enlisted more substantially and effectively to assist increases in productivity in other countries, as well as in the U.S.

For the reasons cited earlier, much of the necessary R&D and experimentation must be carried out in the countries trying to improve their own agricultural enterprises. This implies building more indigenous capability than now exists, and equally strengthening and expanding the enormously successful international agriculture research centers which have been primarily oriented to, and staffed by, developing countries. The recent move to devote more of their resources to the applied problems of improving agriculture (low-cost technologies, water conservation, etc.) are much to be applauded. The international centers must not be seen as alternatives to individual country capacity, but as necessary complements to allow some economies of scale, to focus resources on generic problems, and to provide an essential psychological tie to a world community for a sometimes isolated scientist in a poor country.

But, the U.S. R&D community could play a substantial role, larger than is at present likely. One impediment is the budgetary process cited earlier that bars the Department of Agriculture from effectively committing its own funds for agricultural problems not seen as "domestic."

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[5] Wittwer, p. 3.

Another is the organization of agricultural research in the U.S. that is essentially a state-based structure without the extensive tools for central planning or quality control. That makes it difficult to ensure the essential quality of the entire agriculture R&D effort, to build competence in problems not peculiar to the U.S., or to enable effective planned connections to be established between developing countries and the U.S. on agriculture R&D on any satisfactory scale.

It is important also to note that improvement in agriculture productivity is not dependent solely on advances in traditional areas of agriculture; water conservation, climate, energy, pest control, and low-cost technology, and the social sciences related to agricultural economics, innovation, application and distribution, are, inter alia, of equal importance. The agriculture research agenda must include those areas as well.

c. Population:

Closely related to food and agriculture is the global population situation. Though there have been some encouraging declines in fertility in recent years, the growth projections remain at a level bound to cause serious problems of starvation, economic stagnation, and political unrest.[6] The international system has only begun to feel the effects of forced or voluntary migration across borders which is likely to become a major cause of international political instability in the future, in addition to the already

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[6] Another paper in this series (Teitlebaum) is devoted to the population problem in substantial depth.

evident internal instability that arises from urban migration, un- or underemployment, lack of adequate food and sanitation, and serious health problems.

Science and technology cannot solve the population problem, but can make important contributions, and can provide the necessary tools for public policy. In particular, more R&D is needed to help provide an array of available low-cost contraceptive technologies (especially including male contraceptives), and on the social determinants of effective family planning policy. Fertility decline is so closely related to other aspects of development, in particular health, food, sanitation, transportation and communications, that in a sense all development-related R&D can contribute indirectly, sometimes directly to the population problem.

Once again, the institutional constraints in the U.S. make it difficult to engage U.S. science and technology resources adequately. U.S. departments and agencies are not able to devote substantial resources on problems not defined as domestic, which effectively precludes realizing the scale of contributions U.S. scientists and engineers could make to these issues.

In population-related (and health-related) subjects, a special variant of this institutional problem exists. It is the health and safety regulation of drugs in the U.S. based on risk/benefit criteria applicable only to the U.S. Thus, proposed contraceptive drugs are evaluated for safety based on the risks of health side effects in the U.S. environment, when the risks and benefits are likely to be quite different in another country. In some cases, American pharmaceutical companies are deterred from developing a drug at all, since the benefits of protecting against some diseases (schistosomiasis, for example) are so low in the U.S. that any risk of side effects would overwhelm potential benefits.

The reverse side of the coin is the stringent testing regulations in the U.S. that have led some companies to test drugs for safety in other countries, in effect using their people as guinea pigs for the American market.

Neither situation is tenable. The answer must be found in some means of internationalizing drug evaluation since it would not be appropriate to expect the FDA, for example, to institute its own criteria for evaluating drugs for foreign applications that would be different from U.S.-application criteria.

Even if an international solution is needed, the general problem of providing a means for greater commitment of U.S. scientific and technological attention, whether in government, industry, or university, to population-related issues will be and should be an important issue in the near future.

B. Transborder Issues

A series of transborder and global science and technology issues will be important elements of the international security picture in the next five years, though the separation of these from "economic" issues is rather arbitrary. The importance of environmental, ocean, resource and energy issues will be largely in their economic and ultimately political effects, as is the case for those just discussed.

1. Resources/Energy

In the short-term, the major security-related issues arising in the resoure/energy area have to do with supply interruption engendered by political action, and secondarily, the economic terms on which resources are made available to industrialized societies.[7]

A major political phenomenon of recent years is the assertion of the right of absolute sovereignty over natural resources. It is a natural concomitant of a nation/state system, but has not previously been sanctified as explicitly as today. The growing dependence of industrialized societies on resources under the control of others, and particularly under the control of developing countries, creates major dependency relations, many fraught with great uncertainty and danger for international stability.

The dangers come not only from the threat of disruption of supplies, or of sharp and sudden changes in the economic terms upon which resources become available, but also from the second-order strains created among industrial countries whose disparate dependence on resources from abroad may lead to major and disruptive foreign policy differences. The much greater dependence of Japan and Continental Europe than the U.S. on mid-East oil, or the differential dependence on South African resources could lead to serious conflicts of interest over Middle East, or African, or Soviet policy.

Though the world is painfully conscious of the potential of oil-rich developing countries to put political restrictions on resources, it is not only developing countries that act in that way. Canada and Australia have both restricted export of uranium ore on non-proliferation grounds, and the U.S. severely restricts export of enriched uranium on the basis of specific

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[7] A companion paper in this series (Vogely) deals with resource issues in detail.

political considerations. Moreover, the U.S. embargoed soybean export for a short time in 1974 to stabilize domestic prices, and has embargoed the sale of grain and high technology to the Soviet Union in political protest to the Afghanistan invasion. A Cabinet member of the new American Administration in his first public statement spoke of using American food exports as a foreign policy "weapon" (later retracted to substitute "tool").[8]

These consequences of resource dependency and of the unequal distribution of resources, are all political and economic in character. That is, the issues arising in the resource area in the near future are concerned with distribution and availability, but not with depletion. In the long-term, the adequacy of resources will be determined by economic, not geological, phenomena,[9] and there is no reason to doubt that the industrial system could be sufficiently elastic to cope with long-term changes in the price and availability of materials and energy.

The short-term vulnerabilities must be met with measures that are largely outside the realm of science and technology directly: stockpiling, political negotiations, pooling arrangements in time of crisis, etc. Conceivably, new R&D for resource exploration, or exploitation of deep seabed minerals, could change the degree of vulnerability, but not likely in a 5-year time horizon.

In the longer term, science and technology have major roles to play in the development of substitutes; in expanding knowledge of resource exploration, recovery, processing and use; and more generally in contributing to innovation

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[8] New York Times, December 27, 1980.

[9] Vogely, p. 17.

and productivity in the nation's industrial plant (both to improve efficiency of use of materials and fuels, and to generate the export earnings necessary to pay for imports). The long lead times inherent in reaching these objectives mandates early commitment of R&D to these tasks, even though they are long-term in nature.

It should be noted that the changing price and availability of materials and energy may change critically the comparative advantage of some American industries. The adjustments necessary to allow the orderly decline of those industries will themselves set up serious political and economic strains.

The need for R&D in the resource area is coupled with an inadequate data base both in the U.S. and globally.[10] Basic understanding of geological deposition in the earth's crust, of the determinants of the level and efficiency of the exploration process, and of the impact of the changing industrial structure in minerals on the flow of mineral supplies, are all inadequate.[11] Thus, it is critical that a greatly improved data and analytical system, and R&D commitment, be developed.

These tasks will require reinvigoration of concerned U.S. Government agencies, especially the Bureau of Mines and the Geological Survey, and may also require a new institutional means to develop an objective, credible data base (technical and economic) to provide adequate information for resource-related decisions across the government. In addition, improved means for materials policy coordination in government is required to avoid

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[10] Vogely, p. 28.

[11] Vogely, p. 28.

conflicting policies carried out by individual agencies often without adequate background knowledge or appreciation of what other agencies are doing.

2. Environment; Global Commons

Closely related to resource and energy issues are those involving transborder environmental questions, and more general global issues of the environment: atmosphere, oceans, and outer space, all of which could be seen as basically resource and dependency issues.

To a degree far beyond earlier experience, man's national activities have effects beyond borders and, in some cases, on a global scale. Transborder pollution has already become an important issue in many areas, with some progress in the last decade particularly in melding environmental policies, and reaching agreements on dealing with the traditional problem of the global commons. The issues are likely to become more severe, however, and often will take on the caste of zero-sum games.

The worldwide recession and the rise in energy prices have the effect of raising the indirect costs of coping with environmental degradation, making it more difficult politically in a nation-based world to restrict activities whose harmful effects fall across the border. The standard problem of reflecting full costs in a production process is exacerbated when the externalities are felt outside a national economic system. It can be expected that issues associated with acid rain, water pollution, forest degradation and others will become more contentious internationallly in the next decade as their international externalities become better known.

The depressed economic situation will also lead to greater resistance to domestic environmental regulation if that is assumed to affect adversely the international competitive position of a nation's goods. As noted earlier, it is not always appropriate to call for common environmental standards in all nations, and even when it is, it is not clear they can be successfully negotiated. Thus, the costs and basis for domestic environmental regulations are likely to be difficult issues because of their international implications.

Some issues with a much longer time horizon may become clearer in the next few years as research increases understanding of important global systems. In particular, the effects of CO_2 buildup or of NO_X in the atmosphere may be better understood. The global economic implications of those effects or of attempts to control them would be profound. Unprecedented disputes could arise, with conceivably important changes in the status of individual nations (either from the effects which may benefit some -- say through improved agricultural conditions -- and hurt others, or through the costs of mitigating harmful effects which would likely fall unequally). It is unlikely that these issues will come to a head in a few years, but the debate could be far advanced over the uncertainties evident today.

Exploitation of global commons, especially the oceans and outer space, is likely to proceed during the coming decade. The Law of the Seas negotiation appeared to be nearing completion, with proposed establishment of a new international institution responsible for overseeing the mining of the resources of the seabed, though the position of the U.S. is now in doubt.

Many aspects of that institution would be novel, in particular the assigning of some of the benefits of mining to developing countries. The detailed questions of implementation would be left to the interim arrangements following the completion of the treaty and ultimately to the new Authority. Some serious disputes are inevitable, both with regard to the mining itself, to the operation of the Authority, and with regard to the unprecedented transfer of technology provisions of the draft treaty.[12] Certainly, if there is no treaty, a variety of ocean issues -- navigation, fishing, oil exploration, research, as well as mining, may become the source of serious dispute.

In space applications there may be controversy arising over geostationary orbit allocations, but more likely will be controversy over the international efforts to manage and control space technology systems such as Landsat. That earth resource surveillance system has been until now an experimental American monopoly, but as it moves to operational status many questions will become more pressing. Who owns the information in a world in which sovereignty of resources has been zealously asserted? What rights do nations have for unilateral surveillance of another country's resources? What are the security implications of the high resolution that will now be built into the system? Should the output be available to anyone who asks for it? Who should manage the system, and determine its technical characteristics? What are the economic and political implications of greater knowledge of resource

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[12] Law of the Sea draft treaty, United States Delegation Report, "Resumed Ninth Session of the Third United Nations Conference on the Law of the Sea," July 28 - August 29, 1980, Geneva.

endowments, of more accurate annual predictions of agricultural production domestically and internationally? Undoubtedly, these issues will move more centrally on the international political agenda.

3. Interfacing of National Technological Systems

Many national systems -- aircraft, communications, weather observation, finance, banking, postal -- are basically information systems and require interfacing with counterparts in other nations. The explosive development of information technology systems have begun to cause serious strains, and are likely to be even larger causes of strain in the coming years as the technology moves even more rapidly ahead.

Traditional differences between fields break down (e.g., communications vs. data flows, postal vs. electronic mail, information vs. banking), and the economic calculus of benefits and cost changes perceptibly. Closely tied to that are conflicting philosophies about privacy of information, access to information within nations, the role of central computer banks, the transnational nature of economies of scale, and related issues. The U.S. dominance of the technology serves to make other Western countries wary of allowing unfettered development and application that will leave them in a weak competitive position; the Soviet Union and its allies worry because of the belief that control of information is vital to its political system; the LDC's are concerned because, as in resources, they fear the loss of control over information seen as essential to maintaining independence.

The dynamic nature of the growth of this technology, and its base in the private sector in the U.S., makes this a particularly difficult issue in which to anticipate implications, much less develop clear international policies and conduct negotiations. It is certain to appear prominently on the international agenda in the 1980's.

C. National Security

Science and technology have obviously been central factors in the evolution of weapons and military systems in this century, changing drastically not only the nature and scale of hostilities, but the very meaning of strategic war as an option to achieve national objectives. The strength and productivity of a nation's high-technology community have become major elements in any geopolitical calculation. The effects on science and technology themselves, and on universities, of the massive commitments of resources to security-related R&D have equally changed those enterprises beyond earlier recognition.

The application of science and technology to security objectives shows no sign of abatement; in fact, a new round of major commitments to large-scale strategic systems is in the offing, turning the ratchet one more notch in a search for security that seems steadily receding into the future.

In the context of this paper, only a few general issues in this area can be briefly touched upon; clearly it is an enormous subject that is itself the subject of a large literature.[13]

One central and much-debated concern has to do with whether the constant seeking for more technologically advanced weapons systems in fact contributes

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[13] A companion paper (Boulding) is devoted to one aspect of the subject.

to the nation's (or the world's) security. Whatever the views of the causes of the arms race between the Soviet Union and the U.S., or the current state of relations between the superpowers, the nature of new weapons systems often has the effect of making the arms balance more precarious, more vulnerable to preemptive action rather than contributing to stability. There is some reason to think that will continue, and perhaps worsen, as capabilities are pursued that threaten concealment of weapons systems, that give greater premium to surprise, that make it harder to know whether missiles contain one or many independent warheads. Developments in conventional weapons, moving rapidly, may also change the nature of "local" war, leading to greater instability among developing countries as one or another believes it has the capability for rapid strike and victory.

There are, of course, no simple and obvious alternative courses of action. It is easy in rhetoric to call, for example, for more attention to military and related systems that contribute to stability, and to shy away from those that lead to greater uncertainty and threat: adequate conventional ground forces; improved command, control, and communications in a hair-trigger weapons environment; greater commitment to developing arms control agreements, more attention to "hot-line" communication capability; less emphasis on strategic weapons that pose a first-strike threat in favor of those with clear survivability; and others. Each has its ambiguities, however, and there is no agreement on what is required for security, or even for greater stability.

The fact of the matter is that science and technology are most likely to continue to alter military-related systems, and in ways that are not amenable to certain anticipation of effects. One of the objectives of arms control agreements is to bring the situation under greater control; but even if one were optimistic about SALT II and follow-ons, those agreements deal only with existing or planned technology, not with the results of R&D that might undermine the agreements through new weapons systems or related capabilities not anticipated.

What can be seen, however, is that the general level of analysis, of knowledge of "threat systems," of involvement of the scientific and technological community in strategic debates, of public perceptions of military/strategic affairs, are all inadequate to the increasing importance of the debates. The once substantial public role of scientists and engineers in strategic policy deliberations, for example, has been greatly reduced, and thus the public inputs to arms control and weapons debates have suffered. The spectacle of the stagnation of the SALT II agreement in the U.S. Senate over essentially extraneous issues is a measure of the inadequacy of the framework and understanding of the essential elements of strategic issues.

Some argue that the whole framework of the strategic debate has been rendered inadequate, in large measure through the products of the scientific and technological enterprise.[14] They go on to call for emergence of a new paradigm, a new "discipline" of conflict studies, and that the scientific community has a special responsibility to bring this about. The argument that the arms race is seen in a wholly inadequate framework has considerable merit, though the path for changing that situation is hard to discern in practical terms.

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[14] Boulding.

The scientific and engineering communities have special but more traditional responsibilities within the existing framework, if only because they can deal with the esoteric nature of the technological aspects of strategic and arms control issues. The relative neglect of these responsibilities in recent years must be reversed. In doing so, however, it is important to recognize that the issues themselves are never purely technical. Real participation involves a commitment to master the political, economic and related aspects, which in the end will determine the policy outcomes.

New programs such as arms control fellowships in the National Academy of Science and a concomitant program of studies are much to be applauded. Similar initiatives in other scientific organizations would be appropriate and useful.

Beyond the technical communities, much is needed to improve the quality of debate. More analysis in the public sector, with better information, and greater resources, public and private, committed to the analytical area are badly needed. The momentum of a defense budget close to $200 billion requires genuine open debate of the purposes, details and implications of that budget. In turn, that will require more funding than is presently available to produce information and analysis to make public debate possible. The Congressional Commission to study the establishment of a National Academy of Peace and Conflict Resolution presumably has the same general aims in mind.[15]

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[15] Boulding, p. 12.

One aspect of the role of science and technology in weapons development is peculiarly troubling. It is the simple fact that much of the initial development and generation of ideas for new technology occurs in the laboratory at a very early stage of the R&D process. In fact, discoveries or ideas that are later revolutionary in military terms are just as likely to occur in the research process without military applications in mind, and without military funding. The dynamic of the research process is one of the forces leading to instability, both in weapons development and in the long-term viability of arms control agreements.

There is little that can be done about this now, though it does point to the need ultimately to consider ways of bringing R&D within the scope of some form of arms control agreement. One aspect, somewhat farther along the R&D chain, does deserve institutional attention, however.

Proposals for new weapons developments are, in their early stages, often made at low levels in the bureaucracy, with relatively little R&D funding required. At these levels, choices tend to be made on strictly technical grounds, with little input of broader considerations, such as the ultimate effect on arms control objectives that might appropriately influence those choices. The situation is repeated at higher levels as well, so that it is not uncommon for the government to be faced with mature weapons designs creating major new foreign policy problems that might have been avoided or eased if some alternative technical options had been chosen instead.

It is very difficult to deal with this issue in the bureaucracy, since the organization of government serves to create bureaucracies with compartmentalized objectives and few or negative incentives to introduce considerations for which they are not responsible. An attempt to introduce nonproliferation considerations into the R&D on nuclear reactors, through participation of a State Department representative in the setting of objectives in the Department of Energy, has apparently had some limited success, and deserves evaluation.

In its most general formulation, this task can be stated as the need to include, in defense R&D planning and management, the evaluation of broader effects of the intended results of R&D. The objective is an important one and ought to be the focus of further experimentation.

Other aspects of science, technology, and security are also troubling; some because of the effects on non-military areas. The sharp increase in defense spending proposed by the Administration will have important impact on the civilian sector, not only in the obvious effects on the budget. Engineering manpower, already in short supply, will be siphoned off in larger numbers to defense industry, exacerbating their shortage in consumer goods industries, and likely worsening the nation's competitive position. It will also tend to stimulate even more the momentum of scientific and technological change applied to military hardware, since the level of R&D, and the ideas for new applications, will be fueled by the larger cadre of scientists and engineers creatively at work.

There may also be important effects on the nation's universities, growing out of concern for the almost direct military application of basic research. Signs of that are already evident in cryptological applications of theoretical mathematics, which have led to a kind of voluntary censorship.[16]

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[16] Science, Vol. 211, 20 Feb. 1981, p. 797.

Lastly, it must be noted that the Soviet Union has evidenced its competence to engage in a high-technology arms race with the U.S. Its technology may not be as refined, but it is obviously adequate to hold up its end of this race; it is now almost conventional wisdom that its greater commitment of resources to defense expenditures will actually give them an edge of some sort over the U.S. in the latter part of this decade.

Whether that evaluation is accurate or not (more importantly, whether a strategic "edge" would be significant or not, and if so, in what ways), its anticipation has already fueled a massive new U.S. defense increase. One can only observe that continued seeking for strategic superiority in the face of a determined opponent is a chimera that can only distract from the real quest for security.

East/West Transfer of Technology:

One other science/technology-related issue likely to be of considerable moment in the next five years deserves brief mention. It is the concern over the transfer of technology to the Eastern bloc that could enhance the military capability of the Soviet Union and its allies.[17]

This is an issue with a history stemming from the advent of the cold war, and with recent attention as a result of the embargo on high technology imposed in response to the Soviet invasion of Afghanistan. It is bedeviled by controversy between the U.S. and its NATO allies over the costs and benefits

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[17] "Technology and East-West Trade," Office of Technology Assessment, U.S. G.P.O., Washington, D.C., 1979.

of the policy, by uncertainty over the military relevance of some "dual use" technologies, by sharp differences of view within the American Government, by differences of philosophy over the value of denial in terms of its actual effects, and by differences with industry over enforcement policy.

There is little question about the importance of embargoing specific advanced military technology. Moving from technology with direct military applications, however, quickly leads to gray areas, with uncertainty over military relevance, over availability from uncontrolled sources, or even of whether denial is in Western interests. For example, is it in support of or opposed to Western interests to enable the Soviet Union to improve its ability to explore and recover its vast oil deposits?

Many more specifically technological questions arise, however: how is technology actually transferred and adopted? What is the real potential of diverting a piece of hardware from a "peaceful" to a "military" application? And what actual difference would it make? Is reverse engineering of a piece of equipment possible? At what cost? On what time scale? How long will it take for a particular technology to be developed independently?

All too often, the debate over technology export controls is characterized not only by unreality in political terms, as though it is simple to control the movement of technological information, but also by lack of understanding of technological realities. The importance of the issue, and its potential for damaging the West politically and economically, will require effective integration of the scientific and technological aspects in the policy debates.

III. Institutions and Policy Process

Several themes run through the issue areas discussed above that bear directly on institutional and process problems of the U.S. Government in relation to the international consequences and use of science and technology. The most common theme can be summarized under the general observation that the international dimension of policy -- the international issues, effects, opportunities and relevance -- are inadequately reflected in the policy process throughout the government, and that the formal institutions of government militate against its more effective recognition. Though this observation may be valid for many of the responsibilities of government, it is particularly, and surprisingly, intensive in science and technology matters.

Other themes that emerged related to the need for more effective integration of science and technology aspects in many policy areas, including more mechanisms for effective analysis and anticipation of future implications of science and technology; and the need for new national and international institutions. Some comments on each are in order.

A. International Dimension in Policy

The historical development of the U.S., its geographical position, and its enormous resource base, all led naturally to a system dominated in institutional form and political organization by domestic considerations. Evolution of the system in response to the new global role of the U.S., and to its changed dependencies on others, has been slow and halting, notwithstanding the enormous sums of public money allocated for purposes dictated by international matters. At the detailed level of decision-making -- budget decisions within agencies, negotiations with the Congress or with OMB, setting the technical objectives of programs -- the traditional pressures dominate.

As was described above, this situation affects the involvement of science and technology with international matters in several specific and important ways.

One of the most significant has to do with developing countries where it was noted that the national resources devoted to R&D on development problems is pitifully small, and that the U.S. government lacks an effective instrument for cooperating with that large number of increasingly important nations not eligible for direct assistance (not poor enough), nor sufficiently scientifically advanced to be competitive with domestic research. A new institution (ISTC) was proposed in 1978, authorized in 1979 and ultimately left unfunded by the Congress. Something to serve the same functions, whatever the form, is required.

But the problem is not simply a new institution. An important part of the need is to tap more effectively the scientific and technological resources of the U.S. Government housed in the functional departments and agencies, and to enlist their R&D clients in the nation at large. A single, new small agency cannot accomplish that task alone, though it could have provided the leadership for much larger changes.

Rather, a means must be found for allowing departments and agencies to allocate resources directly for cooperation with other nations and to carry out R&D on problems that are not "American" problems, when such activities are in the national interest. At present, legal authorization or executive budget policy effectively prevents such allocation except under difficult, clumsy (sometimes sub-rosa), and almost always ad hoc arrangements.

The problem, aside from its legal aspects which are capable of being changed by the Congress as has been done for some agencies, is largely one of efficient budgetary management. OMB argues, with considerable justification, that it is difficult, at best, to maintain reasonable discipline in a budget if fuzzy arguments of "foreign policy interest" have to be given weight in ranking proposed programs, or if budgets to serve development assistance objectives crop up in a score of federal agencies.

Yet, the answer must surely be more creative than simply to rule out such programs. One possibility, for example, would be to create a "development budget" that crosses departmental lines and forces a degree of budgetary discipline that cuts across agencies and agency budgets.

Departments and agencies would be allowed, with Congressional concurrence, to budget some of their own funds for development-related R&D, but those projects would have to be compared not only with proposals within the Department, but also with development-related proposals of other agencies. Similarly, for those proposed programs that have mixed foreign policy (other than development) and scientific objectives, a cross-agency evaluation on criteria of foreign policy could be attempted as a way of exerting necessary budget discipline. Though this would obviously be difficult to administer and has its own bureaucratic pitfalls (the opportunity for playing budgetary games would be large, to say nothing of the difficulty of ranking according to foreign policy criteria), something like it requires experimentation.

In another area, ways must be found domestically or internationally to deal with the problem that arises when regulation is based on purely domestic criteria, while the effects of the regulations directly impinge on other countries or have important effects on a country's international trade position. For some situations, the answer may have to be regulatory machinery based within existing or new international organizations. With regard to the effects on trade, more impetus will have to be given to the move already under way to analyze the broader economic effects of proposed regulations before the regulations are approved.

International cooperation with advanced countries also deserves more emphasis in the changing climate of cost and relative competence in science and technology. But this change in emphasis will not happen naturally in the American system, again because of the built-in focus on domestic problems and pressures. This problem of focus is exacerbated by the restrictions imposed by OMB on foreign travel, and the general attitude of the Congress that foreign travel on the part of "domestic" agency personnel more often than not simply implies junkets.

Overall, it is a matter of attitude; of sensitivity to international interests, opportunities and effects; of awareness of the U.S. role in the world and its dependence on others. The blurring of domestic and international affairs, so often cited in rhetoric, is real. Government at all levels must come to realize, and to be able to respond to, the ineradicable interaction of national actions with the international scene. It is not a matter of simply creating an international office in an agency. All have such offices, which more often than not, are weak and removed from the core of the agency's interests.

Rather, it is a matter of infusing the whole government with policies, institutions, and rhetoric to make possible a gradual change of attitude that conforms to today's, and tomorrow's increasing, reality. The Congress must also be no small part of that change, and ought to be forcing the Executive Branch to recognize what is needed.

B. Integration of Science and Technology in Policy

The problems of planning in science and technology-related areas are particularly severe, and pose major problems of governance in technological societies. There are many aspects: how to represent scientific and technological information and uncertainty adequately in the policy process; how to plan for effects of science and technology not only uncertain, but possibly seen too late to alter once the effects are in evidence; how to estimate risks and benefits which fall unequally within a society or internationally, with interested parties often not represented in the policy process; how to deal with issues in which the relevant information is under the monopoly of one segment of society, or of one government; and a host of other issues.

No single solution is adequate; in fact, these problems, as all problems of governance, are not solvable -- all that is possible is amelioration or improvement. However, these are difficulties that directly involve understanding of science and technology, and thus require adequate representation of science and technology in the policy process. That includes not only greater participation of scientists and engineers, but also more means for obtaining objective and credible analysis available to the public, and more involvement of the private sector in the public analysis and debates on these issues. The government has an important stake in seeing that the scientific and technological communities are genuinely involved in the tasks of governance; more efforts need to be expended to bring it about.

It should go without saying that participation alone is not enough; scientists and engineers do not have, on the basis of their professional training, superior credentials for making policy decisions. They are no more free of bias than are other segments of society. No issue turns on technological facts alone, though some are more dependent on technologcal considerations than others.

Participation by the scientific and technological communities implies a commitment to understand the interaction between science and technology and the broader aspects of policy, and a commitment of time that makes such understanding possible. A technocratic approach to the making of policy is not an improvement over the present situation.

It is worth observing that one of the effects of science and technology on both national and international affairs is to make the future much more relevant to the present than in earlier periods of human history. To an unprecedented degree, today's policy must be made in the light of anticipation of future developments, particularly in science and technology themselves, or in the side effects of increasingly technological societies. The importance of more efforts at credible, objective anticipation of the future are obvious.

C. International Organizations and Structure

The need for new international instruments, or for modifying existing ones was mentioned briefly in a few subjects -- drug regulation, ocean mining, space applications -- but was not emphasized. The questions associated with international political machinery, and more fundamentally of desirable international organizations to deal with the requirements growing out of science and technology, are many and complex. Simple calls for new organizations or for improving existing ones may be valid, but belie the underlying problems.

The issue in oversimple form is that the products of science and technology increasingly bring new issues and force traditional domestic issues into the international environment. Unfortunately, existing international governmental organizations charged with dealing with those issues are often inadequate, and are becoming more so. Most global organizations are now politicized along North/South lines, and regional or smaller alternatives even if more efficient do not represent all the countries interested in a particular subject. As representation in organizations broadens, technical efficiency tends to decrease.[18]

This is a gradually-developing situation that is unlikely to reach crisis form within a few years, but in it are the seeds of major confrontation over only a slightly longer time horizon. Current budgetary reductions could, however, so reduce U.S. presence in international organizations as to advance

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[18] See E. B. Skolnikoff, The International Imperatives of Technology, Research Series No. 16, Institute of International Studies, University of California, Berkeley, 1972, for a more complete discussion of technology and international organizations.

the date at which issues become serious. The adequacy of international political machinery is likely to be a fundamental question of international security, for so many of the functions the world (and the U.S.) depends on will increasingly be the responsibility of some form of international organization (communications, transport, nuclear materials control, resource information, health, agriculture, ocean minerals, to say nothing of international financing and lending). Many of the issues are North/South in character; but others involve East/West controversies and conflicts of interest among Western industrial countries.

It is not a matter of indifference whether the organizations exist or not, or work or not. The functions they perform must be carried out in some way by an organization, or by a limited number of countries, or by a country acting on its own. The ultimate character of the international system and the place of the U.S. in it may in large measure be determined by whether these international tasks are carried out through organizations with broad participation, but so designed as to allow reasonable efficiency, or by default are managed by efficient but limited groups of wealthy countries.

IV. Conclusion

It may not be too far wrong to characterize this last issue, and all that have been touched on in this paper, as fundamental choices in the international system between efficiency and equity, and between hegemony and consensus. Those are sufficient for any political agenda.

SCIENCE AND THE STATE DEPARTMENT: An Uncertain Alliance

Eugene B. Skolnikoff

In a speech before the National Academy of Sciences on March 6, 1985, entitled "Science and American Foreign Policy: The Spirit of Progress," Secretary of State George P. Shultz discussed the growing role of technology in international affairs. While criticizing the public policy pronouncements of some scientists and observing that they have "no special claim to infallibility" in political debates, Shultz appealed for greater cooperation between scientists and government leaders. "The great intellectual adventure of the scientific revolution beckons all of us," he said.

Shultz spoke of the need for new ways of thinking about such matters as the revolution in information technology and strategic defense, and he called on scientists to help structure effective controls on the transfer of militarily sensitive technologies and to find ways to inhibit the spread of chemical weapons.

While Shultz was examining selected technical issues and their effect on foreign policy deliberations, others at a one-day National Academy of Sciences workshop entitled "Teaching About the Role of Science and Technology in U.S. Foreign Affairs" were discussing ways to enhance the integration of science and technology into the U.S. foreign policy process and to improve the training of science attachés. In particular, James L. Malone, assistant secretary of state for oceans and international environmental and scientific affairs, described the Department of State's renewed efforts to restructure the science officer corps and to strengthen the role of science and technology in the department and throughout the U.S. Foreign Service.

From this flurry of activity it seems that we are being treated once again to the periodic recognition by the Department of State that science and technology are not only prime movers in shaping world affairs, but that the department's ability to deal with those subjects as they interact with foreign policy is marginal at best. Perhaps it is ungenerous to be skeptical of well-intentioned and even potentially valuable proposals for improvement, but Department of State officials need some greater sense of the problem, of past attempts to deal with it, and of the genuine constraints faced by the department if they are to achieve any real progress.

In fact, since World War II the Department of State has been attempting with only sporadic seriousness to come to grips with the evident importance of major developments in science and technology. A variety of steps have been taken over the years to create new offices and upgrade science advisory functions. In 1979 Congress, frustrated by the apparent lack of progress, added Title V to the Foreign Relations Authorization Act. Title V called on the executive branch to recognize the interdependence of science, technology, and foreign policy and to implement policies and programs that would "maximize the benefits and minimize the adverse consequences of science and technology in the conduct of foreign affairs." It also called for an annual report to Congress on science, technology, and U.S. diplomacy. (This reporting requirement is about the only part of Title V that has been carried out.)

In addition to creating a science attaché corps in the 1950s, the Department of State has periodically attempted to make regular foreign service officers more knowledgeable about science and technology. Various courses or segments of courses have been offered in the Foreign Service Institute (FSI). Characteristically, rapid staff turnover at FSI destroys the institutional memory; a 1983 curriculum review initiative at the institute, for example, duplicated one of 1963—in complete ignorance of the earlier one.

The incredible aspect of these past efforts and of the flurry of recent interest is that the significance of science and technology in foreign policy is still an issue. The effects of scientific and technological development and the many ways in which applications of new technology are altering international relationships would seem self-evident. Even the most casual observer would assume that the dominant U.S. role in science and technology would require that these subjects and their implications be placed high on the agenda of the department most concerned with the nation's foreign policy.

Even when specific issues become politically visible and are placed high on the department's agenda, all too often the department is entirely and uncritically dependent on technical information from other agencies or from outside the government—often from interested parties. In less prominent subjects the department effectively leaves leadership to other agencies, with a few notable exceptions, and often has difficulty maintaining even a monitoring role.

The department's ability to use the great strength of the United States in science and technology for foreign policy purposes is limited indeed (a situation that "passeth understanding" in other countries). Moreover, the department's Bureau of Oceans and International Environmental and Scientific Affairs, which has the mandate to enhance the integration of science and technology into the foreign policy process, has little status or political influence within the department.

We ought to be brutally realistic about what changes are feasible now, given the present department and the constraints it faces. First-class scientists and engineers will never (and should never) be recruited for careers in the Department of State in substantial numbers. Political officer postings abroad and similar positions in Washington will remain the primary routes for career advancement. Personnel ceilings and budgets for the department will continue to be exceedingly tight, preventing substantial growth in new directions. Not only science and technology but many other specialized subjects, such as trade, migration, human rights, and drug enforcement, will strain the breadth of knowledge required of a regular U.S. foreign service officer.

Can anything useful be done? Of course, but expectations must be modest. One necessary step would be to seriously develop means, whether it be courses, on-the-job training, or something else, to sensitize regular foreign service officers to the implications of science and technology for their policy concerns and teach them how to deal with them in relation to their primary functions. A second step of equal importance would be to reserve the post of assistant secretary for oceans and international environmental and scientific affairs for a highly respected career foreign service officer. This is not a comment on the present incumbent, a political appointee. Rather, it is a recognition that in a career service the fastest way to improve the prestige of an office is to staff it with the very best in that service, and to be consistent in that policy.

The Department of State, however, also needs quality help in dealing with areas of science and technology important to it. For that it should turn to the private sector much more than it now does or than its insular culture encourages. It is not difficult to enlist scientists and engineers to help on specific issue areas; the problem is more one of having the internal capability to ask for and use such help efficiently and effectively.

None of these measures, or others that could be suggested, is a panacea. The question is how to do better in an area of obvious and critical importance—an area in which the United States holds undisputed leadership but for which the nation's foreign policy machinery too often appears chaotic, ignorant, hamstrung, or badly misguided. Secretary Shultz, whose own varied career must surely lead to solid understanding of the need to integrate science and technology into the foreign policy process, should be well equipped to bring about some genuine change. The verdict is not in, but the evidence so far is not encouraging. ■

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STATE'S TANGLED WEB

As scientific and technical issues intrude into foreign policy, collaboration between the State Department and domestic agencies has become complex but unavoidable

FITZHUGH GREEN

THE SECRET IS OUT: our State Department does not single-handedly conduct U.S. foreign policy. The other foreign affairs agencies have long shared in the task. But so have an increasing number of federal departments that are primarily responsible for agriculture, treasury, labor, and the environment, among others. This growing—and often tangled—web of involvement is evident both in the number of interagency meetings held in Washington and in the legions of people from domestic agencies who either travel or are assigned abroad. In fact, in some embassies, personnel from other agencies outnumber those in the Foreign Service.

The infusion of domestic agencies into foreign policy can lead to pitfalls. The State Department often loses ground in its daily battle to control foreign policy. At last count some 46 agencies were running international programs, and to at least one key U.S. ambassador, every one of them seems to have its own foreign policy agenda. This can—and often does—create an impression of chaos.

Furthermore, these domestic agencies may menace and weaken an ambassador's ability to represent the U.S. government as unified and consistent. One ambassador recalls his own horror story: An assistant secretary of a U.S. agency normally concerned with domestic matters visits the ambassador's capital city. The ambassador introduces the assistant secretary to Minister Fulano, the relevant official in the host country's government. Fulano soon appears in Washington and has lunch with the assistant secretary. A day or two later the assistant secretary's agency calls a press conference and announces a $50 million grant to Fulano's government. The ambassador sums up his all-too-familiar tale quietly, restraining his ire: "There is no linkage between the decision to help this government and our embassy. I am not consulted or brought into the act at all. The host country notes this, of course, and assumes I am not taken seriously by my own administration. This does not exactly build my influence as ambassador!"

Yet the ambassador concedes that the State Department and its embassies cannot go it alone. They must lean on the technical agencies, even those that are rarely thought of as having international concerns. Such connections are not merely useful, they are essential—and they will remain a fact of life for those who attempt to manage and implement U.S. foreign policy. As science and technology intrude themselves ever more deeply into international relations, our diplomats must have experts at their elbow, whether negotiating an arms treaty, a trade pact, or a multilateral environmental convention or simply participating in an ecological conference. As State seeks technical help from other agencies, they in turn require a hand from State with protocol and intercultural understanding so their own programs will run smoothly.

To handle these technical adjuncts to the United States' international interests, our embassies have already added specialists to their staffs. The ambassador still runs the country team, but must also employ a growing array of attaches (many of whom—with bureaucratic inflation—have risen to become counselors), who exercise authority over military, cultural, agricultural, informational, commercial, and scientific affairs. Likewise in Washington, the State Department also relies on such domestic agencies to provide the expertise needed for coping with these new dimensions of foreign policy. State now has operating partnerships with dozens of federal technical agencies, among them the Environmental Protection Agency.

The EPA provides one illustration of a domestic technical agency that finds it must act internationally to fulfill its mandate. A year ago the State-EPA connection fell victim to the public travail surrounding the agency as it was buffeted by criticism in the national press and congressional committees. Since William D. Ruckelshaus returned as administrator, however, the agency is once more collaborating fruitfully with the State Department in international efforts to protect the global environment.

PRESIDENT NIXON ESTABLISHED EPA by executive order in 1970. In an Adam's rib-type operation, 15 environmental programs from federal agencies and departments were scalpeled out and stitched together: the water pollution control section from the Department of the Interior, air pollution control, radiation protection, pesti-

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The author (left) talks with EPA Administrator William D. Ruckelshaus and French Minister for the Environment Huguette Bouchardeau about cooperative agreements between their agencies.

cides regulation, and more operations from other departments were suddenly thrust under the same roof

Ruckelshaus (who was the first administrator as well as the current one) immediately recognized the worldwide implications of his fledgling agency After all, environmental pollution ignores national boundaries—oil spills do not stay in territorial waters, nor does acid rain respect air space He quickly created a division of international activities charged with relating EPA's statutory assignments in the United States to the needs and opportunities presented by other countries and multinational organizations

Ruckelshaus was not unique in recognizing the value of the international arena By the time they arrived at the newly born EPA in 1970, many of the career employees were already personally bound up in the international environmental community EPA's engineers, lawyers, economists, and scientists enjoy international reputations for their expertise They receive frequent invitations to lecture, share research, provide counsel, and write papers for foreign or multinational publications They have been part of an invisible university, an international academic network in their specific scientific or technical discipline Like fleas on a dog, their foreign contacts and commitments accompanied these employees from their original agencies to their new home.

Indeed, EPA employees were so committed overseas that they caused the agency some difficulty in launching its own program Once these recruits arrived at EPA, the first step was to find out exactly what they were already doing abroad Understandably, many were leery of losing the foreign dimension of their careers. They were proud and protective of their far-flung renown, most liked the perquisites and stimulation of trips and conferences Their EPA managers found that they resisted divestiture of these activities with the fury of a dog protecting his bone. Nevertheless, the agency had to uncover the details of these foreign connections and analyze their value in terms of EPA's priorities and resources of money and personnel This information was secured by having all would-be travelers complete a suitable form

After learning what it had inherited, EPA started forming its own programs. Again, the internationalist nature of the career employees had an impact Resentment was not an unusual reaction whenever permission for a trip was denied However, enthusiasm reigned whenever the agency consented to trips and projects in which its employees had already planned to participate or when additional people were selected to go overseas In fact, since 1970 no EPA employee has refused a foreign assignment!

It soon became clear that both to avoid rankling the troops and, even more important, to fulfill its new duties, the agency would have to take a leading role in international environmental affairs EPA had to lay out basic goals Three were quickly set which still provide the guidelines for the agency's international activities today. First, information bases should be established abroad so that EPA can learn of new pollution control technologies, environmental research, and management systems that have been developed elsewhere. Thus the agency will avoid having to reinvent sliced bread while other countries forge ahead of the United States Second, the progress of the environmental protection movement in the rest of the world should be supported through technical assistance, data exchange, and propaganda. Third, EPA

Charles Caccia, Canada's minister for the environment, meets with Ruckelshaus to discuss the myriad of environmental issues that cross the international border. U.S.-Canadian concerns include acid rain and agreements on the Great Lakes and hazardous wastes.

should operate overseas in concert with the State Department and adhere to stated principles of U.S. foreign policy.

None of these goals will be—or can be—totally achieved. But they provide a kind of north star by which the agency's potential for freewheeling abroad can be kept on course. They encourage EPA to be alert for "bargain-rate" learning experiences. For example, when other countries or organizations stage professional meetings on something like acid rain, EPA can piggyback the efforts of others and avoid duplication, or enlist others in bilateral research or consultations on common targets. Or EPA can join with multilateral groups like the European Community, the Organization for Economic Cooperation and Development, or even the U.N Environment Program to harmonize the setting of standards on pollutants, handling exports of hazardous and toxic chemicals, or protecting some specific vital organ of the environment such as the oceans or ozone layer.

With EPA so busy overseas, it should keep in mind the third goal of the agency's international program: that all activities be consistent with U.S. foreign policy. EPA hopes to avoid misunderstandings and working at cross-purposes. Cooperating with State, rather than contesting it, earns EPA a place at the policymaking table whenever ecological subjects are discussed. As Russell E. Train, a former chairman of the Council on Environmental Quality and administrator of EPA, once quipped, the environment is too vital to be left solely in the lap of the State Department.

STATE ALSO HAS A STAKE in fostering collaboration. Without it, the department would be hard put to safeguard both its own position and the coherence of U.S. foreign policy. U.S diplomats must watch over the sometimes untutored envoys representing scientific and technical agencies to avoid upsetting vital relationships with foreign citizens and governments. State must study and guide the domestic agencies so they can be kept in sync with the dictates of foreign policy. To repeat, State must be able to enlist their support and participation on those matters when their technical expertise is needed.

It is one thing to set cooperation as a goal, and quite another to achieve it. This is particularly so since the lines of authority between the agencies are often rather murky. State is pre-eminent abroad, but at home it lacks the clout to order other agencies to do its bidding. It can only request help and hope for a positive answer. Usually this is forthcoming—after all, State is the senior department of the cabinet. Furthermore, proximity to diplomats carries a certain panache for stay-at-home bureaucrats, and State Department officials do tend to phrase their calls for assistance with a certain finesse.

One road block has been removed: in the past there were several special assistants to the secretary of state with responsibility for a variety of scientific and natural resource programs. Not only was this cumbersome, but the special assistants complained that their very numbers reduced their access to and influence with the secretary. Senator Claiborne Pell (D.-Rhode Island), a former Foreign Service officer, crafted a remedy which abolished the special assistant slots. In 1973, he drafted and saw passed a bill creating the Bureau of Oceans and International Environmental and Scientific Affairs (OES). The assistant secretary for OES could thus speak for numerous constituencies—like population, health, polar affairs, fisheries, natural resources, and nuclear technology. He or she could even get the ear of the secretary when necessary. An assistant secretary also commands more respect from other government agencies, particularly the large ones.

Now, the deputy assistant secretary for the environment within OES works directly with EPA's Office of International Activities. The State Department's area bureaus also deal with that office, sometimes unilaterally, but clearance of EPA telegrams and other messages to U.S. embassies must always keep OES in the loop.

Often State and EPA overlap so much that more is required than simply checking paperwork. Last August a delegation headed by the assistant secretary for OES negotiated a border environment agreement with Mexico. Officials from EPA and the U.S. Coast Guard participated. Since then, EPA has served as national coordinator to implement the agreement This has meant interaction with the Mexicans to ameliorate harmful situations such as untreated sewage or air pollution crossing the border. In short, State and EPA were responsible for different aspects of the same project (one for negotiation and one for implementation), and so their close meshing was essential.

Sometimes collaboration requires cohabitation. A domestic agency may open its own offices in U.S. embassies. For example, the National Science Foundation has staff stationed in the Tokyo embassy, and EPA has detailed a man to the U.S mission to the OECD in Paris. Even in Washington, understanding between State and EPA has been enhanced by detailing personnel back and forth. Despite good humored accusations that these individuals are really moles for their permanent agency, they have been a big plus in teaching each agency about the priorities and procedures of the other. The practice should continue.

Overall the system functions amazingly well. For the most part the domestic agencies have satisfied their need to commingle with their opposite-number experts and organizations abroad, and State has maintained control over international policy. As in any human endeavor, however, a successful partnership between State and EPA (or any other domestic agency) depends on the people involved. Where there is patience, candor, and mutual trust the machinery runs smoothly. When one or more of these elements is missing, mischief can occur and U.S. interests suffer. The day-to-day routine between State and other agencies is not simple. The general modus operandi has developed well, with few glitches, but there are always threats to the necessary cooperative spirit.

THE POSSIBILITIES ARE INFINITE. Think of some specific chicanery and it might actually happen. In fact it may *already* have happened: A joint State-EPA delegation visits a foreign country. They draft a speech and wire it to

Washington for clearance by both agencies. The speech is then altered over the telephone. Unfortunately, someone leaks the original to the press, and the delegation looks bad as it is quoted nationwide with a statement that may be contrary to U.S. aims. The delegation complains righteously that it was tricked, but the damage is done.

A wasteful and all-too-common phenomenon is the oversized delegation. The State's Office of International Conferences tries manfully to trim delegations to sensible limits. The Office of International Activities in EPA, and similar mechanisms in other agencies, are dedicated to paring the fat from travel budgets. Journalists and oversight committees of Congress keep a sharp eye on us, and rightfully so.

Nevertheless, the problem is still very much with us. At the London Dumping Convention last February, State, EPA, the Corps of Engineers, the Department of Energy, the Navy's and Department of Defense's Legal Sections, and the National Oceanic and Atmospheric Administration all showed up in London for the annual meeting. Including congressional observers, the United States fielded nearly a score of federal employees, three or four times the size of other national teams. These constituent agencies should meld their different approaches in Washington and go to London next year with a firm U.S. position agreed upon by all. Then we should be able to keep our delegation to a maximum of six.

Three factors are usually to blame for such mammoth delegations. First, everyone wants to be included in prestigious meetings, such as the famous 1972 Stockholm U.N. Conference on the Human Environment. Dwarfing every other country's group, in some cases by more than 10 to 1, the United States sent 65 representatives—all expenses paid, of course. Second, there is the desire to travel to posh or exotic locations, particularly the great capitals of Europe. Third—and inexcusable—there is the aim of safeguarding the interests of one's own agency by keeping any eye on the activities of those other agencies that might steal a march on yours if not watched.

The appeal of the junket is strong. U.S. specialized agencies are still imbued with the missionary drive of our turn-of-the-century forebears' desire to enlighten the heathen—those, for example, who have not yet discovered the mysteries of environmental stewardship. Travel is broadening, too, and it has a peculiar talent for making home seem even sweeter. But these are not reasons for letting our delegations become so large that they hinder the accomplishment of our objectives. Many hands do not lighten delegation work overseas. They just confuse the issues, policies, and interagency relationships. The result of smaller delegations will be more fruitful orchestration between State and the domestic agencies.

The prospect of a large delegation to an important meeting also can inflame people in both State and other agencies to vie for the chairmanship. This position is one plum in the State–domestic agency arena that sparks the same kind of trouble as the apple in the Garden of Eden. The conflict can become so intense that the struggle may have to be settled by the White House, as it was before the 1972 Stockholm meeting. In principle, State should be free to chair any team it chooses. It is the senior department in government and presides over all U.S. activities overseas short of war. Sometimes it even presides *during* war, as in Vietnam and Laos.

In practice there are obstacles. OES has too few people to chair every group. Or, the State Department generalist may have trouble mastering the substance of a technical issue. If many scientists and technicians of a domestic agency are engaged, it is better management to have them serve under their own leader.

In some situations, such as in EPA's bilateral agreements with Mexico, the Soviet Union, China, West Germany, and France, the U.S. coordinator needs to be from EPA simply because so much of the work entails year-round, intra-agency decisions and implementation. The design of projects, selection of EPA participants, decisions on monetary and time requirements, these are all matters that must be threshed out by the program administrators. State stays in the picture throughout, communicating with EPA officials, overseeing policy, and monitoring the agreements with regard for overall U.S. relations with the country in question. At present, State and EPA discuss the chairmanship question well in advance of meetings and decide when and how the chair will be assigned. The excellent communications between the two agencies at present enables sound selections to be made unemotionally—a practice not always possible in the past.

There is another, extreme form of knavery not yet mentioned. If the delegates from one U.S. agency disagree with the national policy or fear the delegation's chairperson is failing to protect their interests adequately, they might stoop so low as to connive with the representatives of other countries. They could plant their views with a friendly foreigner who would introduce it as his or her own. This nightmare scenario is (at least to this writer's knowledge) still conjectural, but it might actually surface just as drugs do among our teenagers. The federal overseas establishment should be alert to stamp out such behavior before it happens.

Over the years such guerrilla warfare has been rare. It contaminates the ambience of faith that is essential for intramural cooperation to flourish in our government. Continual vigilance by those employees who participate in cooperative endeavors between the State Department and domestic agencies must protect us from such shenanigans.

The 14-year alliance between State and EPA boasts a fine record of accomplishment. Every month hundreds, perhaps thousands, of useful transactions take place. State and EPA together have forged a strong mechanism for advancing global environmental protection, serving as middleman between the United States and foreign countries. They have put together first-class conferences, joint reports, and a healthy collaboration. The daily stream of telephone calls, memos, letters, cables, and people between the two agencies is the lifeblood of this symbiosis. It is surprising that these complex arrangements work at all. Yet, remarkably, a combination of energy and good humor in both agencies has brought forth results in which toiling bureaucrats can take pride. ☐

Yurity A. Izrael and Douglas M. Costle, co-chairmen of the Soviet and U.S. delegations to the eighth joint committee meeting under the U.S.-U.S.S.R. environmental agreement. The agreement comprises 42 projects, from pollution control to wildlife conservation.

INTERNATIONAL COLLABORATION

INTERNATIONAL COOPERATION IN SCIENCE AND TECHNOLOGY RESEARCH AND DEVELOPMENT: SOME REFLECTIONS ON PAST EXPERIENCE

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This paper selectively examines past experience in science and technology cooperation with a view to identifying the key characteristics accounting for successful and less successful ventures that might be applicable to fusion research, development, and demonstration activities. Included in the analysis are the European Organization for Nuclear Research; Euratom; the Joint European Torus; the Nuclear Energy Agency's Eurochemic, Dragon, and Halden projects; European breeder cooperation; Urenco; and INTELSAT.

The analysis takes as a point of departure the proposition that past experiences carry limited and selective lessons for shaping future enterprises, that there is no single generic model of cooperation that can simply be applied to new ventures, and that success is likely to be more probable where the organization and ground rules have been tailored to accommodate the objectives to be achieved, the character of the participants, and the salient environing political factors.

Among the central conclusions of the analysis are:

1. *effective cooperation requires strong political will to enter and sustain cooperation and a reasonable matching of skills and interests of cooperating partners*
2. *there should be an acknowledged leader or authoritative manager*
3. *the objectives of any cooperative arrangement should be clearly defined at the outset, precise with respect to the distribution of responsibilities and means for dealing with conflicts that may arise, and limited in scope*
4. *as projects come closer to potential commercialization, relevant industrial actors should be brought into the arrangement*
5. *the importance of cooperating states being seen as reliable partners.*

I. INTRODUCTION: SCOPE AND CHARACTER OF INTERNATIONAL RESEARCH AND DEVELOPMENT (R&D) COOPERATION

International cooperation for R&D in science and technology has grown substantially during the past several decades. The scope of cooperation ranges from basic scientific research [e.g., the European Organization for Nuclear Research (CERN)] to joint development of technology (e.g., Urenco), and from simple exchanges of information generated in nationally based programs (e.g., U.S.-Canadian Heavy Water Reactor Exchange Program) to the joint construction and/or operation of experimental facilities [e.g., Joint European Torus (JET), Dragon]. It encompasses, among others, such areas as communications [International Telecommunications Satellite Organization (INTELSAT)], transportation (Concorde), space [European Space Vehicle Launcher Development

Organization (ELDO), European Space Research Organization (ESRO), and European Space Agency (ESA)], and energy [e.g., CERN, Euratom, European Nuclear Energy Agency (ENEA), and Solvent Refined Coal project (SRC-II)]. Cooperative ventures have increased most rapidly and dramatically in the energy sector in the wake of the 1973 oil crisis and the ensuing search for alternative sources of energy supply. Although the 1973 crisis was a stimulus to augmented international cooperation, a record of cooperative activities was already firmly established in the field of nuclear energy, dating to the mid-1950s with the U.S. "Atoms for Peace" program and the subsequent creation of Euratom and the Organization for Economic Cooperation and Development's (OECD's) ENEA. The nuclear experience offered lessons and some alternative models for cross-national cooperation, several of which were reflected in later international ventures.

The mechanisms through which cooperation has been effected include bilateral, multilateral, and international arrangements.[1] The record appears to indicate a preference among technologically advanced countries for bilateralism especially where something more than exchange of information and personnel is involved, while multilateral arrangements seem to fit more easily with agreements emphasizing information exchange. Decisions on the mechanisms for cooperation are of course subject to political considerations that may dictate different outcomes than otherwise might result.

The International Energy Agency (IEA), created in response to the 1973 energy crisis, adopted an organizational mechanism for R&D that falls between bilateralism and multilateralism and parenthetically reinforced the principle of national sovereignty against the development of a strong centralized international institution. The mechanism is the assignment of principal management responsibility for a specific research activity to a lead country or agency that has a major interest and commitment in the research area. On the one hand, this approach provides flexibility in the selection of key participants and in helping to ensure some equivalence between costs and benefits and avoiding the free rider problem that has concerned technologically advanced states anxious to preserve their technological knowledge and to share or exchange it only on equitable terms. On the other hand, it risks excluding technologically weaker states who, having only a limited or even no program in the technological area under investigation, are unable to bring some equity to the table.

In effect, this approach, which with some variation also has been used in the North Atlantic Treaty Organization, Committee on the Challenges of Modern Society (NATO-CCMS) and in several ENEA projects (Halden, Dragon) may be more properly seen as a form of extended bilateralism. Indeed, several key projects that go significantly beyond information exchange are essentially bilateral or trilateral agreements among technologically advanced states and really could have been developed quite apart from the IEA framework. This is true of two coal technology agreements on gasification and hydrogeneration involving only the United States and the Federal Republic of Germany (FRG) and of a trilateral coal agreement on fluidized bed combustion involving the United States, the FRG, and the United Kingdom.[2] For the United States, at least before 1973, cooperation tended to be primarily in the nuclear area, primarily bilateral, and largely limited to information exchange. For international cooperation at large, the emphasis on passive, information exchange tended to dominate. And where it was exceeded (e.g., Euratom, Concorde, ELDO) the record reveals difficulty.

Some of the propensities noted above – bilateralism or, in the case of IEA, extended bilateralism – and the limited extent of hardware-oriented joint technology development efforts are reflected in the following tables drawn from two studies on U.S. energy R&D cooperative programs in the OECD-related context. Table I displays the scope and pattern of cooperation in 1973, Table II provides similar data

TABLE I

U.S.-OECD Cooperative Energy R&D Programs in Late 1973

Nature	Nuclear	Fossil Fuel	Other Source	Resource Identification	Energy Use, Facility Construction	Totals	Beyond Information Exchange
Bilateral	12	1	2	2	2	19	5
Multilateral	2	1	0	0	0	3	3
With international organizations (NATO, Commission for the European Communities, OECD, Euratom)	2	1	0	0	1	4	1
Totals	16	3	2	2	3	26	9

TABLE II

U.S.-OECD Cooperative Energy R&D Programs in Late 1976

Nature	Nuclear	Fossil Fuels	Other Sources	Other Topics[a]	Totals	Beyond Information Exchange
Bilaterals	12	1	5[b]		18	8
IEA	12	5	7	9	33	7
Other international organizations[c]	1		4	8	13	
Totals	25	6	16	17	64	15

[a] Includes facility construction, energy use and conservation, energy systems analyses, and R&D strategy.
[b] Umbrella agreement with Japan covering nine nonnuclear subjects is treated as one agreement.
[c] The CCMS of NATO and the NEA of the OECD.

for late 1976 with IEA substituting for multilateral mechanisms, and Table III displays for 1978 the range of IEA cooperative programs and the extent of national participation.[3]

II. SOME GENERIC OBSERVATIONS ON INCENTIVES AND LIMITATIONS

The purpose of this paper is to selectively examine past experience in science and technology cooperation with a view to identifying the key characteristics accounting for successful and less successful ventures that might be applicable to fusion R&D activities. A number of enterprises are examined, among them CERN, Euratom including JET, Urenco; the Nuclear Energy Agency (NEA) projects, Halden, Dragon, and Eurochemic, and INTELSAT. One caveat should be stated at the outset: it is not the case, nor should it be expected, that there is any generic model of cooperation that can be simply applied to new ventures. By the same token, past experiences carry limited and selective lessons for shaping future enterprises. Successful ventures are more likely to be those whose organization and rules of the game have been tailored to accommodate the objectives to be achieved, the character of the participants, and the salient environing political factors. Before seeking to draw on particular past experiences, it would be useful to set down some general observations about incentives and limitations to international cooperation in research and technology. The intention is to be representative only, not exhaustive.

II.A. Incentives

The incentives to cooperate internationally on science and technology matters are relatively straightforward and familiar and for the most part relevant to fusion. Several are enumerated here.

1. *Cost.* R&D costs are very substantial, particularly in basic research and high technology. It is not a question of whether a state can afford to underwrite the full costs of a particular R&D program, but rather of the totality of costs that must be incurred across the spectrum of desired R&D activity and the impact of this on resource allocation. No state can really afford the costs and associated economic dislocations that would result from trying to develop the full spectrum of potentially promising technologies, and all states would inevitably have to make choices among conflicting technological pathways with the risk of sacrificing some attractive R&D strategies. This is particularly pertinent in the present when considerations of energy resource diversification and increased self-sufficiency are high priority national objectives, and emphasis is being given to exploring a broad range of alternative sources of energy supply. Other cost-related benefits include avoiding duplication of research efforts, potentially accelerating the pace of technological development, and possibly achieving earlier amelioration of the broader energy problem, which carries the added benefit of removing a potential source of interstate conflict.

2. *Concepts.* No country has a monopoly on ideas or scientific ingenuity. Cooperation arrangements are perceived as a means of identifying and exploiting new research approaches and enhancing national efforts by increasing the technological base through the interaction of technical manpower and expertise. While this is an argument that could be applied in any particular research sector, it has special bearing where it is deemed desirable to pursue a broad range of energy strategies and the relevant science and technology advantage is dispersed among a number of countries.

3. *Political considerations.* Advanced industrial high technology states with a strong scientific base

may find economic and technical reasons to cooperate less compelling than weaker and less-advanced states. However, political considerations, such as enhancing national influence abroad or the pursuit of particular foreign policy objectives (e.g., U.S. support of European integration as a principal source of U.S. cooperation with Euratom) may provide strong incentives to enter into cooperative arrangements. Although perhaps stimulated by political considerations, successful implementation of R&D cooperation ultimately depends on the fit of the participating states' scientific and technical programs and the presence or absence of legal or institutional impediments to fulfillment of the program's objectives. At the same time, it is unlikely that a good programmatic fit will lead to a productive operational outcome in the absence of a strong political will to succeed. The case of Euratom perhaps best illustrates this point.

In light of who the past and probable participants in fusion cooperation are (the United States the Soviet Union, Japan, and western Europe) and the U.S. objective to develop the highest potential of fusion rather than to pursue exclusively the first fusion concept to reach the energy breakeven milestone,[4] the political considerations would appear to be less relevant and the cost and concept considerations to be more salient and considerably more persuasive in support of a cooperative strategy insofar as fusion cooperation is concerned.

II.B. Limitations

There are problems in and limitations to international cooperation, and the benefits are not cost free. Frequently this is a consequence of the particular features of the cooperative arrangements, such as the character of the parties or the subject matter, the origins of cooperation (e.g., political but lacking scientific and/or technological compatibility), or the organization itself. There are however some generic characteristics that deserve mention.

1. *Basic versus applied R&D*. Where the program objectives are scientific development, and are still remote from commercialization, cooperation tends to be easier. The closer one comes to applied R&D, however, the closer one comes to economic interests that have stakes in the results of research, and the more difficult it becomes to achieve successful cooperation. This is a reason why historically the technical projects offered as the basis of international cooperation tend to be projects of relatively low salience to the participants. Thus, Euratom was offered lead responsibility in the development of organic-cooled reactors but not in the development of breeders much in the same way that Dragon, a technically interesting but commercially uncertain project, became one of the centerpieces of Britain's contributions to the ENEA. In short, national concern over the control of commercially useful information serves as a restraint on the scope of support for proceeding on the basis of international cooperation. But it does not foreclose it.

2. *Structural prohibitions*. National policies and laws regarding the protection or dissemination of information generated in research programs involving government funding and participation differ, and in the case of the United States are subject to publication and dissemination unless classified or somehow privileged, as in the case of proprietary information. The availability of such information under freedom of information has two potentially inhibiting effects on R&D cooperation. On the one hand, it creates the possibility of access by potential R&D partners to useful technical information without having to share the costs incurred in producing the information in the first place. On the other hand, the risk that information generated at home will, upon transfer to a foreign jurisdiction with a liberal information policy such as the United States, not be afforded adequate protection can serve to inhibit the willingness of others to cooperate with the United States.

A related issue is patent policy, which also can affect cooperative R&D. In some cases (e.g., France), the government owns the patent on anything resulting from R&D involving government sponsorship and participation. Firms pay the government a government-determined royalty for use of the product and also are subject to rules the government lays down about where the product can be marketed. In other cases (e.g., the United States), the information and resulting patents derived from government-funded research are available on a royalty-free basis and the law precludes entering into agreements that effectively divide up the market and dictate where companies can or cannot operate. Under these circumstances, cross-national cooperation can be impeded if not foreclosed. Such a situation arose when the United States entered into an agreement with France to test a 1-MW U.S.-built solar-heated power plant boiler in the French solar energy test facility at Odeillo. French insistence on access to test data and on exclusive marketing rights in Europe and Africa on any patentable result nearly led to termination of the cooperative agreement. While in that instance a mutually acceptable agreement was reached (each country to be responsible for the application of patents in its own country and both to consult on the application in third countries), differences in patent provisions, like information policies, can significantly affect R&D cooperation.

3. *Juste retour*. International cooperation can be inhibited by the need to satisfy the political criterion

TABLE

Country Participation in IEA Cooperative Programs and Projects in Energy

	Austria	Belgium	Canada	Denmark	FRG	Greece	Ireland	Italy	Japan
Energy research development and demonstration strategy		•[a]	•	•	•		•	•	•
Energy conservation									
Wiehl/Esslingen					⊡[b]				
Building energy load determination			•	•				•	
Urban planning						⊡			
Heat pumps	•			•	•		•	•	
Combustion									
Cascading	•	•	•		•				•
Heat transfer/heat exchangers									
Coal technology									
Technical information service	•	•	•		•			•	•
Economic assessment service			•		•			•	
World coal reserves and resources data bank		•	•		•			•	
Mining technology clearing house		•	•		•			•	
Fluidized bed combustion					•				
Low Btu coal gasification[c]					⊡				
Coal derived liquid fuel refining[c]					•				
Treatment of coal gasifier effluent liquors									
Coal pyrolysis					⊡				
Geothermal energy									
Man-made geothermal energy systems					⊡				
Solar energy									
Performance of systems for heating and cooling[d]		•		⊡	•	•		•	•
Development of components for heating and cooling[d]	•	•		•	•	•		•	⊡
Testing collectors for heating and cooling[d]	•	•	•	•	⊡	•		•	•
Instrumentation package[d]		•	•		•			•	
Treatment of meteorological information[d]	•	•	•	•	•			•	
Small solar power demonstration	•	•			⊡	•		•	
Ocean energy									
Wave power			•						⊡
Wind energy									
Large scale wind energy demonstration				•	•				
Technology of wind energy conversion systems	•		•	•	⊡				•
Fusion energy									
Intense neutron source			•						•
Superconducting magnets									•
Plasma/wall interactions (Textor)			•		•				•
Hydrogen									
Hydrogen production from water		•	•		⊡			•	•
Biomass conversion									
Technical information service							⊡		
Nuclear power									
Nuclear reactor safety experiments	•			•	⊡				⊡
Other activities									
Coordinated planning of coal hydrogenation programs					•				
Coordinated planning of forestry energy (biomass) programs			•				•		

[a] • = participation in project

[b] ⊡ = operating agent

[c] These two projects are not yet in implementing agreements. They are covered by statements of intent.

[d] These five projects are combined in the same implementing agreement.

III

Research, Development, and Demonstration (Mid-Summer 1978)

	Luxembourg	Netherlands	New Zealand	Norway	Spain	Sweden	Switzerland	Turkey	United Kingdom	United States	European Communities
		•		•	•	•	•		•	•	•
										•	
						•	•		•	⊡	
										•	
		•	•			•	•			•	
						•			•	⊡	
		•				•	•			⊡	
						•	•		⊡	•	
		•	•		•	•			⊡	•	
		•			•	•			⊡	•	
									⊡	•	
			•		•				⊡	•	
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		•							⊡	•	
						•			•		
						•	•		•	•	
		•	•		•	•	•		•	•	•
		•	•		•	•	•			•	
		•	•		•	•	•		•	•	•
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						•				•	
						⊡			⊡	⊡	
										•	
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of distributing supply, engineering, research, and hardware contracts among the participants in roughly the proportion that the state is contributing to the common enterprise. This frequent insistence on *juste retour* runs against sound management principles and can have a serious if not crippling effect on project efficiency and effectiveness. It is a particularly severe problem where the project is not easily amenable to modularization but instead involves a single, indivisible entity. Euratom, ELDO, and INTELSAT were affected in varying degrees with this problem.

4. *Control*. Whatever the propensity to cooperate, states generally are concerned about control over program and project management and over resource expenditures beyond national jurisdiction. This can be seen in the pattern of resource allocation between national and international programs in the same area. The international component even in the best of circumstances represents only a small percentage of what the state invests nationally.

It is also reflected in the organizational arrangements devised to carry out joint programs. The U.S.-Euratom Joint R&D program is a case in point. In 1958, the United States signed a cooperation agreement with the newly formed Euratom community. The agreement called for a $350 million capital investment in U.S.-type nuclear power plants with the United States providing up to $135 million in Export-Import Bank credit loans. This was accompanied by a joint R&D program to be carried out in Europe and the United States on the types of reactors to be constructed. Each partner was to commit $50 million to this program over a five-year period. To avoid the combining of U.S. and European funds and to permit each partner to remain in full control of its own contributions, two boards were established. European proposals went to the Euratom board and U.S. proposals to the Atomic Energy Commission. While in no way diminishing the value of the work done and probably minimizing if not eliminating a possible basis for controversy over R&D contract distribution—a problem that commonly plagues joint arrangements—this approach exemplifies the sensitivity of states to losing control over project management and expenditures. Along with such matters as concern over the control of commercially useful information, the development of national capabilities, and other considerations of national interest, these are factors that can weigh heavily in decisions on whether or not to pursue R&D independently or cooperatively.

III. SELECTED PAST EXPERIENCE IN SCIENTIFIC AND TECHNOLOGICAL COOPERATION

International cooperative arrangements, as we have seen, fall along an organizational spectrum ranging from (a) information exchanges between national programs to (b) coordination and confrontation of national programs through (c) lead country approaches in which one country assumes responsibility for linking related programs around an R&D exercise with a view to maximizing efficiency and effectiveness to (d) more formal central institutional approaches in which responsibility is vested in a central institution that makes R&D decisions and allocates responsibilities on behalf of the membership. Euratom, CERN, and INTELSAT represent variations closer to the latter end of the spectrum while the Halden, Dragon, and Eurochemic undertakings in the ENEA context, and Urenco, are examples of cooperative arrangements closer to the middle of the spectrum.

It bears repeating that the choice of organizational arrangement will depend on the project characteristics including scientific, technical, economic, and political considerations. It also needs to be emphasized that a truly objective assessment of the success or failure of different ventures is most difficult to achieve. Reliable objective criteria of performance that effectively isolate the host of external political and related factors that can affect outcomes are not available. Judging outcomes against original intentions can easily overlook the evolution of interest or the emergence of unanticipated consequences that bring good and bad consequences in their wake. In addition, ventures may be simultaneously successes and failures. Concorde, for example, was a technical success but an economic and commercial disaster. Similarly, while the ENEA enterprises did not lead to visible commercial success (Halden and Dragon did not yield industrial collaborative programs on the reactor types involved and Eurochemic disbanded as a collective enterprise in the face of competition from larger national programs in member countries), they were smoothly operating ventures, which helped to engender a positive and constructive climate of cooperation. The Euratom experience, on the other hand, led to neither visible programmatic successes nor generation of a positive will, but rather was a victim of, and in some ways contributed to, tension and combativeness. A modest review of aspects of these experiences follows.

III.A. CERN

The earliest of the major and significant international cooperative scientific endeavors is CERN. It is generally regarded as the most successful in terms of achieving its initial objectives, maintaining a strong and active scientific cadre, and largely avoiding some of the difficulties that have afflicted other cooperative efforts.[5] Much of this is explained by the character of CERN, which is fairly unique in that (a) its activities are confined to pure scientific and fundamental research, (b) it generates information of no direct commercial value, and (c) it has the continuing and exclusive support of the founding governments with virtually no industrial involvement. Only rarely, therefore, could CERN serve as a complete model for international collaboration, although in some senses fusion research comes closer than almost any other energy-based joint program.

Western European governments founded CERN at the strong urging of the high energy physics community, which emphasized that Europe could not catch up with the scientific progress made in the United States during the war unless the necessary resources and equipment, which lay beyond the capacity of any single European country, were developed. This underlying political concern helps to account for the initial and continued positive responsiveness of the participating governments.

A council of state representatives governs CERN. This council determines the broad scientific and administrative policies of the organization by simple majority except for budget issues and staff appointments and dismissals, where a two-thirds majority is required. Management of activities is supervised by a director-general supported by four deputies responsible for different functional areas. With the exception of some tensions over the siting of a second accelerator in the late 1960s (possibly best explained by the impact on the organization of extraneous political tensions related to efforts to achieve European unity and a resurgence of nationalism on the continent) and occasional pressures from national industries seeking bigger shares of large engineering contracts, CERN has had a remarkably productive and uneventful existence.

Among the lessons that can be drawn from the CERN experience are the importance of strong and sustained political commitment, the value of having a clear and concisely defined set of objectives, and relative ease of cooperation (which is nevertheless significant and meaningful) where industrial and commercial interest are not engaged.

III.B. Euratom

If Euratom shares with CERN the attribute of a formal central institution for R&D-related decision-making, it shares little else.[6] In terms of political and industrial-commercial considerations, political commitment, and specificity and preciseness of objective, the two organizations could not be further apart. This is reflected in the distance between them insofar as successful fulfillment of their mandates is concerned.

Euratom had eminently political foundations. Although functionally dedicated to the development of nuclear energy, it was visualized by its main proponents as a step in the construction of an integrated and united western Europe. As such, Euratom was a means to an end as well as an end in itself. The fact that its objectives extended beyond scientific and technological R&D, and included stimulating and controlling nuclear industrial development under supranational auspices, burdened Euratom with major responsibilities that could have been successfully carried out only if powerful political commitments were present on a sustained basis. In fact, such political will was lacking and the organization fulfilled only a shadow of its original objectives.

Political limitations were not the only difficulty Euratom faced. Unlike CERN, which focused on noncommercial R&D, Euratom was charged with an explicitly industrial task. It was not, however, vested with the necessary industrial authority, such as an independent source of revenue to support development strategies, or even the ability to participate in national industrial investment strategies in the nuclear sector. This effectively foreclosed Euratom from the commercially important activities and industrial developments that became the fulcrum of nuclear energy development. Perhaps nowhere is this more vividly demonstrated than in Euratom's inability to mount effective community action in the field of fast reactors.

The community's own R&D program (funded in two consecutive five-year programs of \$215 and \$425 million, respectively, and thereafter by annual allocations) was relegated to emphasizing projects of limited national or industrial interest (e.g., the organic-cooled heavy water reactor study, and longer term studies such as fusion and high temperature reactors). While Euratom lost, the national states did not necessarily gain. Their industrial structures were weakened by the resulting fragmentation. In 1968, 12 European firms were competing to build 16 nuclear plants in a market the size of the United States where one-third that number of firms were competing to build five times as many reactors.

A third problem that has plagued Euratom, but is not peculiar to it, is the *juste retour* mentioned earlier. States contributing to common undertakings that are largely implemented through contracts to supporting industrial and research organizations are sensitive to the distribution of these contracts. Perceived inequities are not taken lightly and are often responded to at the political level with pressures for a more equitable distribution. One more extreme example was the refusal of Italy to approve Euratom's annual budget for any work unless assurances of a more "equitable" distribution of common resources were given. While participants do not insist on a dollar-for-dollar settlement, disparities beyond 25 to 30% between contributions and receipts will tend to evoke sharp response.

Euratom's experience in the field of fusion research is also instructive. The JET, which was designed by a team of European scientists on the basis of Soviet tokamak technology (at Britain's Culham

Laboratory, ran into major difficulties over the question of where it should be located. At one point, France, Italy, the FRG, and Great Britain were all serious contenders and determined to win JET for their own research centers. The European Commission, which was proposing that the Euratom community pay 80% of the anticipated $108 million (subsequently $330 million) project cost, charged an independent site committee to evaluate different potential locations based on scientific and social (i.e., housing, educational facilities for a multinational team, access, etc.) criteria. This report favored the Italian site at Ispra, one of the components of the community's Joint Research Center, and one which is grossly underused. Italy, lobbying strongly for JET, refused to approve the Community's five-year (1976 to 1980) fusion and plasma physics research program unless a decision was taken simultaneously on the JET site.

A decision ultimately was taken to locate JET at Culham thus denying Italy its prime objective. The reasons why one site was selected over another (lack of confidence in Italy's political stability and concern over labor unrest, which historically plagued Ispra, are key factors) are less important than what the conflicts over siting represent—the difficulties that can arise with respect to large-scale collaborative R&D. At this level of activity, the stakes become significant. A project like JET is accompanied by substantial investments, home country advantages in future activity in that technological sector, and a variety of host state spin-off benefits that do not lend themselves to easy quantification. The spreading of contracts in some reasonable proportion to the financial commitments of the participating states is a safeguard, but only an incomplete one, with respect to the allocation of medium and longer term benefits.

Although in many ways comparable to CERN (a basic research endeavor far from commercialization, a concise, specific research activity, a shared interest of all the participating governments for none of whom alone an undertaking of such magnitude would be easy), JET has been much more of a political football. If, as is virtually certain, this is not attributable to the technology, one must look to the environing political circumstances and the patterns and characteristics of European scientific and technological cooperation in the community context for an explanation. Nevertheless, it should not be discounted that similar problems and concerns could arise with respect to siting other experimental fusion devices such as the International Tokamak Reactor (INTOR).

The joint U.S.-Euratom power reactor and related R&D programs have already been mentioned. This cooperative arrangement, which called for total expenditures of over one-half billion dollars, was a major undertaking for its time. The United States had been more interested in the reactor program while the Europeans emphasized the R&D program, especially to avoid the impression that the agreement was merely a scheme to import U.S. reactors into the community. This explains in part why the United States opted for an arrangement in which each of the participating partners controlled the expenditure of their respective R&D contributions instead of vesting responsibility in a single overarching committee. Neither the reactor nor the R&D efforts ever came to more than partial fruition, principally because of the radically changed energy environment, which deemphasized the urgency for developing nuclear power. Organizationally, the concept of two joint boards with equal U.S. and Euratom membership and voting power to supervise the programs, and separate boards to allocate the respective contributions to the R&D programs, created no problems and it could serve as a model for other cooperative activities. Failure of the undertaking to achieve its objectives was not the result of organizational arrangements, but of extraneous factors.

Overall, Euratom is not a good model for other cooperative efforts as it really was conceived as a means of achieving broader objectives that were political in character and far transcended the particular R&D activities involved. The extensiveness of its objectives is reflected in the nature and complexity of its administrative apparatus, which exceeded what is necessary for cooperative R&D alone. Euratom's experience reinforces the argument in favor of specificity, limitation, and clarity of purpose in entering into cooperative arrangements. It also offers some insights into the economic-commercial dimensions of international cooperation: Euratom's successes came in areas that were only remotely related to the competitive status of the national nuclear industries of its most important members—France, the FRG, Italy, and later Great Britain. Finally, the Euratom experience also underscores the importance of strong and sustained political commitment to successful implementation of cooperative undertakings.

Euratom country experience in breeder reactor R&D cooperation supports many of these conclusions and highlights the contrast between broad community and more selective bi- and multilateral cooperation arrangements. Euratom early sought to develop a central role in the breeder field, regarding it as posing fewer obstacles to effective community action than did light water reactors because national breeder programs were either nonexistent or were still in a rudimentary phase when Euratom came into being and commercialization was a much more distant and uncertain prospect. In addition, projected costs were high and funding opportunities, while not unavailable, also were not unlimited. It was consequently believed that the ability to make a community contribution would provide incentives to community action and coordination.

Community action, however, turned out to be more difficult than anticipated. Individual countries exhibited reluctance to share national control of facilities or decisions related to programmatic development, particularly with centralized institutional decision-making bodies. Political and prestige considerations intervened to foreclose the possibility of establishing a single community association accord in the breeder area. Instead, three association accords were negotiated with France, the FRG, and Italy, respectively. These agreements tended to be overlapping and competitive rather than reflecting a technically based division of labor. Duplicative critical assemblies were built in France and the FRG and community resources were spread more thinly than desirable over a large number of projects. Differences in national programmatic objectives, pace, and investment led to strains among the participants and to nonrenewal of the association when expiration came in 1967 to 1968.

In the late 1960s and early 1970s, however, non-community-anchored bilateral and trilateral cooperative agreements were negotiated among a number of Euratom states. In 1967, Belgium and the Netherlands had established a breeder agreement involving R&D with the FRG and in 1974 France and Italy agreed to a full exchange arrangement for all R&D information on the liquid-metal fast breeder reactor approach. More importantly, in 1977 France and the FRG consummated an agreement involving themselves and their partners that called for a full exchange of R&D results and of commercial information, the establishment of a joint company, Serena, for licensing of know-how, and provided for equal funding of their respective programs by France and the FRG. This is the most advanced cooperative arrangement on breeder reactors to date, placing the two major European breeder programs in a partnership situation. One of the salient characteristics is that each of the major programs retains its separate national identity and national commercial interests are respected and protected. On the other hand, the community's coordinating role has declined to a very minimal level, working through a fast reactor coordination committee with no regulatory or decision-making authority. European cooperation on breeder reactors over the past five years is generally regarded as a significant example of international cooperation possibilities in the development of advanced technology.[8]

III.C. NEA

The NEA (earlier known as the ENEA) was created as a semi-autonomous arm of the Organization for European Economic Cooperation (later OECD).[9] Like Euratom, it was in large measure an institutionalized response to Europe's growing concern over energy, and to the challenge of helping to establish a nuclear industrial structure in Europe, and to narrowing the technological and economic gap between Europe and the United States. Unlike Euratom, with its strong supranational political overtones, its operational responsibilities, which made it sometimes appear as a competitor with national industry rather than a support to it, and its weighty administrative apparatus, NEA was conceived essentially as a forum to facilitate the creation of joint projects. It is for its organizational innovativeness in fulfilling this mandate that NEA is interesting.

Two joint intergovernmental projects involving applied R&D were established in Norway and the United Kingdom, using an organizational concept of lead country approach. In both instances, the host country served as operating contractor to the NEA. The Halden boiling heavy water reactor in Norway became a joint multinational instrument for testing prototype fuel elements and instrumentalities in which a number of outside countries and entities (such as Euratom) participated. The host country owned, operated, and managed the project on behalf of the participants, each of whom held a seat on a governing board that made all R&D and budget decisions.

The Dragon project, which involved joint multinational development and use of a high temperature reactor facility, involved an even larger number of participating countries and entities. The United Kingdom and Euratom put up 85% of the financial support, the balance being funded by the remaining participants. As in the case of Halden, operational and managerial responsibility for the multinational team and joint enterprise is in the hands of the host country's institution acting under the authority of a board of management on which representatives of the participants sit. The project also proceeded in stages, a new agreement being reached to cover each stage. Among other things, this avoided the problem of runaway budgets and the political tensions that accompany budgetary politics.

This approach of establishing an international governing board of participants to provide policy guidance to an international team functioning with the legal, administrative, and technical support of a host organization avoids the problem of having to negotiate and establish a separate legal entity, and allows flexibility in terms of the nature of the participants and the degree of their involvement and commitment. Indeed, flexibility is the hallmark of the NEA lead country approach, and it cannot be said, when comparing NEA with Euratom, that the price of flexibility is triviality insofar as the relevance and utility of the work is concerned. On the other hand, as the pattern of IEA project development seems to indicate, the *à la carte* approach to cooperative R&D is highly sensitive to the matter of equivalence between costs and benefits, and countries lacking or only having weak research programs in a given R&D sector may find it difficult to participate in joint undertakings as the more advanced participants act to prevent countries receiving benefits out of proportion to their contributions.[2] In addition, Dragon is testimony to the ability of a multinational consortium to effectively implement a joint program in a timely manner and with a minimum of conflict. Twelve countries participated in the project design and construction, and procurement was based on an equally widespread tender action. Only a few disputes arose over bids and were quickly resolved by the board, and the reactor reached criticality five years after the agreement came into force.

Eurochemic is the third major NEA-based venture and for its time (1960s) was one of the most advanced and frankly industrially oriented joint ventures in the energy R&D sector. Its objective was the construction and operation of a reprocessing plant and the carrying out of related R&D work. Organizationally, it offered the same kind of flexibility as Halden and Dragon although it had a separate legal entity—an international joint stock company, which operated under the authority of a board of directors and a general assembly of shareholders—and it was constituted by treaty rather than the private form of agreement that characterized the other NEA joint undertakings. Eurochemic is described frequently as a failure because it eventually succumbed to the competitive pressures of national reprocessing facilities in some of its member countries. However, its main purpose was to serve as a training ground to acquire experience in handling reprocessing of different fuel types and to lay the base for industrial development. Failure only can relate to the political criterion of creating a single European level consortium governed by some overarching European managerial board. As a technical enterprise, Eurochemic facilitated and helped launch the basis for industrial capability. Measured against that criterion, it was a success.

III.D. INTELSAT

The INTELSAT was created to develop, construct, and operate, on a commercial basis, the space segment of a telecommunication satellite system. Of the cooperative experiences considered in this paper, it is the one with the most extensive U.S. involvement. This reflects the somewhat surprising finding that, relative to its size and the scope of its scientific and technological activities, the United States has entered into only a modest number of joint R&D undertakings that go beyond basic exchanges of information and personnel. In the latter category, there are a large number of bilateral and multilateral agreements on the books. But in the realm of more extensive cooperation and genuine joint projects, rhetoric dominates reality and the record is parsimonious and focuses largely on several coal technology undertakings (FBC, SRC-II), the nuclear cooperation with Euratom, and INTELSAT. This is consistent with findings in a number of studies that suggest that the greater the level of economic and technological resources of a nation, both absolute and relative to the international community in which cooperation is taking place, the weaker the propensity to cooperate internationally unless extraneous political and diplomatic reasons are taken into account.[10-12]

Not only interesting but significant, INTELSAT is a technically successful organization that demonstrates joint ventures to implement and manage a high technology system, where commercial and industrial interests loom large and national political interest is high, can be carried out successfully. This is not however to imply that success was achieved without difficulty as was manifest in part in the R&D sector.

At the outset, the United States held a technological monopoly extending from satellites to launchers to ground stations, which it was interested in maximizing and which others had a very powerful interest in acquiring. European interest in joining the United States in INTELSAT reflects less their desire for global communication, and more their concern that the United States not translate superiority in space technology into a communications monopoly. They entered into partnership with the United States to acquire some influence over the course of future events. The INTELSAT evolved in two phases, the first of which was an interim agreement constituted by an international consortium without legal personality and which reflected U.S. dominance. Other member states acquiesced in the initial arrangements because of U.S. superiority and their desire to acquire technological resources they did not possess.[13]

System management in this first phase (1964 to 1972) was entrusted to Communications Satellite Corporation (COMSAT), a privately owned U.S. operation and the designated U.S. entity in the arrangement. The definitive arrangements provided for substitution for COMSAT by an international administrative and technical staff responsible for managing the system under the direction of a board of governors on which signatories sit and vote in proportion to their investment shares. The substitution of an international secretariat for COMSAT is scheduled to be implemented on a progressive "phase-in-phase-out" basis with COMSAT continuing to perform technical operations and maintenance services under renewable five-year management service contracts.

As the designated overall manager for design, development, construction, and operations of the space segment, COMSAT developed a practice of giving R&D and procurement contracts to the firms that had the most technological advantage, which essentially meant U.S. firms. In addition, COMSAT tended to favor in-house research in its own laboratories over contractual research. This generated considerable hostility by the European consortium members who, interested in diluting, not perpetuating, the American monopoly, sought a broader and more equitable distribution formula. Efforts to get the Interim Communications Satellite Committee of INTELSAT to supervise COMSAT R&D and to give prior approval to COMSAT awards were defeated, but over time the percentage of contracts placed in-house began to diminish and a more equitable distribution (roughly 50-50) emerged. Under the permanent arrangements, contract responsibility passed to the secretariat. Interestingly, strong pressures have been placed on the latter by the less-advanced member countries to base contract placement not on a principle of equitable distribution but rather on the criteria of technological quality and least cost.[14]

The INTELSAT experience underscores the extent to which joint venture approaches can be taken. It is characterized, as are many other successful ventures, by clarity of purpose and specificity of objectives. And as the contract criteria apparently preferred by many members suggest, confidence in a high technology organization may well depend on its capacity to avoid formal national quotas in resource allocation. This, however, has been a political liability that most large-scale R&D organizations and ventures have to bear. As the Euratom case demonstrated, not all undertakings are always able to cope successfully with that problem.

III.E. Urenco

Urenco, the tripartite organization in which three European countries (the United Kingdom, the FRG, and the Netherlands) collaborate in the enrichment of uranium, the manufacture of gas centrifuges, and the conducting of related R&D, is perhaps the most far-reaching of the joint arrangements dealt with in this paper. It comes much closer to such other production-oriented international technology projects as the bilateral Concorde and the quadripartite Airbus, both of which, like Urenco, have been technically successful cooperative enterprises, than it does to either CERN or Euratom. The success of Urenco may be all the more surprising and encouraging as it involves a technology that was and still is classified and involves serious security issues.

Urenco's organization is complex, involving four contracting parties who equally share one-third ownership and who have formed two companies to handle international marketing and technology licensing and two enterprises to handle design construction, ownership, and operation. It is, however, run as a single entity. One of the companies, Centec, is charged with responsibility for coordinating a joint tripartite R&D and information exchange program. A joint committee composed of representatives of the contracting parties has authority to approve R&D programs, which are to be financed in whole or part by joint government grants. It is this set of activities that bears most directly on the fusion R&D question.

Over time, Urenco has undergone several organizational adjustments, partly for operational, partly for investment philosophy reasons, and partly for reasons of technology choice. With respect to the last, it was originally intended that Urenco would develop a single centrifuge technology that would be exploited on a common basis. All of the participants, however, already had made substantial investments in centrifuge technology by the time Urenco was established, and they proved unwilling to forego this investment in favor of a common technological approach. A new arrangement was negotiated whereby each party is responsible for its own R&D program and, as controlling shareholder in its own national enterprise, determines which technology it will use. Full exchange of technological information among the shareholders makes possible the taking of an informed decision.[15,16] Other attributes of Urenco have also undergone changes that tend to reinstate greater national control over activities. Thus, whereas the original investment pattern was to be one in which Urenco plants were to be built on the principle of equal ownership and investment, this has evolved through several stages to a point where Urenco facilities will be 90% nationally owned. The underlying reasons relate to differences among shareholders regarding the timeliness of constructing new facilities and the appropriate marketing philosophy.

These experiences suggest some of the difficulties that can arise in multilateral settlement on a common technological strategy. How applicable this is to the next stage in fusion R&D is for those most involved in the technology and the alternative development pathways to determine. At the same time, the ability of different countries to converge in a common enterprise involving joint decisions where the commercial and economic stakes are so high underscores the latitude of action open to those who would consider a common enterprise.

IV. CONCLUDING OBSERVATIONS

The record of international cooperation in scientific and technological R&D is mixed, an outcome that should not be surprising. Despite the intuitive sense that cooperation, which can reduce costs, expand ideas, and enhance overall scientific and technological experience and competence, is the logical and rational thing to do, it does not turn out to be an instinctive characteristic of international behavior. While governments understand that cooperative R&D can bring economic and technological advantages, and recognize the value of supporting fundamental R&D in this way, the natural inclination of many is to seek to preserve as much national control and exclusivity as they can and to gain maximum national advantage from what is achieved. The record of largely independent determination of national scientific and technological research and development efforts in energy and other matters confirms this.

Many factors explain this disposition: a preference for national managerial and decision-making control; the preservation of proprietary and commercial interests; the difficulties in negotiating around legal and institutional conditions, which reflect cultural and structural differences among societies; the problems of ensuring that there is an equitable sharing of benefit as well as risks; the strong desire to avoid giving something for nothing; and the difficulties of assessing the values to be assigned to the intellectual and substantive factors that are exchanged.

But the record also shows that cooperative arrangements can be successfully negotiated and implemented; that they can deal with high technology as well as basic research, and with commercially proximate as well as commercially remote activities; that while multilateral ventures tend to introduce a greater set of complexities than do bilateral counterparts, they can be as productive in terms of technical outcomes and organizational durability. Or, to put it another way, while bilateralism may simplify matters, it does not ensure either technical or organizational success.

It also would appear, however, that the proximity of a given scientific or technological activity to commercialization does affect the probability of widespread support for cooperative action; that while multilateral fora are satisfactory means for coordinating general policies and programs, they are more problematic as a basis for joint R&D projects, and that a close alignment of national interests and an ability to make roughly equivalent scientific and technological contributions to the common enterprise probably is necessary if it is to proceed efficiently and effectively.

These general observations suggest the following guidelines for entering into cooperative arrangements.

1. Effective cooperation requires two basic elements: strong political will to enter and sustain cooperation and a reasonable matching of skills and interests of the cooperating partners. Both are necessary; neither alone is sufficient. The larger the number of participants, the more heterogenous the group and the more difficult it becomes to meet these criteria. Even in the face of political support and convergent national interests, an ability to make roughly equivalent financial and technological inputs is an essential element.

2. There should be an acknowledged leader or authoritative manager. The lead country concept, while not a panacea for cooperative organization, does show a good record in comparison with arrangements more closely approximating classic international organizations. One reason may be its apparent ability to minimize, if not avoid, the *juste retour* problem and to resist pressure for recruitment, procurement, and resource allocation in some fixed proportion to contribution. And this in turn may reflect the fact that lead country approaches are voluntaristic, ad hoc, and selective with respect to participants.

3. The objectives of any cooperative arrangement should be clearly defined at the outset, precise with respect to the distribution of responsibilities and means for dealing with conflicts that may arise, and limited in scope. Open-ended arrangements have almost invariably run into serious difficulties while more precisely defined and limited arrangements—even one with as rocky a career as Concorde—tend to survive.

4. As projects come closer to potential commercialization, i.e., as they move out of the basic science phase, the relevant industrial actors should be brought into the arrangement. Involvement at the basic planning stage is preferable to involvement only at the point of implementation. To date, there are relatively few examples of satisfactory resolution of ways to effectively engage the private sector despite its being essential when industrial applications begin to become relevant.

A number of years ago, a State Department task force concerned with energy laid down the criteria by which the potential benefits of cooperation, and therefore the desirability of taking initiatives, could be judged. They would appear to be as valid today as they were in 1974:

1. the existence of unexploited opportunities
2. the existence of useful technology abroad
3. potential for reduction of the energy deficit
4. reasonable time of transfer to commercial use
5. lack of legal or proprietary barriers.[1]

Leaving aside the question of transfer time to commercial use, it would appear *prima facie* that state-of-the-art fusion meets most reasonable interpretations of these criteria. (I am interpreting potential for reduction of the energy deficit through fusion in the spirit of Walter Marshall's judgment: "The chance of success is zero, but the promise is infinite.")

The costs of fusion R&D are substantial, activity is progressively entering the technological and engineering phase of development, but numerous uncertainties remain and critical path development is yet to be defined. This would seem to dictate enhanced international cooperation among the four centers of excellence in this field. Of what this next step in cooperation should consist of is primarily a technical issue, but to the nonexpert it would seem that, at a minimum, a joint planning strategy that identifies the next set of major problems and parcels out the responsibilities even to the point of joint building of prototype machines with full and complete exchange of R&D results would be logical. Organizationally, the JET experience highlights the problems associated with commitment to a single machine, and technically that may be the wrong step to take at this time. One of the worst conceivable outcomes, however, would be for the fusion programs to fall into the "fast reactor syndrome" that characterized western Europe in the late 1960s and early 1970s in which all of the principal countries involved in breeder reactor R&D pursued the same costly development strategy, building the same machines separately.

A final observation relates not to the desirability of cooperation but to the attractiveness of the United States as a cooperating partner. On the one side, we have the advantage of intellectual, managerial, and economic resources and the reputation as a world leader in science and technology. On the other side, there are the patent, licensing, and information rules of the game discussed earlier but also, and more importantly, an uncertainty about the United States as a reliable partner. This is not a problem endemic to science and technology cooperation and in fact is more evident in other branches of activity—soybean exports in the early 1970s, and nuclear export and cooperation policy in the late 1970s for example. But recently reliability once again became an issue in R&D cooperation in the form of whether to proceed with the trilateral SRC-II project. The project was eventually cancelled.

Consequently, other nations cannot but wonder whether cooperation with the United States might not entail risks and costs that exceed any benefit that might ensue. The United States is not the only country afflicted with this problem. Three times during the Concorde project the British sought to withdraw. Twice the French prevailed on them not to, the third time entrenched domestic interests prevented a decision of withdrawal. The project was completed and subsequent joint efforts have been entered into. Can the United States live up to that standard? If not, can it hope to remain a central actor in international science and technology cooperation?

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GLOSSARY

CERN	European Center for Nuclear Research. An organization of 13 European states the purpose of which is to ensure collaboration in fundamental research in subnuclear physics. CERN conducts only fundamental nuclear research and has no activities related to nuclear energy applications.
COSMAT	Communications Satellite Corporation. A U.S. monopoly corporation that was designated as primary U.S. entity and manager in the INTELSAT international venture. This role was altered under the INTELSAT definitive arrangements in which COMSAT was to provide only technical and systems operation services to INTELSAT.
Concorde	Joint Franco-British supersonic transport venture.
Dragon	Intergovernmental collaborative project led by the United Kingdom involving the high temperature reactor at Winfrith, England, One of three projects established under the auspices of the (European) NEA (along with Halden and Eurochemic).
ELDO	European Space Vehicle Launcher Development Organization. An organization of seven European states established to provide Europe with an independent satellite launching capability for peaceful applications. Counterpart to ESRO.
ESA	European Space Agency. Successor organization to ELDO and ESRO.
ESRO	European Space Research Organization. An Organization of ten European states established to provide for and to promote collaboration among European states in space research and technology for peaceful purposes. Counterpart to ELDO.
Euratom	European Atomic Energy Community. One of the three supranational communities (along with European Coal and Steel Community and European Economic Community) established in the 1950s to promote European integration.
Eurochemic	European Company for the Chemical Processing of Irradiated Fuels. A multinational fuel production project of the (European) NEA. The cooperative venture involved 13 member states of the OECD and operated from 1966 through 1974.
Halden	Boiling water reactor project in Norway conducted under the auspices of the (European) NEA. One of three projects established under NEA auspices along with Dragon and Eurochemic.
IEA	International Energy Agency. Organization established following a proposal by the United States in the wake of the 1973-1974 Arab oil embargo to coordinate energy policy of the industrial oil-importing states. Established under the auspices of the OECD.
INTELSAT	International Telecommunications Satellite Organization. An organization established to design, develop, construct, establish, operate, and maintain a global commercial communications satellite system.
INTOR	International Tokamak Reactor. An international collaborative venture concept in magnetic fusion.
Ispra	Italian nuclear research center, which is one of several national facilities incorporated into Euratom's Joint Nuclear Research Center.
JET	Joint European Torus. Centerpiece of European cooperative fusion effort under the auspices of the European communities.
NATO-CCMS	North Atlantic Treaty Organization, Committee on the Challenges of Modern Society. Committee that focuses on how to marshal Western experiences and resources in the interest of improving the quality of life.
NEA	Nuclear Energy Agency (formerly ENEA). Nuclear agency established under the auspices of the predecessor of the OECD and the OEEC to facilitate development of peaceful uses of nuclear energy.
SRC-II	Solvent Refined Coal project involving the United States, the FRG, and Japan in synthetic fuel development. Terminated in 1981 before construction due to budgetary and other reasons.
Urenco	A tripartite (British/Dutch/FRG) uranium enrichment consortium that uses the centrifuge method of enrichment. The consortium is involved in research, development, and marketing of enriched uranium.

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For Want of a Nail?

An Assessment of Prospects for the United Nations Conference on Science and Technology for Development

Rodney W. Nichols

It is fashionable in some circles to be cynical about conferences of the United Nations. After all, the cynics say, throwing conferences has become a numbingly rhetorical and naggingly unproductive response to international problems. So what good could come from still another conference—the United Nations Conference on Science and Technology for Development (UNCSTD)? Yet this Conference *will* be held in Vienna during August 1979. Why is it being held? Could it be a waste of time? Could it make a genuine difference in planning for the 1980s?

In this introduction to the UNCSTD Issue of *Technology In Society, An International Journal*, the tasks are to sketch the origins of the UN Conference on Science and Technology for Development, to evaluate the status of the preparations, and then to estimate the prospects of the Conference itself. Just as too much candor can sometimes be the enemy of success in pursuing diplomacy, too little candor can sometimes be the enemy of realism in managing technology. So the style will be informal and frank in exploring the convergence of UN-style diplomacy with economic facts and social hopes, in the context of the scientific and technological themes for the Conference.

Reconnaissance

We shall first scout out the terrain. Since the early 1970s, the proponents have believed that a conference on the applications of science and technology would help to solve the hardest developmental problems of most countries, especially the poorest. The rationale is straightforward: development problems are urgent and their solutions depend partly on science and technology.

During the 1970s, and particularly after the Organization of Petroleum Exporting Countries (OPEC) gained power, political relationships changed dramatically between the developing countries (DCs) and the less developed countries (LDCs). Most LDCs, despite their enormous differences in many respects, were united in feeling confident about making more demands on the DCs. These new demands

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often related to science and technology. The political leadership among the LDCs believed that UNCSTD should focus on international inequities and on the "failures" of the past two decades in development assistance. They aimed to extract agreements pledging more aid, with a view to ultimately eliminating their "technological dependency." The diplomatic climate was hot as North South negotiations deteriorated and stalled in 1974 75.

Despite these diverse strains, a tentative consensus emerged in 1976 on three views of the value of the Conference. First, governments sensed that such a meeting could become a usefully disciplining goad to their own policymakers and to international officials; 1979 was then far enough away to provide a cooling-off period and to serve later as a deadline. Next, the nongovernmental professional communities sensed that the UN forum could become the catalyst for increasing popular awareness of many global issues that have been both fuzzy and urgent. Finally, radicals and moderates came to share the idea that UNCSTD could try to integrate, clarify, and extend the connections among the issues confronted at the major UN conferences held during the 1970s, such as those on environment, population, food, habitat, and water.

How well were these three perspectives being pursued by late 1978? Unfortunately, it became easy to be skeptical about the quality and impact of preparations for UNCSTD. Much of the work so far has been shallow and fragmented. Many communications have appeared to be unclear, even obscure. Serious analysis has been scarce, and new approaches even scarcer.

In fairness, there are few new ideas that persuasively show how to accomodate all the complex dimensions of science and technology in the development process. So, at the start, the preparations were severely hobbled conceptually. And there also were defects in the initial plans for helping countries prepare for UNCSTD.

Nonetheless, the national and international "aid" institutions—despite their confident rhetoric in headquarters, their occasional floundering in the field, and their heavy bureaucratic appearance—probably are serious about looking for new directions in adapting more effectively their mechanisms for applying the modern sciences and technologies to developmental goals.

More important, new segments of the private scientific community in the industrialized countries are showing signs of more lively interest in the "Third World," and a few governments are bringing fresh efforts to their work on development.

Thus it would not be wise to write off the UNCSTD. Indeed, as the old saying reminds us, "For want of a nail the shoe is lost, for want of a shoe the horse is lost, for want of a horse the rider is lost." Is UNCSTD a nail in the shoe of international cooperation? Is technology a horse for the international community to ride?

After this quick reconnaissance, let us now review more fully the many strands of preparations for the Conference.

Capsule History

Describing the history of UNCSTD is a good deal easier than evaluating the quality of preparatory work to date. Millions of words have already been written and spoken. No one has read and heard them all, much less had the time to try to discover any cogent thoughts that may be bobbing in the oceans of cliches.

The first UN meeting on this subject was held in 1963. That sprawling forum produced little practical action. It is remembered as a "science fair"—a pejorative term meaning that it was too academic, too technical, too wordy, and too passive. Inevitably, as rising expectations in the LDCs were frustrated towards the end of the 1960s, the first musings were heard about another UN conference on applying science and technology for the benefit of the developing world. Near the end of 1970, the General Assembly went on record with a request to the Secretary General for his evaluation of science and technology in the international scene and of the results that had been achieved after the 1963 conference. The chronology of events is summarized in Figure 1.

The principal organizational vehicle for planning UNCSTD has been the Committee on Science and Technology for Development within the UN's Economic and Social Council. Formed in 1972, this group of 52 national delegations has had the difficult assignment of trying to coordinate policies for all UN wide scientific and technological activities. In the process, it became the Preparatory Committee for UNCSTD.

FIGURE 1. Key Events Related to UNCSTD.

1963—UN holds Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas

1970—As first UN Development Decade (1960s) ends and Second Development Decade (1970s) begins, General Assembly asks Secretary General to evaluate science and technology and to appraise results achieved after 1963 UN Conference.

1972—First meetings of the Committee on Science and Technology for Development (a major group within the Economic and Social Council) are held, providing a central forum for discussion of UN-wide matters involving science and technology.

1974—Economic and Social Council emphasizes necessity for another international conference on science and technology.

1975—Intergovernmental Working Group (of Committee on Science and Technology for Development) examines possible objectives and agenda for a UN Conference

1975—General Assembly passes major resolutions on "New International Economic Order" with substantial references to science and technology.

1976—Committee on Science and Technology for Development approves resolution which is adopted by Economic and Social Council (August) and by General Assembly (December), confirming official agenda for UNCSTD in 1979.

1977—Formal preparations for UNCSTD begin with appointment of Secretary General for UNCSTD in January.

1978—Governments submit National Papers and attend meetings of Preparatory Committee.

1979—Many nongovernmental meetings held between January and June (see Figure 3).

1979—UNCSTD convenes in Vienna (August) as Second Development Decade ends and planning for Third Development Decade begins.

Although the industrialized countries were at first reluctant to plan another UN conference, no one doubted the need for raising quality and efficiency in the UN itself concerning the uses of science and technology in development. Furthermore, most LDCs—often speaking through the surprisingly effective caucus of nations called the "Group of 77"—pressed their case for more favorable economic terms in building their technological base for industrialization.

In 1974-75 when North-South tensions peaked, some DCs were hoping that plans for the UNCSTD would "de-politicize" part of the contentious debates by separating certain science and technology issues from the rest of the UN's economic forums. But many LDCs had the opposite objective: to link science and technology issues more closely with negotiations for a "new international economic order."[1] Thus, with only a partial recognition of the incompatible goals and a full diplomatic acknowledgement of everyone's high hopes, it was agreed by consensus in 1976 to go ahead with UNCSTD.

Secretary General and Secretariat

The appointment of João Franck da Costa, a career diplomat from Brazil, as Secretary-General for UNCSTD was made in January 1977. He and his associates in the Conference's Secretariat got off to a shaky start. Although he had been virtually the unanimous choice of all who had been planning the conference, da Costa surprised everyone by getting involved almost immediately in debilitating disputes within the UN bureaucracy. Thus, despite his considerable personal qualifications and his strong background in the conceptual evolution of UNCSTD, cooperation within the UN itself during the preparatory process has been less effective than had been hoped.

By the end of 1978, after two years of being buffeted by the almost countless diplomatic cross-currents that affect organization of a world conference, the Secretary-General and his small, able staff were still troubled by external and internal constraints. The problems of the preparatory process have made leadership exceedingly difficult. As we shall see in a moment, an encouraging sign, as 1979 began, was the Secretariat's compilation of National Papers and the subsequent synthesis of documents for discussion at the Third Session of the Preparatory Committee in January-February 1979. Unfortunately, that Third Session was totally unproductive because the Group of 77, sensing the importance of the final stage of preparations, could not agree on its substantive strategy and forced a delay of serious negotiations until May.

Agenda, Guidelines, National Papers

The official Guidelines for preparing National Papers were completed in early 1977.[2] They have been widely ignored. The inherent complexity of responding to the deceptively simple Agenda (see Figure 2) was made more opaque by the tortuous UN syntax of the Guidelines. That the Guidelines were the product of lengthy negotiations between contending factions from North and South may be a foreshadowing of technical and political conflict at Vienna.

FIGURE 2. The Official Agenda for UNCSTD.

1. *Science and technology for development*
   - (a) The choice and transfer of technology for development:
   - (b) Elimination of obstacles to the better utilization of knowledge and capabilities in science and technology for the development of all countries, particularly for their use in developing countries;
   - (c) Methods of integrating science and technology in economic and social development;
   - (d) New science and technology for overcoming obstacles to development.
2. *Institutional arrangements* and new forms of international cooperation in the application of science and technology:
   - (a) The building up and expansion of institutional systems in developing countries for science and technology;
   - (b) Research and development in the industrialized countries in regard to problems of importance to developing countries;
   - (c) Mechanisms for the exchange of scientific and technological information and experiences significant to development;
   - (d) The strengthening of international cooperation among all countries and the design of concrete new forms of international cooperation in the fields of science and technology for development;
   - (e) The promotion of cooperation among developing countries and the role of developed countries in such cooperation.
3. *Utilization of the existing United Nations system* and other international organizations: to implement the objectives set out above in a coordinated and integrated manner
4. *Science and Technology and the Future*. Debate on the basis of the report of a panel of experts to be convened on this subject.
   (Author's Note: Item 4 has always been vaguely defined.)

All UN conferences have a broad agenda and all require national contributions, of course. But UNCSTD and its National Papers were complicated from the start by at least three factors. First, the subject—science and technology *for* development—is essentially concerned with comprehensive social *process*, rather than with more narrowly definable, goal-oriented topics, such as food or population. Scientific and technological means are involved with virtually every one of the diverse ends sought by modernizing societies. What is worse, the same means often relate to several goals and may even conflict with each other. Thus a National Paper, in principle, should assess all national priorities and relate science and technology to each one of them.[3] This task is immensely difficult. Few nations have done it well, and most have not done it at all.

The second reason why the guidelines for National Paper have been awkward to apply is that it had been decided in 1975–76 to stress a highly decentralized approach to the preparations. There was to be virtually no centrally directed priority setting, or analysis of international trends, from the Conference's international secretariat. Instead there was to be an exclusive emphasis on work in the field by each nation.[4] This attractive strategy—to begin analysis at the grass roots—has been called an "ascending process" by Mr. da Costa.

But the vast majority of countries need a new surge of building science and technology into their development because they now have little in the way of what, in unhappy jargon, is called "S&T infrastructure," i.e., the groups of individuals and institutions that can carry out scientific and technological projects. For that very reason, they are not well-equipped to participate substantively in the preparatory activities. In particular, they needed outside help in preparing their National Papers. Although this need was anticipated, it probably was not weighed heavily enough in the original planning. In any case, apparently too few consultants were sent to the field. Most National Papers from LDCs are said to not reflect new analyses of policy at the highest levels of government.

A third reason for the ineffectiveness of the guidelines for the preparatory process is that the particular instructions intended for the industrialized countries were given a rather hostile and biased tone. Despite that tone, most of the developed countries launched preparations. The United States, for example, assigned a highly capable and energetic career ambassador with a special, full-time office which has been devoting unusual efforts to a government-wide process that is in touch with many private groups throughout the country.[6]

Stronger cooperation by most DCs was, in truth, unlikely even with a much happier environment at the UN, because the North perceives growing economic threats from the South. On balance, then, having not yet come to terms with any long range answers to North-South equilibrium as 1978 ended, the North did not assign the highest priority to UNCSTD.

Worldwide Pattern

Among the governmental activities, the collection of regional papers was envisioned as a key component in the "ascending character" of the preparatory process. For many reasons, this component has also not yet produced cogent results. If the "ascending process" had yielded new depth and realism in analysis at the national level, then new ideas for regional cooperation might have been stimulated. More energetic action may be forthcoming during the first half of 1979, particularly if the national preparations begin to pick up steam. Regional organizations may also be encouraged into new lines of effective partnership by initiatives such as those identified by the UN Conference on Technical Cooperation among Developing Countries, which was held in Buenos Aires during the late summer of 1978.

Nongovernmental organizations have always been participating within the range and with the verve that always characterize them. Major nongovernmental forums will be held in Vienna before and, probably, during the formal Conference. But by early 1979 it was not clear whether many definite proposals—or, indeed, strong grievances—would be presented forcefully by private coalitions for debate by governments at Vienna.

A surprising number of technical leaders and professional societies—from most fields of science, engineering, medicine, and technical management—have been active at all levels, national and international. Specific nongovernmental, technically-oriented meetings will be held during the period from January through June 1979. Some have shown excellent signs of being productive, perhaps even inventive. Several major meetings are listed in Figure 3. Most of these focus in part on the "global assessments" that could be crucial for giving a solidly technical core to the diplomatic exchanges at Vienna.

No doubt the most influential paper for worldwide debate prior to Vienna will be the drafts of UNCSTD's Programme of Action. A Preliminary Draft was prepared during late December 1978 for discussion at the Third Session of the Preparatory Committee in January-February 1979.[7] As was hinted earlier, this document shows that the Conference's Secretariat was thinking systematically about useful new ways to focus the debate. In fact, the Secretariat's new proposal to set up six "target areas" (see Figure 4) could change the Agenda!

FIGURE 3. A Few of the Private Conferences Preceding the UNCSTD.

Month	*Place*	*Highlights of Agendas*
January	Singapore	Science and Technology for Development; Food, Population, Employment, and Overall Contexts
January	Soviet Union	Science and Technology for Solving Global Problems Facing Mankind; Forecasts for Year 2000; Perspectives from Natural Sciences and from Social Objectives.
April	Ivory Coast	Technology for Development; Policy Choices; Infrastructure; Long-Range Horizons.
June	Mexico	Science and Technology in Development Planning; Long Range Strategies; Sectoral Planning; Manpower; Resource Allocation.
August	Vienna	Science, Technology, and Society: Needs, Challenges, and Limitations As Seen Through Case Histories.

FIGURE 4. UNCSTD Secretariat's Proposal for Six Target Areas.

Target Area	Topic
I	Sharing of knowledge and experience by all members of the International Community
II	Increasing the capability for policy making in science and technology framework of development planning
III	Transfer of technology for the benefit of development.
IV	Enhancing endogenous capabilities in a context of national self-reliance.
V	Promoting collective self reliance through cooperation among developing countries.
VI	Strengthening the role of the United Nations in the field of science and technology cooperation

This proposal was offered during late December 1978 in UN Document A/CONF.81/PC.21

Despite the highly critical reactions of some observers during 1977 and 1978—who, for example, called one of the Secretariat's earlier drafts a "smorgasbord instead of a plan"[8]—this new draft makes it more plausible to conceive of work during the first half of 1979 as leading to a coherent framework for agreeing on meaningful actions to be taken after Vienna. But surges of flamboyant, divisive rhetoric about radical international economic changes still dampen optimism about obtaining significant agreement.[9]

Such brief surveys of global activities may give the impression that the preparatory work is intense, continuous, broad, and well known to the public. This is not the case.

Few of the world's scientific and technological professionals are involved at all in the Conference. The business community, seeing potential for some trouble and a lot of rhetoric, has been quietly observing the trends. Because scientists and engineers have never been well integrated into most of the official programs of development aid, even the professional "development planners" have not been engaged fully.

The general public—those everywhere whom the Conference is supposed to serve certainly does not know about the meeting. Since the subject is complex, gaining greater popular recognition is difficult. In DCs, the challenge is probably insurmountable not only because foreign aid generally has almost no support from voters, but also because technical aid specifically is debatable at best and unpopular at worst.[10] In LDCs, the sought after popular involvement is almost unattainable until the foundations are laid for raising the levels of scientific literacy while investing in local technological enterprises.

If this estimate of low public involvement is correct, the Conference may come and go without receiving much attention.[11] But the professionals and diplomats who know the stakes must try to seize a remarkable opportunity to deal with the issues. Let us look at those issues.

Puzzles for Policy

Policy issues at the Conference will be raised in ways that will range from the trivial to the sublime, from current political fluctuations to profoundly important choices about the long-range future of man. It is useful to group issues into three categories: (a) *buzz-words* that symbolize, in a cliche, important but frequently misunderstood topics; (b) *hard realities* that too often are ignored in diplomatic debates; and (c) *critical uncertainties* (including gaps in knowledge) that will complicate policy making even when it is well informed.

Two of the most disruptive *buzz words* are "technology transfer" and "appropriate technology." *Technology transfer* almost always conjures up wrong images of packages of know-how being identified cleanly, transported around tidily, opened up easily, and used efficiently. The phrase ought to be abolished, for it never clarifies anything. It compresses too much into a code that scrambles many of our messages. The crucial issue is to recognize how much work, over a long time, is needed to build up a technical base where now no such base exists.

How is such a base built? To begin with, there can be no substitute for improved education at all levels, geared to local needs and traditions, while being continuously adapted from the highest standards throughout the world. But there is an enormous range of specific ways to build a scientific and technological base – from creating local economic incentives for manufacturing to purchasing turn key plants; from formal participation in international research networks to informal encouragement of individuals in technical exchanges; from entering into bilateral (and multilateral) financial agreements between governments to fostering private foreign investments; from international bargaining on licensing and patents to national legislation calling for more local R&D by multinationals. There are many catalogues of such "transfer" mechanisms. Countries will inevitably be involved in almost every mechanism as they develop their technical capabilities.

Like *technology transfer*, the phrase *appropriate technology* means many different things, often contradictory. It aims to be a precise way of categorizing technically tailored solutions to particular ensembles of LDC goals and resources. But for many LDCs, the phrase has taken on the pejorative connotation of second hand, second best, or primitive technologies. It may also suggest a patronizing stance by the DCs.

Surely appropriate technologies are needed – who favors *in*appropriate technology?—but the recent abuse of the term rarely helps to meet specific needs, many of which will involve rather advanced technology. The puzzle is to work out truly feasible and imaginative solutions, not to categorize the "correct answers" narrowly in advance. Such solutions usually will call upon modern insights to produce carefully crafted technologies.

In Schumacher's definition, "intermediate" technology (a better term, perhaps) is "vastly superior to the primitive technology of bygone ages but at the same time much simpler, cheaper, and freer than the supertechnology of. . .those already rich and powerful."[12] He goes on to emphasize that what is difficult—and what usually takes "a certain flair of real insight"—is to apply all of our knowledge to bringing such intermediate technology into visible, readily available forms that help people. He is correct, although the cultists following him are much less gifted than he in doing what he urged.

When considering needs in particular LDCs, simplistic ideas about "small always being beautiful" tend to break down. Consider a few easy examples. More advanced communication networks help to use scarce professional talent more efficiently, e.g., linking an urban hospital's staff to rural paramedical teams. Modernized transportation systems help to distribute food, establish markets for local industries, and perhaps build the social dynamics for creating acceptable "new towns" that will reduce the migration towards existing urban centers. Satellite technology permits entirely new access to previously unobtainable information about natural resources, crop production, and environmental trends.[13]

Now consider a few examples that are only a few steps beyond the laboratory. Contemporary research is providing: (a) better materials for many products especially useful in LDCs (e.g., solar energy applications); (b) new techniques for inexpensively preventing and treating infectious and parasitic diseases (e.g., meningitis, malaria); and (c) new ways to assemble and sort the information needed for making decisions (e.g., minicomputers)—and these advances, the results of sophisticated research, provide greater performance at less cost in simplified technology. Such examples could be extended for a long time.[14] Can LDC Ministers of Planning ignore these opportunities?

Among the other obvious *hard realities* too seldom kept in mind is one we have already mentioned: most technology is available at low cost from open sources, but it must be sought with a sharp awareness of what is needed. Widely available technological means can be used to assist almost every LDC's high-priority social and economic programs. The more quantitatively and specifically the goals are stated, the more essential is social and economic analysis about when it is feasible to achieve them through which of the accessible means.[15] Yet this outlook is usually forgotten in the negotiations that wrongly tend to assume that most technology, if accessible at all, is both expensive and *the* major element of reaching a social goal. Sometimes we are also told the extreme opposite: that *only* "basic human needs must be met," as if modern technical skills rarely helped (or usually ruined) the efforts to attain social goals.

A second reality is that the "New International Economic Order" has been presented as a demand for redistribution of the industrialized nations' technologically-based economic power and wealth. This proposition should not be blinked away. But observers rarely think about the long range and substantial stakes associated with the demands of that new economic order. In particular, the recent rhetoric at the UN General Assembly almost never indicated who might get less of what and when. In the US and other DCs, organized labor and members of parliaments are concerned. Some US leaders have said that, in effect, there is "no greater threat to the US economy and its domestic job market than the diffusion of US technology abroad." That this viewpoint is hotly debated does not diminish its political impact.

Another obvious proposition of reality is that even though the actual problems of developing countries are massive, their near term capability for absorbing additional science and technology is often modest. Yet relatively small increments of qualified individuals and relevant technical information—applied astutely and consistently within a context of carefully related national initiatives—could make a difference rather soon.

Finally, it cannot be repeated too often that the most obvious boundary condition in every LDC today is the shortage of trained manpower. Until nations step up the lengthy process of technical training, progress will continue to be slow, spotty, and despairingly insufficient.

Many uncertainties for policymakers arise simply because it isn't clear what technical approaches work best in assistance and collaboration with developing countries. Historical analyses in a few LDCs do not lead to unequivocal conclusions about ideal formulas for the future. Moreover, the critical differences among past and present efforts throughout the world mean that comparative analysis is both difficult and essential.[16]

Economic uncertainties—expressed in international and national terms—are also complicated. For example, balancing the short run gains from protectionalist barriers versus the long-run advantages of free trade is important for most countries in sorting out their incentives for reliably introducing science and technology.[17] Furthermore, the economic health of the DCs may depend more heavily in the future upon the economic progress of the LDCs. But analysis of such matters has yielded politically ambiguous results.[18] To mention success in Singapore, for instance, is to touch off political debate rather than economic discussion.

Political choices and uncertainties are overriding. The drives towards nationalism and state planning conflict with the historically proven strategies for international action and for nongovernmental technological partnerships in many areas of development.[19] To take a comparatively uncontroversial example, it is natural for each country to want to possess a research-oriented graduate university, but, since few countries can afford to do that well and even fewer are prepared to think about such a goal in regional terms, scarce talent and resources are often spread too thinly. As another illustration, ideologically oriented governmental rules about restricting imports of private capital often obstruct, rather than promote, the transfer of effective technologies.

Generally speaking, the diffusion of power within many Western decision making systems and the international scattering of power centers combine to make it difficult to reach intergovernmental political decisions and make them stick, even in those cases where what might be called an experts' consensus has emerged. In particular, the constant criticism of multinationals often seems to be based on a political agenda rather than on a pragmatic search for how to unleash more potential for achieving the economic and technological priorities.

Such varied uncertainties underscore the challenge of dissecting these policy dilemmas in a full length book, much less in this short essay. And the connections between East West issues and North-South issues, such as the significant new military trends that affect the future of the developing areas, have not even been brought up.

However, to conclude this quick survey of policy issues that relate to UNCSTD, let us scan a short list of the "obstacles" that, according to the Second Session of the Preparatory Committee, constitute key topics for Vienna. The lists in Figure 5 grew out of the commonsense view that the LDCs should identify and overcome their most critical, specific obstacles hindering social and economic development. Fascination with debate about such obstacles seems to have waned during the last half of 1978, although the concept fits so neatly into a demand-negotiating tactical approach that it may return to prominence at Vienna.

FIGURE 5. A Summary of Obstacles to Development.

At the national level:

(i) Policies, regulation, priorities for science and technology, research and development;
(ii) Education and human resources;
(iii) Infrastructure;
(iv) Information systems;
(v) Financial resources;
(vi) Choice, transfer, adaptation, and diffusion of technology;
(vii) Technological innovation systems.

At the regional level:

(i) Identification of problems of common interest;
(ii) Coherent systems for educational, scientific and technological cooperation;
(iii) Economic and technological cooperation agreements among Member States;
(iv) Arrangements for common training centers;
(v) Joint investments in R&D programs of common interest.

At the international level:

(i) Appropriateness of programs for the education and training of personnel from developing countries in developed countries;
(ii) Migration of talents and skills from developing countries;
(iii) Concerns about research and development needs and infrastructure of developing countries: role of the United Nations system;
(iv) Concerns about research and development needs and infrastructure of developing countries: role of non United Nations international system;
(v) Financial resources: the role of international financial institutions and the nature of financial assistance;
(vi) Human and financial resources devoted to armaments and military research and development;
(vii) Relevant scientific and technological information systems.

Some observers list many more "obstacles" and other analysts list fewer. This "official" listing was used by the UN's Advisory Committee on the Applications of Science and Technology to Development, drawing upon the longer list developed by the Preparatory Committee for UNCSTD during its meeting in January February 1978.

Remarkably, during 1978, the Group of 77 shifted its position, recognizing that such lists should *begin* with specific *national*-level obstacles rather than with vaguely defined and usually provocative international issues. In the past, international obstacles were always listed at the top, the implication being that external forces (even the elements of "aid" itself) were the primary cause of underdevelopment. This ensured that North-South negotiations would be less manageable and more unfriendly. However, many observers in DCs are still concerned that the negative motif of obstacles cannot encompass more positive, broader considerations such as the need to provide stable policies fostering long-range incentives for technology.

Prospects for Paralysis

To understand the practical prospects for the Conference, it is necessary to first be clear about a number of longstanding operational problems that have paralyzed—or, at the least, inhibited—the ability of national and international institutions to take successful actions.

One problem is that, in most DCs, little internationally oriented research is done and what little there is has been an "orphan."[20] It is an orphan because using technology to aid the developing areas has not been a primary goal of any government in the advanced countries or of any major part of their private sectors. Furthermore, the degree of international pertinence of national scientific and technological activities is hard to define. This topic has received almost no systematic national study. There has been even less international coordination, with science and technology policy analysis being managed at low levels of both funding and political attention.[21]

When spokespersons for the Group of 77 insisted on trying to get more quantitative delineation of what LDC-related research is going on, they were making a reasonable request. Although many delegates from DCs argued convincingly that a great deal of internationally pertinent results flow from R&D which is funded mainly to serve the DCs' national purposes (e.g., health, weather, oceans, space), that argument cannot be repeated much longer unless it is given greater specificity.

A related problem in charting meaningful action is that specific *technical priorities* have been hard to set. We might consider four options for setting priorities.[22] The formal agenda for UNCSTD ducks the priority-setting problem altogether by being broadly exhortative (see Figure 2); this option is useful perhaps for popularization, but not for policy analysis and action. A second approach, often taken by development-oriented technocrats (in the best sense), is to group the many goals of LDCs into clusters that are large enough to elicit international political interest and homogeneous enough to evoke scientific attention; Figure 6 is one such useful grouping. A third option is to let everyone vote—all member governments of the UN, that is. When such an attempt was made recently, we got the "illustrative subject areas" shown in Figure 7; this may be better than having no priorities, but not much. Fourth, many critics of UNCSTD have chimed in with their views on what is important; the questions in Figure 8 typify such perspectives, which are usually full of conflicts. With this welter of ideas, who will set priorities, and how?

FIGURE 6. One Clustering of Substantive Issues.

1. Industrialization and Employment
2. Health, Nutrition, and Population
3. Food, Climate, Soil, and Water
4. Energy, Natural Resources, and Environment
5. Urbanization, Transportation, and Communication
6. Cross cutting Themes: Science and Technology Policy making; Information; Education; Research and Development Incentives.

This framework was used by the US National Academy of Sciences (*US Science and Technology for Development. A Contribution to the 1979 UN Conference*, printed by US Department of State, April 1978). The basic clustering had been suggested in a letter from Frederick Seitz, et al., to President Carter in December 1976.

FIGURE 7. The List of Illustrative "Subject Areas" for UNCSTD.

1. Food and agriculture:
   (a) Agriculture technology and techniques, and their improvement;
   (b) Nutrition;
   (c) Fisheries;
   (d) Food storage and processing

2. Natural resources and energy:
   (a) Renewable and nonrenewable;
   (b) Conventional and nonconventional sources of energy;
   (c) Development and conservation;
   (d) National management and utilization.

3. Health, human settlements, and environment:
   (a) Medicinal plants and pharmaceuticals;
   (b) Health services;
   (c) Housing;
   (d) Social services and environment

4. Transport and Communications

5. Industrialization, including production of capital goods.

FIGURE 8. Selected Unofficial Questions for UNCSTD.

1. How much emphasis should be placed on industrialization and economic growth, and how much on meeting "basic human needs?"

2. What does it mean to say that a "new scientific and technological order" must be part of the New International Economic Order?

3. Have science and technology been "perverted" everywhere, so that the entire global structure must be totally reoriented? If so, what would be the implications (as has been suggested) of stopping all present channels through which DCs transfer technology to the Third World?

4. Should bilateral, regional, topical, or multilateral arrangements be emphasized in changing and/or expanding the lines of cooperation on scientific and technological activities?

5. Are there reasonable compromises within the debates about new agreements concerning international activities of private corporations?

6. What are the ways in which DCs can justify considering any increases in foreign aid and technical assistance to LDCs?

To consider and rank priorities in some semi quantitative way, there is a pressing need to create new systems for measuring the scale and intensity of "development problems." With better measurements, it would be feasible to shape future priorities more confidently in relation to past rates of success (or failure). For example, most observers use an economic index of either the prosperity of a country or the rate of growth. Although such an index is helpful and economic growth is essential, this index alone does not reveal sufficiently clearly the short run changes in the lives of most of the population. (In many countries it has been shown that, over long time periods, the upper 20% of the population receives 50% of the national income, while the lowest 20% receives 5%.) Since measures of per capita income do not disclose the whole picture of developmental patterns, new concepts—such as the Physical Quality of Life Index being explored by the Overseas Development Council—must be refined.[23]

If we had a better measure of developmental progress, then we would have a better handle on assessing the more general *interactions between R&D policies and economic policies*. R&D policies include the full sweep of plans and budgets, both short range and long range, that relate the missions of each country's public and private sectors with its scientific and technological capabilities.[24] Economic policies refer to the full sweep of national decisions affecting priorities, rates, levels, and directions of investments for socioeconomic evolution. For both these domains of policy, national trends also must be meshed increasingly carefully with international trends. Instead of having confidence in these assessments, all countries face the glaring superficiality of present analytical understanding about the relationships between investments in R&D and the pace of economic development.

One bitter issue in this context is that multinational corporations may be criticized generally at Vienna by some of the more advanced LDCs who themselves are spawning many successful new multinational enterprises.[25] Yet the UNCSTD may debate this and other technologically related economic issues as if the 1980s were the 1950s. Instead of moving toward realistic accomodations by and for private enterprise, some delegations will assume that there is plentiful evidence about better strategies for deploying technology efficiently.[26]

So far, three problems have been noted that will darken, if not paralyze, the prospects for practical agreements at UNCSTD. In recapitulation: first, we don't really know how much internationally pertinent R&D is going on. We think it isn't enough—and that's probably right. But facts are scarce because in DCs this subject is an orphan, in LDCs the technical effort is small and diffuse, and in every country the required data collection is difficult.[27]

Second, the term "science and technology" represents enormously broad fields of knowledge and know-how that, in turn, relate to the even broader range of social purposes, cultural milieus, and international competition within which "development" goes on.[28] To set priorities and measure progress at the national level is difficult—and in international forums and institutions, it is virtually impossible. Now add to this the third problem—the controversial elements of the relationships between R&D and economic change and you have a thorny thicket indeed.

One final reason for sluggish policy-making at UNCSTD ought to be noted: the politics of UN negotiations depend upon diverse coalitions of varied nations. Although it is a truism that individual nations can be expected to act in ways that serve their interests—and to be tough-minded about what those interests are—the most difficult problems in policy arise when interests only become very important as projections into the distant future and when those interests go beyond the national boundaries. In most capitols, as the saying goes, "the urgent drives out the important." In the headlines, a civil war or a summit conference tends to drive out reports on the world's agricultural productivity or population control.

Speaking of population, for example, it is hard to fathom what it really means for the entire world to talk about the *billion* poorest and most malnourished people today, much less about the additional billion people in many nations who desperately will be seeking food and shelter by the year 2000.[29] By that year, the potential for social disorder will be great unless the industrialized countries soon come to terms with their fundamental interests in their relations with the Third World. Yet most of the time such longer-range international interests (and the technological relationships affecting them) remain largely beyond the horizons of senior officials.

Prospects for Progress

In conclusion, some bright spots should be mentioned. Despite the frequent chants of gloom about UNCSTD, there are prospects for progress along three broad lines.

The first line, still dimly perceived, is the encouraging realization that global issues matter and that those issues must be resolved with global participation. Building for some years, this perspective has been dramatized by several UN conferences, by organizations such as the Club of Rome and the International

Congress of Scientific Unions, and by careful analysts such as Harrison Brown.[30] We now see that global trends—including food supplies, environmental forces, and energy demands—require global action. Recent global assessments reveal a long list of urgent needs for research that would answer key policy relevant scientific questions and provide new technologies. Yet any global follow through on new programs—for clarifying assessments and corrective actions—will demand greater popular understanding and higher levels of political will and financial commitment. UNCSTD could further deepen the sense that these strikingly global perspectives are the only responsible ones for the future.

The second line of prospects for progress at UNCSTD emerges out of the new emphasis in many LDCs on coupling "self reliance" *with* complementary international activities. Seen most vividly in recent changes of policy by the Peoples Republic of China, this strategy puts building national capabilities—rather than demanding international assistance—at the top of national priorities.[31] But it also welcomes international commerce. No longer so rigidly doctrinaire, the PRC and the Group of 77 assign "national obstacles" the highest place, while working out pragmatic agreements for foreign technical institutions. To the extent that this more open and realistic spirit can flourish at Vienna, the discussions could take off.

Third, and more speculative, lively progress may flow from the new private networks that could become more useful than the many cumbersome governmental and UN organizations which probably have taken on too many tasks during the past two decades. Operating flexibly and keeping only a loose partnership with official channels, private institutions (both profit making and nonprofit) can be the most effective in some circumstances. Further encouragement may be drawn from the fact that certain private initiatives have been catalyzed and fostered by the preparations for UNCSTD.

Optimism and Science

Most of this paper has emphasized a skeptical view of preparations for the Conference and a practical approach in applying science and technology to development. To round out each of these perspectives, two points of explanation should be recorded. One point is that a kernel of optimism is essential. The other is that science is practical.

There is evidence, as we have seen, for skepticism about many elements of the Conference's preparations. There is no reason to paper over the difficulties that have been and will be encountered. Difficulties arise from the genuine complexity of the subject, the understandable political and economic conflicts among participants, and the unwieldy international communications among governments and private institutions.

Lest there be misunderstanding in these circumstances, skepticism should not be allowed to produce pessimism and "do nothing ism." Quite the contrary. Many people have been trying hard to live up to the high stakes. There is enough time left to make Vienna a successful turning point. Whether Vienna is as successful as one might hope—measured against whatever criteria one might have—virtually everyone is convinced that the subjects on its agenda will be central in the years ahead. Since the underlying premise is that problems must and can be solved, a measure of optimism is in order.[32]

The emphasis here has been on a practical approach to all plans for applying science and technology to development. To some degree, this practical approach can be criticized as being too much in the Western technocratic tradition. Does it pay too little heed to political forces and give too little attention to science?

As far as the political criticism is concerned, many observers plead happily content with the following assumption: only as the developing nations create systems of personal freedom with incentives for science and technology will they foster humane, vital institutions capable of serving their societies. Do other systems work better?

As far as the role of science is concerned, a general correction should be made to the shorthand references about technology. The correction is this: it is a mistake to think of "pure" and "applied" work, suggesting that these are always distinct categories and that LDCs can (or should) afford only to sponsor applied science.[33] The categories are not distinct. Just as productive governmental and industrial organizations must carry out research in order to be effective, any research program ought to be balanced across the spectrum from highly fundamental and long-range efforts to concretely applied and short range projects. Moreoever, "science is knowing [and]. . to understand how things work is to see how, within environmental constraints and the limitations of wisdom, better to accomodate nature to man and man to nature."[34]

It would be a mistake to leave science out of a nation's long term plans for social development. The essential requirement is for at least a small number of excellent, working scientists—probably located in only one or two national centers—who can (a) stay in touch with worldwide research trends and thereby anticipate key choices for the future; (b) educate younger colleagues about local and international opportunities; (c) contribute to "quality control" of larger technical activities related to the highest priority national missions in economic development; and (d) insist upon appropriate standards for the national educational system in the sciences, engineering, medicine, and technical management.

A Final Note

The mega conferences of the 1970s under UN auspices have not been the events to attend if one seeks new data, penetrating analyses, fresh policies, reliable programs, or new pots of gold. The topics of these conferences have concerned the most demanding aspirations of the world. The persons who attended were frustrated. That will occur again this year at Vienna. Sharp rhetoric at Vienna will not shorten the time that it takes to achieve the goals of nations. It can only be hoped that the delegates do their homework and arrive ready to be realistic about the curving road ahead.[35]

In deciding how to move along that road, delegates to UNCSTD will have to confront the facts about the world's presently shaky economy. Thus it seems unlikely that large new financial commitments would be made and, if that guess is correct, the LDCs will have to revise their goals. The delegates will also have to evaluate whether the UN system, staggering under its current responsibilities, could take on additional assignments. Thus, instead of new Programs or Agencies, the organizational recommendations of UNCSTD would probably be improvements of the existing structure (which looks fine on paper) so that there would be stronger analytic budgeting and programming at the top of the system with more effective technical efforts in the field.

There would not be much drama in such recommendations. The message would be: we can't afford to invest much more money, we don't want new organizations, we must think more about what we're doing, and we must deliver soon on modest promises. But all of this would be compatible with the best of the scientific and engineering ethos. And it might just be the nail we want.

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8 *The Lund Letter on Science, Technology and Basic Human Needs*, no. 2 (Lund, Sweden: University of Lund, December 1978).

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12 Schumacher, E.F., *Small Is Beautiful* (New York: Harper & Row, 1973), p. 154.

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14 It appears that much too little attention will be devoted by UNCSTD to the next generation of technologies. See, for example, *The Workshop on Technology* [illegible] (Paris: EIRMA, 1978) for European views of longer range trends in all key sectors.

15 Stevan Dedijer has shown unequivocally that the "secret" intelligence functions could depend upon open sources. See his cogent introduction on the relevance of this view for UNCSTD in *The Lund Letter* (Lund, Sweden: University of Lund, July 1978), pp. 1-6.

16 See, for example, the extremely useful data and analyses in *World Development Report, 1978* (Washington: World Bank, August 1978).

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26 See, for example, Harvey W. Wallender III, et al., *Public Policy and Technology Transfer: Viewpoints of US Business*, Vols. I-4, March 1978, Library of Congress no. 78-51600.

27 For a US perspective, see Schlie, Theodore W., *Quantification of US S&T Activities Oriented Toward the Developing Countries*, Report SRS 77-27791 (Denver: University of Denver, July 1978).

28 Regarding competitive concerns, for example, see Rachel McCulloch's recent review in *Research and Development As a Determinant of US International Competitiveness* (Washington: National Planning Association, 1978).

29 See James P. Grant, "Basic Human Needs and the World's Poorest Billion: What Future Prospects?" mimeo transcript of address at California Institute of Technology, April 1977, available from ODC, Washington, DC.

30 Brown, Harrison, *The Human Future Revisited: The World Predicament and Possible Solutions* (New York: W. W. Norton, 1978).

31 See, for example, the bluntly phrased guidelines in the PRC Central Committee's communique in late 1978, excerpts in *The New York Times*, December 26, 1978, p. A4. Also see *Time*, February 5, 1979, p. 34.

32 See "UNCSTD's Year," *Nature*, 4, January 1979, for a moderately optimistic view of what could emerge at Vienna. Also see Horner, Charles, "Redistributing Technology," *Commentary*, January 1979, for a skeptical political assessment.

33 There have been many debates about whether "science" (as contrasted with "technology") should have a major role in the plans of LDCs. Professional journals have included much of this commentary, such as Sardar in *Nature* (May 18, 1978) and Salam in *Physics Today* (November 1978). For an especially stimulating analysis, see John Ziman, "Research As If Relevance Mattered," *New Scientist*, September 21, 1978.

34 *Physics in Perspective*, Vol. I (Washington: US National Academy of Sciences, 1972).

35 Typical of many private attempts at formulating a program for what governments ought to agree upon as international action is *Technological Transformation of Developing Countries*, Discussion Paper no. 115 (Lund, Sweden: University of Lund, February 1978). A more recent report from the Conference on Non-Governmental Organizations is available from the NGO Forum in New York, *Preliminary Draft of NGO Report on Draft Program of Action for 1979 UNCSTD*, January 1979.

Foreign Policy*

RODNEY W. NICHOLS

INTRODUCTION

VIRTUALLY EVERY MAJOR scientific and technological policy issue comes within the span of *both* domestic and foreign policy. Unquestionably, all the "functional" topics—such as Food, Health and Energy that are considered elsewhere—have to be thought about today in global terms.

Even worse, we must keep other themes in mind. For example, two subjects are not explicitly included in this conference's program: Defense and Space. It would have been inconceivable to have an international meeting on science and technology policy in the 1950s or 1960s without devoting considerable attention to national and international security. Similarly, other important foreign-policy-related topics were left off the formal agenda for reasons that no doubt related to limits of time; e.g., the problem of population growth, and the concern about proliferation of nuclear weapons.

Furthermore, several "cross-cutting" subjects are not explicitly on the program here because they are less important for industrialized nations. But because some of these subjects are crucial for developing countries, they create foreign policy problems for developed nations. In this category would be issues such as the priorities for industrialization; the needs for much broader education and training; and the problems in retrieving and distilling information (at the working level in R&D and at the policy-making levels) for national priority-setting affecting R&D.

So while our assigned task is difficult, it would have been even more complex if the full agenda were known. Bringing coherence to this domain is long overdue. A brief outline may help to structure discussion and reveal the envelope within which most of the current policy debates take place (see TABLE 1).

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* The author spoke from notes. This paper was prepared later and, although it is somewhat longer than the 20-minute presentation at the meeting, it retains the aim of opening up many subjects rather than assessing a smaller number in greater depth.

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TABLE 1

1. Goals: How to Define the Subjects?
    - Power and welfare among "the worlds"
    - Deterrence and defense
    - International security and peacekeeping
    - East-West issues
    - North-South issues
    - Global concerns and principles

    - Historical trends
    - Future stresses
2. Policy Puzzles: The Urgent, the Important, and the Uncertain
    - Competing geopolitical views
    - Economic models, policies, consequences
    - Priorities for resource allocation
    - Realistic time-tables for results
    - Evaluation and output indicators

    - Cross-cuts on every S&T policy
    - Infrastructure of ideas
3. United States Patterns: Turning a Corner or Turning Away?
    - Congress
    - Executive branch
    - Industry and organized labor
    - Universities

    - Media, public understanding, influential ideas
4. International Patterns: Centripetal or Centrifugal Forces?
    - Bilateral arrangements
    - Alliances, regional systems, coalitions
    - UN system
5. Illustrative 5-Year Priorities: What is S&T in (for) "Foreign" Policy?
    - Traditional missions of national governments
    - New missions linking industrialized nations
    - Economic competition
    - Cooperation with LDCs
    - New initiatives for policy-analysis

GOALS: HOW TO DEFINE THE SUBJECTS?

The first heading states the main question I have already introduced: In considering the goals of foreign policy, how can we bound the many global subjects and complex international programs that depend in part upon science and technology?

For example, goals related to *power* are still significant for most officials responsible for foreign policy. An astute French observer commented some years ago that "neither legions nor raw material nor capital are any longer the signs of instruments of power. Force today is the capacity to invent, that is—research; force is the capacity for converting inventions into products, that is—technology." In this observation lies the kernel of what many nations see as a critical role for science and technology serving foreign policy's purposes.

Consider the newspaper's categorization of the globe into various "worlds"—the "first world" of the OECD industrialized nations, the "second world" of the Soviet Union and its Eastern European allies, and the "third world" which is the developing countries. (More discriminating journalists divide the globe further into fourth and fifth worlds, based roughly upon resources per capita.) These numbers suggest a power-related rank-ordering. In fact, we often measure changes in international relations, and the status of a nation's geopolitical power today, in terms of the degree to which nations have applied technology successfully to building up their domestic and foreign strengths. Will national power in the future continue to be proportional to the capacity for, and the productivity of, research and development?

A related major goal derives from the hopes of people everywhere for increased *welfare*—or, in the current phrase, greater "equity." For the developing nations, the aim is to draw on the world's technological experience to increase economic activity and meet the basic human needs of their people. For the industrialized nations, a meaningful policy to improve welfare increasingly demands better *control* of the new technology that is required to achieve humane purposes.

With this admittedly superficial skimming of the profound issues of power and welfare in the world—and the way in which science and technology serve those goals—we can race rapidly through a number of other crucial goals of foreign policy.

Deterrence and defense are of interest to all nations. For the OECD nations, we think of the NATO alliance and the Strategic Arms Limitation Talks as prime examples of the use of advanced technology to serve the goals of war-prevention and arms control. Indeed, it is a cliché to note that without the most sophisticated technology, there could not even be hope for assured verification (by national means) of the proposed SALT II treaty.

Turning to a likely superpower of the next century, the People's Republic of China includes both defense and science/technology among its "four modernizations." China says that science and technology will be essential to assure success in its defense and, thus, in its foreign policy. However, its alliances may shift over the next generation as international technological trends unfold.

As a final example, in almost any scenario about how the superpowers would avoid World War III—or limit escalation and possible consequences, should a major war seem to be threatened—the most advanced technology would be employed by the highest officials in communications, command, and control.

International security and peacekeeping have only begun to be studied in the robust analytic and institutional traditions that have been characteristic of past research and development on many other subjects. Yet the shrewd use of advanced sensors was important in making possible certain temporary peace agreements in the Middle East. Other advanced technologies—in transport and communications, for example—may keep small conflicts from flaring into larger fights by allowing small forces to contain larger ones for a short period while diplomats confer. Yet what shall we do about reducing the arms trade in conventional weapons, about controlling terrorism, and about dampening regional arms races? Could any technologies be helpful in new ways of *solving* these problems? Even if there were no technological "fixes" for such largely political issues, the non-nuclear technologies of "conventional arms" turn out to be very important for diplomats to master; and the Foreign Service pays little attention to this (or any other) technical trend.

In the category of *East-West issues* are compressed many topics that relate to technology. For instance, debates about controls on the exports of certain products usually involve the possible long-range military and economic impacts of *multiple* uses of the technology embodied in equipment that would be exported initially for one narrow purpose. The difficulties in dealing with classified technical information—and particularly engineering data, rather than general scientific materials—pose major problems for foreign policy debates on such exports. Another example of how technology relates to East-West issues is the ability of major (and lesser) powers to employ modern airlift capabilities to transport troops across large distances and thus project the image of power as well as the actual instruments of force. Historically deep-running strategic stakes emerge at the interface between international technological trends and East-West balances of military and economic forces.

Similarly, *North-South issues* include an enormous range of topics that almost always involve technology. Rarely, however, is technology the most important variable. For example, the clamor for a "Code of Conduct" governing multinational companies (MNCs) often encompasses demands for technology, but it is mainly the sheer economic power of the MNCs that has produced the perceived need for such a Code. Patent rights are debated internationally, because many LDCs believe they have a "right" to essentially any technology anywhere.

More broadly, from the perspective of the LDCs technological "dependency" upon developed countries, every contemporary dialogue about North-South relations touches on how to increase the level of international research and development that relates directly to the needs of developing countries.

Many challenging, long-run topics can be placed under the heading of *global concerns and principles*. Perhaps the most dramatic change in the world during the 1970s—a change that has put science and technology more squarely in the middle of the diplomatic map—has been the sharply broadened understanding that *global* problems really matter. Consider, for example, the new senses of interdependence in relation to earthquake prediction, changes in climate, incidence of famine, supplies of energy, surveys of resources. Even public health is viewed internationally in new ways, although health for a much longer time had been understood as a worldwide responsibility owing to the risks of epidemic infectious diseases. Cogent subcategorizations can and must be made among these global concerns as they affect specific countries. But technology is drawn from world-wide sources and partly for this reason diplomats around the world have been forced to deal more frequently with scientists. Furthermore, the universal goals of human rights resonate with the international ethos of the scientific community.

Our discussion-outline shows a dotted line at this point offering two further headings about themes of a different kind: historical trends, and future stresses.

Mr. Delapalme presented interesting data regarding the recent industrial production trends in Europe, the past dramatic changes in demographic projections, and the less dramatic but nonetheless decisive changes in power relations among the major industrial nations within the past 100 years. All of these data underscore a remark that Brzezinski made a few months ago: "There is a redistribution of both political and economic power in the world today . . . this means that the older industrial countries have to rely increasingly on technological innovation to maintain their place in the world."

Just as Brzezinski was looking historically in that remark, we must refine our analysis of how and why past trends have driven so many issues of science and technology into the concerns of foreign policy. We must also be clear about the likely future stresses—such as on food supplies, on energy resources, and on our organizational mechanisms for international collaboration and conflict-resolution.

I have tried so far to illustrate—briefly, yet systematically—that the perspective of foreign policy complicates many issues in national science and technology policy. Let us now turn to some specific "policy puzzles" that are raised in trying to resolve international issues.

POLICY PUZZLES: THE URGENT, THE IMPORTANT, AND THE UNCERTAIN

In this second part of the discussion, we will follow the same pattern as in the first part. Let us categorize major areas of difficulty.

To begin with, *competing geopolitical views* guide the directions of science and technology policy. For example, if the intentions of the Soviet Union were known accurately, that knowledge would certainly affect the way in which the United States proceeded in defense R&R; in the absence of reliable knowledge about USSR goals, competing estimates arise and defense R&D can be viewed as insurance. Similarly, longer range projections for Asia often turn upon estimates of the technological strength of Japan and of China, in relation to the U.S. and the Soviet Union (as well as to other smaller, industrializing countries in the region). More generally, if the United States saw technology as its principal lever for ensuring both military and economic power, then our political uses of such technologically based power would depend heavily upon making larger, more visible investments in new technological capabilities. To the extent that any country wishes to use technology for pursuing foreign policy goals, it must take account of long term political trends reflected in national technical efforts around the world. Whether or not one takes classical geopolitics as the dominant perspective, technological capabilities probably will play a key role in geopolitical trends.

A second area of puzzles, particularly pressing at the moment, is in the use of *economic models* to test the consequences of alternate policies. To oversimplify somewhat, there is no "theory of R&D" that holds water in our present economic models. In DCs, we cannot compute how to achieve the right level of "innovation"—the level sufficient to avoid stagflation and sustain increasing productivity. For LDCs, we cannot demonstrate convincingly what will be the varied immediate impacts of technical change during the process of modernization; and even less well can we predict the more long-range cultural changes caused by "development." Thus, for two of the most far-reaching economic frustrations in the world today, the apparently critical role of technology remains murky.

Stunning evidence about these crippling gaps in our economic knowledge emerged last year from a *Fortune* poll of professors of economics at 55 American universities. The results of the poll showed an extraordinary loss of confidence in the ability to make accurate macroeconomic forecasts and deep doubts about the usefulness of any government-stimulated interventions in the economy. In such a situation, it is not surprising that the more complex intereactions of technology with foreign economic policy are wracked with uncertainty.

Along with the global benefits from the introduction of new technology—such as in the agricultural Green Revolution—come undesirable side-effects that, even though exaggerated by some critics, are nonetheless real. Even when there is a major achievement in one country—e.g., Malaysia's successful R&D on natural rubber—other countries have great uncertainty about their technological choices with different natural resources and different social systems. In fact, the fad about "appropriate technologies"—usually meaning comparatively small scale and "less advanced" technologies that are adapted to a particular environment—has been stimulated by the assumption that if technology were more understandable, the consequences of its use would be better anticipated. Yet that is rarely true. In short, the social and economic components of S&T policies are important areas for further research in most international choices about technology.

One of the reasons that economic issues loom so large is the major puzzles concerning *priorities for resource allocation within any R&D establishment*. To begin with, there are trade-offs between what roughly can be categorized as the domestic purposes *vs*. the international purposes for programs of science and technology: e.g., in biomedical research the U.S. must choose how much research to devote to cancer *vs*. tropical diseases. Another trade-off affecting the "third world" concerns (a) investments in general scientific and technical education *vs*. (b) investments in the urgent, more problem-oriented activities such as population control or water resources. None of these trade-offs is easy. Many of them emerge in stark terms during decision-making within national governments and international institutions. There is little analytical guidance for confidently striking such judgements in allocating scarce R&D resources.

Another puzzle concerns the *time-tables for action*. Many developing countries show a remarkable lack of realism about the *long* time-periods required for building scientific and technical institutions. Similarly, many industrialized countries show astonishing apathy about how *urgent* are the South's problems requiring science and technology to meet humane goals in development. Without a world-wide consensus on what the time-tables actually are—or at least a less politically charged climate for reconciling the different views about these time-tables—there is slim hope for sustained action on broader, coordinated efforts.

Finally, among such analytical problems, consider the difficulty in *evaluating results*. We have precious few indicators about the outputs of research and development programs, even the mature programs in advanced countries. We have even fewer reliable indicators about the results of technical assistance efforts abroad (not to speak of the defense area, in which often what is a technological success to one observer is a failure to another observer). Since research and development projects are means to ends—and, more generally, scientific and technological skills are diffused throughout a society—evaluation is extremely hard. Indeed, foreign policy itself is often viewed in terms of a continuing *process* in diplomacy, rather than in terms of the merits of specific end-points of a certain negotiation. Until we have at least somewhat better ways to measure the impacts of the use of science and technology in pursuing foreign policies, there will be little hope for substantially better integration of the policy domains.

This last viewpoint leads to the final sub-topics in this part of the outline (see p. 188). There are *cross-cutting considerations* with respect to every science and technology policy that relates to foreign policy. When we ask about giving technological *aid* abroad, we are faced with trade-offs with respect to its impacts on technologically based *trade* (e.g., steel; electronics; textiles). When we consider East-West relations, we are aware of their impacts on North-South relations in both political and technological terms (e.g., oil prices and supplies; arms trade). When we ask for broader benefits from our science and technology activities within foreign aid, do we emphasize basic human needs or economic growth? If a global perspective showed that domestic economic policies were short-sighted, would R&D policies have a bearing on possible new directions?

In general, we also must contend with subjects for which there is not yet a solid "*infrastructure of ideas*" akin to the structure that, for example, has existed for at least 20 years with respect to debates on national security questions. As implied earlier, historical scholarship and contemporary policy-relevant research must be deepened a good deal more. The few full-time professionals in this field must be supported and a new generation of analysts must be trained so that the ideas and policies are understood as profoundly as the problems merit.

UNITED STATES PATTERNS: TURNING A CORNER OR TURNING AWAY?

We shall shift now to a quick review of the U.S. patterns in dealing with these issues. I will sketch a few points in the spirit of a "national case study," exploring the institutional factors in policy development.

The U.S. Congress has been showing a strikingly broader alertness to the international dimensions of scientific and technological activities. Increasingly, many committees explicitly relate the national to the international R&D scenes. Congress and its supporting agencies have insisted on trying to understand the national impacts of international technological trends, especially, for instance, regarding trade and defense.

In the U.S. Executive Branch, international research and development has been an "orphan." It is quite difficult to obtain even crude data on the scale of science and technology carried out with any international purposes in mind. Recent legislation calls upon the State Department to give much greater attention to the planning, the coordination, and the training aspects of the Department's responsibilities for science and technology serving American diplomacy. In the staffs of the National Security Council, the Council of Economic Advisors, and the Office of Science and Technology Policy, senior staff members focus on every one of the issues mentioned so far. Nonetheless, the various mission-agencies send and receive mixed signals about, and give a generally low priority to, their activities in technology related to foreign policy.

We could summarize all of this in a rather breezy way by noting that the U.S. Government frequently tends to see technology as (a) "a trump card," (b) "a last resort," or (c) "a scarce resource." Such headline-phrases might characterize most of the major U.S. initiatives in recent years concerning R&D with diplomatic implications. For instance, cruise missile technology has been a "trump card" in defense; general exchange agreements on scientific topics have been a "last resort" when other diplomatic efforts have failed or must be nurtured; and advanced computer technologies have been "a scarce resource" to be protected rather than shared. Simplifications with new vocabulary introduce concepts that require definition, which probably ought to be avoided in a subject that is already plagued by ambiguities. But the phrases may help to highlight the occasionally conflicting premises (or purposes) that most governments confront.

It would be impossible to generalize reliably about the roles of industry, organized labor, and universities in the technological relations of the United States abroad. But it is fair to say that an entirely new set of deeper tensions has emerged in the past decade. Competition from around the world has meant that our manufacturers face new problems and our workers face new insecurities. Protectionism is surely not the long term answer. One reconcilation of the many current pressures is to launch, as the Carter Administration has done and as the Ford Administration did earlier, new initiatives in R&D that would help the United

States maintain a measure of genuine technological leadership. Although even more substantial moves of theis sort are needed, recall that this is what Brzezinski had in mind. In passing, we also must note that U.S. universities train tens of thousands of foreign students and interact in research with hundreds of academic institutions round the world. Such training, while it runs the risk of increasing "brain drain," must be sharpened and sustained.

Finally, connecting all of the major sectors in the United States, the media are important. There are broad deficiencies in the public's literacy about science and technology as well as about international issues. Newspaper and magazine coverage of science has been weak, but it is improving. The general public probably does not understand the future global stakes in maintaining our scientific and technological capabilities. And, of course, foreign technical aid is so extremely unpopular that our relations with the "third world" are fragile and contentious.

International Patterns: Centripetal or Centrifugal Forces?

We will touch briefly on international institutions. Here, of course, are many kinds of bilateral connections, as well as multilateral alliances and other coalitions, together with the United Nations.

Bilateral government agreements on science and technology involving the U.S. number many more than even well-informed observers are aware. It took 15 single-spaced pages to list the important ones in a January 1979 survey by the State Department. Beyond these are thousands of relationships involving industrial and academic groups. Comparable statistics apply to most of the other industrial countries and their private institutions. These bilateral partnerships are often the most effective—some would say the *only* effective—ways to get things done.

Yet it is the multi-lateral political-economic coalitions, as well as formal treaties and the military-oriented alliances, that usually receive attention internationally—e.g., NATO, OECD, the Group-of-77, and OPEC. To be sure, there also are many internationally effective nongovernmental associations (such as ICSU), particularly in the sciences, medicine, and engineering. And there are topic-centered groups—say, in health and agriculture—that cross the public/private sectors in rather productive ways, transferring technical skills with high leverage and overcoming tall political barriers with deft pragmatism; e.g., CGIAR.

The United Nations system today is a frustrating blend of idealism, technical commitment, bureaucratic waste motion, and weary rhetoric. Ironically, the reputation of the U.N. seems to be falling as rapidly as the need for its potential action is rising. Gravely disabling political and economic pressures often diminish the U.N.'s once-honored professionalism. Not least in the preparations for the Conference on Science and Technology for Development (held in Vienna during August 1979) we have seen how inter-agency squabbles and vague agendas can erode much of the base for seriously focussed international action.

ILLUSTRATIVE FIVE-YEAR PRIORITIES: WHAT IS S&T IN (FOR) FOREIGN POLICY?

It might be stimulating to assess a few *hypothetical* priorities for a five-year program spanning the roles of science and technology in (and for) foreign policy. Let us take five areas for a brief review.

The *mission-oriented governmental agencies* of the OECD countries possess ample justification for renewed emphasis on R&D. Along with a good case for a clearer definition of the R&D mission of each agency, there also is an increasingly strong argument for explicitly adding international technical activity. For example, since the U.S. and NATO must depend more heavily upon R&D as a hedge in arms control policies, there is great justification for cooperating actively on more R&D—serving goals in arms control, intelligence, communications, and all stages of weapons development.

Some observers argue that the U.S. National Science Foundation should reemphasize its traditional priority on *basic* research in agriculture, reproductive biology, tropical diseases, energy, and other areas; such work would help the U.S. *and* other countries.

In the State Department, as another example, there is cogent justification for more research on many of the policy-problems mentioned earlier.

Overall, most agencies need modest additional funding (even very small sums would go a long way) to support international exchanges, seminars, and short collaborative visits linking scientists from various countries.

We have listed a series of possible increases in support and so we must consider *what might be cut among the existing agencies*. For example, parts of the more conventional "technical assistance" programs of agencies such as AID could be trimmed—*if* there were simultaneously a reorientation toward genuinely collaborative work, building up the capabilities *in* LDCs that can enable them to carry out more self-reliant choice-making about technology. Another area that might be cut is the stage of defense R&D that is intermediate between research and production; very large investments are made in this stage and, of course, only a few systems survive into deployment.

"Global concerns" provide a natural justification for more tightly *linking the activities of the industrialized nations.* Among the current technical topics of unusual urgency would be: climate and water resources; energy and related natural mineral resources; and the broader tasks of achieving a better *joint* analysis of how to proceed on the longest lead-time activities required for modernizing the third world while fostering reasonable stability.

Prospects for greater economic competition in the world's trade can not be blinked away. The growing number of "middle tier countries" will become both potential collaborators and stronger competitors with the industrialized nations. One worthwhile step in this complicated pattern would be to arrange for a new set of investments in *university-industrial linkages within the private sector,* meeting national and international responsibilities that are now drifting toward already overburdened governmental and intergovernmental institutions.

Building meaningful *cooperation by industrial countries with LDCs* will continue to be a major challenge, ultimately determining the degree of peace and progress in the world. There will certainly have to be some accommodations by, and greater respect for, the multinational companies from *both* DCs and LDCs. Taking account of the ways in which science and technology actually are diffused internationally, MNCs are essential. At the same time, there will have to be more sober realism among many developing countries about the likely slow rates of change in achieving their goals.

A point to emphasize in closing is that we have absolutely urgent needs for *new initiatives in policy analysis.* We should have much deeper "cross-national comparisons" among both developed and developing countries, to show the historical roles of technology in modernization. To reach more reliable analysis, we should stimulate a few new centers—preferably on an international basis—that would examine the interactions between science/technology policy and economic policy, within the larger international diplomatic context.

It is of course also true that we need a fresh analysis of the consequences of SALT II with respect to the longer term prospects for meaningful detente, for SALT III, and for actual disarmament. This topic is now more discussed than studied, and it requires a high priority with respect to world-wide trends affecting the independence of many countries

As a final example of a subject that requires deeper policy-analysis, consider one that might be regarded as too ideological: examining whether governmental, or private, management has been most effective in efficiently steering R&D toward productive social and economic purposes. This subject has obvious implications for both North-South and East-West trends.

For analyzing many policy-issues, we shall have to muster unusual talent and courage. We shall have to explode myths, puncture rhetoric, avoid euphemism, measure what is important to measure, and stand up for the humane principles where technology and foreign policy meet.

. . . the advance of science is something to be welcomed and encouraged, because it multiplies our possibilities faster than it adds to our problems.

Science and American Foreign Policy: The Spirit of Progress

THE HONORABLE GEORGE P. SHULTZ

Soon after the dawn of the nuclear age, Albert Einstein observed that everything had changed except our modes of thinking. Even so dramatic a development as the nuclear revolution took a long time to be fully understood. In recent decades, the world has seen other extraordinary advances in science and technology—advances that may be of even more pervasive importance and that touch every aspect of our lives. In so many of these areas, the pace of change has been faster than our ability to grasp its ramifications. There have even been moments when our mood was more one of fear than of hope.

In the 1970s, many were preoccupied with the idea that ours was a small planet and getting smaller, that natural resources were limited and were being depleted, that there were inescapable limits to growth. Food would run out; forests would disappear; clean water would be scarce; energy sources would vanish. There was, in short, a deep pessimism about the future of our planet and of mankind itself.

Fortunately, that spirit of pessimism has been replaced in recent years by a new spirit of progress. More and more, we are returning to the belief traditionally held by post-Enlightenment societies: that the advance of science is something to be welcomed and encouraged, because it multiplies our possibilities faster than it adds to our problems. More and more, we see that unleashing the vast potential of human ingenuity, creativity, and industriousness is itself the key to a better future. Science and technology cannot solve all our problems, but the experience of recent years reminds us that they can alleviate wide areas of human suffering and make a better life possible for millions around the world. We can only imagine what they might achieve in the decades to come.

When I was at MIT, I knew an economist at Harvard who had an uncanny knack for making accurate predictions. I always wondered about the secret of his forecasting ability, and when he died, someone going through his papers found part of the explanation. He had written that he was more successful at economic predictions than others because he was "an optimist about America," a trait he attributed to two things: his origins in the Midwest, "where the future is more important than the past," and the fact that he grew up in a family of scientists and engineers, forever "discovering" and "doing" new things.

Optimism alone will not be enough to carry us through the difficult times that lie ahead, and mindless optimism would be as foolish as the mindless pessimism of years past. The scientific and technological revolutions taking place all around us offer many great opportunities, but they also present many challenges—challenges that come from the need to make choices, challenges that lie at the intersection of science and politics, and perhaps most important, challenges to our ways of thinking about ourselves and our world.

DILEMMAS AND CHOICES

The revolutions in science and technology have opened up seemingly limitless possibilities for transforming our world. With each new breakthrough, however, come new and difficult dilemmas. For while we may seek ways to change the world around us, there is also much we would like to preserve. Our civilization is not based on material things. Our culture, our moral values, and our political ideals are treasures that we would not sacrifice even for the most amazing scientific miracle.

Secretary of State Shultz presented this speech during an Academy Industry Program (AIP) seminar on "Science, Technology, and the National Agenda" on March 6, 1985. The AIP is sponsored by the National Academy of Engineering and the National Academy of Sciences.

George P. Shultz

Breakthroughs in biological engineering, for instance, raise fundamental moral questions about man's proper role in the creation and alteration of life, even as they offer new hope to cure diseases, produce food, and broaden our understanding of the origins of life. We need to be concerned about the dangers to our environment that may accompany some new technologies, even while recognizing that other new technologies may be the source of solutions to these problems. We need to ensure that the revolution in communications does not infringe on our right to privacy, even while recognizing the enormous benefits of improved communication for education and for bringing the world closer together. This is the human condition: the creativity that is one part of our nature poses constant challenges to the morality that is another part of our nature. There is no final resting place, no permanent solution—only a continuing responsibility to face up to these hard dilemmas.

We also face some difficult practical choices, and as societies we address them through our political process. Scientific research and development, for example, require financial support. Where should that support come from? And what should be supported? The United States will invest some $110 billion in scientific research and development next year—more than Japan, France, West Germany, and the United Kingdom combined. Of that amount, nearly half comes from the federal government. That is a large investment, taken by democratic process from the American taxpayer. But it reflects a choice we have all made to support scientific progress.

It reflects our understanding that scientific advance serves everyone in our society—by improving health and the quality of life, by expanding our economy, by enhancing the competitiveness of our industries in the world market, by improving our defenses, and perhaps most important, simply by pushing back the frontiers of knowledge.

Yet we have also learned that government can become *too* involved, that government bureaucracies are not always the best judges of where such money can most usefully be spent. Today, private industry, not government, is pushing hardest at the technological frontiers in many fields—in electronics and biotechnology, to name just two.

The problem is to discover how government support for science and technology can best serve the broad goals of society.

The problem, then, is to discover how government support for science and technology can best serve the broad goals of society. In the field of basic research, for example, we cannot always count on the profit motive to foster progress in those areas where research may not lead to the development of marketable products for many years. Government support for basic research gives learning and the pursuit of knowledge a chance to proceed without undergoing the rigorous test of the market place.

One particularly worthy recipient of government support, therefore, is the university. The unfettered process of learning and discovery that takes place mainly in academia is vital. From the university comes the fundamental knowledge that ultimately drives innovation. And from the university comes the pool of creative and technically proficient young men and women who can use that knowledge and apply it to practical problems. The Reagan administration recognizes the importance of this; since 1981, support for basic research at universities has grown by nearly 30 percent.

Even so, the government has limited funds, and further choices have to be made about which projects to support and which to cut back. Government, universities, and the private sector have to work together to make these difficult but inescapable decisions. We as a society cannot afford to turn away from the challenge of choosing.

SCIENCE AND POLITICS

These are not the only hard choices that have to be confronted at the intersection of science and politics. Scientific advances have increasingly become the focus of political debate. Today, scientific questions, and the scientists themselves, play a prominent role in the political arena.

On a wide variety of complex issues the American people look to scientists as an important source of information and guidance In a nation like ours, where knowledge is valued and the search for truth is considered among the noblest of human endeavors, the scientist naturally and properly commands great respect. With that respect, however, comes responsibility.

Too often in recent years we have seen scientists with well-deserved reputations for creative achievement and intellectual brilliance speaking out on behalf of political ideas that unfortunately are neither responsible nor particularly brilliant.

It is not surprising that scientists will have strong views on such technically complex matters as nuclear weapons, arms control, and national defense. But the core issues in dispute here are really not technical, but political and moral Scientists should not expect their words to have special authority in nonscientific areas where they are, in fact, laymen. Scientists are not specialists in the field of world politics, or history, or social policy, or military doctrine As citizens of a free society, they have every right to take part in the public debate. But they have no special claim to infallibility

CHALLENGES TO OUR WAYS OF THINKING

The great intellectual adventure of the scientific revolution beckons all of us—scientists, government leaders, and all Americans—to march ahead together. In collaboration we can achieve a better and deeper understanding of these new developments and what they portend. The changes occurring all around us have far-reaching implications not only for our personal lives, but also for the conduct of our foreign policy, for national security, and indeed for the very structure of the international order. And as we confront these changes, we must heed Einstein's observation: Perhaps the greatest challenges we face are to our ways of thinking.

The Age of Information Technology. One of the most revolutionary recent developments is what Walter Wriston has called "the onrushing age of information technology." The combination of microchip computers, advanced telecommunications—and a continuing process of innovation—is not only transforming communication and other aspects of daily life, but is also challenging the very concepts of national sovereignty and the role of government in society.

The implications of this revolution are not only economic. First of all, the very existence of these new technologies is yet another testimony to the crucial importance of entrepreneurship—and government policies that give free rein to entrepreneurship—as the wellspring of technological creativity and economic growth. The closed societies of the East are likely to fall far behind in these areas—and Western societies that maintain too many restrictions on economic activity run the same risk.

Second, any government that resorts to heavy-handed measures to control or regulate or tax the flow of electronic information will find itself stifling the growth of the world economy as well as its own progress. This is one of the reasons why the United States is pressing for a new round of trade negotiations in these service fields, to break down barriers to the free flow of knowledge across borders.

For two years the Organization of Economic Cooperation and Development (OECD) has been considering an American initiative for a common approach to this problem. Today we are very close to obtaining a joint statement by OECD governments pledging themselves to:

- maintain and promote unhindered circulation of data and information,
- avoid creating barriers to information flows, and
- cooperate and consult to further these goals.

Even here there are dilemmas, however. Government efforts to prevent the copywriting of computer software only reduce incentives for developing new types of software and inhibit progress. We need to understand clearly the crucial difference between promoting the flow of information and blocking innovation. The entire free world has a stake in building a more open system, because together we can progress faster and farther than any of us can alone.

This points to another advantage the West enjoys. The free flow of information is inherently compatible with our political system and values. The Communist states, in contrast, fear this information explosion perhaps even more than they fear Western military strength. If knowledge is power, then the communications revolution threatens to undermine their most important monopoly—their effort to stifle their people's information, thought, and independence of judgment. We all remember the power of the Ayatollah's message disseminated on tape cassettes in Iran; what could have a more profound impact in the Soviet bloc than similar cassettes, outside radio broadcasting, direct broadcast satellites, personal computers, or photocopy machines?

We are reminded . . . that only a world of spreading freedom is compatible with human and technological progress.

Totalitarian societies face a dilemma: Either they try to stifle these technologies and thereby fall further behind in the new industrial revolution, or else they permit these technologies and see their totalitarian control inevitably eroded. In fact, they do not have a choice, because they will never be able entirely to block the tide of technological advance.

The revolution in global communication thus forces all nations to reconsider traditional ways of thinking about national sovereignty. We are reminded anew of the world's interdependence, and we are reminded as well that only a world of spreading freedom is compatible with human and technological progress.

The Evolution of Strategic Defense. Another striking example of the impact of scientific and technological change is the issue of strategic defense. Here the great challenge to us is not simply to achieve scientific and engineering breakthroughs. As real a difficulty is to come to grips with "our ways of thinking" about strategic matters in the face of technical change.

For decades, standard strategic doctrine in the West has ultimately relied on the balance of terror—the confrontation of offensive arsenals by which the two sides threaten each other with mass extermination. Deterrence has worked under these conditions and we should not abandon what works until we know that something better is genuinely available. Nevertheless, for political, strategic, and even moral reasons, we owe it to ourselves and to future generations to explore the new possibilities that offer hope for strategic defense that could minimize the dangers and destructiveness of nuclear war. If such technologies can be discovered, and the promise is certainly there, then we will be in a position to do better than the conventional wisdom which holds that our defense strategy *must* rely on solely offensive threats and *must* leave our people and our military capability unprotected against attack.

Adapting our ways of thinking is never an easy process. The vehemence of some of the criticism of the President's Strategic Defense Initiative (SDI) seems to come less from the debate over technical feasibility—which future research will settle one way or another in an objective manner—than from the passionate defense of orthodox doctrine in the face of changing strategic realities.

We are proceeding with SDI research because we see a positive, and indeed revolutionary potential: Defensive measures may become available that could render obsolete the threat of an offensive first strike. A new strategic equilibrium based on defensive technologies and sharply reduced offensive deployments is likely to be the most stable and secure arrangement of all.

SCIENCE AND FOREIGN POLICY

These are but two examples of how technological advances affect our foreign policy. There are many others. It is in our national interest, for example, to help other countries achieve the kinds of technological progress that hold such promise for improving the quality of life for all the world's people. The expansion of the global economy and new possibilities of international cooperation are among the benefits that lie ahead of us as technical skills grow around the world.

Therefore, cooperation in the fields of science and technology plays an increasing role in our relations with a range of countries. We have important cooperative links with China and India, for example, as well as with many other nations in the developing world.

We are working with nations in Asia, Latin America, and Africa to achieve breakthroughs in dryland agriculture and livestock production to help ease food shortages, and in medicine and public health to combat the scourge of disease. Our scientific relations with the industrialized nations of Western Europe and Japan aim at breaking down barriers to the transfer of technological know-how.

Clearly, our science and technology relationships with other industrialized nations are not without problems. There is, in fact, a permanent tension between our desire to share technological advances and our equally strong desire to see American products compete effectively in the international market. We cannot resolve this dilemma, nor should we. The interplay between the advancement of knowledge and competition is productive. Some nations may focus their efforts too heavily on competition at the expense of the spread of knowledge that can benefit everyone, and certainly we in the United States should not be alone in supporting basic scientific research. The industrialized nations should work together to strike a balance that can promote the essential sharing of scientific advances and at the same time stimulate the competitive spirit which itself makes such an important contribution to technological progress.

The interplay between the advancement of knowledge and competition is productive.

TECHNOLOGY TRANSFER

A further dilemma arises where new technologies may have military applications. We maintain a science and technology relationship with the Soviet Union, for instance, even though we must work to ensure that the technologies we share with the Soviets cannot be used to threaten Western security.

The innovations of high technology are obviously a boon to all nations that put them to productive use for the benefit of their peoples. But in some societies, it often seems that the people are the last to get these benefits. The Soviet Union has for decades sought to gain access, through one means or another, to the technological miracles taking place throughout the free world. And one of their goals has been to use these new technologies to advance their political aims—to build better weapons, not better health care; better means of surveillance, not better telephone systems.

This, of course, poses another dilemma. We seek an open world, where technological advances and know-how can cross borders freely. We welcome cooperation with the Soviet Union in science and technology.

And yet in the world as it exists today, the West has no choice but to take precautions with technologies that have military applications. Cooperation with our allies is essential. Countries that receive sensitive technologies from the United States must maintain the proper controls to prevent them from falling into the hands of our adversaries.

Scientists can help us think through this difficult problem. What technologies can be safely transferred? How do we safeguard against the transfer of technologies that have dual uses? Where do we strike the balance?

THE PROLIFERATION OF NUCLEAR AND CHEMICAL WEAPONS

Scientists can also be helpful in other areas where the free flow of technical knowledge poses dangers. One priority goal of our foreign policy, for instance, is to strengthen international controls over two of the grimmer products of modern technology: weapons of mass destruction, both nuclear and chemical.

The world community's success or failure in preventing the spread of nuclear weapons will have a direct impact on the prospects for arms control and disarmament, on the development of nuclear energy for peaceful purposes, and indeed on the prospects for peace on this planet. The United States pursues the goal of nonproliferation through many avenues:

- We have long been the leader of an international effort to establish a regime of institutional arrangements, legal commitments, and technological safeguards against the spread of nuclear weapons capabilities. We take an active part in such multilateral agencies as the International Atomic Energy Agency, the Nuclear Energy Agency, and the International Energy Agency.
- Although we have major differences with the Soviet Union on many arms control issues, we have a broad common interest in nuclear nonproliferation. In the fall of 1982, Foreign Minister Gromyko and I agreed to initiate bilateral consultations on this problem; since then, several rounds of useful discussions have taken place, with both sides finding more areas of agreement than of disagreement.
- This year, the United States will sit down with the 126 other parties to the Nonproliferaton Treaty for the third time in a major review conference. We will stress the overarching significance of the Treaty, its contribution to world peace and security, and the reasons why it is in every nation's fundamental interest to work for universal adherence to it.

The progress in nuclear nonproliferation has unfortunately not been matched in the area of chemical weapons. The sad fact is that a half century of widely accepted international restraint on the use or development of chemical weapons is in danger of breaking down. In 1963, we estimated that only five countries possessed these weapons. Now, we estimate that at least thirteen countries have them, and more are trying to get them. As we have seen, the problem has become particularly acute in the war in the Persian Gulf.

We have had some marked success in limiting the spread of nuclear weapons, in part because the world community has worked together to raise awareness and to devise concrete measures for dealing with the problem. We must do the same in the field of chemical weapons. It will not be an easy task. Chemical industries and dual-use chemicals are more numerous than their counterparts in the nuclear field, and chemical weapons involve lower levels of technology and cost less than nuclear weapons. But the effort must be made:

- First, we need to raise international awareness that there *is* a growing problem and that developed nations, in particular, have a special obligation to help control the spread of chemical weapons.
- Second, we need to expand and improve our intelligence capabilities and provide for greater coordination between intelligence services and policymakers in all countries.
- And third, we must take bilateral and multilateral actions to deal with problem countries and to curb exports of materials that can be used in the manufacture of chemical weapons.

The scientific community can help in a variety of ways. Chemical engineers can help us identify those items that are essential to the manufacture of chemical weapons and then determine which countries possess them, so that we can promote more effective international cooperation. Scientists can help us find better ways to check the flow of the most critical items without overly inhibiting the transfer of information and products that serve so many beneficial purposes around the world.

These are difficult problems, but if we work together we can begin to find better answers.

THE VISION OF A HOPEFUL FUTURE

I want to end, as I began, on note of hope. If we confront these tough issues with wisdom and responsibility, the future holds great promise. President Reagan, in his State of the Union message in February, reminded us all of the important lesson we should have learned by now: "There are no constraints on the human mind, no walls around the human spirit, no barriers to our progress except those we ourselves erect." Today we see this fundamental truth being borne out again in China, where a bold new experiment in openness and individual incentives is beginning to liberate the energies of a billion talented people. The Chinese have realized that farm productivity is not merely a matter of scientific breakthroughs; it is also a matter of organization and human motivation.

The technological revolution is pushing back all the frontiers on earth, in the oceans, and in space. While we cannot expect these advances to solve all the world's problems, neither can we any longer speak in Malthusian terms of inevitable shortages of food, energy, forests, or clean air and water. In the decades ahead, science may find new ways to feed the world's poor—already we can only look in wonder at how increased farm productivity has made it possible for a small percentage of Americans to produce enough food for a significant portion of the world's people.

We may discover new souces of energy and learn how to use existing sources more effectively—already we see that past predictions of energy scarcity were greatly exaggerated. We may see new breakthroughs in transportation and communication technologies, which will inevitably bring the world closer together—think back on the state of these technologies forty years ago, and imagine what will be possible forty years hence.

Change—and progress—will be constant so long as we maintain an open society where men and women are free to think, to explore, to dream, and to transform their dreams into reality. We would have it no other way. And in a society devoted to the good of all, a society based on the fundamental understanding that the free pursuit of individual happiness can benefit everyone, we can have confidence that the products of science will be put to beneficial uses, if we remain true to our heritage and our ideals.

Therefore, we retain our faith in the promise of progress. Americans have always relished innovation; we have always embraced the future. As President Reagan put it, we must have a "vision that sees tomorrow's dreams in the learning and hard work we do today."

Membership Election Calendar

Twenty-Third Election (1986)

March 1, 1985	Nomination packets mailed to Academy Members	August 12, 1985	DEADLINE for receipt of anonymous comments from Academy Members
May 31, 1985	DEADLINE for receipt of nominations	December 3, 1985	Meeting of Committee on Membership to formulate ballot
June 28, 1985	DEADLINE for receipt of reference forms for nominees	January 13, 1986	Ballot Book mailed to Academy Members
July 12, 1985	List of nominees (Anonymous Comments Package) mailed to Academy Members	February 3, 1986	DEADLINE for receipt of ballots

UNESCO SCIENCE PROGRAMS:
IMPACTS OF U.S. WITHDRAWAL AND SUGGESTIONS FOR ALTERNATIVE INTERIM ARRANGEMENTS

A Preliminary Assessment

Office of International Affairs
National Research Council

National Academy Press
Washington, D.C. 1984

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This report has been reviewed by a group other than the authors according to procedures approved by the Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1863, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

This report has been prepared by the Office of International Affairs, National Research Council, for the Office of Communications and UNESCO Affairs, Bureau of International Organizations, U.S. Department of State, under Contract DOS 1021-410172.

PREFACE

In reply to a letter from the Chairman of the House Committee on Foreign Affairs requesting views on the announced U.S. withdrawal from UNESCO (scheduled to take place on December 31, 1984), the President of the National Academy of Sciences stated that "the Governing Board of the National Research Council and the Council of the National Academy of Sciences are deeply concerned about the potential impacts on science of a withdrawal by the United States from UNESCO." Withdrawal will have significant implications for global science programs in which U.S. scientists are deeply involved, often in a leadership role. Therefore, the Academy, through the Office of International Affairs (OIA) of the National Research Council (NRC), agreed to respond to an invitation to provide the U.S. Department of State with an assessment of potential impacts and to suggest possible alternative arrangements in order to maintain essential U.S. scientific contacts with UNESCO-sponsored programs in case the U.S. were no longer a member of UNESCO on January 1, 1985.

The strategic considerations that provide the basis for the study, including significant caveats and limitations that pertain to the findings, are discussed in Chapter 2. An important summary of general preliminary findings will be found in Chapter 3. The assessments and proposed interim arrangements for specific programs and subprograms within the three major science program sections of the UNESCO Approved Programme and Budget for 1984-85 are further detailed in Chapter 4.

Constraints of time and money, in addition to limited analytical background material, seriously influenced the scope of the study. Normal NRC procedures, which typically include a specially appointed study committee, proved impossible in this instance. We did, however, avail ourselves of a well-balanced ad hoc group, and the present report has been reviewed by several distinguished members of the scientific community. The detailed analysis of the UNESCO program and budget was conducted by a consultant, Dr. Philip Hemily, and the OIA staff. This examination was augmented by interviews with U.S. scientists engaged in, or familiar with, the science activities of UNESCO.

U.S. budgetary cycles make it imperative to convey some preliminary findings now since preparation of funding recommendations is under way. It is clear, however, that a much more detailed and critical analysis of the science programs of UNESCO and of other intergovernmental organizations is badly needed. The present study is dedicated to the hope that such a broad-gauged review will be implemented.

Walter A. Rosenblith
Foreign Secretary
National Academy of Sciences

CONTENTS

Chapter 1

INTRODUCTION

> The United Nations Educational, Scientific, and Cultural Organization (UNESCO) was founded in 1946 "for the purpose of advancing, through the educational and scientific and cultural relations of the peoples of the world, the objectives of international peace and of the common welfare of mankind. . ."

The announced U.S. intention to withdraw from membership in UNESCO at the end of 1984 has prompted concern within the scientific community, both national and international, about the consequences for global science cooperation. Problems of the earth, oceans, atmosphere, environment and the cosmos require the collaboration of scientists on a worldwide scale. Although science represents only a part of the total UNESCO mandate, and about one-third of the budget, it is a significant element that historically has facilitated important contributions to the spirit of international cooperation and to the advancement and health of the scientific enterprise. UNESCO is one of many international institutions for science cooperation that have developed in the post-World War II era and is unique in the breadth of its concerns, giving testimony to the important linkages between education, science and culture. Although official U.S. withdrawal from this forum has implications for all the programs of UNESCO, this report focuses only on the science programs. The prospect of U.S. nonmembership in UNESCO raises questions about the immediate implications for ongoing collaborative programs in which the United States is an active participant as well as for the long-term future of U.S. involvement in international science activities.

As a private institution, the National Academy of Sciences is not a formal participant in UNESCO, an intergovernmental organization. However, because of the involvement of the U.S. scientific community in many UNESCO-sponsored science activities, the Council of the NAS and the Governing Board of the National Research Council have expressed concern regarding the impacts on science of a U.S. withdrawal from UNESCO.[1] In March, the Academy, through its National Research Council, offered to assist the Department of State in assessing the impacts on some of the major science programs and to suggest possible alternative arrangements whereby essential U.S. scientific collaborations could be maintained. It is important to note that the issue posed was not whether the United States should or should not withdraw from UNESCO. The Academy had already expressed the view that, on balance, U.S. science gains more than it loses from participation in UNESCO science programs. This report, therefore, makes no statement on the fundamental question of withdrawal. The present approach is one of helping to minimize the costs of a decision that was made, not on the basis of scientific considerations, but on a range of other, largely political, factors. Also, although it is recognized that UNESCO as an institution could benefit from some reform, particularly at the management level, this report does not, to any significant degree, deal with that issue.

The growth and diversification of science and the rapid expansion in the number of participants in international activities has created a tremendously complex situation that is straining the capabilities of international institutions for cooperation. In the science area there is a vast array of organizations, intergovernmental and nongovernmental, dedicated to the promotion of international cooperation . In large part, this stems from the universality of the scientific enterprise itself and the need to share and confirm research findings world wide, an inherent feature of scientific progress and global cooperation. The development of the UN system of specialized agencies has been an important complement to the many nongovernmental organizations that have emerged within individual professional communities. UNESCO, in particular, has fostered contacts and interactions with such organizations, most notably in the science area, with the International Council of Scientific Unions (ICSU) and its individual disciplinary unions.[2] It is possible, therefore, to begin to identify a number of potential alternative organizations based largely on existing patterns of cooperation with UNESCO as a <u>partial</u> response to the problem. However, as will be amplified in the following chapter on strategic considerations, there has not been either time or resources in this study to consult with these organizations to determine their capability and/or willingness to serve in this capacity. This has to be a major concern, in terms of the viability of the proposed alternatives. Since the time frame of the present report relates primarily to FY-86, other alternative options that are outlined feature support to UNESCO for specific activities, particularly for the major intergovernmental programs, and increased resources to national agencies to be utilized for facilitating U.S. participation in UNESCO programs within their areas of competence.

The present study emphasizes the need to inquire more deeply into the objectives, consequences, and benefits of U.S. participation in intergovernmental science programs and relationships between intergovernmental and nongovernmental organizations. The absence of an overall strategic policy framework for U.S. participation in international science is a severe handicap. There is a need to clarify the various means of intergovernmental scientific and technological cooperation and to reach common understandings on the most imaginative, productive ways of utilizing our intellectual and financial resources. This is an important issue not only for the United States, but also for other countries which will be affected by U.S. withdrawal. The U.S. inclination to utilize alternative forums also has implications for the overall funding of international science that need to be viewed in a larger policy context than just UNESCO. New models for international science cooperation may be required to meet contemporary needs both for advancing science and for strengthening infrastructures in developing countries.

Questions are being posed with regard to the value of specific areas of UNESCO-sponsored programs to the U.S. scientific community: How well does UNESCO carry out these programs? Are the programs that are directed primarily toward the needs of developing countries adequately designed and implemented? Is UNESCO the most effective organization for carrying out these programs? If so, is there sufficient guidance and participation from the worldwide science and technology community to ensure effective and efficient program implementation? What measures might be taken to improve the performance of UNESCO? What might be the loss to our scientific community, as well as to those of other countries, if the United States withdraws fom UNESCO on December 31, 1984? Coupled with this last question is the significance of the contributions of the American scientific community to UNESCO. It is some of these questions that the following assessment attempts to address.

REFERENCES

1. Letter from Dr. Frank Press to Congressman Dante Fascell, April 17, 1984.

2. The International Council of Scientific Unions (ICSU) represents the principal nongovernmental mechanism created by scientists to advance scientific interests on an international basis. The structure of ICSU is based on dual membership, encompassing 20 disciplinary scientific unions and 70 national members. The national members are usually academies or national research councils. In the United States, the National Academy of Sciences is the adhering body to ICSU as well as individually to 17 of the member unions. ICSU and the unions, with a combined annual budgetary level of $5 million, provide an important framework for the orderly handling of international, nongovernmental scientific cooperation.

Chapter 2

STRATEGIC CONSIDERATIONS

THE U.S. DECISION TO WITHDRAW FROM UNESCO

The Secretary of State notified the Director General of UNESCO on December 29, 1983, that the United States would withdraw from UNESCO on December 31, 1984. This letter of notification charged that UNESCO had "extraneously politicized virtually every subject it deals with; exhibits hostility toward the basic institutions of a free society, especially a free market and a free press; and demonstrated unrestrained budgetary expansion."[1]

Assistant to the President for National Security Robert C. McFarlane noted, in a memorandum of December 23, 1983, to the Secretary of State, the President's approval of notification of withdrawal, but also his desire to promote meaningful changes in UNESCO during 1984.[2] A second memorandum of February 11, 1984, from McFarlane proposed a strategy including an action plan and the mobilization of international support to assist the effort to promote changes in UNESCO during 1984.[3]

A U.S. Monitoring Panel, comprising 15 eminent citizens knowledgeable in UNESCO's various areas of activity, was established in March 1984. It was instructed to report to the Secretary of State near the end of 1984 on the degree and kinds of change that might have occurred in UNESCO in the interim, with a view to assisting the Secretary in determining whether to recommend revision of the decision to withdraw.[4]

Nonetheless, the State Department has stressed the fact that its decision to withdraw is firm. Barring unforeseen changes and developments, it is assumed that the United States will no longer be a member of UNESCO as of January 1, 1985. The Administration has also stressed that the United States would continue to participate in programs that meet the original goals of UNESCO and thereby "pursue international cooperation in education, science, culture, and communications by shifting our contribution to other appropriate bilateral, multilateral, or private institutions."[5] It should be noted, with reference to pursuing UNESCO types of international cooperative activities through other channels, that the current level of total U.S. mandatory contributions to UNESCO is on the order of $50 million per year, with science activities funded at about $14 million per year.

During the period preceding the December 1983 announcement of the decision to withdraw, a wide-ranging review of UNESCO activities was carried out under the auspices of the Department of State. This review drew on the views of a number of U.S. public and private institutions which benefited from, participated in, or contributed to UNESCO activities in education, science, culture, and communications. The objective was to produce, in light of the information gathered, an analysis of overall political and management trends in the Organization.[6] Some 12 U.S. government agencies contributed to this US/UNESCO Policy Review from their special perspectives, as did the U.S. National Commission for UNESCO and the National Academy of Sciences. The organizations concerned with science programs reached the conclusion that the United States should continue its participation in UNESCO.[7]

However, the State Department's own analysis of political and management trends provided the basis inter alia for the decision to recommend U.S. withdrawal.

At the same time, the Department's US/UNESCO Policy Review stated that "UNESCO science activities generally satisfy U.S. objectives and priorities." It went on to note five consequences of withdrawal:

- U.S. withdrawal from UNESCO science activities, if not compensated by alternative forms of cooperation, could lead to a significant reduction in the direct access of the U.S. scientific community to important data bases, localities, and scientific resources worldwide.

- The decrease in income from dues would damage UNESCO's ability to meet the U.S. objective of assistance to LDCs (less developed countries) in developing scientific capabilities and infrastructure, and to perform the successful international scientific projects which UNESCO has sponsored.

- The United States would lose its present access to an important international framework for scientific cooperation and data gathering.

- UNESCO provides the possibility of scientific exchange with certain countries with whom we maintain limited contact. Withdrawal would make such cooperation more difficult.

- The United States would no longer be eligible for membership on the International Coordinating Council of the Program on Man and the Biosphere, the Coordinating Council of the International Hydrological Program, and the Intergovernmental Council for the General Information Program.[6]

Given these consequences, it is necessary to explore alternative ways of pursuing U.S. objectives of international cooperation and collaboration in the science area. As a partial contribution to the effort, this report presents assessments of the impact on U.S. science of a withdrawal from UNESCO and suggests possible alternative arrangements for assuring continued U.S. association with selected UNESCO programs.

STRATEGY FOR THE SCIENCE ASSESSMENT

The genesis of the task of assessment undertaken by the National Research Council can be briefly summarized. In October 1983, when consultations were in progress on contributions to the US/UNESCO Policy Review, noted above, the Foreign Secretary of the National Academy of Sciences provided the Assistant Secretary of State for International Organizational Affairs (at his request) with some initial views pertaining to the quality and management of UNESCO science activities. In particular, he noted:

- Science-related programs represent, in many ways, UNESCO's most successful effort and fulfill an important function for the U.S. in terms of international science cooperation and science education.

- There is much criticism leveled at UNESCO programs, structure and management, but, in the area of the sciences at least, there is no real alternative to UNESCO at the present time.

- With respect to the management of UNESCO science programs, there is certainly room for improvement.

- The mechanisms necessary to ensure effective U.S. participation in UNESCO are not currently available.[8]

Following the announcement of the intention to withdraw from UNESCO, a number of bodies of the Academy complex considered the implications of withdrawal with respect to U.S. science interests and its impact on science in general. This process resulted in the letter of March 13, 1984, from the Foreign Secretary of the National Academy of Sciences to the Assistant Secretary of State for International Organizational Affairs offering assistance in assessing the impacts of the U.S. withdrawal in the science area and in identifying possible alternative arrangements for U.S. participation.[9] This initiative provided the basis for the contract between the Department of State and the National Academy of Sciences to prepare the following:

- An inventory of existing UNESCO-sponsored programs and arrangements for U.S. scientific cooperation (provided in a Supplement to this report);

- An analysis of the extent to which these arrangements depend or do not depend critically on affiliation with UNESCO;

- Suggestions for alternative interim arrangements for facilitating essential U.S. scientific interactions with UNESCO-sponsored programs;

- Initial recommendations of future U.S. directions in multilateral and global scientific cooperation (both within and outside UNESCO).

Significant Sources

The assessment presented in this report drew on two particularly valuable recent reviews of UNESCO science activities that had been prepared in the light of the UNESCO problem: (1) "Natural Sciences in UNESCO: A U.S. Interagency Perspective,"[7] the October 1983 interagency report coordinated by the National Science Foundation (NSF) as a contribution to the US/UNESCO Policy Review, and (2) Science and Technology Programs in UNESCO,[10] the March 1984 report on the policy implications of a U.S. withdrawal from UNESCO prepared by the Congressional Research Service for the Subcommittee on Science, Research and Technology of the House Committee on Science and Technology. The present assessment, based on a broad range of consultations with professional colleagues who have participated in UNESCO-sponsored science activities, adds to the information provided in the above-mentioned reviews. The Approved Programme and Budget for 1984-1985[11] has been used as a basic UNESCO reference document.

Caveats

Limitations and constraints in carrying out this assessment must be emphasized. They were as follows:

- Time Frame. This assessment was prepared in four months. In reviewing such a comprehensive set of programs in such a short time, it has not been possible to contact the full range of science interests involved. A thorough critical review of all science programs has not been possible; the focus of the present study has been on measures to prevent disruptions in the first year or two of U.S. nonmembership in UNESCO.

- Community of Interests. The time constraints have ruled out any detailed evaluation of UNESCO-sponsored science activities, particularly in the area of developing country interests. An in-depth assessment would require, by definition, consultations with scientific peer groups abroad. This has neither been possible nor attempted. It should also be noted that no real attempt has been made to evaluate the field programs of UNESCO. Furthermore, a comprehensive assessment would need to include a careful evaluation of science programs of other intergovernmental organizations and particularly those of the UN system as a whole to better understand interactions and opportunities for promoting more effective international scientific cooperation.

- Information Base. As noted, UNESCO's Approved Programme and Budget for 1984-1985 has been used as a basis for assessing U.S. interests and participation. Like many budget program statements, the UNESCO document does not always convey a clear sense of substantive endeavor. Moreover, the United States lacks an institutional memory and a focal point for monitoring U.S. scientific interactions, both with respect to UNESCO in particular and to multilateral scientific relationships in general.

Contacts with the U.S. Scientific Community

The present assessment has concentrated on bringing into play the personal views of American scientists and engineers who have participated directly, often in leadership roles, in the science activities of UNESCO. The following means were used to do so:

- Contact was initiated in April 1984 with American scientists serving as officers of international scientific unions or serving on corresponding U.S. national committees.

- Officers of U.S. scientific societies and associations were invited to query their members on the value of participation in UNESCO activities.[12]

- In cooperation with the Consortium of Affiliates for International Programs of the American Association for the Advancement of Science, a query was sent to members requesting information on specific experiences and judgments of UNESCO science activities.

- A letter to the editor, Science, April 13, 1984, invited comments from the U.S. scientific community on their participation in UNESCO scientific activities.

- The potential impact of withdrawal on particular science interests was discussed at meetings of U.S. national committees affiliated with international organizations and unions.[13]

- Personal contact was made through interviews (including phone communications) with U.S. scientists and engineers in academia, government, and industry involved in UNESCO science activities, particularly the major observational programs.

This approach has resulted in several hundred communications with American scientists and engineers.

FRAMEWORK FOR THE ASSESSMENT

In preparing the inventory of UNESCO science programs, assessing their dependence on affiliation with UNESCO, and suggesting alternative interim arrangements, the following areas of UNESCO-funded activities appearing in the Approved Programme and Budget for 1984-1985[11] were examined:

- Major Program VI: The Sciences and Their Application to Development

- Major Program IX: Science, Technology and Society

- Major Program X: The Human Environment and Terrestrial and Marine Resources

To a considerably lesser extent, Major Programs V.2 (Teaching of Science and Technology), VII (with respect to Scientific and Technological Information), and General Activities (statistics on science and technology) were reviewed. This material is included in the Supplement.

In order to put the science activities in perspective within the overall UNESCO program, a summary of the overall biennial budget of UNESCO is presented in Annex A. The activities considered in this review account for approximately 30 percent of budgetary resources devoted to regular UNESCO programs. There are also significant contributions to UNESCO science and training activities from other sources--particularly the United Nations Development Program (UNDP), United Nations Environment Program (UNEP), the UN Financing System for Science and Technology for Development (UNFSSTD), and non-UN sources--which are of the same order of magnitude as those provided to regular UNESCO programs. Summary budgetary information on the individual program activities considered in this review (Major Programs VI, IX, X) is provided in Annex B.

In carrying out the assessment, particular attention has been given to budgetary matters in order to be aware of the current U.S. contributions and to make it possible to suggest options for alternative channels of support in the future, including proposals for augmenting selected high-quality activities.

A certain number of questions and factors have been taken into account in proposing alternative channels:

- What are the means and limitations of maintaining U.S. participation and leadership?

- From the viewpoint of the United States, what are the most efficient and simple administrative procedures?

- Alternative channels suggested in this preliminary stage are most likely to be useful only on an interim basis.

- Account must be taken of the need for staff and overhead costs.

- There are special needs for project oversight by a U.S. scientific organization.

- Major consideration has been given to contributions to UNESCO to support specific programs and projects (e.g., Funds-in-Trust, donations, etc.). This approach may provide a simple means of support at a modest overhead charge.

REFERENCES

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2. Memo, Robert C. McFarlane, Assistant to the President for National Security, to George P. Shultz, December 23, 1983.

3. Memo, Robert C. McFarlane to George P. Shultz, February 11, 1984.

4. Charter of the Monitoring Panel on UNESCO, March 22, 1984.

5. Memo, Robert C. McFarlane to George P. Shultz, December 23, 1983.

6. US/UNESCO Policy Review, Department of State, February 29, 1984.

7. Letter of transmittal from Deputy Assistant Director for Scientific, Technological and International Affairs, National Science Foundation, to the Assistant Secretary of State for International Organizational Affairs, October 21, 1983. The report, "Natural Sciences in UNESCO: A U.S. Interagency Perspective," was based on contributions from the U.S. Geological Survey and the National Park Service of the U.S. Department of the Interior, the Forest Service of the U.S. Department of Agriculture, the National Institute of Education of the U.S. Department of Education, the Agency for International Development, and a number of components of the Bureau of Oceans and International Environmental and Scientific Affairs of the U.S. Department of State.

8. Letter from NAS Foreign Secretary Walter A. Rosenblith to Assistant Secretary Gregory J. Newell, October 21, 1983.

9. Letter from NAS Foreign Secretary Walter A. Rosenblith to Assistant Secretary Gregory J. Newell, March 13, 1984.

10. Knezo, G. J. and M. E. Davey. Science and Technology Programs in UNESCO: A Description of the Programs and Preliminary Analysis of the Policy Implications of U.S. Withdrawal for Science (Washington, D.C.: Congressional Research Service, March 1984).

11. Approved Programme and Budget for 1984-1985, 22 C/5 (Paris: UNESCO, January 1984).

12. Meeting with representatives of professional societies, April 17, 1984: Gordon Bixler (American Chemical Society)
    David M. Burns (American Association for the Advancement of Science)
    Bahaa El-Hadidy (American Society for Information Science)
    Marjorie Gardner (American Chemical Society)
    J. K. Goldhaber (American Mathematical Society)
    Dorothy P. Gray (National Commission on Libraries and Information Science)

William G. Herrold (Institute of Electrical and Electronics Engineers)
Joan M. Jordan (American Meteorological Society)
Steven Kennedy (American Psychological Association)
W. Edward Lear (American Society for Engineering Education);
J. David Lockard (National Association for Research in Science Teaching)
Elliott A. Norse (Ecological Society of America)
Robert L. Park (American Physical Society)
Orr E. Reynolds (American Physiological Society)
Alan N. Schechter (Biophysical Society)
Robert D. Watkins (American Society for Microbiology)
Judith Wortman (American Institute of Biological Sciences).

13. Meetings with U.S. National Committees:
International Union of Pure and Applied Chemistry (3/17)
International Council of Scientific Unions (4/19)
International Union of Pure and Applied Physics (4/25)
International Union of Biochemistry (4/29)
International Brain Research Organization (5/15)
International Geological Correlation Program (6/12)
Internatinal Union of Geological Sciences (6/13)
International Union of Pure and Applied Biophysics (6/14).

Chapter 3

PRELIMINARY CONCLUSIONS

The present chapter summarizes preliminary conclusions of a general nature drawn from the assessments of specific program activities in Chapter 4 and raises a number of issues requiring further analysis. The information is presented in three sections: Assessments of UNESCO Programs, Impacts of U.S. Withdrawal, and Alternative Interim Arrangements. Two tables at the end provide a capsule summary of the assessments, preferred alternatives, and suggested funding levels for each of the principal areas of science activity.

It is important to emphasize that the present study is preliminary in nature. A much more comprehensive study is needed, one which will draw on the knowledge and experience of an even broader spectrum of the U.S. scientific community, as well as colleagues abroad.

ASSESSMENT OF UNESCO PROGRAMS

1. Key Program Areas. This report has attempted to deal with a wide range of scientific and technological activities sponsored by UNESCO. Not surprisingly, these activities vary in size, complexity, quality, and importance. Activities of major interest to the U.S. scientific community are in the following areas:

- Earth Sciences and Resources; Natural Hazards; the International Geological Correlation Program
- Water Resources; the International Hydrological Program
- Oceans and Resources; Coastal Regions; the Intergovernmental Oceanographic Commission
- Man and the Biosphere Program
- Natural Sciences; support of ICSU and activities sponsored by NGOs in the fields of biology, chemistry, physics

Measures need to be taken to plan and facilitate U.S. participation in these program areas if withdrawal from UNESCO becomes effective.

UNESCO work in engineering sciences, social sciences, and science policy appear to be of lesser interest to the concerned U.S. professional communities with only small numbers of U.S. scientists participating. Nevertheless, these are important areas, ones in which there is a potentially important role for American scientists to play.

2. Advancement of Science--Science for Development. Although UNESCO science objectives include the pursuit of new knowledge, particularly in observational scientific fields, increasing attention is being directed toward the science, science education, and advanced training needs of the developing world. The juxtaposition of science at the frontier and science for development highlights the multiple objectives of UNESCO and of nongovernmental scientific organizations. There is need to enhance understanding of the complementary and interactive nature of both these objectives.

3. UNESCO's Intergovernmental Role. As an intergovernmental organization, UNESCO is an important instrument in carrying out global observational programs (e.g., the Geological Correlation Program, oceanographic components of the World Climate Research Program, and the Man in the Biosphere Program). The authority and financial support of governments is often critical to field operations which involve the sovereignty of nations. On their own, nongovernmental organizations cannot substitute for intergovernmental ones in these areas of responsibility.

UNESCO is a critical intergovernmental link to the developing world for the implementation of projects involving advanced training and infrastructure building. These latter projects depend very much on substantive contributions from the advanced countries, primarily through nongovernmental scientific organizations such as ICSU and its constituent bodies.

4. Other Intergovernmental Organizations. Other intergovernmental organizations (e.g., UNDP, UNEP, WMO, FAO, and WHO) participate substantively and financially in many UNESCO-directed science programs. Those that make financial contributions often provide funds of the same order of magnitude as UNESCO's regular program. The UNESCO staff plays an important role in planning, advising, and managing many of these programs.

5. UNESCO and the Scientific Community. One cannot help but be impressed with the large number of UNESCO activities involving significant numbers of scientists who participate either directly or through nongovernmental organizations (NGOs). NGOs play an important role in many aspects of UNESCO's programs, particularly in engaging the participation of scientists in advanced training projects (IBRO, ICRO, MIRCENs) and in guiding/managing certain aspects of observational programs (e.g., IUGS, IUGG, IUBS, SCOR, SCOPE). UNESCO's programs would profit from even greater participation and association with the

NGOs. However, their capabilities to provide guidance and assistance in activities to meet the needs of the developing world could be improved.

6. U.S. Organization. The lack of responsible and scientifically competent oversight of U.S. interests in UNESCO science programs has been and continues to be a serious and chronic problem. A governmental focal point, having the requisite technical capability as well as significant international policy responsibilities, would provide much-needed support for American participation in the science programs of UNESCO. However, such a unit cannot be truly effective in the absence of an integral link to the scientific community and to their organizations. The continuing agenda of this joint enterprise would include:

- Assistance in the planning and implementation of scientific programs at world level;
- Concern for enhancing the participation of developing nations in programs that contribute to the common scientific good;
- Action plans backed by human and financial resources to encourage and support multilateral scientific initiatives.

IMPACTS OF U.S. WITHDRAWAL

1. Scientific Relations. In the short term (through 1985), it will be hard to judge the true impacts of withdrawal on U.S. science interests and on the quality of UNESCO science programs. Even if they appear to be only modest, early provision of resources to ensure continued U.S. participation must be made. In order to maintain confidence both here and abroad in U.S. participation in international science programs, withdrawal must be accompanied by a serious commitment, expressed in policy, institutional, and budgetary terms to a continued and strengthened American role.

2. U.S. Participation in Governance. With the possible exception of the Intergovernmental Oceanographic Commission (IOC) and, to a less certain degree, the International Geological Correlation Program (IGCP), the United States will forfeit the right to participate in the governance of major UNESCO-sponsored cooperative international programs upon withdrawal. Only limited influence can be exerted on the direction of these programs through U.S. participation in the cooperating NGOs. It is important to note again the role played by UNESCO staff in planning, advising, and implementing major programs supported from other sources (e.g., UNDP, UNEP, Funds-in-Trust). Withdrawal may seriously affect possibilities for American participation in program management roles as UNESCO staff members.

3. Discontinuities in UNESCO Planning/Implementation. In the event of U.S. withdrawal at the end of 1984, it will be necessary to

prepare for disruptions in project planning and implementation at UNESCO beginning in early 1985 in view of expected budgetary cutbacks. Although U.S. contributions to UNESCO are not normally due until the beginning of the next fiscal year (October 1, 1985, for FY-86), the lack of assurance of interim support until later in 1985 could contribute to an environment of uncertainty that will hamper UNESCO operations. Different forms of congressional appropriations will have to be found to respond to this extraordinary situation. There is an urgent need to move ahead in the United States with establishment of a joint governmental and nongovernmental mechanism to cope with the situation both in the short and longer term.

4. Disruptions in U.S. Scientific Participation. Uncertainties regarding funding will be disruptive to the many U.S. groups participating in ongoing UNESCO science activities. Some reprogramming of nationally available resources will be necessary. With regard to possible losses in access to data and research localities, it is difficult at this stage to make definitive judgments. The situation will depend, in part, on the degree to which U.S. scientists in their personal capacity would continue to be invited to participate in activities directly under the purview of UNESCO. A decrease in the number of such invitations will have an adverse impact on the quality of UNESCO science projects and consequently also on the benefit of such projects to the U.S. scientific community.

5. Disruptions in the International Research System. A period of uncertainty stemming from withdrawal will be disruptive to international cooperation in science and may strain U.S. scientific relations with peer groups in other countries. U.S. participation in multilateral activities and in the planning of new projects may be affected. Some readjustment and reappraisal of U.S. participation and leadership in international scientific cooperation may occur.

6. Capabilities of NGOs. Once alternative interim arrangements have been put into place, they will need to be evaluated and assessed in terms of how effectively NGOs are able to handle the new and more substantial responsibilities they may have assumed. It is clear that some NGOs as currently structured will have serious difficulties in carrying out greatly expanded roles. Thus, there will prevail, even in the second half of the decade, considerable uncertainty about how proposed new responsibilities can be matched to the capabilities of existing institutions.

7. Need for Enhanced U.S. Scientific Community Involvement. Those science programs that involve direct linkages with the concerned professional communities tend to be the most effective. During the coming months, it will be especially important to maintain and strengthen governmental and nongovernmental interactions, not only in the conduct of present programs, but especially in terms of planning and implementation of future international multilateral science activities.

ALTERNATIVE INTERIM ARRANGEMENTS

The alternative arrangements proposed in this report are aimed at ensuring meaningful U.S. involvement in important UNESCO science activities if the United States withdraws from official membership in the organization at the end of 1984. This report does not address the wider ranging issue of an overall alternative approach to the U.S. role in multilateral science cooperation for the rest of this century. There is clearly an urgent need to do so.

For the major intergovernmental research programs and for other selected science activities in which the United States is involved, utilization of a grant to UNESCO is suggested. For other important science areas of UNESCO activity, support of cooperating organizations is proposed, usually as may be recommended by an appropriate U.S. agent. Thus, it is suggested that a significant portion of the available resources be earmarked for relevant U.S. institutions (governmental and in some cases nongovernmental), which would have important oversight and managerial responsibilities for U.S. participation in UNESCO programs in their particular areas of competence.

The consideration of alternative interim arrangements leads to a number of conclusions, poses a number of unknowns, and raises several issues that require further policy analysis:

1. No Viable Overall Alternative. There is at present no viable overall alternative for UNESCO's science programs. Furthermore, there is no simple set of alternative interim arrangements that will ensure future U.S. collaboration with current or future UNESCO projects. In fact, withdrawal will undoubtedly lead to a multiplicity of channels that may be more or less effective. Whatever alternative mechanisms are implemented, it is extremely important to ensure continuity of funding. Otherwise, irreversible damage to valuable current programs is inevitable. Proposing alternative mechanisms is also complicated by the possibility that the United States may rejoin UNESCO at a later date if appropriate reforms are achieved.

2. Danger of Fragmentation. Putting in place a variety of interim alternative arrangements for future funding and participation will result in a fragmentation of scientific and administrative relations. Moreover, there will be serious substantive, managerial, and financial costs that cannot be underestimated. However, the fact that UNESCO's activities include both development assistance programs and programs aimed at the advancement of scientific research makes the search for a single alternative extremely difficult, if not impossible.

3. Specific Program Support to UNESCO. In many cases, the most attractive and administratively simple alternative might be specific program support to UNESCO through the mechanism of Funds-in-Trust or donations. This type of contribution would be appropriate for large portions of the IOC, MAB, IGCP, and the IHP. It suffers, however, from the fact that there may be a lack of direct oversight (except for the IOC where the United States plans to retain membership). Perhaps some

form of periodic accountability could be required. At the very least, a strong focal point in the U.S. government will be extremely important. Mechanisms for program support to UNESCO will require clarification of the possibilities and limitations involved, particularly in terms of the U.S. role in program planning and implementation.

4. Cooperating Organizations. Subject to acceptance by cooperating organizations, it is relatively simple to propose alternative interim arrangements for those activities and programs for which well-established mechanisms of collaboration are in place, as is the case with ICSU, IBRO, ICRO, etc. One special situation is the Intergovernmental Oceanographic Commission (IOC), in which the United States can retain full membership even in the event of withdrawal from UNESCO. Other arrangements are primarily based on the current active advisory and managerial roles played by international nongovernmental scientific organizations (NGOs) in UNESCO-sponsored activities. However, there may be serious problems in planning new global observational programs that require intergovernmental cooperation and oversight.

5. Need for Consultations. The suggestion or designation of another intergovernmental or nongovernmental organization to act in the interim, on behalf of U.S. scientific interests requires careful negotiations and understandings that are agreed to by all sides involved. This will be a complex process in which the issues will need to be clarified over time. Also, there is as yet no way to judge how colleagues from other countries will react to U.S. proposals for alternative mechanisms of support for UNESCO science programs.

6. Role of ICSU. With respect to NGOs, the International Council of Scientific Unions (ICSU) might be considered the most logical candidate to facilitate U.S. participation in some well-established programs. ICSU could, for instance, be asked to oversee some $1.5 million of U.S. funds in order to ensure continuing U.S. participation and support of current UNESCO-sponsored activities in Major Program VI (Natural Sciences). There are possibilities of doubling this level if ICSU were to assume additional responsibilities with respect to the International Hydrological Program, the Man and the Biosphere Program, and certain aspects of the earth sciences activities. ICSU's willingness and capacity, structural and administrative, to assume this level of responsibility, however, will need to be thoroughly considered and discussed by all parties. In the longer term, ICSU represents an important, existing potential for enhancing international science cooperation.

7. U.S. Management Responsibilities. It is tempting to try to identify a single U.S. government agency to provide oversight, management, and funding for U.S. participation in the science activities of UNESCO. The National Science Foundation (NSF) is one obvious possibility, although the NSF has not been especially active in the area of multilateral science cooperation. Also, some adjustments in existing NSF procedures would have to be made. In addition, there are some

agencies, such as the U.S. Geological Survey (USGS), which have active and direct roles in current UNESCO programs. Nonetheless, given the uncertainties of using other international organizations, an enhanced role by U.S. agencies seems inevitable, particularly at this first stage of nonmembership in UNESCO.

Clearly, there must be a nongovernmental focus as well. A complementary, working relationship between a governmental entity, such as the NSF, and a nongovernmental one, such as the National Research Council, would provide a mutually beneficial, solid foundation for expanded and strengthened American participation in international science. Moreover, such a relationship might reinforce a parallel one at the international level between UNESCO and ICSU.

8. Next Step. The NRC assessment has profited from several hundred communications from American scientists and engineers who have participated directly, often in leadership roles, in the science activities of UNESCO. The resulting information base presents a useful starting point for a deeper analysis, an analysis which will require considerably more time and the involvement of a much broader segment of the international scientific community. In order that such an analysis be of value, it must necessarily relate UNESCO programs to those of other multilateral institutions having science as a significant part of their mandate.

9. The Future of International Institutions for Science Cooperation. This review strongly suggests that considerable thought needs to be given to the kinds of multilateral entities that might be established to deal with the contemporary requirements of international science cooperation. Before making premature judgments on selecting or formulating such entities, it is essential to consult with colleagues here and abroad regarding their concerns, interests, and aspirations. The time may have come to begin discussions of new models for facilitating international cooperation both for the advancement of scientific knowledge and for strengthening infrastructures in developing countries. Lessons can be learned from an examination of current practicies (e.g., IOC, ICSU/UNESCO, MAB) directed toward enhancing the complementary capabilities of nongovernmental and governmental organizations.

Science and technology are no longer secondary interests of governments; they have become primary influences on health, economic development, environmental conditions, and all other aspects of modern society. In view of this complex and pervasive state of science in the world today, it may be necessary in the longer term to consider radical institutional changes ranging from establishment of a separate entity for international science to a complete reorganization and restructuring of present institutions.

CAPSULE SUMMARY OF UNESCO SCIENCE PROGRAM: ASSESSMENTS, INTERIM ARRANGEMENTS, AND PROPOSED FUNDING LEVELS

Program	Preliminary Assessment	Interim Arrangement*	Proposed Funding**
Earth Sciences and Resources; Natural Hazards	High quality program that includes 80-nation IGCP, a program of keen interest to U.S. earth scientists, as well as important projects related to interdisciplinary studies of the earth's crust and data/mapping work. Activities related to hazard assessment and risk mitigation are also useful.	Specific program support to UNESCO to continue U.S. participation in IGCP ($200,000), and other activities ($650,000). Additional resources to cooperating international organizations, governmental and nongovernmental, on recommendation of a U.S. agency such as USGS ($1,150,000).	$2,000,000
Water Resources	U.S. scientists prominent in planning and implementation of 100+ nation IHP, which is concerned with water resource management, particularly in arid and semi-arid regions, and humid tropical regions. U.S. scientists make significant technical contributions and value UNESCO's facilitative role in fostering interactions with foreign colleagues.	Specific program support to UNESCO to cover U.S. share of costs ($750,000) plus support to a U.S. agency such as USGS (Committee on Scientific Hydrology) for additional related activities ($250,000).	$1,000,000
The Ocean and Its Resources	UNESCO is an important mechanism for international cooperative marine science activities. U.S. interest high in oceanographic components of the WCRP, IGOSS, and IODE activities of the IOC. U.S. scientists also involved in studies of marine environment and the continental margin, as well as work on coastal island systems under MAB.	Specific program support to UNESCO for the U.S. share of the current costs ($1,400,000), with additional resources for U.S. oversight and international research activities administered by U.S.agencies (such as NSF and/or PIPICO and USMAB) that would emphasize utilization of cooperating organizations ($1,100,000).	$2,500,000

Man and the Biosphere Program	U.S. scientists active in 105-nation MAB, which is concerned with integrated approaches to natural resource management in 4 areas: humid tropics, arid and semi-arid zones, urban systems, and conservation. UNESCO has facilitated global interations in this interdisciplinary program. UNESCO has recently responded to pleas to improve management structure. USMAB funding problems require resolution.	Specific program support to UNESCO ($900,000) plus support of USMAB-managed activities, including secondment of a U.S. science administrator to the UNESCO Secretariat and increased utilization of NGOs ($1,100,000).	$2,000,000
Natural Sciences; support of ICSU and other NGOs	Important support to research, training, and international cooperation in physical and life sciences. Includes support for NGOs working at the frontiers of science plus development of national infrastructures. Many U.S. scientists active through NGOs.	Direct support to NGOs, via ICSU, for UNESCO-related science activities ($1,500,000) and support through a U.S. agency, such as NSF, for additional related activities ($300,000).	$1,800,000
Informatics, Applied Microbiology, and Renewable Energy	All three areas are important, but except for applied microbiology and certain training aspects in the informatics area, the most appropriate forum may not be UNESCO.	Informatics: Funding through a U.S. agency, such as NSF, with possible use of UN agencies such as UNIDO or UNDP on advice of U.S. professional organizations ($500,000). Applied Microbiology: Direct contribution to UNESCO for MIRCENS ($125,000), plus additional support for related activities via a U.S. agency, such as NSF ($125,000). Renewable Energy: Support activities via UNDP ($250,000).	$1,000,000

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*The consideration of UNESCO subprograms in Chapter 4 proposes more than one alternative interim arrangement. Only the preferred alternative is included in this summary presentation.

**The proposed figures include overhead costs.

Program	Preliminary Assessment	Interim Arrangement	Proposed Funding
Engineering Sciences	Emphasis is on training and development of engineering curricula; program management by UNESCO, but mostly financed by UNDP. Limited involvement by U.S. engineers in these UNESCO-directed activities.	Funding through a U.S. agency, such as NSF, to U.S. engineering societies and universities for work with international and regional professional organizations.	$700,000
Social Sciences	International social science mechanisms are weak and underfunded. UNESCO's program needs significant reform in content and management. U.S. social scientists have had limited involvement in UNESCO projects.	Funding through a U.S. agency, such as NSF, to support international cooperative social science research and training activities. U.S. share of subventions to ISSC should be maintained.	$1,000,000
Science Policy	A minor program with little, if any, U.S. participation; subject is of general interest (S&T planning and impact of S&T on society), but UNESCO program not particularly productive.	Funding through a U.S. agency (e.g., NSF) to support international science policy activities through U.S. institutions, possibly utilizing such organizations as OECD, OAS, ASEAN.	$750,000
		TOTAL	$12,750,000
		OVERALL U.S. MANAGEMENT OF SCIENCE PROGRAM	$1,250,000
		GRAND TOTAL	$14,000,000

UNESCO SCIENCE PROGRAMS

SUMMARY OF SUGGESTED FUNDING LEVELS ($000) AND ALTERNATIVE INTERIM ARRANGEMENTS

		CURRENT ANNUAL PROGRAM	U.S. SHARE	ALTERNATIVE*	PROPOSED U.S. FUNDING
VI.	THE SCIENCES AND THEIR APPLICATION TO DEVELOPMENT				
VI.1	Natural Sciences	6,800	1,700	NGOs (e.g., ICSU, ICRO)	1,500
				NSF/NRC/AID	300
VI.2	Engineering Sciences	4,600	1,150	NSF/NRC/AID	700
VI.3	Key Areas--Informatics, Microbiology Renewable Energy	6,000	1,500	NSF/NRC/AID	625
				FIT**	125
				GOs	250
VI.4-5	Social and Human Science	7,800	1,950	NSF/NRC	1,000
	SUBTOTAL VI	(25,200)	(6,300)		(4,500)
IX.	SCIENCE, TECHNOLOGY AND SOCIETY	6,200	1,550	NSF/NRC/AID	750
	SUBTOTAL IX	(6,200)	(1,550)		(750)
X.	THE HUMAN ENVIRONMENT & TERRESTRIAL & MARINE RESOURCES				
X.1	Earth's Crust	3,500	875	FIT	600
				USGS/NGOs (e.g., IUGS)	900
X.2	Natural Hazards	1,500	375	FIT	250
				USGS/NGOs (e.g., IUGS), IGOs (e.g., UNDRO)	250
X.3	Water Resources	4,400	1,100	FIT	750
				USGS	250
X.4-5	Marine Sciences	9,000	2,250	FIT	1,400
				NSF/PIPICO/USMAB	1,100
X.6-9	Ecological Sciences, MAB	7,400	1,850	FIT	900
				SECONDMENT	150
				USMAB	950
	SUBTOTAL X	(25,800)	(6,450)		(7,500)
	TOTAL VI, IX, & X	57,200	14,300		12,750
	U.S. OVERSIGHT				1,250
	TOTAL				14,000

*The consideration of UNESCO subprograms in Chapter 4 proposes more than one alternative interim arrangement. The preferred alternative is included in this summary presentation.

**Funds-in-Trust = direct grant to UNESCO for specific activities.

Chapter 4

ASSESSMENTS AND INTERIM ARRANGEMENTS

INTRODUCTION

This chapter addresses the following UNESCO Major Programs and sub-programs:

VI. The Sciences and Their Application to Development

- Natural Sciences (VI.1); Technology and Engineering (VI.2); Key Areas (VI.3)
- Social and Human Sciences (VI.4); Key Areas (VI.5)

IX. Science, Technology and Society

- Relations (IX.1); S&T Policies (IX.2)

X. The Human Environment and Terrestrial and Marine Resources

- Earth Sciences and Resources (X.1); Natural Hazards (X.2)
- Water Resources (X.3)
- Oceans and Resources (X.4); Coastal and Island Regions (X.5)
- Environmental Sciences: Man and the Biosphere (X.6-X.9)

Comments on each of the above areas of activity are presented in three parts: (1) a program assessment, including potential impacts of a U.S. withdrawal, (2) suggested alternatives, and (3) a summary of preliminary findings.

Budgetary information is provided to give an order of magnitude of resources invested in the various activities (including particularly the current U.S. contribution of 25 percent). Frequently there is a significant multiplier effect in UNESCO-supported activities due to the contributions from national and other sources.

With respect to budgetary considerations it is important to note the following:

- Budgetary amounts for the various UNESCO activities include three elements: project costs, staff costs, and overhead. In UNESCO usage, program costs are the total of project and staff costs.

- One cannot predict how UNESCO will redistribute its budgetary resources given a 25 percent reduction due to the U.S. withdrawal. It is likely that certain areas may be affected more than others; however, for this analysis, a 25 percent cut across the board has been assumed.

- It is assumed that the funds available to support U.S. scientific collaboration in current UNESCO-sponsored science programs will be in the range of the present U.S. contributions to UNESCO for science, that is, about $14 million per year.

- Preliminary budgetary proposals have been included in program assessments as part of the process of understanding the implications of alternative interim arrangements. These proposals are intended to be helpful in planning and preparing budgets for future U.S. participation.

Several factors have been taken into consideration in suggesting alternatives to permit continued U.S. participation in UNESCO programs once the United States ceases to be a member (see Chapter 2). For certain activities of particularly high quality, augmented levels of resources are recommended. In other instances, reductions are proposed. In a few areas, questions are raised regarding UNESCO's involvement. Considerable attention is given to U.S. oversight requirements to properly plan, guide, and evaluate U.S. participation in multilateral scientific activities whatever the U.S. relation to UNESCO.

As noted, the current annual level of U.S. support of UNESCO science is about $14 million. The present review of UNESCO science programs results in a suggested support level of $12 to $13 million per year. It is important to underscore that oversight/managerial responsibilities on the U.S. side will require significant additional funding and possible adjustment in personnel policies within government agencies to administer these programs. It is proposed that $2 to $3 million per year be budgeted for the support of (a) U.S. oversight responsibilities, (b) new initiatives on development of global observational programs, and (c) resources for increased opportunities for U.S. scientists to participate in multilateral science programs, including scientific meetings sponsored by the international scientific unions and other nongovernmental scientific organizations. These budgetary amounts are, at best, first approximations that will need to be considerably refined.

MAJOR PROGRAM VI:
THE SCIENCES AND THEIR APPLICATION TO DEVELOPMENT

Natural Sciences; Technology and Engineering; Key Areas (VI.1, VI.2, VI.3)

This portion of Major Program VI includes UNESCO-sponsored activities in the natural (physical and life) sciences and engineering. The quality of effort and the role of UNESCO vary considerably among the program activities--these are addressed within the individual assessments for subprograms VI.1, VI.2, and VI.3. The current annual budget for program costs (projects and staff) plus overhead is approximately $17.3 million--the U.S. share (25 percent) would be $4.3 million. Restricting attention to only program costs ($10.5 million), the U.S. share (25 percent) would be about $2.6 million per year. Other "outside" sources of support total more than $17.8 million per year.

It is proposed that support be provided UNESCO-related program activities through a variety of alternative interim arrangements at an indicative annual budget of $3.5 million per year.

Research, Training, and International Cooperation in the Natural Sciences (VI.1)

Assessment/Potential Impacts

This program area, involving international cooperative activities directed toward the advancement of knowledge and the strengthening of national research and training capabilities, is important to the health of world science. Program activities include a variety of advanced research and training courses in mathematics, physics, chemistry, and biology either on a regional basis or at international centers; university curricula development projects in the sciences; and support of regional and international scientific cooperation through subventions and grants to NGOs and universities. The long-standing collaborative arrangement between UNESCO and nongovernmental science organizations permits the building of more effective global networks of researchers at the frontiers of science; this leads, in turn, to fostering the development of infrastructures in the Third World. At the same time, increasing attention is being given to supporting activities in the regular UNESCO science programs to meet the specific needs of developing countries.

The current annual UNESCO budget for program costs (projects and staff) plus overhead is approximately $6.8 million; of this, the U.S. share would be $1.7 million. Considering program costs only ($4.1 million), the U.S. share would be about $1 million per year. Other "outside" sources of support, primarily UNDP, contribute more than $4.9 million per year, or somewhat more than the total for the regular UNESCO program.

This program area contains a large number of training and support activities involving the scientific unions and international centers such as the Trieste International Center for Theoretical Physics (ICTP), and the Johns Hopkins School of Hygiene and Public Health. Specialized organizations such as the International Cell Research Organization (ICRO), the International Brain Research Organization (IBRO), and the newly formed International Organization for Chemistry for Development (IOCD) provide advanced research training and services in support of the needs of the developing world. A large number of U.S. scientists are involved as teachers in an environment that encourages learning on the part of all participants.

Given the role of the International Council of Scientific Unions (ICSU) in the advancement of basic scientific research and in bringing together the leading scientists of both developed and developing countries, many UNESCO activities critically depend on ICSU. Therefore, the UNESCO subvention (about $540,000 per year) to ICSU and the support of specialized activities by ICSU's constituent bodies are of particular importance.

The above-named activities and organizations depend to varying degrees on UNESCO support, but such support (largely catalytic) is particularly important for training activities in the developing world since UNESCO provides the intergovernmental link to countries and regions having limited affiliation with nongovernmental scientific associations. It is true that these collaborating organizations can receive funds from a variety of sources and do so. It is also true that limited administrative structures within NGOs proscribe their capacity to greatly augment program responsibilities were they to choose to do so. However, the nongovernmental scientific organizations and associations could provide a great deal more advice and assistance to UNESCO projects, thus increasing their quality and efficiency. Therefore, staff and administrative costs for NGOs need to be included in consideration of alternative interim arrangements. Furthermore, there would be significant U.S. oversight costs to be borne by an appropriate organization sensitive to U.S. interests (NSF and/or NRC) in channeling support to a variety of organizations and project activities.

Alternatives

A preferred interim arrangement is to provide the current level of U.S. contributions to UNESCO program costs in this area ($1.1 million per year) to the relevant nongovernmental organizations through ICSU. In fact, support of NGO-administered activities should be augmented to a level of $1.5 million per year. This level might include the seconding of a science administrator to ICSU. An additional provision of $300,000 for bilateral programs involving U.S. professional groups and universities is suggested, raising the total to $1.8 million per year. All of these arrangements would require agreements with the organizations concerned; support levels would have to include appropriate managerial, oversight, and overhead costs, which could be significant.

A second option for alternative support of these program activities would be an annual contribution to UNESCO (Funds-in-Trust, donations, etc.) for the U.S. share (25 percent) of regular program costs in this area, plus an estimated 10 percent overhead charge, or a total of $1.1 million. In addition, it is recommended that about $700,000 be provided to selected multilateral science activities through grants to the relevant nongovernmental scientific organizations. Such augmented support would raise the total level of support of VI.1 activities to $1.8 million per year, or about the same as the present U.S. contribution.

Preliminary Findings

1. UNESCO provides significant support to research, training, and international cooperation in the natural sciences. Beyond the subvention to ICSU, of importance to all countries, this program provides valuable advanced training through regional and international projects directed toward the needs of developing countries.

2. UNESCO provides a critical intergovernmental link to these developing countries. But these UNESCO-sponsored projects also depend on substantive contributions from the advanced countries primarily through the nongovernmental scientific organizations, particularly ICSU and its bodies. U.S. support of UNESCO-related scientific projects could be provided to nongovernmental organizations through ICSU. U.S. scientists would probably be able to maintain their current level of participation in these programs through the nongovernmental organizations.

3. These international cooperative activities could be complemented through grants to U.S. universities and professional groups.

4. It is important to establish and support an oversight capability within a body sensitive to U.S. interests, such as NSF and/or NRC. Certain aspects of these programs are relevant to the interests of the Agency for International Development (AID). Administrative overhead costs will be significant.

5. The overall record of VI.1 activities is reasonably good; the program has been of service to UNESCO Member States and to NGOs. With improved management, even further contributions can be foreseen and therefore this area is a candidate for increased funding.

Research, Training, and International Cooperation in Technology and the Engineering Sciences (VI.2)

Assessment/Potential Impacts

This program area is directed toward the improvement of institutional infrastructures in developing countries in the fields of engineering sciences and technology with particular emphasis given to meteorology, materials testing, quality control, data processing, standardization, and technical information services. The major thrust of the program is training, the development of engineering curricula through a variety of activities in the advanced countries, regional cooperation, and strengthening of national research and training infrastructures. The current annual UNESCO budget for program costs (projects and staff) plus overhead is approximately $4.6 million--the U.S. share is $1.2 million. Considering program costs only ($2.8 million), the U.S. share is about $700,000 per year. Other "outside" sources of support in this area, primarily UNDP and

Funds-in-Trust, provide more than $11.6 million per year or about four times the magnitude of the regular UNESCO program.

This program area includes a large number of support activities involving international engineering societies and organizations, as well as national centers in the advanced countries providing special training to meet the needs of the developing world. There are important interactions with UN-financed programs in support of strengthening technical and engineering training linked to specific development projects in the nations concerned. As far as UNESCO-directed activities are involved, there has been apparently limited participation from the U.S. technical/engineering community (no U.S. universities are involved in the provision of training needs). Considerably more analysis is required to understand the reasons for this situation. Presumably the U.S. engineering professions could contribute on a multilateral basis, particularly in the area of strengthening engineering curricula development and training of faculty. Significant levels of support for engineering sciences are provided from other sources, particularly UNDP. UNESCO plays a major role in the management of these funds, and with a U.S. withdrawal from UNESCO, there would be even less opportunity to influence their utilization of these funds.

Certain aspects of the program dealing with industrial policy and the provision of supporting technical services might be more appropriately managed by other UN bodies, such as the United Nations Industrial Development Organization (UNIDO). The UNESCO role should be directed more toward providing guidance in the development of engineering curricula and training of faculty.

Alternatives

U.S. support of UNESCO program costs in this important area of the promotion of engineering sciences is $700,000 per year. Instead of contributing funds directly to UNESCO, it is proposed that this level of resources, under monitoring by an appropriate body sensitive to U.S. interests (NSF and/or NRC), be provided through grants to U.S. engineering societies and universities working closely with international and regional professional organizations such as the World Federation of Engineering Organizations (WFEO). The objective would be to strengthen the involvement of the U.S. engineering community in UNESCO and in other UN engineering training and curriculum development activities.

A second option would involve direct support at a level of $350,000 per year for targeted activities within UN agencies such as UNDP, UNIDO, and the the UN Financing System for Science and Technology for Development. Support of engineering education activities to reinforce UNESCO projects could be provided at a level of $350,000 per year to U.S. professional societies and universities.

It is important to note that proposed levels of resources to be devoted to these activities would have to include appropriate managerial, oversight, and overhead costs.

Preliminary Findings

1. There has been only limited interaction with U.S. engineering societies and universities in this area of UNESCO interests. UNESCO has broadened its engineering interests to intersect with responsibilities of other UN organizations such as UNIDO. UNESCO should concentrate its efforts on engineering education.

2. As an alternative interim arrangement, U.S. engineering societies and universities could provide significant contributions to UNESCO-related educational activities through regional and international professional organizations such as the World Federation of Engineering Organizations (WFEO). A second alternative for supporting these activities would involve other UN organizations such as UNDP, UNIDO, and the UN Financing System.

3. It is important to establish an oversight capability within a body sensitive to U.S. interests, such as NSF and/or NRC, working with U.S. professional societies and engineering institutions.

Research, Training, and International Cooperation in Key Areas in Science and Technology (VI.3)

Assessment/Potential Impacts

This program area is directed toward the dissemination of technologies in informatics (information processing, systems development), applied microbiology (including biotechnology), and use of renewable energy sources. The current annual UNESCO budget for program costs (projects and staff) plus overhead is approximately $6 million--the U.S. share is $1.5 million. Restricting attention to program costs ($3.6 million), the U.S. share is about $900,000 per year. Other "outside" sources of program support provide a total $1.25 million per year.

Special attention has been devoted to these three rapidly developing fields because of their significance to the economic and social development of all countries and particularly because of the need to help developing countries master and effectively exploit such technologies for their national and regional benefit. UNESCO sponsors and supports important training activities, provides advisory services to assist the development of research policies and their infrastructures, and promotes the establishment of regional and global networks of research training and exchange of science and technology (S&T) data and information. Since there are other UN organizations charged with promoting applications and industrial development in some of these areas, one might question the wisdom of UNESCO's assuming responsibilities in many aspects of informatics and the renewable energy resource sector. International collaboration in all of these sectors merits strong encouragement; UNESCO may not be the most suitable or effective instrument.

With respect to informatics, UNESCO-related activities should be concentrated in work pertaining to training and much more limited advisory services for the development of strategies and definition of acquisition needs. A number of options are available to forward these latter interests outside UNESCO.

The UNESCO-sponsored activities in the area of applied microbiology and biotechnology are of particular quality--they are cost-effective and worthy of encouragement. It is recommended that serious attention be given to supporting the further development and strengthening of Microbiological Resources Centers (MIRCENs)* and their interactions in support of global and particularly of developing country interests. A modest increase in support of this work is proposed.

The renewable energy program should be examined in light of the suitability of other intergovernmental agencies concerned with energy R&D, as well as in the light of leadership that could be provided by U.S. institutions. It is proposed that modest support be provided for renewable energy activities through other multilateral institutions or through U.S. nationally managed programs designed to meet the needs of developing countries.

In the short term, the impact on U.S. interests of a U.S. withdrawal from UNESCO in these areas would be minimal--it is likely that U.S. scientists and engineers would continue to be invited on a personal basis to participate in activities pertaining to these three fields, particularly informatics and microbiology. In the long term, both U.S. interests and UNESCO capabilities would be harmed--the United States from diminished access to the global microbiological community, UNESCO programs from the loss of the considerable U.S. technological "know how" that has been developed in these three areas of concern.

Alternatives

In proposing alternatives, the considerations are different in each of the three areas. With respect to informatics, support is suggested to U.S. institutions via NSF ($500,000). In the microbiology area, support is also proposed to U.S. institutions via NSF ($125,000) in combination with direct support to MIRCENs via Funds-in-Trust ($125,000). Support of work on renewable energy sources could be provided directly to other UN agencies such as UNDP or UNIDO ($250,000). The total proposed level of support for all three areas is $1 million per year.

Another option is to provide support of informatics via Funds-in-Trust; MIRCENs via ICSU or ICRO and U.S. institutions; and renewable energy via U.S. institutions.

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*There are centers throughout the world; three are in the United States.

Preliminary Findings

1. UNESCO provides valuable support of the Microbiological Resources Centers (MIRCENs). The United States should consider increasing support of these high-quality activities.

2. Support of informatics projects should be limited to training and some advisory services for the development of strategies and definition of acquisition needs. Future U.S. support should be provided through U.S. institutions which may wish to utilize UN agencies (e.g., UNIDO or UNDP) and the International Federation of Information Processing (IFIP). Oversight by a U.S. body such as the Association for Computing Machinery (ACM) should be considered.

3. Modest support of work on renewable energy sources should be channeled to other UN agencies (e.g., UNDP) with close oversight by an appropriate U.S. body sensitive to U.S. interests.

4. The proposed alternative interim arrangements suggested above probably provide more direct oversight of substantive activities than is currently the case; however, the administrative overhead costs cannot be ignored.

MAJOR PROGRAM VI: THE SCIENCES AND THEIR APPLICATION TO DEVELOPMENT

Social and Human Sciences; Key Areas (VI.4 and VI.5)

Assessment/Potential Impacts

The purpose of VI.4 activities is to develop the social and human sciences by strengthening national potential for university and postgraduate training and research, regional cooperation, and international cooperation--the last through support to NGOs and subventions to the International Social Science Council (ISSC) and the International Committee for Social Science Information and Documentation (ICSSD).

Program VI.5 activities are directed toward improving education and advanced training in selected key areas such as history, geography, linguistics, anthropology, and the administrative and management sciences--with special attention to work and leisure activities, interdisciplinary cooperation for the study of man, and studies on the status of women. The current annual UNESCO budget for VI.4 and VI.5 program costs (projects and staff) plus overhead is approximately $7.8 million--the U.S. share is about $1.9 million. Restricting attention to program costs ($4.7 million per year), the U.S. share is about $1.2 million per year. Other sources of support in this area total $263,000 per year which are insignificant with respect to regular program support.

There is no way to know with certainty the actual extent to which the U.S. social science community benefits from participation in UNESCO.

On the level of the individual researcher, a number of U.S. social scientists interviewed indicated that the level of U.S. participation was "embarrassingly low." Among the reasons suggested were: (1) insistence within UNESCO upon country-specific "microprojects" as defined by the social science community within the country in question, (2) resistance to the global project approach, (3) inability of the U.S. National Commission for UNESCO to involve U.S. researchers, and (4) inability of official U.S. representatives in Paris to communicate with the U.S. social science community. On the other hand, there are issues under debate within the UNESCO context that are of major concern to the U.S. social science community.

Perhaps the most frequently cited example is the methodological debate that has been ongoing since the mid-1970s about the "indigenization" of social science, which is the contention of some developing countries that social science as it has developed in the West has predominantly served the interests of Western countries. It is argued on this basis that social science research in a developing country should be undertaken only by nationals of that country (or only with limited access by foreign researchers) and from a point of view that promotes their national interest. Here, according to some, lies the danger, because they believe that such a methodological prescription is not value free and "veers dangerously toward ideology." Clearly, if the United States is absent from this debate within UNESCO, it will be able to do very little to prevent this view from prevailing, with all of its implications for the direction, vitality, and legitimacy of international research in such fields as anthropology, sociology, and political science.

While U.S. researchers do not participate in UNESCO programs in a major way, withdrawal would cause the United States, as the single largest country contributor, to lose its ability to influence the substantive content of the organization's programs. U.S. social scientists undoubtedly would still be able to obtain UNESCO publications and possibly might even be able to participate in research projects, colloquia, and symposia on an individual basis. But, given the fact that the U.S. social science community is the largest and one of the most highly developed in the world, there would be no direct means of representing its interests in the design or development of programs. Similarly, the United States would lose even its present limited ability to influence the direction of ongoing UNESCO programs, particularly those in current "sensitive" areas, such as arms control and human rights.

Most of the social scientists interviewed were in agreement that withdrawal would have a negligible impact on current research projects ongoing within the U.S. academic community. However, there was also a good deal of speculation that future access by U.S. researchers to field sites in some Third World countries might well be constrained, either in direct retribution for the U.S. withdrawal or because the work was being conducted under UNESCO auspices. Some also suggested that U.S. researchers might find it more difficult to gain access to social science networks in the East European countries, since UNESCO is the principal forum for such contacts.

It was pointed out that many of the nongovernmental organizations dealing with social science depend in some measure on UNESCO subvention for their survival. Thus, organizations such as the International Political Science Association (IPSA) and others might become financially vulnerable and more limited in their substantive activities if their UNESCO support is reduced. But perhaps the most severe financial impact would be felt among the Third World countries (particularly in Africa) where UNESCO support for social science research accounts for a major portion of the work ongoing in those fields. Concerns about "indigenization" not withstanding, the United States would suffer, along with the remainder of the global social science community, if work in these countries were to be diminished through lack of support or if international communication of results were to be reduced.

The benefits to the U.S. social science community* of membership in UNESCO are both direct and indirect. Direct benefits accrue from the limited number of research projects and research colloquia and symposia in which U.S. scholars participate. Access is gained through these activities both to data and to collegial networks, i.e., "invisible colleges," throughout the world. Through UNESCO colloquia and symposia, scholars are able to exchange ideas, concepts, and theories that ultimately promote the advancement of their disciplines.

The Social Science Committee of the U.S. National Commission for UNESCO has urged repeatedly that UNESCO develop a more vigorous research program, similar to that which existed shortly after its creation when it sponsored research on international tensions and on racism. The committee has suggested that UNESCO inaugurate a major program on migration, which has important implications both for social science theory and for policy. Expansion or development of such substantive research foci would add directly to the benefits derived by the U.S. social science community.

U.S. social scientists also derive benefit from several UNESCO publications, including the World List of Social Science Periodicals and the World Directory of Social Science Institutions. It is reported that scholars make use of UNESCO publications in substantive areas such as the impact of new communication technologies on education, communications in developing countries, and the status of women. Some scholars apparently also find useful some issues of the UNESCO-edited Journal of International Social Science,** although there are questions about its overall quality and the cost of its subvention.

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*Thinking in this section benefitted from the ideas of Harold K. Jacobson presented in a statement before the Subcommittee on Human Rights and International Organizations and International Operations of the Committee on Foreign Affairs, U.S. House of Representatives, April 26, 1984.

**It should be noted that the editor of the Journal of International Social Science, Peter Lengyel, resigned recently due to unacceptable constraints imposed by the UNESCO Secretariat.

Indirect benefits of U.S. participation relate to the importance of promoting the worldwide development of the state of the art in global social science research, particularly with respect to the Third World. The argument here rests on the importance of gaining access to data and on the ability to exchange and/or test new ideas, concepts, and theories. It has also been suggested that another indirect benefit of a vigorous social science community within a country is the contribution that many of the disciplines can make on the quality of policy debate.

Alternatives

Prospects appear poor for making alternative arrangements for the United States to continue to play a role in UNESCO social science activities while not actually being a part of the organization. Given the limited involvement of the U.S. scholarly community in these programs and the serious methodological questions that have arisen with regard to the "indigenization" of social science research in the Third World, there would appear to be little incentive or justification for utilizing the Funds-in-Trust arrangement. It is conceivable that other UN organizations, such as United Nations Institute for Training and Research (UNITAR), United Nations University (UNU), United Nations Research Institute for Social Development (UNRISD), the International Labor Organization (ILO), the World Bank, or the various UN regional economic commissions (e.g., the Economic Commission for Latin America [ECLA]) might be able to pursue in a very limited way some of the social science activities of UNESCO.* However, this would require that other countries besides the United States also agree to channel funds through these alternative channels, and it raises the real prospect of serious duplication of effort within the UN system. Many of those interviewed for this study expressed skepticism about this approach.

Outside of the UN system, the opportunities for cooperation and collaboration in the social sciences are somewhat limited. While virtually all of the disciplines involved have active professional societies, the international arms of these nongovernmental organizations are generally weak and underfunded. In fact, most depend in some measure on UNESCO for subvention. The U.S. Social Science Research Council does maintain active working relationships around the world, and this mechanism could well provide a basis for bilateral research projects under some circumstances. There is also the International Social Science Council and the Inter-University Consortium for Political and Social Research, both of which historically have been primarily West-West in their orientation but could conceivably be strengthened and expanded to include a Third World component.

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*It is worthy of note that economics is not found under subprogram VI.4-5. Economics comes into the work of UNESCO under Major Program VIII, which is entitled, "Principles, Methods and Strategies of Action for Development."

In the final analysis, the best alternative funding strategy if the United States follows through on its intention to withdraw from UNESCO would be to make the bulk of the funds available either directly to researchers or through the disciplinary professional organizations. Some portion of the funds might be reserved for the International Social Science Council to make up any loss in subvention due to U.S. withdrawal from UNESCO and also to undertake truly multilateral activities.

A logical new institutional focal point for funding international social science research to be carried out by U.S. investigators would be the Directorate of Biological, Behavioral, and Social Sciences (BBS) of the National Science Foundation. While it is possible that BBS might wish to evaluate grant applications and administer such additional funds directly, there may also be some substantive and symbolic value in establishing close collaborative relationships with the Social Science Research Council (SSRC) or the Commission on Behavioral and Social Sciences and Education (CBASSE) of the National Research Council. The substantive benefit to the program of this approach would be access to some of the leading U.S. social science scholars and the substantive input they could provide in determining priorities and direction. They could also provide assistance in strengthening social science research capabilities in developing countries. Moreover, as nongovernmental organizations, both institutions are probably better equipped to arrange site access and other types of scholarly activities--particularly with socialist and certain Third World countries--that might be difficult if initiated by an agency of the federal government. Some portion of the social science funds would need to be applied to staffing and overhead if the SSRC or CBASSE were charged with these new administrative responsibilities.

Preliminary Findings

1. Social science research needs UNESCO because of the links it provides to researchers and facilities world-wide and because most other international mechanisms are weak and underfunded. At the same time, there is need for significant reforms in the focus, direction, and management of UNESCO social science activities. If the U.S. withdrawal is carried out, it will be particularly important to earmark sufficient resources, about $1 million, through the National Science Foundation--and possibly to channel them through the National Research Council, the Social Science Research Council, and the Consortium of Social Science Associations in support of international cooperative social science research and training activities. Failure to do so would represent a serious setback for an already precarious international social science research environment.

2. There has been minimal involvement of the U.S. social science community in UNESCO projects. If the United States withdraws, interested scholars would still be able to obtain UNESCO publications and attend meetings on an individual basis.

3. There would be negligible impact on current U.S. research interests, but perhaps potential problems with future access to field sites in certain countries. Furthermore, a U.S. withdrawal from UNESCO would result in the absence of a U.S. voice in determining the substantive content and future directions of UNESCO social science activities.

4. Although UNESCO projects are a unique and important source of support to developing country interests, there are reservations about the quality of research and training activities, particularly the emphasis on "indigenization," which veers toward ideology. The UNESCO program in support of Third World social science research would be harmed by the loss of U.S. funding.

5. It is important to ensure that the full subvention currently provided by UNESCO to the International Social Science Council is maintained.

6. There are poor possibilities for alternative interim arrangements for supporting these UNESCO-related projects through multilateral channels. On the other hand, enhanced bilateral funding may facilitate new and better opportunities for collaborative research, particularly in the developing world.

MAJOR PROGRAM IX:
SCIENCE, TECHNOLOGY AND SOCIETY

Relations; S&T Policies
(IX.1 and IX.2)

Assessment/Potential Impacts

Subprogram areas IX.1 and IX.2 provide support for a variety of activities directed toward the development of science and technology policy structures and instruments for policy analysis of particular interest to developing countries. There has been concern with respect to the value of some of these efforts. The current annual UNESCO budget for Major Program IX (projects and staff costs) plus overhead is approximately $6.2 million--the U.S. share would be $1.6 million. Restricting attention to program costs ($3.8 million), the U.S. share would be about $960,000 per year. Other sources of support in this area provide a total of $1.7 million per year, or somewhat less than one half of the regular UNESCO program.

The level of visibility of the Program on Science, Technology and Society, and the extent of U.S. participation in it, are perhaps the lowest of any of the programs supported within the UNESCO science budget. A number of U.S. academicians and science policy administrators contacted in connection with this evaluation either had never heard of the program or were only vaguely aware of <u>some</u> of its components. In general, the activities undertaken through this program would appear to be marginal to the interests of both the U.S. government and academic community.

Part of the reason for this low level of interest and involvement is that, unlike most of the other major elements of the UNESCO program, which are mostly disciplinary-based, there is only a very limited constituency for this activity. The subject is of some general interest to governments of developing countries and to the limited academic community concerned either with the planning of science and technology (S&T) policy or with the impact of S&T on society and particularly on economic development. For this reason, the United States derives little direct advantage from participation, except to the extent that it finds it useful to promote better S&T planning and application in the Third World.

The science, technology, and society program was among the earliest initiated by UNESCO, and it is closely associated with those Americans who were involved in the creation of the UN organization at the end of World War II. More recently, the science policy development theme has been criticized as too theoretical and not applied enough to the needs of the Third World. There is also some competition between UNESCO's science policy effort and the work of other multilateral bodies such as the Organisation for Economic Cooperation and Development (OECD) Committee for Science and Technology Policy.

Because the work undertaken within this program is comparatively marginal to U.S. interests, there will be few substantial negative consequences from withdrawal. One negative outcome may be the loss of cross-national knowledge about the science policies of other governments outside the OECD framework. Moreover, to the extent that the United States wishes to influence other governments to adopt its approaches to the development of S&T infrastructure and science policy, an avenue of contact would be closed off.

As a nation at the leading edge of S&T innovation, the United States is at least as concerned about the impact of science and technology on society as any other developed country. To the extent that this concern involves the need to enter into global dialogue with other technologically advanced countries and concerned developing countries, the U.S. withdrawal would deprive this country of one of the international forums available for analysis and discussion of these matters.

Although the Science, Technology, and Society program is of relatively minor consequence in comparison with other UNESCO activities, there are both symbolic and functional benefits to be derived by the United States from remaining a part of this program. At the symbolic level, there is the fact that the United States has had a historical commitment to the activity since the earliest days of UNESCO. Moreover, improving the S&T capabilities of developing countries has been (and remains) a primary development goal of the current administration. A U.S. withdrawal, if uncompensated with other initiatives, could appear to send a mixed message to developing country governments.

The other symbolic value of continuing support for this program has to do with its potential foreign policy benefits. UNESCO offers an opportunity to interact with scientists from countries where contacts with the West are limited only to official channels, and where informal contacts and bilateral relations with the United States are not a current possibility.

On another level, the U.S. museum world has derived benefit from the advisory and consultative function that UNESCO has performed. The U.S. academic community also has benefited from some of the research projects supported under this UNESCO program, including an effort to develop a cross-national typology of science policy issues.

Alternatives

There are certain other UN organizations that could engage in enhanced science policy activities. These include the UN Center for Science and Technology for Development (UNCSTD), which has already focused on some of these issues, and the UN Development Program (UNDP).

The United States could also enhance its participation in multilateral and bilateral associations outside the United Nations. For example, OECD already is engaged in some of the same type of science policy work of concern to UNESCO, although it focuses primarily on policies of its member states. The UN Economic Commission for Europe (ECE) carries out similar work, and other regional organizations such as the Organization of American States (OAS) or the Association of South-East Asian Nations (ASEAN) could also expand their efforts in this area.

The United States, primarily on a bilateral basis, is already involved in cooperative research or action projects related to science policy and the impact of science and technology on society. Projects on the former are supported or conducted by the Agency for International Development and the National Institutes of Health, and on the latter by the National Science Foundation. These programs could be expanded. Another possibility would be working with developing country associations, such as ASEAN, which are involved in technical cooperation.

Finally, there are possibilities that NGO channels might be utilized to promote further work on the development of science and technology infrastructure. For example, the role of the International Council of Scientific Unions (ICSU) could be expanded to include a greater focus on the problem of building scientific infrastructure and coherent science policies in developing countries. In a similar fashion, intellectual attention to the impacts of science and technology on society could be promoted through formal or informal networks that include private foundations and academic centers of excellence with an interest in the problems both here and abroad.

Future funding of these potentially valuable activities will involve new institutional arrangements. With respect to those projects having to do with science policy and/or S&T infrastructure in developing countries, the U.S. Agency for International Development--which already has similar work ongoing--would represent the appropriate venue with possible collaborative arrangements with the National Research Council; particularly its Board on Science and Technology for International Development (BOSTID). In the case of the science, technology, and society projects, the professional oversight responsibility is less obvious, but it may be possible for the NSF Directorate on Scientific, Technological and International Affairs (STIA) to assume responsibility for grantmaking and oversight in this area in collaboration with non-governmental organizations, for example, professional societies and the American Association for the Advancement of Science (AAAS).

In consideration of the resources currently provided these activities and drawing on results in the present review, it is recommended that funding on the order of $750,000 per year be provided overall for Program IX--Science, Technology, and Society activities under the oversight of a U.S. body sensitive to U.S. interests.

Preliminary Findings

1. It is difficult to make a convincing case that the UNESCO program on Science, Technology, and Society occupies a central role either in the operation of UNESCO itself or in the scientific and technological affairs within or between countries. Some of the activities are undoubtedly worth preserving, since they are also a part of the ongoing agenda of other organizations.

2. The current program must be judged relatively marginal to U.S. concerns and therefore deserving of support only insofar as it can be focused efficiently and appropriately on science policy directions and on the development of infrastructures responsive to the needs of developing countries.

3. With respect to a U.S. withdrawal from UNESCO, there might be some loss in learning about scientific policy trends in the developing world, as well as in the opportunity to influence developments. There has been some benefit from UNESCO work on developing a cross-national typology of science policy issues. On the other hand, there has been criticism that much of the UNESCO science policy work is too theoretical.

4. Regional science meetings at the ministerial level can be useful to developing countries by enhancing the prospects for a follow-up and by providing a forum for interaction with the global scientific community. However, such meetings at the European/North American level are of marginal value.

5. Alternative interim arrangements for supporting science policy projects through multilateral channels are feasible (e.g., OECD, ECE, OAS, ASEAN). It is proposed that funding be provided to an appropriate U.S. organization sensitive to U.S. interests (e.g., NSF, AID, NRC) that could support international science policy activities through professional societies and universities.

MAJOR PROGRAM X:
THE HUMAN ENVIRONMENT AND TERRESTRIAL AND MARINE RESOURCES

The Earth Sciences Program
(X.1 and X.2)

Assessment/Potential Impacts

The earth sciences program of UNESCO is of reasonably high quality. The program is organized into a manageable number of discrete, focused projects, which are pursued in an essentially nonpolitical and scientifically competent manner. Program X.1 (The Earth's Crust and its Mineral and Energy Resources) and X.2 (Natural Hazards) are administered by the UNESCO Division of Earth Sciences with an annual combined project cost of $1.4 million; total annual cost of the program, including staff and overhead, is slightly over $5 million. These funds are supplemented by funds from sources outside of UNESCO that total annually about $2.3 million. The U.S. portion of support of the program is about $1.3 million. A significant number of programs in this area are of direct interest and concern to the American scientific community.

The major activity under subprogram X.1 is the International Geological Correlation Program (IGCP), which is unique in its joint sponsorship since 1973 by UNESCO and the International Union of Geological Sciences (IUGS), a nongovernmental organization. About 80 countries now actively participate in the IGCP. As a continuation of a program initiated by the IUGS in 1969 largely due to the efforts of U.S. earth scientists, the IGCP was established to provide a means to formulate worldwide correlations among geological strata. Since that time, the program has been broadened to include other kinds of geological research. Participation by U.S. geologists remains prominent.

More than 300 U.S. scientists are involved in the roughly 50 IGCP working groups that exist at any given time; U.S. scientists have served as leaders of about a dozen projects, with another 30 or so projects having U.S. members serving on international steering committees. U.S. scientists have served continuously on the IGCP Board and its Scientific Committee. U.S. participation has three principal aspects: (1) project activity including scientific research, symposia, field conferences, and the preparation and production of geological maps and reports; (2) Scientific Committee and Board activity, including the provision of expert advice in program development and planning; and (3) support for conferences on earth science topics that might lead to IGCP projects. U.S. participation reflects a combination of governmental/nongovernmental representation, which stems from joint sponsorship and the fact that access to foreign lands requires and involves government agencies and personnel.

While it is anticipated that U.S. representation will continue on both the IGCP Board and the Scientific Committee,* this is by no means

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*U.S. Department of State Memorandum of Law, December 16, 1983.

totally assured. Appointments to the 15-member Board are made by UNESCO in consultation with the president of the IUGS; the Union apparently does have the final say in the appointments to the Scientific Committee. At the end of 1984, the term of the U.S. representative on the IGCP Board will expire. It is assumed that the United States will be asked to nominate a replacement. In fact, the entire leadership of the Board (chairman and the two vice-chairman) will be changing. It will be important for the future direction of the program that qualified persons be appointed.

There is some question as to how well U.S. scientists will be received in UNESCO earth sciences projects following withdrawal. Will U.S. ideas for new projects be approved? Will non-U.S. project leaders continue to seek the involvement of U.S. geologists? These questions cannot be answered at this time, but they are sources of concern among U.S. earth scientists. Even if the short-term answer was positive, in the long term, U.S. withdrawal from official membership in UNESCO could gradually reduce U.S. involvement in IGCP and other components of Program X.1 (e.g., data/mapping activities). Loss of U.S. scientific contributions to the program will inevitably reduce its quality and could have an adverse effect on interactions with Third World colleagues in particular. Over the past 10 years, the IGCP has provided a significant vehicle whereby scientifically valid global research projects are initiated, organized, and supported. Particularly helpful has been the possibility of engaging the cooperation of science communities and governments in Third World countries under the UNESCO flag. The IGCP projects provide useful international contacts for U.S. scientists that may not be available on a bilateral basis or through purely nongovernmental forums.

There are other elements to the UNESCO earth sciences program as well as the IGCP. For example, U.S. scientists have been active in developing new initiatives in the areas of mineral deposit modeling and remote sensing. Without official membership in UNESCO, U.S. association with these activities will have to be via the IUGS route, insofar as UNESCO utilizes the Union in program planning and development. The land-use planning activity is potentially an important one; the IUGS Research and Development Board has developed some specific suggestions for projects in this area. The work of the Lithosphere Commission (ICL) is of high interest to U.S. scientists, and the recent UNESCO General Conference action to increase support of the lithosphere program was warmly received. Publication of data and maps is another area of high interest to U.S. geologists and one in which U.S. participation is important. Finally, in the area of training, the U.S. geological community could be much more actively involved than it has been. U.S. expertise in map production and resource assessment are just two areas in which U.S. input is sought by colleagues in other parts of the world. Thus, there are several non-IGCP areas of the UNESCO earth sciences program in which U.S. geologists either are or could be usefully involved.

The natural hazards program (subprogram X.2) is a technically competent activity from which the U.S. scientific community benefits. U.S. scientists have participated actively in the work of the UNESCO

International Advisory Committee on Earthquake Risk and its regional subcommittees. The UNESCO program provides an opportunity for U.S. earth scientists to visit hazard-prone areas, study and evaluate disaster patterns and risks, and aid in the development of mitigation techniques, which could have a potentially beneficial domestic use. In the absence of formal U.S. membership in UNESCO, U.S. involvement in the natural hazards program is bound to decline, particularly since the program is exclusively under UNESCO management. U.S. ability to observe hazards assessment and mitigation activities under UNESCO auspices in other countries and to participate in information exchange programs might also prove to be more difficult.

In terms of program management, the earth sciences activities are not immune to the bureaucratic cumbersomeness that characterizes UNESCO activities in general. There is frustration at the comparatively small amounts of money that are available for actual project work as opposed to administration. Moreover, there is evidence that those programs with a strong scientific advisory mechanism, such as IGCP, tend to be of higher scientific quality than those solely directed at the staff level.

Alternatives

It is difficult, if not impossible, to identify a single alternative organization, either intergovernmental or nongovernmental, through which to channel resources to permit continued U.S. association with UNESCO earth sciences programs. There are many organizations doing important work in international geology and natural hazards. This report, however, has focused on identifying channels that provide association with present UNESCO activities. Three intergovernmental organizations involved in various aspects of the UNESCO earth science program--the United Nations Environment Program (UNEP), the International Atomic Energy Agency (IAEA), and the United Nations Disaster Relief Organization (UNDRO)--are specifically mentioned in the program and budget document. About a dozen nongovernmental bodies are also mentioned, the majority of which have some formal or informal linkages to organizations associated with ICSU.

Since it is expected that the United States will retain its formal membership in the IGCP, it may be possible to utilize the Funds-in-Trust arrangement to continue U.S. support for this program. On the other hand, the funds could be provided directly to IUGS. Perhaps the Union would also be willing to serve as an alternative channel for supporting other earth science activities. Earmarking funds for international organizations, whether intergovernmental or nongovernmental, would require a U.S. management mechanism such as the U.S. Geological Survey (USGS) of the Department of the Interior. This would be particularly important in the first year of nonmembership in UNESCO to facilitate the transition to a different support system.

In summary, a preferred option would involve a combined approach of direct support to UNESCO to compensate for loss in program support (including overhead at a level presumably to be negotiated), plus support of the principal cooperating intergovernmental or nongovernmental bodies on the recommendation of a U.S. agent. Another approach is to invite one or more of the cooperating bodies, such as IUGS, to serve as the channel for the totality of funds involved. Details of program management and accountability would have to be worked out, as well as procedures for coordinating work with UNESCO. In both of the options, a strong U.S. focal point is necessary to provide guidance and oversight. A further option is to provide the totality of funds involved directly to a U.S. agent as, for example, USGS, for disbursement to these international programs, or in general support of the objectives of the programs, through whatever vehicle--multilateral or bilateral--is considered most appropriate. If this route is chosen, care must be taken not to dwarf the contributions of other countries. A total U.S. contribution of $2 million per year is suggested for the earth sciences area.

Preliminary Findings

1. The earth sciences programs are of reasonably high quality, and some mechanism should be found to continue to support them during this interim period. Those programs such as the IGCP, which are focused more on the advancement of science, tend to have higher U.S. participation than those concerned with training and education.

2. There is no single intergovernmental organization that can be identified as an appropriate alternative for the totality of the earth sciences program. As far as the IGCP is concerned, it is anticipated that the United States will retain its membership; therefore, a direct contribution to UNESCO through a trust fund arrangement is suggested. However, in the UNESCO budget the IGCP program represents only about 30 percent of the total program within subprogram X.1 and, in addition, there is the natural hazards program to consider (X.2). The cooperating organization with the broadest range of compatible interests is the nongovernmental ICSU union, the International Union of Geological Sciences (IUGS). The Union may be willing to serve as a channel for U.S. funding, but this will require a period of negotiation to determine their interest in such a role and to identify any constraints that may exist.

3. Programs such as the IGCP, interdisciplinary research on the earth's crust, data/mapping, and earthquake risk are considered especially successful. One of the reasons for this is the involvement of the concerned professional communities through nongovernmental organizations. Programs that have an active, expert advisory mechanism tend to be of higher quality than those that do not.

4. Earmarking a portion of the funds to enhance U.S. backstopping is absolutely essential. Increased management responsibilities can be anticipated no matter which alternative is utilized.

MAJOR PROGRAM X:
THE HUMAN ENVIRONMENT AND TERRESTRIAL AND MARINE RESOURCES

Water Resources
(X.3)

Assessment/Potential Impacts

Subprogram X.3, Water Resources, covers implementation of the third phase of the International Hydrological Program (IHP-III). It is concerned with establishing the scientific bases for the rational management of water resources. Particular attention is being devoted to the problems of arid and semiarid regions and of humid tropical regions. This program is closely related to subprograms X.2 (Natural Hazards), X.5 (Coasts and Islands), and X.6-9 (MAB activities). The annual budget for the Water Resources Program (projects and staff costs) plus overhead is about $4.4 million--the U.S. share would be $1.1 million. Restricting attention only to program costs ($2.7 million per year), the U.S. share is about $700,000 per year. Support for program activities from other sources, primarily UNDP, total $2.9 million per year, or somewhat larger than the regular UNESCO program.

U.S. scientists have played leading roles in the establishment, implementation, and planning of the International Hydrological Program. The program is structured around four major headings: (1) Hydrological Processes and Parameters for Water Projects; (2) Influence of Man on the Hydrological Cycle; (3) Rational Water Resources Assessment and Management; and (4) Education and Training, Public Information, and Scientific Information Systems. Eighteen themes and a multitude of projects and subprojects engage scientists, technicians, and decision makers in cooperative national, regional, and multilateral activities directed toward the rational management of water resources. The current phase, IHP-III, is directed toward pragmatic application of water resource management information by users through pilot/demonstration projects. Considerable emphasis is now being devoted to technician-level training to complement university and postgradauate training programs.

The IHP Program is guided by a 30-member Intergovernmental Council charged with establishing the program, evaluating it, recommending scientific projects, and coordinating international cooperation among member states, inter alia. A bureau of the Council works with the UNESCO Secretariat in ensuring the execution of its program in accordance with decisions of the Council. The United States has been represented on the Council and bureau since their formation. National committees in participating member countries form the network for program coordination and cooperation among projects--it is expected there will be 130 participating national committees in IHP-III by 1985. This shows the extensive multilateral collaboration at the base of the International Hydrological Program. There is considerable and necessary interaction with the scientific interests of other intergovernmental and nongovernmental organizations. UN specialized agencies involved include FAO, WHO, IAEA, the regional economic commissions and particularly WMO. The scientific content and significance of IHP program definition, implementation, and achievement are essentially linked to nongovernmental organizations, particularly the International Association of Hydrological Sciences (IAHS), the International Association of Hydrogeologists (IAH), and the Scientific Committee on Water Research (COWAR) of ICSU. It is through these nongovernmental professional associations that the IHP Council is provided scientific and technical advice and guidance in undertaking complex studies and demonstration projects. They also provide important guidance on training and infrastructure development.

One should keep in mind that the IHP has been conceived as a long-term program with results potentially beneficial to all countries, particularly those in regions of the world experiencing grave water resource problems. The United States has benefited from this UNESCO-sponsored program through enhanced technical interactions with many countries and regions of the world where such contacts would have been difficult on a bilateral basis. UNESCO, as an intergovernmental organization, has facilitated these contacts among scientists. These interactions, including the significant technical contributions of U.S. scientists to the solution of problems elsewhere, may be increasingly restricted as a result of the U.S. withdrawal from UNESCO. In the short term, withdrawal may have only limited impacts on U.S. participation in IHP, since it is likely that many U.S. scientists will continue to be associated with this program in their personal capacity. In the longer term, however, the lack of official association with this intergovernmental program involving more than 100 nations could have serious consequences on both U.S. scientific relationships abroad, as well as on the quality of the overall UNESCO program.

With nonmembership in UNESCO, the United States loses its place on the IHP Intergovernmental Council and on the bureau of the Council where the United States has played a critical planning and leadership role. It will be possible to provide some leadership through participation in nongovernmental organizations closely associated with IHP. Scientific bodies in certain other countries are also expected to provide useful liaison with scientific groups, projects, and program developments elsewhere.

Alternatives

In view of the importance of the IHP to the U.S. scientific community, support for this program at a level of $1 million per year (at a minimum) is suggested. This funding is based on the current level of U.S. contributions to the UNESCO-IHP. However, there are opportunities to enrich and significantly expand collaborative work in this program. Such possibilities are being considered by the U.S. National Committee on Scientific Hydrology housed at the U.S. Geological Survey (USGS). In any case, the alternatives considered here with respect to current multilateral IHP activities will require strengthened national management structures (including dealing with personnel ceilings) and funds to support the participation of U.S. scientists in IHP and other multilateral water resource program activities.

The IHP is an intergovernmental program involving over 100 nations, and UNESCO's role as an intergovernmental focal point is important. Interim alternative arrangements are:

Alternative Option 1: Specific program support to UNESCO (Funds-in-Trust, donations, etc.) to cover 25 percent of the regular annual budget plus 10 percent overhead ($750,000 per year). An additional $250,000 should be provided to the U.S. National Committee on Scientific Hydrology, to permit program oversight and to support participation of U.S. scientists in IHP programs.

Alternative Option 2: Provide the same level of financial support ($750,000) through ICSU and/or one of its associated bodies. This option would also require support for the US National Committee on Scientific Hydrology as noted above.

Alternative Option 3: Provide the same level of financial support ($750,000) through the U.S. National Committee on Scientific Hydrology to guide contributions to specific IHP multilateral activities through other governmental and nongovernmental organizations. An additional $250,000 would be required to support oversight as noted above.

Preliminary Findings

1. The International Hydrological Program (IHP), an important global activity involving nearly 130 countries, is concerned with the rational management of water resources. In the current third (5-year) phase, particular attention is being devoted to problems of arid and semiarid regions, and humid tropical regions. The U.S. has played a leading role in program planning and implementation.

2. The IHP is guided by a 30-member Intergovernmental Council on which the United States is represented. Withdrawal will result in a loss in membership on the Council and on the bureau of the Council. In the short term, there may be only modest impacts on U.S. interests and on UNESCO programs after U.S. withdrawal, since it is expected that U.S. scientists will continue to be associated with the IHP in their personal capacity, assuming that funding is available to ensure such participation. In the longer term, the lack of official association could have serious consequences.

3. There have been important benefits as a result of United States participation such as enhanced opportunities for technical interaction and participation in global observational projects. UNESCO as an intergovernmental organization has played a critical role in making this possible.

4. It is important that the United States maintain a strong management structure in support of U.S. participation. The U.S. National Committee on Scientific Hydrology of the U.S. Geological Survey, backed

up by advisory services from the nongovernmental community of hydrologists, can perform this function.

5. Because of the nature of the IHP and the role played by UNESCO, the simplest, most efficient interim alternative arrangement is to make maximum use of Funds-in-Trust, donations, etc., coupled with a strong nationally managed effort to enhance U.S. participation.

MAJOR PROGRAM X: THE HUMAN ENVIRONMENT AND TERRESTRIAL AND MARINE RESOURCES

The Marine Sciences Program: The Ocean and Its Resources; Management of Coastal and Island Regions
(X.4 and X.5)

Assessment/Potential Impacts

UNESCO marine science activities cover a wide range of interests, including promotion of collaborative research; strengthening of national infrastructures concerned with ocean circulation, climate, fisheries, and marine pollution; and environmental management of islands and coastal zones. There are three major units of UNESCO involved in these activities: (1) the Intergovernmental Oceanographic Commission (IOC); (2) the Division of Marine Sciences; and (3) the Man and the Biosphere Program (MAB). Taken together, subprograms X.4 and X.5 have an annual budget (project, staff and overhead) of about $8.8 million, of which the U.S. share is about $2.2 million. Restricting attention to program costs (project, plus staff), the total annual expenditure is about $5.5 million, of which the U.S. share is about $1.4 million. Support for program activities from other sources, such as UNDP and UNEP, totals slightly less than $4 million annually, which is a significant contribution to the overall UNESCO effort devoted to marine sciences. About half the project costs are associated with activities that are primarily scientific in character and are of particular interest to U.S. research interests. The United States is interested in all UNESCO efforts devoted to the effective strengthening of national and global capabilities concerned with the topics covered by X.4 and X.5 program activities.

About half of the resources available for X.4 and X.5 activities are administered by the IOC secretariat. The overall purpose of the IOC, an autonomous body established within UNESCO in 1960, is to promote the development of marine sciences through international collaboration. The IOC facilitates scientific planning and program coordination, assists scientists in member states to participate in international marine science programs, promotes exchange of oceanographic data, and sponsors education and training activities in marine science and technology to enhance the national capabilities of the developing countries. In recent years, the interests of the developing world have received increased attention in the work of IOC. In the view of some

U.S. marine scientists, this has resulted in less attention to issues of science and more to political/organizational topics. There is also some question pertaining to the management capabilities of the IOC, which are made more complex by the overall UNESCO bureaucracy.

About one third of the resources of X.4 and X.5 programs are administered by the Division of Marine Sciences, which has interests closely linked to the IOC. The Division has done a good job in providing training and specialized advisory services for developing countries; increased attention needs to be devoted to this area to enable the developing world to participate more productively in international observational research. U.S. scientists have played important roles in assisting the division to carry out its responsibilities.

Finally, a significant portion of resources in the X.5 area are devoted to work on coastal island systems. These activities are managed by UNESCO components concerned with ecological and environmental problems coming largely under the purview of the Man and the Biosphere Program. The U.S. plays a strong leadership role in all these aspects of the marine science program through a combination of governmental and nongovernmental participation.

U.S. withdrawal from UNESCO may affect these three areas of concern in different ways. The United States plans to retain its membership in the IOC, an intergovernmental organization, even if the United States withdraws from UNESCO. This will preserve official U.S. participation in the only intergovernmental organization concerned solely with international oceanographic problems, broadly speaking. It will be necessary to work out the details of channeling financial contributions and professional staff support to the IOC, but no serious difficulties are foreseen. The support of and participation in the activities of the Division of Marine Sciences and of MAB are more complex.

The United States has an important agenda for international cooperative interactions in the marine sciences area. UNESCO provides one of the most important mechanisms for facilitating and promoting such cooperation. All three areas (IOC, Division of Marine Sciences, and MAB) need to be considered in assessing current activities, including the impact of a U.S. withdrawal from UNESCO, and proposing interim alternatives for enabling U.S. scientists to continue to participate in these activities.

The Intergovernmental Oceanographic Commission (IOC). Three of the IOC activities are of particular concern to the United States: (1) the oceanic components of the World Climate Research Program (WCRP), (2) the Integrated Global Ocean Services System (IGOSS), and (3) the International Oceanographic Data Exchange (IODE).

The oceanographic aspects of the World Climate Research Program (WCRP) are of fundamental interest to the United States. The WCRP has as its objective the prediction on climate over periods of a few months to several decades. It is potentially one of the most economically important scientific programs being pursued by the United States. The United States is playing a leadership role in the WCRP, but active international cooperation among many countries is essential for its success. The oceanographic aspects of the WCRP are being planned cooperatively by the Joint Scientific Committee of the International Council of Scientific Unions (ICSU) and the World Meteorological Organization (WMO) and by the Committee on Climatic Changes and the Ocean (CCCO) of the IOC and the Scientific Committee on Oceanic Research (SCOR) of ICSU. The activities of the CCCO are governed by an agreement between ICSU and UNESCO and a memorandum of understanding between IOC and SCOR.

The International Oceanographic Data Exchange Program is the only mechanism, for example, by which some oceanographic data are accessible to the many agencies in the United States that need these data. Data on subsurface ocean temperatures and salt content obtained by merchant and research ships of many nations are collected and transmitted through IGOSS. Many other IOC activities are also important to U.S. interests, although not at the same level as those highlighted above.

If the United States were to withdraw from IOC, it is conceivable that, over the course of time, alternative arrangements could be made for data exchange and planning for WCRP, IGOSS, and other programs. But this development of new arrangements would be costly in time and resources. The cooperation of many developing coastal states is essential for the world coverage demanded by the global nature of climate and ocean circulation. Without our continued membership in IOC, such cooperation would be difficult to enlist.

Division of Marine Sciences. The complementary activities of the Division of Marine Sciences provide considerable investment of resources through UNESCO regional offices for strengthening national infrastructures and training of scientific and technical personnel for enhancing marine science research programs and the study of ocean resources. Other important activities of this division are directed toward the rational management of marine systems and particularly studies on the marine environment and the continental margin involving close collaboration with ICSU and its associated bodies as well as several specialized agencies of the UN system. The division also disseminates research results and scientific information in the marine sciences through documents, reports, and a newsletter. With respect to coastal and island systems, the division supports a number of interdisciplinary research projects on the productivity of coastal regions and studies pertaining to rational and integrated management of such zones.

Man and the Biosphere (MAB) Program. The major UNESCO support of MAB activities falls in subprograms X.6-X.9. There are also important contributions within subprogram X.5 pertaining to the management of coastal and island regions as they fall within theme 5 of the MAB program. This is particularly true of the activities related to integrated management of islands and coastal zones. Considerable attention is directed to the training of specialists.

All of the marine science areas could benefit from more efficient overall management and increased reliance on the competencies of other bodies such as WMO and particularly ICSU and its associated bodies for substantive input. Furthermore, the marine area has become increasingly preoccupied with development issues that are important in their own right but divert the focus from scientific objectives. International marine science would benefit more from being housed in a division or organization whose mission was purely or predominantly scientific than the current UNESCO institutional mix.

In the short term, there would probably be limited impact on U.S. and UNESCO science interests of a U.S. withdrawal from UNESCO provided there is continuity in funding to enable U.S. scientists to continue to participate in the activities discussed above. The United States would maintain its membership in IOC and pay its dues through the IOC Trust Fund. Other marine science and MAB interests can perhaps be maintained though U.S. associations with NGOs and the participation of individual scientists in UNESCO-sponsored activites. However, in the longer term, depending on the effectiveness of interim alternative mechanisms, these programs might be harmed.

Alternatives

The most efficient and effective mechanism for interim alernative support is to make maximum use of direct contributions to UNESCO (Funds-in-Trust, donations) for the current level of program (projects and staff) costs. Additional resources are recommended for oversight and international research activities to be administered by an organization that is sensitive to U.S. interests, e.g., NSF, with the assistance/advice of the interagency Panel on International Programs and International Cooperation in Oceans Affairs (PIPICO), and the NRC Board on Ocean Sciences and Policy (BOSP). In the augmented IOC program that PIPICO has proposed, it is hoped that consideration will be given to much greater participation of ICSU and its bodies as well as other governmental organizations. In any case, it is important to maintain the current level of Division of Marine Sciences and MAB activities contained in subprograms X.4. and X.5. USMAB is proposed as a body to oversee some of these activities.

A U.S.-supported international marine sciences program related to subprograms X.4 and X.5 is proposed at a level of $2.5 million--$1.4 million as a contribution to UNESCO (Funds-in-Trust, donations, etc.) and $1.1 million to be administered by U.S. organizations sensitive to U.S. interests (e.g., NSF/PIPICO and BOSP, and USMAB). Alternatively, the totality of available resources could be administered by NSF/PIPICO and USMAB, making full use of the capabilities of nongovernmental organizations and their U.S. advisory mechanisms.

Preliminary Findings

1. UNESCO provides one of the most important mechanisms for facilitating and promoting international cooperative interactions in the marine sciences. Current activities cover a wide range of interests of importance to the U.S. marine science community. About half of these activities are primarily scientific in character, while the remaining pertain to strengthening infrastructures through advanced training and advisory services to meet the needs of the developing world. Some concern has been expressed about the wisdom of merging these two program objectives.

2. Marine science activities contained in subprograms X.4 and X.5 are administered under three functional components: about one half by the Intergovernmental Oceanographic Commission (IOC), one third by the Division of Marine Sciences, and the remaining portion pertaining to coastal island systems as part of the Man and the Biosphere Program (MAB). A U.S. withdrawal from UNESCO will affect these three functional areas, all of importance to the United States, in different ways.

3. The United States intends to maintain its membership in the IOC and will be able to profit from the unique collaborative interactions provided by that organization. It is important that the current level of U.S. support of IOC programs be maintained through contributions to the IOC Trust Fund, augmented by a nationally-managed program.

4. It is equally important to maintain the current level of Division of Marine Sciences and MAB activities contained in subprograms X.4 and X.5. On withdrawal from UNESCO, the United States would only be able to provide substantive guidance to these activities indirectly through its participation in NGOs associated with these programs. Financial contributions could be provided to UNESCO (Funds-in-Trust, donations, etc.) and to NGOs via a U.S. agency sensitive to U.S. interests, such as NSF (including the advice of PIPICO amd BOSP) and USMAB.

MAJOR PROGRAM X:
THE HUMAN ENVIRONMENT AND TERRESTRIAL AND MARINE RESOURCES

Environmental Sciences: Man and the Biosphere Program (MAB)
(X.6-X.9)

Assessment/Potential Impacts

This section focuses on the subprogram areas (X.6-9) largely having to do with practical problems of natural resource management, which is the thrust of the MAB program. As noted above, portions of X.5 dealing with management of coastal and island regions are closely linked to the MAB program and objectives. The annual budget for programs X.6-9 (projects and staff costs) plus overhead is about $7.4 million--the U.S.

share is about $1.85 million. If one considers program costs only ($4.5 million), the U.S. contribution would be $1.25 million per year. Support for program activities from other sources is about $4.25 million per year, which is of the same order of magnitude as regular program costs.

Subprograms X.6-9 are being considered together since they form the core of the MAB program, which was extensively assessed on its tenth anniversary in 1982. The objectives of this program are (1) the general study of the structure and function of the biosphere and its ecological regions to provide an improved environmental information base for decision making; (2) systematic observation of changes brought about by man in the biosphere in order to provide new tools for environmental planning and resource management; (3) the study of the effects of these changes upon human populations to improve our ability to predict these effects and to develop new strategies to ameliorate the disruption of human lives; and (4) education of the public and the dissemination of information needed by decision makers and scientists. The initial MAB program is divided into 14 project areas to focus research efforts and facilitate coordination; half deal with particular kinds of geographic areas or ecosystems, the other half with impacts and processes such as conservation, demographic change, environmental perception, and pollution.

U.S. scientists have played leading roles in the planning, establishment, and implementation of the MAB program as well as of its predecessor, the ICSU-sponsored International Biological Program (IBP). This has been at both the governmental and nongovernmental levels. Since the creation of MAB, the United States has been represented on the 30-member International Coordinating Council, which guides the scientific content of the overall program, and has also held one of the four vice-presidencies of the MAB Bureau at all times. In addition, U.S. science administrators have been seconded to the UNESCO MAB secretariat until 1982 when U.S. agency cutbacks made this no longer feasible. There have been many hundreds of U.S. researchers actively engaged in MAB sponsored activities--national, bilateral, and multilateral projects. A small, yet effective, USMAB secretariat, currently located in the OES Bureau of the State Department, facilitates U.S. participation in MAB activities and serves the U.S. National Committee for MAB, which is charged with guiding and overseeing U.S. interests in national and international MAB projects. The U.S. Forest Service of the Department of Agriculture and the Park Service of the Department of the Interior have been particularly supportive of USMAB.

The UNESCO MAB secretariat and UNESCO as an intergovernmental organization have played vital roles in coordinating and facilitating the development of national projects and cooperative international interactions among research groups having common interests and problems. Participating nations have formed national committees to establish priorities and promote funding in support of projects. UNESCO has been instrumental in assisting the formation of these national committees and national programs as well as international cooperative arrangements; there are now some 105 functioning national committees. With the successful advent of integrated approaches to natural resource management needs, the International Coordinating Council agreed to concentrate on four areas: (1) the humid tropics, (2) the arid and semiarid zones, (3) urban systems, and (4) conservation. These developments and the leadership of the secretariat have been appreciated by governments and were especially underscored at the fall 1983 session of the UNESCO General Conference.

Because of the integrated, interdisciplinary nature of the MAB program and the broad range of interests of UNESCO, UNESCO has been able to foster the active collaboration of natural and social scientists and has facilitated contact among researchers. There is fruitful exchange with the USSR in the area of assessing long-term effects to the environment in the context of the Biosphere Reserve Program. Important work is moving ahead on assessing problems in the arctic region. Serious problems of desertification and resource management in the Sahel and similar regions elsewhere in the world have received increased attention. The MAB program and framework are of considerable value to the United States as well as other countries in defining problems and facilitating integrated cooperative approaches to solutions. UNESCO provides an intergovernmental mechanism to structure collaborative arrangements designing future complex global observational programs involving ecological, geological, and behavioral processes. A proposed activity related to enhanced understanding of changes in the global environment is currently being considered by ICSU and affiliated nongovernmental scientific unions for possible implementation during the 1990s; a cooperative role with UNESCO and other U.N. agencies is envisaged.

There have been serious problems, on the other hand, with UNESCO program management--not so much of a political nature but rather of bureaucratic sluggishness and ineptness in defining and delegating authority. There are signs that some of the difficulties are moving toward correction through a recent reorganization of staff responsibilities. Still, there is a need to streamline administrative procedures and to clarify and strengthen the role of the MAB Bureau in serving the scientific objectives of the program. This situation will require monitoring.

There have been problems on the U.S. side with respect to staffing and funding USMAB needs. Previously, the USMAB secretariat was housed in the U.S. National Commission for UNESCO and was reinforced by staff detailed from several federal agencies. Contributions, also from different agencies, provided a common fund from which USMAB activities were supported. However, a budgetary crisis developed in early 1983 which adversely affected USMAB funding and secretariat support. There are currently (summer 1984) signs that some of these difficulties may be in the process of being overcome with increasing interagency involvement in MAB activities and the intention of the Department of State to put funding and staff support on a more permanent basis through budgetary action. Identification of USMAB program activities budgeted at a level of $2 million per year plus supporting secretariat staff costs are basic needs. Consideration of the impacts of a U.S. withdrawal from UNESCO and the examination of interim alternative arrangements for MAB are rather academic questions if the USMAB situation is not resolved satisfactorily and on a longer-term basis.

The impacts of a U.S. withdrawal from UNESCO can be examined on a short- and long-term basis. In the short term, there would probably be minimal disturbance or effect on MAB activities--many of these are national projects or are being carried out through bilateral arrangements. The serious problem in this case is securing national support and funding continuity. In the long term, however, the problems are potentially serious. First, the United States would lose its ability to provide a vice-president on the international MAB Bureau as well as its position on the Coordinating Council. This means that the United States loses its leadership role in guiding and overseeing the international MAB program. Second, the United States would lose its official ability to interact with other MAB mational committees although the UNESCO MAB secretariat might well continue to facilitate informal collaborative efforts. Even so, the extensive U.S. efforts, which have often involved substantial cooperation with other countries and significant direct support from UNESCO, could be endangered. Third, the official designation by UNESCO of biosphere reserves (there are some 40 reserves in the United States) could be compromised in the long term. It is possible that the extensive state and local, as well as national, resources currently provided these activities could be put in competition with other needs and that the commitment to maintain these reserves for long-term research purposes would be diminished. Certainly, cooperative interactions with other countries would become more complicated. Fourth, the United States would lose the international MAB mechanism to examine, promote, and assist the implementation of new observational programs. It would be hoped that the UNESCO MAB secretariat would facilitate USMAB involvement in longer-term programs. Finally, there is the reverse question concerning the effect on the UNESCO MAB program of a U.S. withdrawal. In the short term, U.S. scientists might be invited in their personal capacity to continue to provide leadership and guidance to specific MAB projects by the UNESCO secretariat. However, in the long term, the lack of official U.S. participation and provision of scientific leadership could seriously cripple international MAB unless suitable alternative means are found to involve the U.S. scientific community.

Alternatives

Taking into account the current level of U.S. contributions to UNESCO programs and the nature of multinational activities, an overall international program on the order of $2 million per year provides the basis for considering alternatives. This international program is distinct and above support requirements for a U.S. national program that has been proposed at about the same order of magnitude.

For the reasons noted above, there is no real alternative to UNESCO for administering the MAB program in the sense of designating another governmental or nongovernmental organization. There are over 100 nations participating in international MAB activities through UNESCO; the question of charging UNEP or an ICSU body to administer MAB would have had to be addressed at the time of establishing MAB. Therefore, interim alternatives are proposed, the most efficient and effective one being maximum use of direct contributions to UNESCO (Funds-in-Trust, donations, etc.) backed up by USMAB-managed activities.

A second alternative would emphasize considerable project management by USMAB or some other body sensitive to U.S. interests. In both cases, there would be active involvement of nongovernmental organizations such as ICSU, including the International Union of Biological Sciences (IUBS) and the ICSU Scientific Committee on Problems of the Environment (SCOPE), and the International Union for the Conservation of Nature and Natural Resources (IUCN). Both alternatives include seconding a top-level U.S. science administrator to the UNESCO secretariat to provide substantive input and links to peer participation assuming agreement by UNESCO. Both alternatives also include significant managerial and overhead costs, although the second would certainly be higher. Funds must be earmarked in both alternatives to encourage innovative projects by U.S. investigators for multilateral exploratory work in fields related to MAB interests, such as the longer-term elaboration of a program on global change. For example, it is recommended that consideration be given to supporting the further development of the International Satellite Land-Surface Climatology Project cosponsored by the Committee on Space Research (COSPAR) of ICSU and the International Association of Meteorology and Atmospheric Physics (IAMAP). In all cases, a particularly sensitive matter pertains to ensuring the continuity of funding for scientific work over time--an "on/off" situation would be detrimental to all parties concerned.

In summary, interim alternatives for this overall MAB-related program area are as follows:

Alternative Option 1:

(1)	Funds-in-Trust, contribution (including overhead) for selected X.6-X.9 activities	$ 900,000/yr.
(2)	Secondment of U.S. science administrator, plus support services, to UNESCO staff	150,000/yr.
(3)	USMAB-administered X.6-X.9 activities, new initiatives, oversight/management costs	950,000/yr.
	TOTAL	$2,000,000/yr.

Alternative Option 2:

(1)	USMAB-administered program directly related to ongoing international MAB, new initiatives, oversight/management costs	$1,850,000/yr.
(2)	Secondment of a U.S. science administrator, plus support services, to UNESCO staff	150,000/yr.
	TOTAL	$2,000,000/yr.

Preliminary Findings

1. The Man and the Biosphere Program and related projects in Major Program X, concerned with integrated approaches to natural resource management, include activities that are valuable to the U.S. scientific community. The International Coordinating Council provides scientific guidance to the overall program, which is currently concentrated in four areas: the humid tropics; arid and semiarid zones; urban systems; and conservation.

2. The United States, which has provided leadership throughout the existence of MAB, will lose its official capacity to be a member of the Coordinating Council and Bureau of Officers. There may be limited impact on MAB activities in the short term assuming funds are provided to both UNESCO and USMAB in support of ongoing projects. However, there could be serious consequences in the longer term to both the United States and international MAB programs if suitable interim alternative mechanisms cannot be worked out to ensure active U.S. participation and association.

3. Because of the integrated, interdisciplinary nature of the MAB program and UNESCO's broad range of scientific interests, UNESCO has played a unique role of fostering collaboration of natural and social scientists, and coordinating the interactions of scientific groups in 105 participating countries. There is no real alternative to UNESCO in carrying out these responsibilities. There have been, on the other hand, serious management problems in UNESCO that may be in process of improvement--a situation that needs to be monitored.

4. It is of fundamental importance to put the USMAB program on a sound footing in terms of continuity of funding and staff support. Consideration of the impacts of U.S. withdrawal from UNESCO and this examination of interim alternative arrangements are academic questions if the current crisis facing USMAB is not resolved satisfactorily.

5. Because of the nature of the MAB program and the role played by UNESCO, the simplest and most efficient interim alternative is to make maximum use of direct contributions to UNESCO (Funds-in-Trust, donations, etc.) backed up by a significant level of USMAB-managed international activities. There should be increasing involvement of nongovernmental organizations such as IUCN and ICSU.

ANNEX A

UNESCO APPROVED BIENNIAL PROGRAM AND BUDGET: 1984-85

	Major Programs	($000)
I.	Reflection on World Problems and Future Oriented Studies	$ 2,729
II.	Education for All	31,131
III.	Communication in the Service of Man	16,157
IV.	Formulation and Application of Education Policies	35,546
V.	Education, Training and Society	17,106
VI.	THE SCIENCES AND THEIR APPLICATION TO DEVELOPMENT	30,483
VII.	Information Systems and Access to Knowledge	12,194
VIII.	Principles, Methods and Strategies of Action for Development	11,052
IX.	SCIENCE, TECHNOLOGY AND SOCIETY	7,586
X.	HUMAN ENVIRONMENT, TERRESTRIAL AND MARINE RESOURCES	31,177
XI.	Culture and the Future	25,554
XII.	Elimination of Prejudice, Intolerance, Racism and Apartheid	1,630
XIII.	Peace, International Understanding, Human Rights and the Rights of People	5,540
	SUBTOTAL: Major Program	$227,885
	General Policy and Direction	25,780
	General Activities and Services	143,141
	SUBTOTAL: Direction and Services	$168,921
	TOTAL PROGRAM	$396,806
	Less Other: Balance of Currency Fluctuations, Absorption of Reductions, etc.*	- 22,396
	AGREED 1984-85 PROGRAM	$374,410
	TOTAL FROM OTHER SOURCES	$233,937
	GRAND TOTAL	$608,347

*Adjustments, including the absorption of reductions among various activities have not been distributed since they were not known at the time of preparing this table.

ANNEX B

UNESCO APPROVED PROGRAM AND BUDGET (1984-85)
SUMMARY OF UNESCO SCIENCE ACTIVITIES

The following tables provide an overview in gross terms of the 1984-85 UNESCO biennial program and budget for science activities. Adjustments including the absorption of reductions among the various program activities leading to the final approved biennial budget have not been distributed but rather taken out of overhead plus general policy and direction--this leads to a somewhat larger available program budgets and lower overhead charges than is actually the case. These tables have been prepared to provide orders of magnitude for major science program categories.

Explanation of table headings "Overhead, etc." and "Other" are given below.

- OVERHEAD, etc. - General activities; support, administration, communication services; general policy and direction, less amount (2.8 percent of original proposed budget), which will be absorbed during course of execution of program.
- OTHER - Additional resources provided in support of related activities with oversight by UNESCO; e.g., UNDP, UNEP, UN Financing System, Funds-in-Trust, etc.

UNESCO SCIENCE ACTIVITIES (1984-85)

Summary of Major Programs VI, IX, & X

($000)

		Project Costs	Staff & Indirect	Work Years	Regular Program	Regular Program + Overhead, etc. (64.3%)	Other
VI	The Sciences & Their Application to Development	16,063	14,419	336.5	30,482	50,085	36,203
IX	Science, Technology & Society	3,265	4,321	102	7,586	12,464	3,330
X	The Human Environment & Terrestrial & Marine Sciences	13,834	17,342	407	31,766	51,223	26,461
	TOTAL	33,162	36,082	845.5	69,244	113,770	65,994

UNESCO SCIENCE ACTIVITIES (1984-85)

Major Program VI:

"The Sciences and Their Application to Development"

($000)

		Project Costs	Staff & Indirect	Work Years	Regular Program	Regular Program + Overhead, etc. (64.3%)	Other
VI.1	Natural Sciences	5,085	3,155	71	8,240	13,540	9,873
VI.2	Technology & Engineering	2,068	3,482	81	5,550	9,120	23,305
VI.3	Key Areas in S&T	3,844	3,399	80	7,243	11,900	2,500
VI.1-3	Subtotal	[10,997]	[10,036]	[232]	[21,033]	[34,560]	[35,678]
VI.4	Social & Human Sciences	4,320	3,711	88.5	8,031	13,195	525
VI.5	Key Areas in Social & Human Sciences	746	672	16	1,418	2,330	---
VI.4-5	Subtotal	[5,066]	[4,383]	[104.5]	[9,449]	[15,525]	[525]
VI	TOTAL	16,063	14,419	336.5	30,482	50,085	36,203

UNESCO SCIENCE ACTIVITIES (1984-85)

Major Program IX:

"Science, Technology and Society"

($000)

		Project Costs	Staff & Indirect	Work Years	Regular Program	Regular Program + Overhead, etc. (64.3%)	Other
IX.1	Science, Tech. & Society	1,249	1,379	32	2,628	4,319	360
IX.2	Science, Tech. Policies	2,016	2,942	70	4,958	8,145	2,970
IX	TOTAL	3,265	4,321	102	7,586	12,464	3,330

UNESCO SCIENCE ACTIVITIES (1984-85)

Major Program X:

"The Human Environment and Terrestrial and Marine Resources"

($000)

		Project Costs	Staff & Indirect	Work Years	Regular Program	Regular Program + Overhead, etc. (64.3%)	Other
X.1	Earth's Crust, Mineral and Energy Resources	2,202	2,041	47	4,243	6,971	3,960
X.2	Natural Hazards	612	1,281	30.5	1,893	3,110	668
X.1-2	Subtotal	[2,814]	[3,332]	[77.5]	[6,136]	[10,081]	[4,628]
X.3	Water Resources	2,411	2,891	68	5,302	8,710	5,822
	Subtotal	[2,411]	[2,891]	[68]	[5,302]	[8,710]	[5,822]
X.4	Ocean & Resources	3,714	4,370	102	8,084	13,281	6,490
X.5	Coasts & Islands	802	1,849	44.5	2,651	4,355	999
X.4-5	Subtotal	[4,516]	[6,219]	[146.5]	[10,735]	[17,636]	[7,489]
X.6	Land Use & Terrestrial Resources	1,932	1,875	43.5	3,807	6,254	4,306
X.7	Urban Systems	851	995	23.5	1,846	3,033	708
X.8	Natural Heritage	504	641	15	1,145	1,881	2,228
X.9	Env. Ed. & Info.	807	1,401	33	2,208	3,627	1,280
X.6-9	Subtotal	[4,094]	[4,912]	[115]	[9,006]	[14,795]	[8,522]
	TOTAL	13,835	17,344	407	31,179	51,222	26,461

ANNEX C

LIST OF ACRONYMS

AAAS	American Association for the Advancement of Science
ACM	Association for Computing Machinery, U.S.
AES	Associated Expert Scheme
AGID	Association of Geoscientists for International Development
AID	Agency for International Development, U.S.
ALESCO	American Library and Educational Services Company
AMU	African Mathematical Union
ANSTI	African Network of Science and Technology Institutions
APSO	Asian Physical Society
ASEAN	Association of South-East Asian Nations
ASFIS	Aquatic Sciences and Fisheries Information System
AUP	African Union of Physics
BBS	Directorate of Biological, Behavioral and Social Sciences (NSF)
BOSP	Board on Ocean Sciences and Policy (NRC)
BOSTID	Board on Science and Technology for International Development (NRC)
CBASSE	Commission on Behavioral and Social Sciences and Education (NRC)
CCCO	Committee on Climatic Changes and the Ocean (SCOR/IOC)
CODATA	Committee on Data for Science and Technology (ICSU)
CGMW	Commission for the Geological Map of the World
CIFEG	International Center for Geological Training and Exchanges
CIPL	Permanent International Committee on Linguists
CLAB	Latin American Centres for Biological Sciences
CLAF	Latin American Centres for Physics
CLAMI	Latin American Centres for Mathematics and Informatics
CMEA	Council for Mutual Economic Assistance
COSPAR	Committee on Space Research (ICSU)
COSTED	Committee on Science and Technology in Developing Countries (ICSU)
COWAR	Committee on Water Research (ICSU)
CTS	Committee on the Teaching of Science (ICSU)
DFD	Data for Development

ECA	Economic Commission for Africa
ECE	Economic Commission for Europe
ECLA	Economic Commission for Latin America
ECOR	Engineering Committee on Ocean Resources
ECOSOC	Economic and Social Council of the United Nations
EPS	European Physical Society
FAO	Food and Agricultural Organization
FIT	Funds-In-Trust
GARS	Geological Applications of Remote Sensing
GEBCO	General Bathymetric Chart of the Oceans
GERT	Giant Equatorial Radio Telescope
GIPME	Global Investigation of Pollution in the Marine Environment
GOs	Governmental Organizations
IABO	International Association for Biological Oceanography (IUBS/ICSU)
IAEA	International Atomic Energy Agency
IAGC	International Association for Geochemistry and Cosmochemistry
IAGOD	International Association on the Genesis of Ore Deposists
IAH	International Association of Hydrogeologists (IUGS/ICSU)
IAHS	International Association of Hydrological Sciences (IUGS/UCSU)
IAMAP	International Association of Meteorology and Atmospheric Physics (IUGG/ICSU)
IAPSO	International Association for the Physical Sciences of the Ocean (IUGG/ICSU)
IASPEI	International Association of Seismology and Physics of the Earth's Interior (IUGG/ICSU)
IAVCEI	International Association of Volcanology and Chemistry of the Earth's Interior (IUGG/ICSU)
IBI	Intergovernmental Bureau of Informatics
IBN	International Biosciences Networks (ICSU)
IBP	International Biological Program (ICSU)
IBRO	International Brain Research Organization
ICC	International Coordinating Council
ICES	International Council for the Exploration of the Sea
ICL	Interunion Commission on the Lithosphere (IUGG-IUGS/ICSU)
ICMS	International Center for Mathematical Sciences
ICPAM	International Center for Pure and Applied Mathematics
ICPHS	International Council for Philosophy and Humanistic Studies
ICRAF	International Council for Research on Agroforestry
ICRO	International Cell Research Organization
ICSEM	International Commission for the Scientific Exploration of the Mediterranean Sea
ICSSD	International Committee for Social Science Information and Documentation
ICSU	International Council of Scientific Unions
ICTP	International Centre for Theoretical Physics
IDEA	International Institute of Advanced Studies (Venezuela)

C-3

IFAC	International Federation of Automatic Control
IFDO	International Federation of Data Organizations in the Social Sciences
IFIAS	International Federation of Institutes of Advanced Studies
IFIP	International Federation of Information Processing
IFLA	International Federation of Library Associations
IFS	International Foundation for Science
IGCP	International Geological Correlation Program
IGOSS	Integrated Global Ocean Services System
IHO	International Hydrographic Organization
IHP	International Hydrological Program
IIAS	International Institute of Administrative Sciences Analysis
IIASA	International Institute for Applied Systems Analysis
ILO	International Labor Organization
IMEKO	International Measurement Confederation
IMO	International Maritime Organization
IMU	International Mathematical Union (ICSU)
INISSE	International Institute of Space Sciences and Electronics
INQUA	International Union for Quarternary Research
IOC	Intergovernmental Oceanographic Commission
IOCARIBE	IOC Association Carribbean Adjacent Regions
IOCD	International Organization for Chemistry for Development
IODE	International Oceanographic Data Exchange
IOLM	International Organization of Legal Metrology
IPSA	International Political Science Association
ISC	International Seismological Centre
ISSC	International Social Science Council
IUAES	International Union of Anthropological and Ethnological Sciences
IUBS	International Union of Biological Sciences (ICSU)
IUCN	International Union for Conservation of Nature and Natural Resources
IUFRO	International Union of Forestry Research Organizations
IUGG	International Union of Geodesy and Geophysics (ICSU)
IUGS	International Union of Geological Sciences (ICSU)
IUMS	International Union of Microbiological Societies (ICSU)
IUPAP	International Union of Pure and Applied Physics (ICSU)
MAB	Man and the Biosphere Program
MARPOLMON	Marine Pollution Research and Monitoring Program
MIRCENs	Microbiological Resources Centers (World Network)
NAS	National Academy of Sciences
NGOs	Nongovernmental Organizations
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSF	National Science Foundation
OAS	Organization of American States
OAU	Organization of African Unity
OECD	Organization for Economic Cooperation and Development
OES	Bureau of Oceans and International Environmental and Scientific Affairs (Department of State)
OSTP	Office of Science and Technology Policy

PGI	General Information Program
PIPICO	Panel on International Programs and International Cooperation in Oceans Affairs (U.S. Interagency)
PSMSL	Permanent Service for Mean Sea Level
SCOPE	Scientific Committee on Problems of the Environment (ICSU)
SCOR	Scientific Committee on Oceanic Research (ICSU)
SEAMS	South-East Asian Mathematical Society
SPIN	Strategies and Policies for Informatics
SSRC	Social Science Research Council
STI	Scientific and Technical Information
STIA	Directorate on Scientific, Technological and International Affairs (NSF)
TCDC	Technical Cooperation between Developing Countries
TEMA	Training, Education and Mutual Assistance
UIA	International Union of Architects
UITA	Union of International Technical Associations
UN	United Nations
UNCSTD	United Nations Center for Science and Technology for Development
UNDP	United Nations Development Program
UNDRO	United Nations Disaster Relief Organization
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFPA	United Nations Fund for Population Activities
UNFSSTD	United Nations Financing System for Science and Technology for Development
UNICEF	United Nations Children's Emergency Fund
UNIDO	United Nations Industrial Development Organization
UNISIST	UNESCO-ICSU Joint Project to Study the Feasibility of a World Information System
UNITAR	United Nations Institute for Training and Research
UNRISD	United Nations Research Institute for Social Development
UNSO	United Nations Sudano-Sahelian Office
UNU	United Nations University
USGS	U.S. Geological Survey
USMAB	U.S. National Committee for Man and the Biosphere
WCP	World Climate Program
WCRP	World Climate Research Program
WDC	World Data Center
WFEO	World Federation of Engineering Organizations
WHO	World Health Organization
WMO	World Meteorological Organization
WOCE	World Ocean Climate Experiment
WWF	World Wildlife Fund

UNESCO SCIENCE PROGRAMS:
IMPACTS OF U.S. WITHDRAWAL AND
SUGGESTIONS FOR ALTERNATIVE INTERIM ARRANGEMENTS

A Preliminary Assessment

SUPPLEMENT

(Including an inventory and program commentary)

INTRODUCTION

This Supplement provides an inventory of the following program areas within Major Programs VI, IX, and X:

VI. The Sciences and Their Application to Development

- Natural Sciences (VI.1); Technology and Engineering (VI.2); Key Areas (VI.3)
- Social and Human Sciences (VI.4); Key Areas (VI.5)

IX. Science, Technology and Society

- Relations (IX.1); S&T Policies (IX.2)

X. The Human Environment and Terrestrial and Marine Resources

- Earth Sciences and Resources (X.1); Natural Hazards (X.2)
- Water Resources (X.3)
- Oceans and Resources (X.4); Coastal and Island Regions (X.5)
- Environmental Sciences: Man and the Biosphere (X.6-X.9)

The presentation corresponds to the program discussion in Chapter 4 of the NRC report, UNESCO Science Programs: Impacts of U.S. Withdrawal and Suggestions for Alternative Interim Arrangements, A Preliminary Assessment.

At the beginning of each program, there is an overall comment followed by options for alternative arrangements to maintain U.S. scientific interactions. The content of the individual programs are summarized with identification of interactions with other governmental and nongovernmental organizations. (See UNESCO Approved Programme and Budget for 1984-85 for additional details.) A brief summary of programs V.2, VII, and General Activities (these are not discussed in the NRC report) is presented at the end of the Supplement.

At the request of the Department of State, an attempt has been made to characterize the programs using the following codes:

(1) primarily of concern to the U.S. scientific community;
(2) primarily of concern to the scientific community of the developing world;

and within each of these categories:

(a) high value;
(b) medium value or unknown;
(c) marginal or no value.

It is important to note that these characterizations, particularly (a), (b), or (c), have often been assigned on the basis of minimal information; any proper evaluation would require a careful, time-consuming examination. In assigning value codes, UNESCO performance in implementing a program activity was also considered. Little information was available on many programs, which were therefore qualified (b).

At the beginning of each program, biennial budget figures drawn from the UNESCO Approved Programme and Budget for 1984-85 are given. These figures are annualized in a second column and from that point on, all figures are presented on a yearly basis. The UNESCO budget includes project costs, staff costs (roughly equal to the project costs) and overhead (64.3%). In the inventory, the figure given at the beginning of the description of each subprogram is the project cost only. The purpose in giving this figure is to provide an indication of the relative magnitude of each subprogram. Budgetary figures within parentheses at the end of each entry represent project support from outside sources.

With respect to alternatives, particular attention has been given to specific program support through "Funds-in-Trust" and "donations" mechanisms when appropriate. These mechanisms make it possible for outside sources to contribute to specific UNESCO-sponsored activities. However, direct oversight of the contributions is limited; some form of periodic accountability may be possible.

- Funds-in-Trust are monies received by UNESCO from Member States or organizations (international, regional or national governmental or nongovernmental) for the purpose of enabling UNESCO to carry out specific activities on their behalf and at their request. Under this system, UNESCO acts as the trustee to oversee the uses of the funds that are usually directed towards a specific need in a particular country or region.

- Donations are gifts, bequests, and subventions (or contributions) that UNESCO may receive directly from governments, public and private institutions, associations and private persons. The Director-General of UNESCO, with the approval of the Executive Board, is authorized to add to the current appropriation funds from donations and special contributions for activities within the Approved Programme and Budget for 1984-85.

MAJOR PROGRAM VI: THE SCIENCES AND THEIR APPLICATION TO DEVELOPMENT

VI.1: Research Training and International Cooperation in the Natural Sciences

	Biennial ($000)	Annual ($000)
Regular program	$ 8,240	$4,120
of which staff costs	3,155	1,578
of which project costs	5,085	2,542
Regular program plus overhead (64.3%)	13,540	6,770
Other sources (see below)	9,873	4,937

Overall comment on VI.1: This program area provides continuity in the basic cooperative objectives of the original UNESCO science program as extended to support the needs of the developing countries. This area is of primary concern to the health of world science. U.S. oversight of program planning and management could be indirectly maintained, at least in part, through U.S. participation in NGOs as well as through monitoring the expenditure of U.S. funds by an appropriate body sensitive to U.S. interests such as NSF and/or NRC. The total annual program budget (projects, staff and overhead) for these activities is approximately $6.8 million; the U.S. share is $1.7 million. Current annual U.S. contributions in support of VI.1 regular program activities (projects, staff costs, but not overhead) are about $1 million. If further funds are available, selected activities should receive additional support. It is recom- mended that support of activities in this area be about $1.8 million per year including oversight/overhead costs.

Alternative Option 1: Most UNESCO-sponsored VI.1 projects might be supported by providing funds to the organizations managing them through ICSU. This option may provide better monitoring of scientific activities than is currently the case. If the United States provides support for program activities through ICSU to the NGOs, there will be a need to explore possibilities for the secondment of a science administrator to ICSU to implement this approach. In addition, funds could be provided to a U.S. agency (e.g., NSF or AID) to support U.S. participation in bilateral programs. There will be significant administrative costs for ICSU and the other NGOs, as well as for the U.S. agency. These costs are included in the figures that follow:

Alternative Option 1:

Support to NGOs for UNESCO-related science activities	$1,350,000
Secondment of science administrator and supporting services to ICSU	150,000
Bilaterals through U.S. institutions	300,000
TOTAL	$1,800,000

Alternative Option 2: The record to date of UNESCO management of program area VI.1 is acceptable. Under these circumstance, a second option for alternative support would be a contribution to UNESCO (Funds-in-Trust, donations, etc.) to cover the current U.S. share of regular program costs, plus 10% overhead. This would total $1,100,000. Augmented support of NGO-sponsored science activities is proposed at a level of $700,000. The total under this option is $1,800,000.

Contribution to UNESCO (Funds-in-Trust, donations, etc.)	$1,100,000
Support to NGOs activities under U.S. oversight	700,000
TOTAL	$1,800,000/yr.

VI.1.1 Strengthening of National Research Potential and Improvement of Infrastructures

VI.1.1.1 Mathematics
$98,450 2 - b
10 courses for developing countries; research grants; seminars; periodicals; directory in cooperation with IMU, International Center for Pure and Applied Mathematics (ICPAM), International Center for Mathematical Sciences (ICMS) and IIASA.

VI.1.1.2 Physics
$55,150 2 - b
Research grants to Africa and Asia in cooperation with IUPAP and regional/national associations; 6 research seminars with concentration on microelectronics and solar conversion; proceedings.

VI.1.1.3 Chemistry
$138,550 2 - a
Research grants to developing countries; technical assistance; 4 courses in advanced research techniques--natural products, electrochemistry, agricultural and environmental chemistry; International Organization for Chemistry for Development (IOCD) training and research activities through regional networks in Southeast Asia, central and south Asia, Caribbean and Latin America; cooperation with International Foundation for Science (IFS) for symposium and grants with reference to 5th Asian Symposium on Medicinal Plants and Spices.

VI.1.1.4 Biology
$148,200 2 - a
Regional and national research activities in molecular and cellular biology, microbiology, genetics, neurobiology; cooperation with ICRO, 10 research courses--grants to 10 laboratories/research workers in neurobiology; IBRO, 10 research seminars in Latin America, 2 in Asia and traveling lectures in Europe.

VI.1.1.5 Network of Postgraduate Training and Research Courses
$163,950 2 - a/b
40 courses of 6 months duration in developing countries in a variety of basic fields.

Comment on VI.1.1: These program activities in basic and applied natural sciences have proven of considerable value for strengthening infrastructures and solving specific research problems in developing countries. American scientists have been active in all of these activities and have played leading roles particularly in the biology and chemistry projects. Assuming that funds might be available from other parts of the overall U.S. contribution to UNESCO programs, priority attention should be given to possibilities for augmenting the following UNESCO-sponsored activities through support to the relevant organizations:

International Organization for Chemistry for Development (IOCD)	$200,000
International Cell Research Organization (ICRO)	100,000
International Brain Research Organization (IBRO)	100,000
International Center for Theoretical Physics (ICTP)	100,000
Johns Hopkins School of Hygiene and Public Health	100,000
ICSU, International Biosciences Networks (IBNs)	100,000
SUBTOTAL	$700,000/yr.

VI.1.2 University and Postgraduate Training with Special Efforts Aimed at Inceasing the Participation of Women
$136,450 2 - a/b
Curricula for physics and chemistry, particularly in Arab states and Africa, familiarizing 80 university teachers with laboratory equipment, training of 50 laboratory technicians (Asia); pilot projects, special training courses in Africa, Asia and Pacific, biological sciences in Arab states, mathematics curricula in Africa; 3 demonstration workshops, services of consultants in cooperation with Centre for S&T Education in India, and Ljubljana International Center for Chemistry Studies; grants to attend international symposium on chemistry education in Japan, union science education activities.

Comment on VI.1.2: Specific U.S. support for university curricula development should be included under VI.1.1, above. This area of work is linked to UNESCO major program area V.2 on S&T education, a key area of activity.

VI.1.3 Development of Regional and International Cooperation

VI.1.3.1 Cooperation with ICSU

$689,500 1 - a

Subvention and special support activities--International Biosciences Networks (IBNs); 2 fellowships; S&T information exchange.

VI.1.3.2 Cooperation with Other NGOs

$89,150 2 - b

International Foundation for Science (chemistry and biology research workers); travel grants in cooperation with Committee on S&T in Developing Countries (COSTED)--meetings and symposia of IBRO, ICRO and IOCD; technical assistance to developing countries.

VI.1.3.3 Advanced Postgraduate Research and Training

$517,600 2 - a

Support to International Center for Theoretical Physics (ICTP) for postgraduate studies.

VI.1.3.4 Regional Cooperation in Basic Sciences

$303,750 2 - a/b

Cooperation between European and North American institutions--cellular and molecular biophysics, molecular biology and biomaterials electrochemistry; chemistry of natural organic substances, natural substances, applied mathematics; cooperation extended to developing country institutions, pilot project with School of Hygiene and Public Health (Johns Hopkins); Africa, mathematics, chemistry, biosciences; Arab states, informatics, all sciences; Latin America and Caribbean, IUPAP-sponsored seminars; Asia and Pacific, all disciplines.

VI.1.3.5 Regional Centers

$68,950 2 - b

Latin American Centres for Biological Sciences (CLAB), Mathematics and Informatics (CLAMI), Physics (CLAF); International Institute of Space Sciences and Electronics (INISSE), studies of Giant Equatorial Radio Telescope (GERT).

VI.1.3.6 Regional Scientific Unions

$42,550 2 - b

African Mathematical Union (AMU), South-East Asian Mathematical Society (SEAMS), Latin American Federation of Mathematics; African Union of Physics (AUP); Asia (Asian Physical Society, APSO); Europe (European Physical Society, EPS).

Comment on VI.1.3: Most subprograms in this program area require sustained U.S. participation, leadership, and increased support. Particular emphasis is given here to the advancement of scientific knowledge through subventions to the International Council of Scientific Unions which, in turn, supports the activities of individual unions including an increasing number of special advanced training activities. Support is also provided to cooperative activities involving significant numbers of American scientists sponsored by other NGOs, centers of advanced studies, and regional training in the sciences.

U.S. contributions to UNESCO project and staff costs, exclusive of overhead (approximately $800,000), could be channeled to NGOs and U.S. professional societies and universities (the budget figures which follow include overhead and managerial costs):

3.1 ICSU Subvention: $300,000
Increase U.S. share of subvention (currently $135,000 via UNESCO) to include secondment of a science administrator to ICSU.

3.2 Other NGOs: $ 100,000
International Foundation for Science (IFS), COSTED, IBRO, ICRO, IOCD (see VI.1.1, above) for meetings and advisory services.

3.3 Physics: $100,000
ICTP (see VI.1.1, above).

3.4 Regional Cooperation: $200,000
Johns Hopkins University; IOCD, IUPAP (see VI.1.1, above); bilaterals via NSF/AID/NRC.

3.5 Regional Centers: $50,000
Bilaterals via NSF/AID/NRC.

3.6 Regional Scientific Unions: $50,000
Bilaterals via NSF/AID/NRC.

Another option is to provide the current level of U.S. contributions to VI.1.3 program and Funds-in-Trust overhead charges totaling approximately $800,000/year to UNESCO (Funds-in-Trust, donations, etc.).

TECHNICAL COOPERATION PROGRAMS

1. Consulting services, study grants, etc.: $90,100 2 - b
Comment: No specific additional support is recommended. Requirements should be considered under arrangements proposed in VI.1.3, above.

2. UNDP: ($4,497,500)
(Some 18 projects: faculty training and programs and development of research centers in Chad, Uganda, China, Laos, Pakistan, Albania, Bulgaria; Brazil, India, Indonesia, Vietnam; African Biosciences Network plus new projects)

3. UN Financing System: ($125,000)
   (Faculty training in Paraguay, Swaziland, plus new projects)

4. Funds-in-Trust: ($250,000)
   (Sri Lanka, Libya institutes and national academies, self financed)

5. Voluntary Contributions: ($10,000)
   (Theresa McKay Fund in cooperation with ICSU)

6. Associated Expert Scheme (AES): ($54,000)

VI.2: Research, Training and International Cooperation in Technology and the Engineering Sciences

	Biennial ($000)	Annual ($000)
Regular program	$ 5,550	$ 2,775
of which staff costs	3,482	1,741
of which project costs	2,068	1,034
Regular program and overhead (64.3%)	9,120	4,560
Other sources (see below)	23,305	11,653

Overall comment on VI.2: This program area includes potentially valuable training and cooperative research activities in the engineering sciences and in technology directed towards the needs of developing countries. Of the slightly more than one million dollars provided for projects, about $250,000/year go to infrastructure building possibly appropriate for oversight by other UN agencies; $400,000/year to engineering educational purposes; and $350,000/year to promotion of cooperative interactions primarily at a regional level, also possibly appropriate for other UN agency oversight. Although there appears to be limited interaction with the U.S. engineering/industrial community in implementing program VI.2 activities, there would be even less direct U.S. oversight of program planning and management after U.S. withdrawal from UNESCO. Current annual U.S. contributions in support of VI.2 regular program activities plus overhead ($4.5 million) are about $1.1 million; the U.S. share of program costs ($2.8 million) would be $700,000/year. Significant sup- port from other sources, particularly UNDP and Funds-in-Trust, total more than $11.6 million per year. It is proposed that support for multilateral activities on the order of $700,000/year, including oversight/overhead costs be provided beginning with FY 86. It is important to support an appropriate body sensitive to U.S. interests, such as NSF and/or NRC, to monitor these activities. This is an important area which will benefit from much greater involvement by U.S. professional engineering societies.

Alternative Option 1: This overall program could involve U.S. engineering professional organizations working with international and regional engineering organizations and exploiting the strength of U.S. engineering and technological institutions of higher learning. Activities could reinforce UNESCO-sponsored projects. Support would be provided through grants to U.S. professional societies and institutions of higher learning for complementary activities with nongovernmental organizations such as the World Federation of Engineering Organizations (WFEO):

Infrastructure Building Activities (VI.2.1)	$150,000
Training of Engineers (VI.2.2)	350,000
Regional Engineering Cooperation	200,000
TOTAL	$700,000

Alternative Option 2: Support could be provided through UN auspices such as UNDP, UNIDO, and the UN Financing System for Science and Technology for Development, for activities directed toward infrastructure building and regional cooperation. Engineering education activities could be managed by U.S. professional societies or U.S. universities:

Infrastructure development and regional cooperation activities--UN agencies	$350,000
Engineering education activities to complement UNESCO projects through U.S. engineering professional societies and universities	350,000
TOTAL	$700,000

VI.2.1 Strengthening of National Potential for Research and Technological Adaptation, and Improvement of Infrastructures and Technological Facilities

VI.2.1.1 Infrastructures and Technical Facilities 2 - b/c
$105,600
Support to specialized technological institutions in developing countries; travel grants to metrology courses organized by International Measurement Confederation (IMEKO); 5 workshops in regions, consulting services in collaboration with Union of International Technical Associations (UITA) and International Organization of Legal Metrology (IOLM), World Federation of Engineering Organizations (WFEO) for development of information services in engineering schools and training materials in metrology and materials sciences.

VI.2.1.2 Technological Research, Adaptation, and Innovation 2 - b/c
$146,550
Consulting services for the development of research activities and training materials; cooperation with Habitat,

International Union of Architects (UIA) training courses and services in various regions; pilot project with African Network of S&T Institutions (ANSTI) for seminars, studies; technical cooperation with various regions.

Comment on VI.2.1: This technologically-oriented program aimed at strengthening infrastructures could provide useful support to important development assistance activities involving NGOs such as the International Measurement Confederation (IMEKO), the Union of International Technical Associates (UITA), the International Organization of Legal Metrology (IOLM), and the World Federation of Engineering Organizations (WFEO). This area, of important concern for developing country interests, could be guided by other UN organizations. U.S. contributions in support of these activities, currently at a level of $150,000/year for project and staff costs but not overhead, should be monitored by U.S. professional engineering societies.

Alternative Option 1 is support through U.S. professional societies for bilateral/multilateral engineering development activities; Alternative Option 2 is support through other UN agencies such as UNDP, UNIDO, and the UN Financing System monitored by U.S. professional engineering bodies.

VI.2.2 Training of Engineers and Technicians, with Special Efforts Aimed at Increasing the Participation of Women

VI.2.2.1 New Methods for Teaching Engineering
$201,650 — 2 - b
Training through sequences of study; seminars in 8 countries, seminars, case studies on new technologies, social impacts, symposium on innovations in training of technicians in cooperation with WFEO; 2 publications, 5 handbooks, directory of engineering education institutions in developing regions; study tours.

VI.2.2.2 Cooperation between Universities and Industry
$68,900 — 2 - b
Six national projects linked to regional offices; network for information exchange.

VI.2.2.3 Postgraduate Training and Continuing Education
$123,350 — 2 - b
Meeting of international working group on continuing education; 15 courses, primarily Western institutions (other than the United States and Canada).

Comment on VI.2.2: Similar in concept to VI.2.1, these particular program activities are focused on strengthening training of engineers and technicians in developing countries, an appropriate area for UNESCO (and within its capability). There may be modest involvement of U.S.

engineering educators in these activities. However, no U.S. universities are involved in postgraduate training activities. Reinforcement of these training activities should be provided through U.S. professional engineering societies in close collaboration with UNESCO project activities. U.S. contributions to project and staff costs, but not overhead, are currently about $350,000/year.

Alternative Option 1 would provide this level of support to U.S. professional societies and universities for bilateral/multilateral engineering training and curricula development activities; Alternative Option 2 is provision of $350,000 to UN agencies (UNDP or UN Financing System) for reinforcing UNESCO engineering education activities.

VI.2.3 Development of Regional and International Cooperation

VI.2.3.1 Promotion of Cooperation
$119,850 2 - b
Cooperation among institutions in developing countries, information exchange, cooperation with regional professional institutions (International Center for Heat and Mass Transfer, International Institute of Advanced Studies in Caracas; travel grants, participation in activities of WFEO, and a multitude of regional engineering associations.

VI.2.3.2 Networks of Training Institutions
$54,250 2 - b/c
In all regions, undefined.

VI.2.3.3 Southeast Asia and Pacific Project
$135,150 2 - b
5 working groups (workshops/seminars, cooperative joint projects, exchange of teachers, cooperation with Federation of Engineering Institutions in SE Asia and Pacific.

Comment on VI.2.3: This area of concern would profit from integration into a single line item. For the same reasons noted under subprogram VI.2.1, above, it would seem appropriate for U.S. support of these activities, currently at a level of $200,000/yr. for project and staff costs but not overhead, be provided to U.S. professional engineering societies and institutions of higher education for bilateral/multilateral activities. A second option for supporting regional cooperative activities is provision of $200,000 to other UN agencies, such as UNDP and the UN Financing System, with monitoring by a U.S. body sensitive to U.S. interests.

TECHNICAL COOPERATION PROGRAMS

1. Consulting services: $78,550 2 - b
   Comment: No specific additional support is recommended. Requirements for consultant and training needs should be considered under arrangements proposed in VI.2.3 above.

2. UNDP: ($4,452,500)
   24 projects: Faculty training and development of technical centers in Burundi, Mali, Malawi, Nigeria, Uganda, Jamaica, Trinidad & Tobago, Bangladesh, India, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Lebanon, Morocco, Turkey; regional African Network of S&T institutions, plus new projects.

3. Regional Banks: ($1,000,000)

4. Funds-in-Trust: ($5,965,000)
   (Iraq, Libya--self financed, Bangladesh financed by Norway.)

5. Associate Expert Scheme (AES): ($235,000)

VI.3: Research, Training and International Cooperation in Key Areas in Science and Technology

	Biennial ($000)	Annual ($000)
Regular Program (84-85)	$ 7,243	$3,622
of which staff costs	3,399	1,670
of which project costs	3,844	1,922
Regular Program and Overhead (64.3%)	11,900	5,950
Other sources	2,500	1,250

Overall comment on VI.3: This program area includes a range of applied research and training activities having mixed usefulness within the designated fields of informatics, applied microbiology, and renewable energy resources. All are directed towards the needs of developing countries. Some might benefit from oversight by other UN agencies. As far as UNESCO program planning and implementation are concerned, the United States would have a limited role in guiding such efforts after a U.S. withdrawal from UNESCO except through indirect contacts via NGOs. The total annual program budget (projects, staff and overhead) for these activities is about $6 million of which the U.S. share would be $1.5 million. The U.S. contribution to program costs ($3.6 million) is approximately $900,000/year. It is proposed that selected activities, noted below, be supported at a level of $1 million/year. There is a mix of alternatives to consider depending on the particular area and preferred mechanism:

Alternative Option 1:

Informatics (selected activities): Nationally managed activities with possible use of other UN agencies	$ 500,000

Microbiology MIRCENs ($125,000) via Funds-in-Trust U.S. institutions ($125,000)	250,000
Renewable energy UN agencies; UNDP, UN Financing System	250,000
SUBTOTAL	$1,000,000

Alternative Option 2:

Informatics (selected activities): UNESCO (Funds-in-Trust, donations, etc.)	$ 500,000
Microbiology MIRCENs via ICSU or ICRO - $125,000 U.S. institutions - $125,000	250,000
Renewable energy U.S. institutions	250,000
SUBTOTAL	$1,000,000

In all cases, there would be a need to have an appropriate body sensitive to U.S. interests (NSF/AID/NRC) to oversee, monitor and guide these project investments. Staff/overhead costs for such management needs are included in the above budget proposal.

VI.3.1 Informatics

VI.3.1.1 Strategies for Development of Informatics 2 - b
$55,300
Assessments, regional seminars, consultative services.

VI.3.1.2 Applied Informatics and Informatics Training Centers 2 - a
$578,350
General training in microinformatics, development of teaching materials, pilot experiments--training of specialists in cooperation with International Federation for Information Processing (IFIP), seminars, postgraduate courses, Japan, Italy, Greece, mobile courses; Council for Computing Development (UK); 4 training and retraining courses in various regions, development of data banks and services.

VI.3.1.3 Social Consequences of Informatics Applications 1 - c
$55,300
Case studies linked to IX and VI.4; regional cooperation with European Coordination Center for Research and Documentation in Social Sciences; informatics and human rights linked to XIII.

VI.3.1.4 Acquisition and Adaptation of Technologies
$80,150 — 2 - b
Pilot experiments on applications of microinformatics, linked to IV.1.

VI.3.1.5 Development of Informatics
$274,150 — 2 - b/c
Statutes for intergovernmental program on informatics; regional cooperation in developing countries; cooperation with Intergovernmental Bureau for Informatics (IBI) linked to International Federation of Automatic Control (IFAC) and Data for Development (DFD); preparation of 2nd Conference on Strategies and Policies for Informatics (SPIN II) in cooperation with IBI.

Comment on VI.3.1: Some of the activities, particularly pertaining to training in applied informatics, are of value. Fruitful interactions with the U.S. informatics community are anticipated because of the U.S. position in this field. Future support of these activities should be limited to training (VI.3.1.2), strategies (VI.3.1.1), acquisition (VI.3.4) and that part of VI.3.5 pertaining to regional training activities. Program costs (projects, staff but not overhead) for recommended items total about $1.7 million/year, of which the U.S. contribution would be $425,000/year.

Alternative Option 1: The U.S. share of program costs plus overhead ($500,000), as limited above under Comment, could be provided through nationally mananged activities with possible use of other UN agencies such as UNIDO, UNDP and the UN Financing System in cooperation with the International Federation of Information Processing (IFIP). An important complementary support mechanism to these multilateral agencies would be the involvement and oversight by U.S. professional organizations to guide international projects, particularly the U.S. Association for Computing Machinery (ACM).

Alternative Option 2: Provide U.S. contribution in support of program costs to UNESCO (Funds-in-Trust, donations, etc.) limited to items noted above. Taking into account provision of overhead on Funds-in-Trust, this would total approximately $500,000. There would be minimal oversight of the use of these funds.

VI.3.2 Applied Microbiology and Biotechnology

VI.3.2.1 Microbiological Resources Centers (MIRCENs)
$60,900 — 2 - a
Research grants to developing country centers on nitrogen-fixation, fermentation technology, biomethanogenesis; newsletter documentation, MIRCEN journal, regional projects in Africa and Arab states; cooperation with UNEP on microbial strains.
UNEP: ($75,000)

VI.3.2.2 Policies for Biotechnology Research

$52,150 — 2 - b

Cooperation with FAO, UNIDO, UNEP, International Union of Microbiological Societies (IUMS); International Organization of Biotechnology and Bioengineering and ICRO (Panel on Microbiology) to provide consultant services on drawing up policies; contribution to regional societies concerned with applications.

VI.3.2.3 Applied Microbiology and Biotechnology

$75,300 — 2 - a

Twelve 3-week MIRCEN courses, 10 training courses (12 month duration) in various countries in advanced applications; research grants and postgraduate studies with institutes such as the International Institute of Advanced Studies (IDEA) in Caracas; organization of international conferences on Global Impacts of Applied Microbiology (Africa, Arab states, etc.).
UNEP support: ($50,000)

VI.3.2.4 Conservation of Microorganisms

$34,700 — 1 - a

Establishment of national collections in cooperation with FAO, WHO, UNIDO, UNEP, International Union of Microbiological Societies, International Organization of Biotechnology and Bioengineering and ICRO (Panel on Microbiology), World Data Center on Microorganisms (Brisbane), Nordic Register, fellowships; support of MIRCEN, Stockholm.
UNEP Support: ($25,000)

Comment on VI.3.2: This is an important area of work involving a number of international scientific organizations and unions in which U.S. scientists are leaders. Program costs (projects, staff support but not overhead) for these activities total about $500,000/year of which the U.S. share would be $125,000/year. It is recommended that additional support on the order of $125,000/yr. be provided to various MIRCENs activities, assuming that such funds might be available from other areas of the overall U.S. contribution to UNESCO.

Alternative Option 1:

Provide the U.S. contribution to program costs to UNESCO (Funds-in-Trust, donations, etc.) including overhead:	$125,000/yr.
Provide additional support to MIRCENs activities via U.S. institutions:	125,000/yr.
SUBTOTAL	$250,000

Alternative Option 2:

Provide the U.S. share of program costs ($125,000) for MIRCENs activities via ICSU or ICRO, plus a further contribution of $125,000 to MIRCENs activities through U.S. institutions:

MIRCENs direct support via ICSU/ICRO	$125,000/yr.
Grants for training and consultative services to U.S. institutions in support of MIRCENs activities	125,000/yr.
SUBTOTAL	$250,000/yr.

These options require oversight by an appropriate body sensitive to U.S. interests such as NSF and/or NRC.

VI.3.3 Renewable Energies

VI.3.3.1 New and Renewable Sources Utilization
$72,000 2 - b/c
10 research projects plus 10 demonstration projects via regional offices.

VI.3.3.2 Specialists Training
$102,500 2 - b/c
Audiovisual materials, preparation of manuals; seminars; 8 postgraduate training courses of 6 months duration.

VI.3.3.3 Regional Cooperation in Development of Energy Sources
$106,950 2 - b/c
Seminars; publications, promotion of South-South cooperation; adaptation of technologies (undefined).

VI.3.3.4 Networks for Information Exchange on Energy Resources
$269,950 2 - b/c
Studies, data bases, 2nd edition of directory, consultant services; pilot projects in regional centers; International Liaison Committee coordination.

Comment on VI.3.3: This area of potentially useful work directed towards the needs of developing countries has had little interaction with U.S. government agencies--the contact with the private U.S. scientific and engineering community is not known. The annual UNESCO budget for program costs (projects and staff) plus overhead is approximately $1.7 million. Annual program costs are on the order of $1.2 million, making the U.S. share $300,000/year. In view of the other UN agencies, GOs, and NGOs that are active in dealing with renewable energy issues, there is some question as to why UNESCO should be in this area at all. It is suggested that the U.S. share of support be provided through other channels at a level of $250,000.

Alternative Option 1:

Support selected renewable energy projects through other UN agencies, such as UNDP and the UN Financing System.	$250,000/yr.

Alternative Option 2:

Support projects specifically directed towards the needs of developing countries through grants to U.S. institutions under the oversight of AID and/or the National Research Council.	$250,000/yr.

TECHNICAL COOPERATION PROGRAMS

1. Consultative, advisory services: $77,450/yr. 2 - b

2. UNEP (cooperation with MIRCEN network for conservation of microbial genetic resources: ($200,000/yr.)

3. UNEP (Barbados - energy saving devices; Brazil - training; new projects): ($650,000/yr.)

4. UN Financing System for S&T and Development (Lesotho - solar energy; new projects): ($50,000/yr.)

5. Funds-in-Trust (Asia - regional cooperation in chemistry and microbiology from Japan): ($350,000/yr.)

MAJOR PROGRAM VI:
THE SCIENCES AND THEIR APPLICATION TO DEVELOPMENT

VI.4: Research, Training and International Cooperation in the Social and Human Sciences

	Biennial ($000)	Annual ($000)
Regular program	$ 8,031	$4,016
of which staff costs	3,711	1,856
of which projeot costs	4,320	2,160
Regular program and overhead (64.3%)	13,195	6,598
Other sources	525	263

Overall comment on VI.4: The purpose of this program is to develop the social sciences, the human sciences, and philosophy by strengthening national research potential, developing education and higher education programs, and improving access to specialized information and documentation. There are potentially useful activities to develop educational materials, reinforce advanced training in the social sciences, and promote international cooperative research on important topics of interest to U.S. social scientists. The current U.S. contribution to the regular UNESCO program (projects and staff), plus overhead, is approximately $1.6 million/year. The U.S. contribution to program costs is about $1 million/year. Particular concern needs to be devoted to ensuring that subventions are maintained to the NGOs in this area --U.S. contributions through UNESCO are on the order of $150,000/year. It is proposed that an overall program budget of $1 million/year be managed by an appropriate U.S. organization sensitive to U.S. interests with the objective of supporting multilateral collaborative research and training activities in the area of social and human sciences related to current UNESCO-sponsored projects. Consideration should also be given within this proposed budget to possible suitable activities falling under program VI.5. There is no particular funding proposed in the commentary covering VI.5 activities.

VI.4.1 Strengthening of National Potential for University and Postgraduate Training and Research

$165,850 2 - b

Inventory of national potential in research, training at the higher education level, information and documentation in the social and human sciences and philosophy. Promotion of basic and problem-oriented research. Advisory services provided to Member States and NGOs at their request. Development of training and teaching at the national level in the social and human sciences.

VI.4.2 Regional and Subregional Cooperation
$369,000 2 - b
Strengthening of organizations and programs for regional, subregional and national cooperation. Launching of a series of regional publications. Contribution to intergovernmental regional conferences.

VI.4.3 Development of Interregional and International Cooperation
$1,103,900 1 - b
Expand cooperation with the main NGOs in the social and human sciences. Disseminate information in the fields of social and human sciences. Subventions to International Social Science Council (ISSC) and International Committee for Social Science Information and Documentation (ICSSD). Cooperation with following NGOs: International Council for Philosophy and Humanistic Studies (CIPSH), ISSC, ICSU, Inter-African Council for Philosophy, and the Association of African Universities.

TECHNICAL COOPERATION PROGRAMS

1. Consulting services, study fellowships, equipment or financial contributions: $521,100 2 - b

2. UNDP, postgraduate training in applied social sciences in Caribbean; new projects: ($100,000)

3. Associate Expert Scheme (AES), provision of experts to operational projects by Member States: ($162,500)

VI.5: Research Training and Regional and International Cooperation in Some Key Areas in the Social and Human Sciences

	Biennial ($000)	Annual ($000)
Regular program	$1,418	$ 709
of which staff costs	672	336
of which project costs	746	373
Regular program and overhead (64.3%)	2,330	1,165
Other sources	---	---

Overall Comment on VI.5: The purpose of this program is to promote the development of a number of disciplines in the social and human sciences, including history, geography, linguistics, anthropology and the administrative and management sciences, by increasing research and improving education and advanced training. A further purpose is to launch regional, subregional, and international cooperation in certain priority fields associated with Major Programs VIII and XIII and research and education on the status of women. The program is also to "encourage philosophical reflection and interdisciplinary research on mankind seen in its unity." Special attention is to be devoted to the study of work and leisure activities, interdisciplinary cooperation for the study of man, and studies on the status of women. The annual U.S. contribution to program costs plus overhead would be on the order of $300,000; considering program costs, the contribution would be about $175,000/year. Because of the questionable quality of the described activites in this section, no special contribution for any of these subprojects is recommended. Consideration of possible cooperative support of certain projects based on peer review could be included within funds proposed in support of VI.4 activities.

VI.5.1 Development of a Number of Disciplines in the Social and Human Sciences

$88,050 — 1 - b/c

Promote training and research in the science of history, anthropology, geography, linguistics and administrative and management sciences. Linkages with International Union of Anthropological and Ethnological Sciences (IUAES), International Geographical Union (IGU), Permanent International Committee on Linguistics (CIPL), and the International Institute of Administrative Sciences (IIAS).

VI.5.2 Research and Cooperation in Key Areas AND
VI.5.3 Management, Work and Leisure Activities

$20,050 — 1 - c

Promote research in the social and human sciences in key areas which lend themselves to a multidisciplinary approach--to be undertaken in close relation to Major Programs VIII, XII, and XIII. Among the topics to be included: relations between peace, disarmament and development, human rights, rural development and the history of nutritional traditions, unemployment among young people, the status of women, and relations among management, work, and leisure activities.

VI.5.4 Interdisciplinary Cooperation for the Study of Man

$82,400 — 1 - c

Stimulate serious and widespread consideration of the unity of mankind both as a subject for scientific investigation and as a value in itself.

VI.5.5 Studies on the Status of Women and Development of New Approaches

$100,600 — 1 - b/c

Contribute to the development of theoretical frameworks and methodological approaches for the study of the role of women in history, and improve research on the status of women. Cooperation with the UN Regional Economic Commissions.

TECHNICAL COOPERATION PROGRAM

Consulting services, study fellowships, equipment or financial contributions: $82,000 — 2 - b

MAJOR PROGRAM IX: SCIENCE, TECHNOLOGY AND SOCIETY

IX.1: Study and Improvement of the Relationship Between Science, Technology and Society

	Biennial ($000)	Annual ($000)
Regular program	$ 2,628	$1,314
of which staff costs	1,379	689
of which project costs	1,249	625
Regular program and overhead (64.3%)	4,319	2,160
Other sources	360	180

Overall comment on IX.1: The purpose of this program is to achieve a better understanding of the process of acquiring, disseminating and applying new knowledge, with a view to promoting its assimilation and employment in the service of development in a variety of social and cultural situations. Case studies are to be prepared on the relationship between scientific and technological progress and the evolution of society in various social, economic and cultural contexts. This is an area of work containing a large variety of projects; many of limited or questionable value. Others worthy of encouragement involve NGOs such as ICSU and ISSC in carrying out case studies on the impacts of S&T on society and the examination of trends in research and S&T progress. The contributions to the commemoration of the centenary of Niels Bohr and the publication of the journal "Impact of Science on Society" should be supported. Much of the remaining work could profit from a careful review and evaluation. The current U.S. contribution to this UNESCO program (projects and staff), plus overhead, is about $540,000/year; the contribution to program costs would be about $330,000/year. It is proposed that an overall program budget of $250,000/year be managed by an appropriate U.S. organization (NSF/AID/NRC) sensitive to U.S. interests in order to support or complement selected UNESCO-related activities through NGOs and bilateral programs.

IX.1.1 Study of the Phenomenon of Science and Technology, its General Evolution and its Relations with Society

$183,050 2 - b/c

Produce comprehensive studies of the relationship between science, technology and society and the social assessment of technological innovations. Contribute to the creation or reinforcement in developing countries of interdisciplinary programs on the relationship between science, technology and society. Provide training for 40 specialists from LDCs.

IX.1.2 Participation of Scientists, Engineers, Technicians and the Public in Setting Priorities for and Evaluating the Effects of Scientific and Technological Progress

$65,100 1 - b c

Encourage a greater participation by scientists from all disciplines and engineers in studies of the relationship between scientific and technological research and the arms build-up and in strengthening their efforts to support disarmament.

IX.1.3 Science and Technology Extension Work and Making the Public Aware of What Science and Technology Have to Offer

$332,000 2 - b

Contribute to the establishment and consolidation of national programs in S&T extension work and active cooperation between Member states. Train some 20 science journalists. Publication of the journal, "Impact of Science on Society." Award science prizes.

TECHNICAL COOPERATION PROGRAMS

1. Study grants, contributions to training activities and purchase of laboratory equipment: $44,700 2 - b

2. UNDP support: ($130,000)

3. UN Financing System for S&T for Development: ($50,000)

IX.2: Science and Technology Policies

	Biennial ($000)	Annual ($000)
Regular program	$4,958	$2,479
of which staff costs	2,942	1,471
of which project costs	2,016	1,008
Regular program and overhead (64.3%)	8,145	4,072
Other sources	2,970	1,485

Overall comment on IX.2: The purpose of this program is to promote the framing of national science and technology policies which will translate socioeconomic objectives into plans of action and program budgets for research and development and science and technology services. This is an area containing a large variety of activities; many of limited or questionable value. However, the encouragement and support of regional science ministerial meetings can provide many beneficial results to the developing world enhancing the efficiency of training projects and continuing interactions with the global science community (such meetings at the European/North American level are of marginal value). Other science policy work appears to be academic or theoretical although advisory services to developing countries could be valuable if they include special training opportunities coupled to pragmatic development problems and measures to increase the effectiveness of research institutions. Much of the remaining work could profit from a careful review and evaluation. Other UN components may be more appropriate instruments for carrying out much of this work. The current U.S. contribution to the regular UNESCO program (projects and staff costs), plus overhead, is about $1,040,000/year; the contribution to only program costs would be $620,000/year. It is proposed that support of selected activities be provided at a level of $500,000 under the supervision of an appropriate U.S. organization (NSF/AID/NRC). Such support could be directed to NGOs, bilateral programs, and U.S. professional societies and institutions of higher learning. This program support should be coupled to proposed interim arrangements, noted in IX.1, above.

IX.2.1 Analysis of National Experience and Exchange of Information Relating to Science and Technology Policies

$464,650 2 - b

Conduct a regional survey of national S&T policies in the Latin American and Caribbean region and in the Arab states, and an analysis of the policies of Member States in Africa. Encourage interchange of experience relating to bibliographic and factual data bases for the formulation of S&T policies. Update of SPINES Thesaurus, further development of modules to process numerical data on S&T potential.
Funds-in-Trust (CASTARAB): ($162,500)

IX.2.2 Formulation of Science and Technology Policies at the National, Regional and World Level

$137,500 2 - b/c

Contribute through technical assistance to the framing, implementation and evaluation of the S&T policies of a number of Member States in the developing world. Promote preparation of operational S&T development projects in two countries, one in Asia and the other in Latin America. Facilitate coordinated implementation of joint R&D projects within economic communities established by groups of states. Participate in the development of a comprehensive S&T policy for all UN organizations.
Special Fund for Research and Experimental Development in Africa: ($50,000)

IX.2.3 Refinement of the Methods, Know-How and Techniques Needed to Manage National Scientific and Technological Development

$125,950 2 - b

Contribute to the determination of R&D priorities in a number of Latin American Member States. Facilitate the development of technological development indicators based on the unit technologies employed in the electronics, chemical and civil engineering industries. Evaluate efficiency levels of research units and institutions in Brazil, India, Spain, Nigeria, and the Ukranian SSR. Linkages with FAO, ILO, and the International Federation of Data Organizations in the Social Sciences (IFDO).

IX.2.4 Training the Skilled Personnel Needed for the Planning and Management of National Scientific and Technological Development
$136,600 2 - b/c
Establish an international scheme to develop and improve the training of planners and managers for S&T development. Create a regional network in Asia and in the Pacific region for teaching and research units in S&T policy. Develop and distribute manuals, select bibliographies and audiovisual teaching aids.

TECHNICAL COOPERATION PROGRAMS

1. Consulting services, organizing national seminars, setting up university teaching and research units, arranging study tours: $143,050 2 - b

2. UNDP: ($870,000)
Brazil - S&T policies; Czechoslovakia - fellowships; new projects

3. UN Financing System for S&T for Development: ($250,000)
Guinea - Documentation Institute; Thailand - Ministry of S&T; new projects

4. Funds-in-Trust: ($247,500)
CASTARAB Continuing Committee; special training with reference to IX.2 activities

5. Associate Expert Scheme: ($67,500)

6. Special Fund for R&D in Africa: ($50,000)

MAJOR PROGRAM X:
THE HUMAN ENVIRONMENT AND TERRESTRIAL AND MARINE RESOURCES

X.1: The Earth's Crust and its Mineral and Energy Resources

	Biennial ($000)	Annual ($000)
Regular Program (84-85)	$4,243	$2,121
of which staff and indirect costs	2,041	1,020
of which project costs	2,202	1,101
Regular Program and overhead (64.3%)	6,979	3,489
Other sources	3,960	1,980

Overall comment on X.1: In general, the earth science program of UNESCO is well-focused and conducted in a sound manner. The International Geological Correlation Program is one of the most productive and respected of the science activities sponsored by UNESCO. This is due in large part to the fact that the scientific integrity of the program is assured through joint sponsorship by UNESCO and the nongovernmental International Union of Geological Science (IUGS), an ICSU union. The major concern is to ensure no loss of support for the IGCP, the interdisciplinary research on the earth's crust and the data/mapping activities. In all cases, project support could be significantly enhanced. Additional IGCP project support will permit increased involvement by Third World countries and needed attention to more interdisciplinary activities. A 25% loss to the total regular program budget, including UNESCO staff costs, is on the order of $600,000; with the overhead charge added, that figure is on the order of $900,000. Given the value of the program and its presently under-funded situation, a total U.S. contribution of $1.5 million is suggested.

Alternative Option 1: Provide the program costs (project, plus staff) for the IGCP ($200,000) and the other program elements ($400,000) to UNESCO through the Funds-in-Trust or donations arrangement, as well as direct support to cooperating nongovernmental and/or intergovernmental organizations (e.g., ICSU/IUGS, UNEP, IAEA) coupled with support to appropriate U.S. backstopping agencies (e.g., USGS, NSF, and/or the National Research Council) to recommend on specific implementation/allocation and to provide continuing oversight ($900,000) for a total U.S. contribution of $1.5 million.

Alternative Option 2: Provide funds directly to IUGS for support of the IGCP and invite the Union also to act as agent for channeling U.S. support to other elements of the earth sciences program. Earmark increased support for particularly needy programs such as the IGCP, interdisciplinary research of the earth's crust, i.e., the IUGS-IUGG Lithosphere Commission (ICL), special programs such as the Geological Applications of Remote Sensing (GARS) and mineral deposit modeling and other new initiatives. Negotiations would be required with IUGS to determine the overhead charges for this management task. A U.S.

national focal point would be necessary to provide oversight and guidance. A total U.S. contribution of $1.5 million is suggested.

Alternative Option 3: Provide the totality of funds (about $1.5 million) to a U.S. government agent, such as the U.S. Geological Survey, possibly with advice from the U.S. National Committee on Geology (the parent body of the U.S. national committee for the IGCP), for appropriate utilization in multilateral governmental and nongovernmental forums. A portion of the funds would be required for management purposes.

X.1.1 Spatio-temporal Geological Correlation

X.1.1.1 International Geological Correlation Program Coordination
$103,150 1 - a
IGCP coordination; IGCP annual board meeting; cooperation with other organizations such as ICL, Geological Congress; publication of progress reports in the "Geological Correlation" series and the IGCP catalogue and indexes.

X.1.1.2 IGCP Program and New Projects
$147,950 1 - a
Support of IGCP working groups for meetings and publication of results of their work; selection of new IGCP projects (15).

X.1.1.3 Interregional Cooperation and Information Exchange
$83,250 1 - a
Dissemination of IGCP project results; promotion of regional and interregional cooperation.
SUBTOTAL: $334,350

Comment: This subprogram provides support for the IGCP which is conducted jointly with the IUGS. The purpose of the program is to encourage international research on basic geological problems, the identification and assessment of natural resources, and the improvement of the environment. The program is of high interest to members of the U.S. earth sciences community many of whom actively participate in implementing projects and in setting policy directions. Because of the joint character of IGCP sponsorship, U.S. scientists will be able to continue to participate through the IUGS although the United States does expect to continue to be represented on the IGCP Board and its Scientific Advisory Committee. Support for IGCP accounts for only 30% of the program budget despite its high merit. The resources allocated for IGCP project support, in particular, are woefully inadequate (about $150,000 annually) and should be at least three times that amount to be truly meaningful. At a minimum, the 25% of the program costs that may be lost by U.S. withdrawal (about $200,000) should be provided via one of the alternative arrangements.

X.1.2 Geology for Economic Development

$148,850 — 2 - b/c

Improvement of knowledge about the geological structure and mineral resources of Africa; field work; 3 postgraduate training courses; equipment, publication facilities, and data access for African institutions; participation by African geologists in meetings.

Comment: This subprogram is designed to help developing countries acquire, process and analyze geological data needed to assess their mineral and energy resources and emphasizes the design and operation of computer-based files for geological information. The program is conducted primarily by the Association of African Geological Surveys. There is virtually no U.S. involvement in the planning of the program. The intent of the program is acceptable, but it is flawed by the absence of any scientific guidance. The loss of the U.S. contribution to the program costs (about $70,000) should be provided through one of the alternative arrangements noted above. Consideration could be given to allocating resources to IUGS for the express purpose of providing a scientific advisory mechanism for this program or, alternatively, the funds could be used for the IGCP.

X.1.3 Geology for Land-Use Planning

$24,850 — 2 - a

Study of selected geological constraints in land-use planning; working groups and symposia; dissemination of findings, including via science films; with UNEP, IAEA, IUGS, and ICL. UNEP: ($200,000)

Comment: This program has addressed such problems as urban land subsidence and the geologic setting of major dams. U.S. participation is limited to occasional consultancies. The program funds that may be lost by U.S. withdrawal (about $12,000) should be provided through one of the alternative arrangements. Additionally, consideration should be given to supporting the IUGS-proposed workshop to be held in Hong Kong on geology for development, the first in what is planned as a series of workshops developed by the IUGS Research and Development Board.

X.1.4 Interdisciplinary Research on the Earth's Crust

$57,450 — 1 - a

Information exchange through support of meetings held by Lithosphere Commission, two IUGS-affiliated associations (IAGC & IAGOD), and others; support of LDC participants.

Comment: This is a new subprogram and apparently responds to the decision of the recent General Conference to support interdisciplinary research efforts by the Lithosphere Commission, an activity of two ICSU unions (IUGG & IUGS), and by two other IUGS-affiliated associations. This was a welcome decision supported by U.S. scientists. The loss in program funds (about $30,000) should be provided through one of the alternative arrangements. If available, additional resources could be channeled to the IUGS-IUGG Inter-Union Commission on the Lithosphere (ICL).

X.1.5 Processing and Dissemination of Data Relating to the Earth Sciences

X.1.5.1 Remote Sensing Techniques and Data Processing

$65,750 1 - a

Support and development of data processing techniques and of data obtained through remote sensing; cooperation with UN and NGOs such as CODATA (ICSU); meetings, expert missions, model development and testing, training of specialists.

X.1.5.2 Publication of Continental Thematic Maps

$177,350 1 - a

Preparation and publication of continental thematic maps; cooperation with Commission for the Geological Map of the World, INQUA and others; cartographic inventory of Africa.

SUBTOTAL: $243,100

Comment: This subprogram supports earth science information activities, especially geological maps and data acquired through remote sensing techniques. U.S. leadership in remote sensing makes the contributions of U.S. earth scientists eagerly sought by UNESCO. The activities of the Commission for the Geological Map of the World (CGMW), particularly the preparation of small-scale earth science maps, are important; the U.S. contributes heavily and the resulting maps are widely acclaimed and utilized by geologists in U.S. universities and in mineral and exploration companies. Also, there is interest in getting the CGMP to broaden its program to include oceanic areas and geophysical maps. The $120,000 that will be lost in program costs should be provided through one of the alternative arrangements noted above. Any additional resources could be channeled directly to IUGS with the understanding that other concerned bodies, such as CODATA, INQUA and the CGMW should receive funds via IUGS to support their involvement.

X.1.6 Training of Specialized Personnel, With Special Attention to Ensure the Training of Women Specialists

X.1.6.1 Postgraduate Courses in Earth Sciences

$224,600 2 - b/c

Postgraduate courses in earth sciences (21) in both developed and developing countries (none in the United States).

X.1.6.2 Training Seminars in Earth Sciences

$33,450 2 - b/c

Training seminars in earth sciences (4) plus exchanges of teachers "preferably" in developing countries; in collaboration with the Association of Geoscientists for International Development (AGID), International Centre for Geological Training and Exchanges (CIFEG) and others.

SUBTOTAL: $258,050

Comment: The postgraduate courses and training seminars supported under this program have little, if any, U.S. involvement. Unfortunately, no courses are held in the United States. The approximately $130,000 that may be lost in terms of U.S. program support should be provided through one of the alternative arrangements. Additional resources, if available, could be channeled to the geo-unions of ICSU, earmarked for training activities. The United States should be more actively involved in training seminars, for example. Two areas of U.S. expertise in which there is great international interest are publications, especially the editing, processing and publication of maps, and resource assessment.

TECHNICAL COOPERATION PROGRAMS

1. Participation program--help to member states in the organization of meetings and training: $43,400 2 - b/c

2. Extra-budgetary programs: ($1,050,000)
   a) UNDP
   b) Ghana: terminal support for Tarwa School of Mines
      Morocco: development of mining school, Rabat

   b) Regional development banks: ($225,000)

   c) Funds-in-Trust: ($460,000)
      Regional (Africa)--2nd regional training course in mining geology by Norway
      Expected new projects

   d) Associate Expert Scheme: ($90,000)

X.2: Natural Hazards

	Biennial ($000)	Annual ($000)
Regular Program	$1,893	$ 947
of which staff and indirect costs	1,281	641
of which project costs	612	306
Regular program and overhead (64.3%)	3,111	1,555
Other sources	668	334

Overall comment on X.2: This is an important program of direct benefit to the United States in terms of access to territories and information about natural hazards that could be useful if and when similar events occur within the United States. UNESCO, as an intergovernmental agency, provides a useful channel for data exchange and access to first-hand monitoring, assessment, and mitigation efforts within other countries.

U.S. experts in hazard assessment and risk mitigation are frequently utilized and there is a focus on the development of modern equipment and instrumentation. The possible loss in program support due to U.S. withdrawal is about $250,000; if overhead charges are included, the loss may be on the order of $400,000. Given the value of the program, U.S. support of $500,000 is suggested.

Alternative Option 1: Provide the U.S. contribution to program costs (project plus staff), $250,000 through the Funds-in-Trust or donations arrangement, with the remaining amount of U.S. funds, $250,000, for cooperating intergovernmental (e.g., UNDRO) and/or nongovernmental (e.g., IUGS and IUGG) organizations, on the recommendation of a designated U.S. national agent such as the U.S. Geological Survey, possibly with advisory services from the nongovernmental sector.

Alternative Option 2: Invite ICSU and/or IUGS to act as agent for the disbursement of U.S. funds, based on the advice and guidance of a designated U.S. group. Management (i.e., overhead) charges would need to be negotiated at both the national and international level.

Alternative Option 3: Provide the totality of funds ($500,000) to a national agent, such as the U.S. Geolgical Survey, to manage, utilizing alternative multilateral organizations as well as bilateral arrangements as appropriate.

X.2.1 Development of Scientific and Technical Knowledge with a View to a Better Assessment of Natural Hazards to Their Prediction

$132,250 1 - a

Technical studies with UNDRO; special study of seismic risks with UNDRO (seminars, meetings, field missions); evaluation of earthquake prediction techniques and networks; study of seismotectonic synthesis, seismic zoning, and volcanic risk; analysis of historic data on major earthquakes and volcanoes, and floods and droughts; expert training program with International Seismological Centre (ISC); a seismology seminar in the Arab States and in S.E. Asia; cooperation with NGOs.

Comment: The activities within this subprogram are aimed at enhancing scientific knowledge of natural hazards such as earthquakes, volcanic eruptions, floods and landslides, through increased international coordination and data exploitation leading to improved monitoring and prediction capabilities. The program is considered to be of high quality and involves a large number of experts throughout the world. U.S. experts are frequently utilized. The program is of direct benefit to those who live in hazard-prone areas. The opportunity to learn about the causes and effects of hazards, and options for mitigation of risk is important. There is no real alternative organization to UNESCO in this area. Nonetheless, at a minimum, the potential loss of the U.S. contribution to the program costs (about $70,000) should be made available through one of the alternative arrangements, noted above.

X.2.2 Mitigation of Risks Arising from Natural Hazards
$153,850 1 - a
Reorganization of operating procedures of International Advisory Committee on Earthquake Risk in cooperation with UNDRO; multidisciplinary studies on mitigation (working meetings and seminars: two on the Balkans and one each in Africa and Latin America); study of an international mobile monitoring system of volcanic activity in cooperation with UNEP, UNDRO, World Organization of Vulcanological Observatories, and two ICSU/IUGG associations: IASPEI and IAVCEI; mitigating climatic hazards, recommendations on preparing civil engineering codes and improvement of low-cost housing programs in earthquake-prone LDCs and preparation of seismic engineering manual; Andean region seminar on methods of earthquake-resistant construction; 7 postgraduate fellowships; public information project in Asia; study missions at request of Member States to assist with preparatory and rehabilitation measures before and after disasters.

Comment: The objectives of this subprogram are to promote studies of natural hazard warning systems and to decrease human and material losses resulting from natural disasters. The UNESCO International Advisory Committee on Earthquake Risk is an important forum for information exchange. Members are appointed by the Director-General and there is presently one U.S. member. If this position is lost following U.S. withdrawal, a form of compensation might be provided by seconding a U.S. person to the UNESCO staff. In this area of activity, UNESCO permits a degree of access to other countries and data that is not easily duplicated. There is no other single alternative organization that offers a comparable alternative mechanism. However, it should be noted that several of the ICSU unions in the geological/geophysical/geographical areas do address problems of natural hazards and support could be provided to enhance these efforts directly. Minimum program support of about $80,000 should be provided through one of the alternative arrangements presented above.

TECHNICAL COOPERATION PROGRAMS

1. Participation program: $19,950 2

2. Extra-budgetary programs: ($284,000)
   a) UNDP: Algeria--seismic microzoning study seismological network, Himalayan region

   b) UNDP: ($50,000)

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MAJOR PROGRAM X: THE HUMAN ENVIRONMENT AND TERRESTRIAL AND MARINE RESOURCES

X.3: Water Resources

	Biennial ($000)	Annual ($000)
Regular Program	$5,302	$2,651
of which staff costs	2,891	1,445
of which project costs	2,411	1,206
Regular Program and Overhead (64.3%)	8,710	4,355
Other Sources	5,822	2,911

Overall comment on X.3: This program area involves active participation of U.S. scientists and engineers in important global cooperative observational research activities. It is also a program that provides training and experience to meet the needs of developing countries. The United States has played a leading role in the establishment and implementation of the International Hydrological Program and is currently participating in a large number of IHP activities through the U.S. National Committee on Scientific Hydrology, located in the U.S. Geological Survey of the Department of Interior. Extensive multilateral and bilateral interactions have been promoted and enhanced through this UNESCO program. The United States loses its eligibility to be a member of the Intergovernmental Council and the Bureau of the Council on U.S. withdrawal from UNESCO. It will be possible to provide some leadership, at least in part, to the IHP in the future through U.S. participation in the nongovernmental organizations closely associated with the IHP. This is a valuable program in which the United States would profit from continuing participation. With respect to program X.3 activities, the current U.S. annual contribution to program costs (projects and staff costs) plus overhead is about $1,090,000. It is proposed that international cooperative efforts be supported in the future at a level of $1 million/year.

Alternative Option 1: The record to date of UNESCO management of program VI.3 is acceptable and the preferred option for maintaining interim support for these activities is to provide an annual contribution to UNESCO via Funds-in-Trust for 25% of the regular annual budget of about $2,700,000 (plus about 10% overhead) or $750,000. It is suggested that $250,000 be provided for U.S. backstopping via the U.S. National Committee on Scientific Hydrology. This latter amount would also provide additional support for the participation of U.S. scientists in IHP programs.

Alternative Option 2: It may be possible to support most aspects of the current IHP UNESCO activities at a level of $750,000/year on an interim basis through ICSU and/or one of its associated bodies such as the International Association of Hydrological Sciences (an association within IUGG), or the International Association of Hydrogeologists (affiliated with IUGS), with the agreement, of course, of these bodies. It is suggested that $250,000/year be provided to the U.S. National Committee on Scientific Hydrology as noted above.

Alternative Option 3: This program, at a level of $1 million/year, in direct support of ongoing and planned IHP activities, could be managed through a U.S. national focal point such as the U.S. National Committee on Scientific Hydrology with possible advisory services from the nongovernmental sector.

X.3.1 Improvement of Understanding of Hydrological Processes

X.3.1.1 Planning and Coordination

$115,050 1 - a

Third-phase (IHP-III) over next 5 years to provide scientific bases for water management; Intergovernmental Council of IHP and Bureau of Council to oversee program implementation; expert groups for studies; strengthening of IHP national committees; linked to other UN agencies and Intersecretariat Group for Water Resources.

X.3.1.2 Hydrological Processes and Parameters

$171,050 1- a

Preparation of management and modeling manuals; contribution to World Climate Program; support of national projects for illustrative value; linked to X.2, X.5, and X.6; urban hydrological processes linked to X.7; periodic publication of "Discharge of Selected Rivers of the World"; cooperation with and assistance to national IHP committees; symposia and workshops.

X.3.1.3 Influence of Man on Water Cycle

$82,500 1 - b

Synthesis of existing knowledge; development of assessment methodology linked to X.6 and X.8; study with UNEP of hydrological indices; symposium; publication of reports; linked to UNESCO/UNEP lithosphere project; monographs.

UNEP: ($175,000)

Comment: This area covers two of the four principal aspects of the IHP, which has identified 18 themes involving a multitude of projects and subprograms. Essential coordination services are provided under the oversight of the IHP Intergovernmental Council and the Bureau of the Council, bodies on which the United States would lose its eligibility to serve. Program costs for central coordination purposes total about $800,000/year--the U.S. share would be $200,000. As a preferred alternative, it is proposed to provide a contribution of $250,000 (including overhead) to an earmarked Funds-in-Trust account. Another option is to invite ICSU and/or one of its associated bodies to manage these resources for the United States. As noted, these options would require oversight by a U.S. body sensitive to U.S. interests, e.g., the U.S. National Committee on Scientific Hydrology, at a level of about $250,000.

X.3.2 Development of Scientific and Technical Knowledge with a View to the Assessment, Planning and Management of Water Resources

X.3.2.1 Methodologies for Evaluation

$51,600 1 - a

Planning and integrated management of water resources; final report on methods and infrastructures; studies and recommendations on optimization techniques; energy policies and water resources; link of IHP theme 4 activities to X.5.

X.3.2.2 Regional Cooperation

$217,900 2 - b

Experts and consultants working out of UNESCO regional offices; seminars in Africa under International Association of Hydrological Sciences and Association of Hydrological Research; technical assistance in hydrological and hydrogeological maps in collaboration with OAU and ECA and in South America, cooperating with regional economic commissions of the UN.

X.3.2.3 Rural Area Problems

$183,700 2 - b

Continuation of 3 major projects; launching of 2 new projects; seminars and training; technical assistance to regional major projects for Africa; cooperation with ECA; Funds-in-Trust (South of Sahara); Latin American and Caribbean project linked to ECLA, OAS, FAO, UNICEF, WHO and UNEP; mass media materials; major Arab project linked to ACSAD.

Comment: These areas are concerned with further implementation of Section III of the overall IHP program, and with a large number of interactions with governmental and nongovernmental organizations in several regions of the world. The simplest and most effective way of supporting this multilateral cooperative work would be provision of the current magnitude of U.S. contribution to Funds-in-Trust at a level of $300,000/year (including overhead). Another option would involve interim management and provision of this level of support ($300,000/year) to related cooperative activities through ICSU and/or one of its associated bodies. Both options would require U.S. oversight, as noted in X.3.1, above.

X.3.3 Training of Specialists, with Special Attention to Ensure the Training of Women Specialists

X.3.3.1 Methodologies

$45,000 2 - b

Training methodologies, public information, scientific and technical information systems; publications on teaching methods with IHP-III; training of specialized personnel; mass media, posters, etc.; preparation of report in cooperation with ILO, FAO, WHO for Natural Resources Committee of ECOSOC linked to International Drinking Water Supply and Sanitation Decade.

X.3.3.2 <u>Postgraduate Training</u>
$262,500 <u>2 - a</u>
For specialists and technicians; network of 25 institutions providing courses of 2-11 months duration; technical assistance for required training and IHP national committees.
UNEP: ($50,000)

<u>Comment</u>: These activities include further implementation of Section IV of the overall IHP and involve educational and training activities, including extensive postgraduate courses, for specialists and technicians in a large number of institutions throughout the world; U.S. institutions are actively involved in this work. A preferred option would involve provision of the current magnitude of U.S. contribution to a Funds-in-Trust account at a level of $200,000/year (including overhead). Another option is provision of this level of support ($200,000/year) to related cooperative activities through ICSU and/or one of its associated bodies. Both options would require U.S. oversight, as noted in X.3.1, above.

TECHNICAL COOPERATION PROGRAMS

1. Assistance for information systems, in-service training, regional publications, follow-up, equipment. $75,800 <u>2 - b</u>

2. UNEP: ($225,000)
Noted within program activities, above.

3. UNDP: ($1,996,000)
Continuation of projects in India, Mozambique, Nigeria, Portugal, expected new projects.

4. Funds-in-Trust: ($475,000)
Regional Africa (south of Sahara) financed by Islamic Call Society; training of hydrology technicians financed by Norway

4. Associated Expert Scheme: ($215,000)

MAJOR PROGRAM X:
THE HUMAN ENVIRONMENT AND TERRESTRIAL AND MARINE RESOURCES

X.4: The Ocean and Its Resources

	Biennial ($000)	Annual ($000)
Regular program	$ 8,084	$4,042
of which staff costs	4,370	2,185
of which project costs	3,714	1,857
Regular program and overhead (64.3%)	13,281	6,641
Other sources	6,490	3,245

Overall comment on X.4: This program has four basic objectives: 1) advance scientific knowledge of the ocean including improved management of both living and nonliving resources, 2) enhance research and training capacities, 3) promote international cooperation in marine research, and 4) foster dissemination of oceanographic data and information. The prime focus is on enhancing the marine science capabilities of the Third World although observational and data exchange activities are critical for all marine science communities. Thus, there is a focus both on basic science and building Third World capabilities in marine science. The prime organ for promoting this program is the Intergovernmental Oceanographic Commission, a semi-autonomous body within UNESCO in which the U.S. plans to retain its membership. Of the UNESCO program managed by the Division of Marine Sciences, 40% has been decentralized to the UNESCO Regional Offices for Science and Technology in Montevideo, Jakarta, New Delhi, Nairobi, and Cairo/Paris. The Division estimates that one-third of the program promotes the global advancement of marine science and two-thirds promotes marine science in developing countries. Both the IOC and the Division work closely with marine science bodies associated with ICSU, as well as various intergovernmental agencies such as WMO, FAO, and UNDP.

Alternative Option: The U.S. contributes about $1.1 million in support of project and staff costs in this UNESCO marine science program. Slightly more than 60% of the expenditure is by the IOC and close to 40% is by the Division of Marine Science. One option in terms of U.S. support for the program is to provide the IOC share of program support to the IOC Trust Fund ($700,000) and the rest as a Funds-in-Trust contribution ($400,000) for the work of the Division of Marine Sciences. Direct contributions via a U.S agency to cooperating organizations, such as SCOR, ECOR, ICES, WMO, FAO, and UNDP, are possible based on the recommendations of U.S. oversight and monitoring groups such as the Panel on International Programs and International Cooperation in Oceans Affairs (PIPICO/OES), NSF, and the NRC Board on Ocean Science and Policy (BOSP). A total program of about $2 million would permit continuation and a slight enhancement of international marine science activities at U.S. direction.

IOC/Trust Fund	$ 700,000
NSF/PIPICO/BOSP	600,000
Funds-in-Trust: Division of Marine Science	400,000
NSF/PIPICO/BOSP	300,000
TOTAL	$2,000,000

X.4.1 Promotion of Scientific Investigation and the Ocean and Its Resources

X.4.1.1 Study of the Role of the Ocean in Climatic Change
$101,900 1 - a
Planning research studies on the role of the ocean in climatic variablity and change; two intergovernmental meetings organized by IOC and annual meetings of the joint SCOR/IOC Committee on Climatic Changes and the Ocean (CCCO); experts meetings on WOCE and on the monitoring system.

X.4.1.2 Studies on Oceans and their Living Resources
$55,950 1 - b
Comparative studies, sponsored by the joint UNESCO/FAO program on ocean science and living resources, in the north and central Atlantic, the Western and Eastern Indian Ocean and the Pacific on economically important fish stocks; research program on nonliving resources implemented by the IOC regional subsidiary bodies, under joint sponsorship of the UN Office for Ocean Economics and Technology.

X.4.1.3 Study and Monitoring of Pollution in the Marine Environment
$116,250 1 - a
Development of the future world marine pollution research and monitoring program (MARPOLMON)--two meetings on methods, standards and intercalibration techniques. Exercise on intercalibration of methods of analysis for trace metals and organochlorines in the North Atlantic. Meetings of the Working Committee on the Global Investigation of Pollution in the Marine Environment (GIPME), and implementation of the GIPME program in cooperation with UNEP, the International Council for the Exploration of the Sea (ICES), the Commission for the Scientific Exploration of the Mediterranean Sea (ICSEM) and the IAEA. Training courses, fellowships, laboratory equipment, and service of experts in GIPME and MARPOLOM programs to developing countries.

SUBTOTAL: $274,100

Comment: This program is conducted completely by the IOC. The annual U.S. share of the program costs (project, plus staff) is about $140,000 and presumably could be provided to the IOC Trust Fund. Substantively, the program addresses the ocean component of the World Climate Research Program (WCRP) including the design of the World Ocean Circulation Experiment (WOCE), certain tropical studies and ocean monitoring. It is of fundamental interest to the United States. An important part of the planning is done by the Committee on Climatic Changes and the Ocean (CCCO), which is jointly sponsored by IOC and the ICSU Scientific Committee on Oceanic Research (SCOR). Other areas of activity include advancing knowledge of fish stock management and utilization of mineral resources, as well as encouragement of a system for monitoring the marine environment, in which U.S. interest is also high. Additional resources, if available, could be well utilized in this program, particularly for the CCCO which is seriously underfunded by UNESCO through the IOC budget. Regular coordination of activities need to be strengthened as well as efforts to enhance training in instrumentation (e.g., tide gauges for developing coastal states). A U.S. focal point for management of additional resources would be required.

X.4.2 Development of Scientific Knowledge with a View to the Rational Management of Marine Systems

$189,850 (Division of Marine Sciences) 1 - a

Studies on the marine environment and the continental margin; work of Joint Panel in Oceanographic Tables and Standards with ICES, SCOR, and IAPSO; remote sensing studies with ICSU, SCOR and IABO; monographs, keys on fishes, geological maps with CGMW; biological productivity of beaches and continental shelf areas with SCOR and IABO in association with subprogram X.5.1; historical studies; cooperation with IOC and other UN agencies, especially on marine pollution.

Comment: This program is operated by the UNESCO Division of Marine Sciences. The U.S. contribution to the program (project plus staff) is about $100,000. The studies involved are conducted largely by a number of nongovernmental organizations, most of which are associated with ICSU. One option is to contribute the U.S. share of program support through a special donation to UNESCO with additional resources ($75,000) earmarked for direct support of the cooperating nongovernmental and intergovernmental agencies. Another option is to provide the totality of recommended support directly to a single nongovernmental agent, such as ICSU, to manage. Both options would require some U.S. oversight, however. A third option is to provide funds directly to a U.S. agent, such as NSF or NOAA, to manage.

X.4.3 Ocean Services, Provision of Oceanographic Data, Information, Charts and Warnings

X.4.3.1 Development of Integrated Global Ocean Services System (IGOSS)

$55,300 1 - a

In cooperation with IOC and WMO, the development of IGOSS activities through meetings of experts.

X.4.3.2 Development of the Tsunami Warning System in the Pacific

$40,650 1 - b

Activities of the International Coordination Group for the Tsunami Warning System in the Pacific including annual meeting in U.S. in 1984; coordination with Program X.2; missions to countries of the Pacific to advise on national warning systems, meetings.

X.4.3.3 Ocean Mapping

$48,150 1 - a

Meetings of the Joint IOC/IHO Guiding Committee for the General Bathymetric Chart of the Oceans (GEBCO), other meetings of experts for the preparation of atlases.

X.4.3.4 Development of the International Oceanographic Data Exchange

$82,250 1 - a

IODE meetings on new data collection systems; exchange of oceanographic data; development of data centers; meeting of Joint FAO/IOC/UN Experts on the Aquatic Sciences and Fisheries Information System (ASFIS).

X.4.3.5 Dissemination of Oceanographic Research Results

$57,400 1 - a/b

Publications on oceanographic research; newsletter with UN, FAO, IMO and WMO; technical papers; cooperation with FAO on ASFIS publications.

SUBTOTAL: $283,750:	
$226,350	(IOC)
52,100	(Division of Marine Sciences)
5,300	(Other)

Comment: Data on subsurface ocean temperatures and salt content obtained by merchant and research ships of many nations are collected and transmitted through IGOSS; only a small fraction is obtained by U.S. ships. The IGOSS is of value but it needs improvement and expansion of coverage, particularly in the developing world. The IODE is important as a source of foreign marine data through the World Data Center (oceanography) programs, especially in terms of access to Soviet data through WDC-B located in Moscow. All programs except 4.3.5 are conducted by the IOC. U.S. support of these IOC activities is about $120,000 (project plus staff) and could be provided directly to the IOC Trust Fund; about $30,000 might be provided to the Division of Marine Sciences as a donation or contribution. Additional resources might be allocated to cooperating UN agencies based on recommendations of a U.S. agent such as PIPICO.

X.4.4 Strengthening of National and Regional Capacities for Marine Research, Ocean Services, and Training

X.4.4.1 Development of Marine Science and Technology Infrastructures
$329,100 2 - b
Training programs, workshops, consultants, technical assistance. Latin American and Caribbean cooperation with IOCARIBE and the UNEP Action Plan for the Wider Caribbean; in Asia and the Pacific: regional Mangrove Project cooperation with IOC and UNDP; in Africa: cooperation with UNEP Regional Seas Program, network of tide gauges for climate change studies; cooperative activities with Arab Council for the Marine Environment of ALESCO.

X.4.4.2 Training of Scientific and Technical Personnel
$136,350 2 - b
Fellowships for 6-9 months duration for study in physical, chemical, geological and biological oceanography and ocean engineering; workshop on marine science curricula; regional meeting on university ocean engineering curricula in Latin America in cooperation with Engineering Committee on Ocean Resources (ECOR).

X.4.4.3 Training, Education and Mutual Assistance in Marine Sciences (TEMA)
$108,200 2 - b
Enhance marine science capabilities of developing countries; workshops; consultants to help prepare Marine Science Country Profiles and development of national marine science policies.

X.4.4.4 IOC Ocean Science Programs and Ocean Services Activities
$215,800 1 - b
Assistance to developing countries to participate in IOC training seminars, workshops; interregional activities and cooperation; provision of experts at meetings.
Voluntary contribution (IOC Trust Fund): ($175,000)

SUBTOTAL: $789,450:

$324,000	(IOC)
199,900	(Division of Marine Sciences)
265,550	(Other)

Comment: This program is focused on technical training activities and helping the developing countries to enhance their marine science capabilities. Much of the work is undertaken regionally. It appears that IOC activities in this area are not well advanced. The UNESCO regional offices are apparently active in this area, and maintain liaison with the UNESCO Division of Marine Sciences. This program could be especially strengthened in Latin America and the Caribbean. One option is to make a grant of $175,000 to the IOC Trust Fund and a donation or contribution for the Division's activities of $100,000. Additional resources could be made available through UNDP. Also, support is suggested for a TEMA (Training, Education, and Mutual Assistance) management mechanism in the United States to promote technical assistance through, for example, the Agency for International Development.

X.4.5 Strengthening of International Oceanographic Cooperation and Formulation of Intergovernmental Policies

X.4.5.1 Governing Bodies and Secretariat Services of IOC
$123,450 1 - a
Meetings of the IOC Executive Council; missions of officers and IOC; publications for specialists and general public illustrating activities of IOC.

X.4.5.2 Regional Subsidiary Bodies of IOC
$74,550 1 - b
Meeting of regional subsidiary bodies of IOC.

X.4.5.3 Scientific and Technical Support for the IOC Program
$67,200 1 - a
Advisory support to IOC by nongovernmental organizations, such as SCOR, ECOR, IABO, and Permanent Service for Mean Sea Level (PSMSL).

SUBTOTAL: $265,200

Comment: This section of the IOC program covers meetings and other administrative expenses for the IOC secretariat. Support is also provided to nongovernmental advisory bodies such as SCOR. A contribution to the IOC Trust Fund in the amount of $150,000 would cover the U.S. share of program costs (project plus staff). Additional funds could be allocated directly to SCOR and to the other cooperating bodies via NSF based on recommendations of a national (U.S.) body such as PIPICO or BOSP.

TECHNICAL COOPERATION PROGRAM

1. Training, fellowships, grants: $54,650 2 - b

2. Development projects: ($1,000,000)
UNDP, Burma, Cuba, Egypt, Greece, Mexico, Thailand, Uruguay, expected new project.

3. UN Financing System for Science and Technology for Development: ($250,000)
Madagascar, expected new projects.

4. UN Environment Programme: ($225,000)
Regional (Africa), Cuba, expected new projects.

5. Islamic Development Bank: ($325,000)
Yemen

6. Funds-in-Trust: ($1,155,000)
For Burma (from Norway), Iraq, Oman, Qatar, for IOC (from Japan)

7. Associate Experts Scheme: ($90,000)

X.5: Management of Coastal and Island Regions

	Biennial ($000)	Annual ($000)
Regular program	$2,651	$1,326
of which staff costs	1,849	925
of which project costs	802	401
Regular program and overhead (64.3%)	4,355	2,176
Other sources	999	500

Overall comment on X.5: The objective of this program is to promote effective management of coastal and island zones and to aid in resource preservation. Most of the activities are a part of the MAB program; the remainder are conducted by the Division of Marine Sciences. Activities include pilot projects, training and workshops. There is substantial involvement by UNEP, FAO, and WHO as well as SCOR and IABO. Program support (project plus staff) of about $300,000 is suggested as a contribution to UNESCO (Funds-in-Trust, donations) and by an appropriate national focus: USMAB - $100,000 and NSF/PIPICO - $100,000 for a total support package of $500,000.

X.5.1 Development of Syntheses of Knowledge Relating to Interactions between Terrestrial and Marine Environements in Coastal and Island Systems

X.5.1.1 Interdisciplinary Research Projects — 1 - b

$53,450

Nine interdisciplinary research projects undertaken regionally and six pilot projects with UNDP and UNEP.

X.5.1.2 Study of Coastal and Island Systems — 1 - b

$45,250

International studies with IABO and SCOR; Mediterranean regional MAB activities; SCOR/UNESCO panel on coastal systems.

SUBTOTAL: $98,700

Comment: This program comprises a series of regionally based research projects, some of which are in collaboration with UNDP and UNEP, and some coastal systems studies with SCOR and IABO. The U.S. share of the activities is in the range of $25,000. A donation or contribution to UNESCO may be possible or a U.S. agent, such as NSF/PIPICO, could manage them.

X.5.2 Establishment of the Basis for the Integrated Management of Coastal Zones

X.5.2.1 Study on Coastal Zone Development — 2 - b

$60,800

Survey of status of coastal zone development in developing countries; consultant missions and workshops; cooperation with X.3.

X.5.2.2 Pilot Projects for Integrated Management
$36,500 1 - b

SUBTOTAL: $97,350

Comment: This program is a mixture of activities, some conducted by the Division of Marine Sciences and some within the MAB program. A direct donation or contribution to UNESCO to make up the U.S. share of program support, plus resources for USMAB, are suggested.

X.5.3 Integrated Management of Islands

X.5.3.1 Pilot Projects on Intergrated Research
$71,600 1 - b
Multidisciplinary studies on regional basis with X.6; management of island environments and land-use planning in three regional stations with MAB national committees and UNEP.

X.5.3.2 Dissemination of Management Data
$34,100 1 - b
Dissemination of data on management of island systems within MAB framework; report on population environment/resource interaction with UNEP and UNFPA; training and handbook.

SUBTOTAL: $105,700

Comment: These activities are within the MAB program. Alternative arrangements might include a direct donation to UNESCO plus support for USMAB to provide oversight and to enhance U.S. involvement.

X.5.4 Training of Specialists
$55,950 2 - b
On-site training of specialists and managers; postgraduate training; advanced training in ecology of coastal and brackish water in MAB context; short courses.

Comment: The majority of these activities are a part of the MAB program; only a small portion are conducted through the Division of Marine Sciences. A direct contribution to UNESCO plus support for USMAB is one way to assure U.S. involvement. Enhanced utilization of U.S. universities and scholars to assist with training scientists of the Third World could be fostered.

TECHNICAL COOPERATION

1. Fellowships, grants: $43,250 2 - b

2. UNDP: ($374,500)
Asia and Pacific mangroves

3. UNEP: ($125,000)
Regional (Africa) expected new projects

MAJOR PROGRAM X:
THE HUMAN ENVIRONMENT AND TERRESTRIAL AND MARINE RESOURCES

X.6: Land-Use Planning and Terrestrial Resources

	Biennial ($000)	Annual ($000)
Regular program	$3,807	$1,904
of which staff costs	1,875	938
of which project costs	1,932	966
Regular program and overhead (64.3%)	6,254	3,127
Other sources	4,306	2,153

Overall comment on X.6: This area of acticity, directed towards applied research on natural resources management and the dissemination of practical results, is the centerpiece of the Man and the Biosphere (MAB) Program. MAB includes many activities initiated by the U.S. scientific community. The USMAB Secretariat and scientific advisory apparatus should continue to provide intellectual and managerial guidance. There are four levels of concern: (1) that the USMAB Secretariat and support structure be on a sound footing; (2) that the international (UNESCO) MAB Secretariat be provided managerial support and leadership from the U.S. scientific community; (3) that quality projects within the current program area be reinforced with U.S. funding as may be necessary due to constraints on resources resulting from the withdrawal of U.S. overall support of UNESCO beginning in 1985; and (4) that within the overall MAB program, catalytic support be provided to innovative U.S. longer-term initiatives to achieve MAB objectives.

USMAB must be assured adequate support on a continuing basis as an *a priori* condition for consideration of contributions to international Man and the Biosphere activities. Resources are need to help ensure participation and leadership of the U.S. scientific community in these important global observational activities. A USMAB secretariat backed up by adequate scientific advisory support is a requirement for managing and overseeing the interim alternative mechanisms proposed in this assessment. USMAB should also provide encouragement and support to the development of innovative interdisciplinary contributions to new programs such as the one on global change currently being considered by ICSU.

With respect to program X.6 activities, the current U.S. annual contribution to program costs, including overhead, is approximately $800,000/year. The U.S. share of project/staff costs without overhead is about $500,000. This amount could be provided to UNESCO through Funds-in-Trust, donations, etc.

Alternative Option 1: Assuming that recent decisions within UNESCO to significantly improve overall MAB management are successfully implemented, the most efficient and effective means to support the program would be through an annual contribution to UNESCO (Funds-in-Trust, donations, etc.) of $500,000 including overhead. In addition, it is recommended that a U.S. science administrator be seconded to the UNESCO MAB secretariat ($150,000/year) and that $450,000 be provided USMAB for program planning, new initiatives, and staff and overhead costs. This would total $1.1 million.

Alternative Option 2: Support of international MAB activities could be provided totally through USMAB ($950,000). Secondment of a U.S. science administrator plus administrative support to the UNESCO staff ($150,000) is also recommended. The total is $1.1 million/year.

X.6.1 Promotion of International and Interdisciplinary Cooperation in the Field of Land-Use Planning and Terrestrial Resources

X.6.1.1 MAB Coordination

$104,500 1 - a

Coordination of activities under 14 research themes; cooperation with UNEP, FAO, WHO, WMO, UNU; support of NGOs (ICSU, IUCN, IUFRO, SCOPE, IGU); work of MAB Council and MAB Bureau.

X.6.1.2 Promotion of National Activities and Regional Cooperation

$41,900 1 - a

Strengthen national MAB committees; evaluation criteria; consultant services.

Comment: This section covers overall management of MAB. Since on withdrawal from UNESCO the United States would lose official status on the International Coordinating Council (ICC) as well as eligibility to serve on the bureau as one of the four vice presidents, consideration should be given to seconding a U.S. scientist to UNESCO to assist in the direction of the program (est. cost: $150,000/year).

Alternative Option 1: With respect to UNESCO program costs (project and staff costs, but not overhead), it is recommended that discretionary funds be provided to UNESCO to coordinate and assist national MAB committees. The provision of a U.S. contribution (approx. $100,000/year) to UNESCO (Funds-in-Trust, donations, etc.) plus $100,000 to USMAB for cooperative land-use planning activities would total $200,000.

Alternative Option 2: Provision of the same amount of support ($200,000) to USMAB for collaborative projects with UNEP, ICSU, and the International Union for the Conservation of Nature and Natural Resources (IUCN).

X.6.2 Intergrated Land-Use Planning and the Utilization of Resources in Humid and Subhumid Tropical Regions

X.6.2.1 Pilot Research Projects

$100,150 1 - a

Practical land-use planning, and management of resources in humid and subhumid tropical zones; 12 projects plus new pilot

projects (e.g., energy, ecology, hydrology) linked to IHP and biosphere reserves; dissemination of research results linked to interests of FAO, World Bank, UNEP, WHO, WMO; joint efforts with UNEP, IUCN, WWF, Global Forest Fund (Jaycees International).
UNEP Fund: ($200,000)

X.6.2.2 Comparative Studies
$35,700 1 - b
Studies and summaries on tropical ecology; cooperation with NGOs, seminars, link to applied microbiology and biotechnology, IUBS, IUFRO.

X.6.2.3 Training in Ecology, Land-Use Planning
$58,950 1 - b
Training in tropical zones coordinated with international bioscience networks, ICSU; FAO (ICRAF).
Funds-in-Trust: ($250,000)

Comment: This is an area of interest to the United States; projects appear to have been well-designed and implemented.

Alternative Option 1: An efficient means of maintaining current support of program costs (project, staff costs) at a level of $100,000 would be through a contribution to UNESCO (Funds-in-Trust, donations, etc.). Additional resources should be made available to USMAB for the support of international activities in this area ($100,000). The total is $200,000.

Alternative Option 2: Provision of the same amount of support ($200,000) to USMAB. These funds would be used for grants to selected projects, such as those in Indonesia and Venezuela. Grants to U.S. professional institutions might also be considered. This option would require strengthening the USMAB Secretariat.

X.6.3 Integrated Management and Rural Development of Arid and Semi-Arid Zones

X.6.3.1 Networks of Pilot Projects
$102,000 2 - a
Coordinated pilot research projects in arid and semiarid zones; 4 regional networks of research and training projects; cooperation with biosphere reserves, UNEP, IUCN; links to FAO, UNSO, WMO.
UNEP extension activities: ($75,000)

X.6.3.2 Use and Circulation of Research Findings
$51,550 2 - a
Demonstration courses; provide research results to rangeland congress, conference on arid lands.

X.6.3.3 Training in Integrated Management

$39,000 2 - b

Desert and semiarid zones; cooperation with FAO, UNEP, UNSO, Institut du Sahel, etc.

Comment: This is an area of primary benefit to developing countries and of fairly high value as far as design and performance is concerned. The United States benefits from cooperative exchanges and the provision of data and results from other countries' research: Sahel, China, USSR, etc.

Alternative Option 1: As noted in the previous item, support of program costs (projects, staff) could be provided through a contribution to UNESCO (Funds-in-Trust, donations, etc.) at a level of $100,000/year. Additional resources should be made available to USMAB for the support of international activities in this area ($100,000). The total is $200,000.

Alternative Option 2: This same level of support could be provided directly under USMAB oversight to selected projects under bilateral arrangements involving U.S. professional institutions; total $200,000.

X.6.4 Integrated Land-Use Planning and Continuous Monitoring in the Temperate and Cold Zones

X.6.4.1 Cooperation at Subregional Level

$43,750 1 - b

Scientific cooperation within temperate and cold zones; networks; cooperative project grants.

X.6.4.2 Environmental Implications

$35,700 1 - c

Industrialization and intensification of agriculture; ecological effects of pollutants, engineering works, etc.

X.6.4.3 Monitoring Long-Term Environmental Change

$25,250 1 - a

Baseline (e.g., desert spread, acid rain) areas; cooperation with UNEP, WHO, WMO.

UNEP: ($50,000)

Comment: Projects of subprograms 6.4.1 and 6.4.3 are valuable and of direct interest to U.S. scientists.

Alternative Option 1: Support of the U.S. share of program costs for selected projects could be provided at a level of $50,000/year to a UNESCO Funds-in-Trust account. Additional resources should be made available to USMAB for the support of international activities in this area ($50,000); total $100,000.

Alternative Option 2: This same level of support could be provided to selected project areas through USMAB oversight of grants to professional institutions ($100,000).

X.6.5 Training of Specialists and Technicians, with Special Attention to Ensure the Training of Women Specialists, and Testing of New Systems of Instruction in Land-Use Planning

X.6.5.1 Postgraduate Training Courses
$67,950 2 - c
Up to 5 medium duration courses.
UNEP: ($75,000)

X.6.5.2 Seminars
$72,900 2 - a
Short postgraduate courses; 10 new courses in cooperation with regional centers.

X.6.5.3 Institutional Improvement
$46,900 2 - a
Research and training facilities; consultant services, teaching materials to national institutions.

Comment: Of primary interest to developing countries. High-value projects (6.5.2 and 6.5.3) could be supported through Alternative Option 1 by a contribution to UNESCO (Funds-in-Trust, donations, etc.) of $100,000 plus resources to USMAB for collaborative international activities, $100,000; total $200,00. Alternative Option 2 provides this same level of resources ($200,000) to USMAB for international activities in this area.

X.6.6 Dissemination of Information on the Various Aspects of Land-Use Planning and Innovations in this Field

X.6.6.1 Land-Use Planning Results
$64,950 1 - a
Dissemination of MAB research results in land use planning; MAB INFO system; educational material on resource management; directory of scientists; reports; regional newsletters.

X.6.6.2 Publications
$15,700 2 - b
Methods for integrated resources planning.

Comment: This is an area of value to U.S. scientists as well as developing countries.

Alternative Option 1: Provision of current U.S. share of program costs (estimated at $50,000/year) through the UNESCO Funds-in-Trust or donations arrangement.

Alternative Option 2: Provision of this same level of resources through USMAB.

TECHNICAL COOPERATION PROGRAMS

1. Research, Training, Information Activities: $58,500 2 - c
   Comment: No additional support is recommended, included in the above.

2. UNDP: ($240,500)
   Sahel pastoral development, training

3. UN Sudano-Sahelian Office (UNSO): ($236,500)
   Desertification control

4. Funds-in-Trust: ($700,000)
   Kenya arid land research station by Federal Republic of Germany; new projects

5. Associate Expert Scheme: ($325,000)
   Provision of experts to operational projects by Member States.

X.7: Urban Systems and Urbanization

	Biennial ($000)	Annual ($000)
Regular program	$1,846	$ 923
of which staff costs	995	498
of which project costs	851	425
Regular program and overhead (64.3%)	3,033	1,517
Other sources	708	354

Overall Comment on X.7: This program area is largely directed toward the needs of rapidly evolving, large urban conglomerations, particularly those of economically evolving countries. However, projects are uneven in quality. It is recommended that U.S. support and participation be monitored by USMAB and/or an appropriate U.S. body sensitive to U.S. interests. The same caveats prevail as noted under program X.6. This is a potentially valuable program. Therefore, it is recommended that resources be allocated for support of urban MAB activities at a level of $300,000/year within a total X.6-9 budget of some $2 million.

Alternative Option 1: An efficient means of providing support and encouragement for selected activities falling under subprogram X.7.1 ($70,000/year) and X.7.2 ($30,000/year), totaling $100,000, would be through a contribution to UNESCO (Funds-in-Trust, donations, etc.). Additional support for these activities at a level of $200,000 is proposed through USMAB administered international activities. Total proposed support in this area is $300,000/year.

Alternative Option 2: Support of MAB/urban activities at a level of $300,000/year to be administered by USMAB.

X.7.1 Planning and Integrated Management of Urban Systems as Ecosystems

X.7.1.1 Pilot Projects
$78,900 2 - b
Urban systems pilot projects in different biogeographical regions; 6 pilot projects in 4 regions; collaboration with UNEP; links to Habitat, WHO, IFIAS, IFLA, IHP.
UNEP: ($50,000)

X.7.1.2 Technical Information Exchange
$52,200 2 - b
Urban and land-use planning; regional seminars, documents.
UNEP: ($25,000)

Comment: This is a useful area of primary benefit to developing countries. Support of projects and training could be provided under Alternative Option 1 on a selected basis through contributions to UNESCO (Funds-in-Trust, donations, etc.) at a level of $70,000 to cover current U.S. annual contributions for program costs. It would be possible to provide such support through USMAB administered international arrangements (Alternative Option 2). In both alternatives, there is an opportunity to provide for significant multilateral activities at a level of $100,000/year through USMAB resources.

X.7.2 Training in the Planning and Management of Urban Systems

X.7.2.1 Training of Urban Managers and Planners
$62,350 2 - b
Regional courses, booklets.
UNEP: ($25,000)

X.7.2.2 Information Exchange
$108,800 2 - c
Training in town planning and architecture; collaboration with International Union of Architects; UNESCO Prize.
UNEP: ($25,000)
Funds-in-Trust: ($125,000)

Comment: This is also an area of primary benefit to developing countries and consideration should be given to providing selective support to program 7.2.1 through Alternative Option 1, as a contribution to UNESCO (Funds-in-Trust, donations, etc.) at a level of $30,000/year to cover current U.S. contributions to program costs. A good Alternative Option 2 is to provide this level of support to selected related projects through bilateral arrangements managed by USMAB. In both alternatives, it is proposed that USMAB manage additional international activities at a level of $100,000.

X.7.3 Promotion of Public Awareness of the Problems of Urbanization

X.7.3.1 Public Participation 2 - c
$32,000
Environment for living pilot project.

X.7.3.2 Future of Habitat and Environment 2 - c
$33,200
Studies and regional seminars.
UNEP: ($25,000)
Habitat: ($25,000)

Comment: This is an area of unknown quality. No additional support is recommended.

TECHNICAL COOPERATION PROGRAMS

1. Research, training, information activities: $115,700 2 - c
Comment: No additional support is recommended.

2. UNEP: ($175,000)

3. Habitat: ($25,000)

4. Funds-in-Trust: ($125,000)

5. Associate Expert Scheme: ($54,000)
Provision of expert to MAB secretariat by member country.

X.8: The Natural Heritage

	Biennial ($000)	Annual ($000)
Regular program	$1,145	$ 573
of which staff costs	641	321
of which project costs	504	252
Regular program and overhead (64.3%)	1,881	941
Other sources	2,228	1,114

Overall Comment on X.8: This high-quality program area covering the Natural Heritage is of direct interest to the U.S. scientific and environmental community and concerns the elaboration and coordination of a global network of biosphere reserves. It is a program receiving support from the World Heritage Fund and UNEP at a level about two times the regular UNESCO budget. The same caveats prevail for overseeing these activities as noted under program X.6.

Alternative Option 1: Contribute $150,000/year to UNESCO (Funds-in-Trust, donations, etc.) to cover current U.S. share of program costs. This important area should be provided additional support through international cooperative projects at a level of $150,000 under USMAB oversight.

Alternative Option 2: Under the supervision of USMAB, support ($300,000/year) could be provided to project activities through nongovernmental professional organizations including particularly the International Union for the Conservation of Nature and Natural Resources (IUCN). A third alternative would include provision of this resource level as a special contribution to the World Heritage Fund.

X.8.1 Establishment of Systematic Inventories of the Natural Heritage and Research Concerning its Preservation

X.8.1.1 Systematic Inventories

$27,100 1 - a

Monitoring of representative ecological areas to determine global trends; research on conservation of genetic material; biosphere reserve network; technical assistance to national MAB committees; cooperation with Ecosystem Conservation Group (UNEP, IUCN, FAO); MAB Technical Notes.

UNEP: ($50,000)

Comment: This is an area of direct interest to U.S. scientists. Discretionary funds are required by the central MAB secretariat to cover current U.S. contributions. These could be provided through UNESCO Funds-in-Trust, donations, etc., or alternatively through USMAB working closely with the World Heritage Fund.

X.8.2 Preparation and Application of International Instruments for the Preservation and Enhancement of the Heritage

X.8.2.1 World Heritage Convention

$21,200 1 - a

International instruments; collaboration with World Heritage Committee, IUCN; World Heritage List.

World Heritage Fund: ($500,000)

X.8.2.2 International Instruments in Natural Heritage

$12,000 1 - b

Comment: This is also an important item. The United States could cover its share of program costs by providing support through UNESCO (Funds-in-Trust, donations, etc.), or through USMAB working closely with the World Heritage Fund.

X.8.3 Development of the International Network of Representative Ecological Areas

X.8.3.1 Development of Biosphere Reserve Network
$73,300 1 - a
New reserves; assistance to states; international soil museum; monitoring.
UNEP: ($155,000)

X.8.3.2 International Cooperation in Biosphere Networks
$34,950 1 - a

Comment: This is a significant item for the United States. Particular attention should be devoted to supporting the development of biosphere reserve networks.

X.8.4 Training of Specialists, with Special Attention to Ensure the Training of Women Specialists
$53,300 2 - a
Technical assistance; regional training centers; collaboration with World Heritage Fund, UNEP.
World Heritage Fund: ($250,000)
UNEP: ($105,000)

Comment: This is an item of significant benefit to the developing world; high-value training activities could be supported on a selective basis through Funds-in-Trust or bilateral arrangements managed by USMAB as a second alternative option.

TECHNICAL COOPERATION PROGRAMS

1. Research, training, information activities: $28,350 2 - b
   Comment: included under comment X.8.4, above.

2. World Heritage Fund: ($750,000)

3. UNEP: ($310,000)

4. Associate Expert Scheme: ($54,000)

X.9: Environmental Education and Information

	Biennial ($000)	Annual ($000)
Regular Program	$2,208	$1,104
of which staff costs	1,401	701
of which project costs	807	403
Regular program and overhead (64.3%)	3,627	1,814
Other sources	1,280	640

Overall Comment on X.9: This program area, including environmental education and information, contains a mixture of activities of varying quality, yet all potentially useful. These activities are largely directed towards producing practical resource management information for developing countries through projects pertaining to communications and publication of research results. Some of these activities are of interest to the United States.

Alternative Option 1: Provide the U.S. share of support for selected activities ($150,000) to UNESCO through Funds-in-Trust, donations, etc., plus an additional $150,000 to USMAB; total $300,000.

Alternative Option 2: Provide support ($300,000) through USMAB to U.S. institutions and nongovernmental organizations.

X.9.1 Production and Dissemination of Scientific Information on the Environment

X.9.1.1 Dissemination of Technical Information

$78,700 1 - a

Communication of research results and technical information to policy makers and users; expanded poster exhibit in cooperation with ICSU/CTS; support to MAB national committees for translations; support to MAB field projects for preparation of information; preparation of teaching materials.

X.9.1.2 Land-Use Research Results for Decision Makers

$26,550 2 - b

Presentation of results to deal with practical problems of managing natural resources; use of research sites and biosphere reserves for demonstration purposes.

X.9.1.3 Teaching Materials

$19,000 2 - b/c

Experimental teaching material for general environmental education; dissemination through information and innovation networks of UNESCO; linked to program V.2.

X.9.1.4 Publication of "Nature and Resources"

$104,600 1 - b

Quarterly bulletin in English, French and Spanish; co-publication in Russian; provides information on MAB, IHP, and IGCP.

X.9.1.5 Educational Films on Environment

$8,000 2 - c

In conjunction with MAB program and in cooperation with Habitat exchange and distribute films relating to International Year of Shelter for the Homeless (1987); film competition among LDC film-makers.

Habitat: ($25,000)

Comment: This area includes a mixture of information dissemination activities, all potentially valuable but some of poor quality. Projects of value to U.S. interests are contained in X.9.1.1 and X.9.1.4; those of value to developing country interests are in X.9.1.2.

Alternative Option 1: Since this centrally coordinated activity requires discretionary funding, consideration should be given to provision of $150,000 for earmarked activities to UNESCO through Funds-in-Trust, donations, etc.. An additional $150,000 should be provided USMAB to support international activities directed towards development of educational materials. The total is $300,000.

Alternative Option 2: Provide $300,000 to USMAB for U.S. participation in multilateral environmental education activities.

X.9.2 Development of General Environmental Education

X.9.2.1 Pedagogical Research

$10,550 2 - c

Exchanges of information and experimental data; pedagogical research and experiments; newsletter "Connect"; symposia, regional seminars on inclusion of environmental education in university courses.

X.9.2.2 Pedagogical Materials

$22,250 2 - c

Promotion of research and experimentation; pedagogical materials at all levels linked to IV.2, V.2, V.5.1, V.3.3; mass media.

X.9.2.3 Training Activities

$32,150 2 - c

Training of teaching, administrative and technical staff linked to II.3.2, IV.3, V.3.3 and V.5; national and regional in-service seminars; preparation of courses for in-service training.

X.9.2.4 Adaptation of Education Materials
$21,050 2 - b
Preparation and adaptation of educational material; content and methodology manuals translated into official languages; general environmental education module; audio-visual materials linked to II.3.2 and II.5.2; module for training education planners.

X.9.2.5 Regional Cooperation
$22,950 2 - c
Regional and international cooperation; technical support through regional offices; consultation with international institutions.

Comment: This area of current limited value should be strengthened to provide "users" with information on resource management. Consideration could be given to covering the current U.S. contribution for these activities (X.9.2.4) through Funds-in-Trust. Alternatively, a second channel would involve providing support for selected parallel projects under the oversight of USMAB. The amount is included under options noted above for X.9.1.

X.9.3 Promotion of Awareness of Environmental Problems in Vocational Training

X.9.3.1 Administrators
$22,650 2 - c
Promotion of awareness in administrators and economists; meeting of experts; preparation of training syllabuses.

X.9.3.2 Engineers
$21,550 2 - c
Promotion of awareness in engineers of environmental issues.

Comment: No provision of resources is recommended.

TECHNICAL COOPERATION PROGRAMS

1. Research, training, and information activities: $13,350 2 - b
Comment: Provision of U.S. support included under X.9.2.5, above.

2. UNDP: ($615,000)
Joint implementation of International Environmental Education Program; production of educational materials.

SCIENCE ACTIVITIES FROM OTHER MAJOR PROGRAMS

Although the purview of this assessment centered on Major Programs VI, IX, and X, there are certain activities in other Major Programs of interest to U.S. scientists and engineers. A brief commentary on three specific activities is provided, but it must be emphasized that it is necessarily not as detailed as that provided for the major programs in the report itself. Activities included here are:

- Scientific and Technological Information: Major Program VII (in part)
- Teaching of Science and Technology (secondary school level): subprogram V.2
- Statistics on Science and Technology: General Activities, Chapter 2

Budgetary considerations for these activities are not included in the overall discussion of programs and budgets at the beginning of Chapter 4 of the NRC report.

UNESCO's Program on Scientific and Technological Information

Assessment/Potential Impacts

UNESCO's concern for development of scientific and technological information services and networks goes back about 15 years to the establishment of the UNISIST Program, largely a U.S. initiative. Current UNISIST activities are contained within the General Information Program (PGI) which is described in Major Program VII. The United States is a member of the 30-country Intergovernmental Council for the General Information Program. Overall Program VII activities, including overhead, are budgeted at a level of $10 million per year; regular program costs are about $6 million per year. Funding from "outside" sources totals about $3.5 million per year.

The access to and free flow of scientific and technical information (STI) are of great importance to all countries. A major objective of the United States in taking the initiative to establish the UNISIST program in the early 1970s was to help the developing world avoid becoming information "have-nots" during a period of rapidly evolving technology influencing information handling on a worldwide scale. Another objective was to be an active participant in discussions on information standards and on information network development.

There have been beneficial results from the UNISIST Program and some problems--it has not achieved all that had been hoped. Some of the problems stem from the fact that there has been diminished U.S. leadership and presence in the program. For some years, there has been no focal point in the federal government for considering policies, coordinating programs, and dealing with international issues in the area of STI.

Serious attention should be given to examining the international aspects of STI policies, programs, and needs (including the work of UNESCO and other international bodies) with regard to U.S. national interests in this area. It is in the national interest to promote a stable period for international scientific communication during the decades ahead. To achieve this, an assessment or blueprint should be prepared, whether the United States withdraws from UNESCO or not, to clarify U.S. objectives and the appropriate role it should play in international STI. The Office of Science and Technology Policy (OSTP) or NSF might be called upon to convene a meeting where the interests of technical agencies and departments, as well as those of the private sector, could be assessed. The U.S. National Commission on Libraries and Information Science with the cooperation of nongovernmental organizations could also contribute to this process.

Alternatives

UNISIST is an important area of UNESCO's work that needs to be addressed in the context of overall international scientific and technological information programs and clarified U.S. objectives. Selected science information activities should be supported in the light of this assessment through funds administered by NSF and/or the U.S. National Commission on Libraries and Information Science.

Notes on Major Program VII: Information Systems and Access to Knowledge with respect to scientific and technological information activities

VII.1 Improvement of Access to Information: Modern Technologies, Standardization, and Interconnection of Information Systems

refers to work on:

- UNISIST Guide to Standards for Information Handling.
- UNISIST Reference Manuals for Machine-Readable Bibliographic Descriptions and for Description of Research Projects and Institutions.
- UNISIST normative texts and materials for improving the compatability and interconnection of UN information systems and services.
- Networks for the exchange of information and experience in science and technology, for example, in Asia and the Pacific (ASTINFO).

- Development of compatible information systems and the establishment of the Global Network on Scientific and Technological Information.

VII.2 Infrastructures, Policies, and Training Required for the Processing and Dissemination of Specialized Information

refers to work on:

- Promotion of national information policies and the multilanguage publication of the UNISIST quarterly newsletter.
- Development of information services for scientific and technical literature.
- Scientific and technological data services.
- Establishment of an information consolidation unit following recommendations of a UNISIST Working Group on Information Analysis and Consolidation.
- Consultant services for establishing scientific and technological information centers

VII.3 UNESCO Information and Documentation Systems and Services

refers to:

- The International Oceanographic Data Exchange (IODE).
- International information system relating to new and renewable energy sources.

All program areas refer to work on establishing information policies, the provision of information services, and training of information specialists.

V.2: Teaching of Science and Technology

Assessment/Potential Impacts

UNESCO has devoted considerable attention to the improvement of the teaching of science and technology, particularly at the secondary school level, over the past 25 years. The products of "in-school" work are of value to all countries although most of the efforts are directed toward the needs of developing countries. This program is administered in the Division of Science, Technical, and Vocational Education under the Assistant Director General for Education. It is a program concerned with the development of science and technology teaching materials (networks and documentation services, course content development, training workshops, technical advisory services) and their dissemination (extension courses, clubs and summer camps, out-of-school projects). The total program budget (staff and projects) plus overhead is about $5 million per year--the U.S. contribution is about $1.25 million. Considering only program costs ($3 million), the U.S. contribution is $750,000 per year. Support from "outside" sources totals about $2.4 million per year.

The improvement of secondary school science education through the development of course content materials and teacher training is important throughout the world. Initial work in this area at UNESCO, inspired by U.S. scientists, was carried forward by a particularly able staff unit, originally established within the science and technology component of the Secretariat. This responsibility has since shifted to the Education Directorate.

U.S. scientists and science educators have been actively involved in UNESCO-sponsored course content development projects and teacher training activities in many countries and regions. An impressive example of this participation is the Institute for the Promotion of Science and Technology Teaching in Thailand funded by UNDP and administered by UNESCO, where Americans have participated for over 10 years. Other examples of American involvement in this area are projects in the Middle East and in China.

Another important area of work of value to the United States is the support and encouragement given to establishing an information network on the teaching of science and technology in liaison with the International Bureau of Education. The activities of the affiliated International Clearinghouse on Science and Mathematics Development located at the University of Maryland are of national as well as worldwide importance.

With respect to the current UNESCO program, increased support should be provided to subprogram V.2.1, concerned with the Development of School Teaching of Science and Technology (the qualification of out-of-school in the UNESCO program title is inappropriate and should be deleted). The work on so-called out-of-school projects, V.2.2 is of questionable value.

Alternatives

It is proposed that resources at a level of $1.5 million per year be channeled to U.S. professional groups and universities operating international programs to reinforce selected UNESCO activities. These efforts should be managed by an appropriate body sensitive to U.S. interests such as the NSF and/or NRC.

V.2 Teaching of Science and Technology

	Biennial ($000)	Annual ($000)
Regular Program (1984-1985)	$6,070	$3,035
of which staff and indirect costs	4,127	2,064
of which project costs	1,943	971
Regular Program and overhead (64.3%)	9,973	4,987
Other sources	4,835	2,418

V.2.1 Development of School and Out-of-School Teaching of Science and Technology

V.2.1.1 Exchange of Information
$127,115
Network on teaching of S&T in liaison with International Bureau of Education; publication on innovations in five languages; documentation services; international symposium.

V.2.1.2 Experimental Activities
$106,250
Curricula research and evaluation; inquiry on place of S&T in curricula; improvement in curricula; 4 new pilot projects in experimental areas.

V.2.1.3 Course Content
$118,450
Content development in various disciplines and interdisciplinary curricula; publication of reference documents; seminars; preparation of materials; studies in math education; new trends in biology teaching; nutrition education.

V.2.1.4 Training Workshops
$136,250
Preparation of training materials; development of equipment; travel grants to developing countries; establishment of national training programs; regional cooperation for design and production of inexpensive lab and teaching equipment.

V.2.1.5 Technical Assistance
$64,900
Strengthening of national infrastructures; regional consultative committee in Africa.

V.2.2 Dissemination of Scientific and Technological Knowledge

V.2.2.1 Extension Courses
$82,100
Nutrition and health through media; preparation of teaching materials; technical documents and kits; preparation of international symposium; case studies.

V.2.2.2 Out-of-School Activities
$79,050
S&T programs for young in rural areas; clubs, summer camps, periodicals; preparation of teaching materials; source book on out-of-school activities; volume in studies in math education.

V.2.2.3 Training for Out-of-School Work
$121,450
Technical support for implementation of experimental training programs; workshops for out-of-school organizers; travel grants for study tours; symposium.

V.2.2.4 Technical Cooperation
$49,600
Technical assistance for strengthening national out-of-school programs; better public understanding of S&T.

TECHNICAL COOPERATION PROGRAMS

1. Participation of UNESCO in national programs: $86,450

2. UNDP: ($560,000)
Afghanistan, Caribbean, China, Egpyt, Indonesia, Hungary

3. Islamic Development Bank: ($1,500,000)
Lebanon

4. Funds-in-Trust: ($357,500)
Nigeria (self-financed); Asia and Pacific financed by Japan; Caribbean financed by Arab Gulf Program

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General Activities, Chapter 2: Statistics on Science and Technology

Assessment/Potential Impacts

UNESCO's efforts in the area of science and technology statistics are carried out in a central Office of Statistics under the Assistant Director General for Program Support. The large staff, working with statistical services of member countries, focuses on (1) collection, dissemination, and publication of statistical data; (2) support of international and regional conferences; (3) development of international standards, concepts, and definitions to improve comparability of data; and (4) training and improvement of statistical infrastructures. The total program budget (projects and staff) plus overhead of this activity is about $800,000 per year--the U.S. contribution is $200,000 per year. If one considers program costs only (about $500,000 per year), the U.S. contribution is $125,000.

The UNESCO Statistics on Science and Technology program has developed common concepts, definitions, and statistical methods for use by all UNESCO member countries in surveying the expenditures and manpower employed in R&D by the several sectors of their economies. The UNESCO definitions differ in some respects from those of the OECD Frascati Manual in order to make it possible for countries with free enterprise, socialist, and development economies to reply to the periodic questionnaire. (In the United States, the NSF organizes the replies to both the OECD and UNESCO inquiries.) Member countries forward their completed surveys--usually carried out by their respective central statistical bureaus--to UNESCO, which publishes the results in the UNESCO Statistical Yearbook. This UNESCO effort is the only one that provides more or less comparable data on the magnitude of employment and investment in R&D in a large number of countries beyond the OECD circle. The work has been carried on since its inception in the late 1960s by the Division of Statistics on Science and Technology of the UNESCO Office of Statistics, largely independently of any UNESCO activities in science policy formulation.

Developing and interpreting standards for statistical surveys of R&D investment is a highly technical activity, particularly when it spans many countries. It depends on continuing contact with statisticians in member countries and on periodic conferences to reinforce common concepts, consider problems of reporting and interpretation of data, and identify useful new directions, such as the proposed survey of member country outlays for science and technology information and documentation.

The data emerging from the periodic surveys are available for analysis those interested in the science and technology commitment of other countries and for experts concerned with intercountry differences in trends. U.S. nonmembership in UNESCO would limit the availability of U.S. expertise for this area.

Alternatives

This statistical work on science and technology is difficult, useful, and should be encouraged. The United States has played an important role in guiding these efforts including staff services on the Secretariat. A preferred interim alternative arrangement to enable continuing U.S. professional interactions would be the provision of $200,000 per year to the NSF to support advisory services to the UNESCO staff and member country statistical services. Another interim alternative would be the provision of this same level of resources to the OECD Science Technology Indicators Unit to provide such services to the UNESCO staff.

Statistics on UNESCO Science and Technology

Chapter 2, under General Activities, pertains to UNESCO work on Statistics. A portion of these efforts is concerned with Statistics on Science and Technology. The 1984-1985 approved program and budget include the following items:

I. Collection, Dissemination and Publication of Statistical Data and Improvement of Techniques for Processing Them
Annual Projects: $7,950
Experimental questionnaires on S&T information and life-long training.

II. Analyses and Studies and Support for International and Regional Conferences
Annual Projects: $3,300
Analytical studies, estimates of interregional disparities, indicators.

III. Improved Standardization and International Comparability of Data, and Advancement of Statistical Methods
Annual Projects: $14,600
Cooperation with other international bodies (ECE, OECD, CMEA, OAS); preparation of first international survey on S&T information and documentation; guides on survey methods.

IV. Training of Personnel and Improving Statistical Infrastructures
Annual Projects: $47,650
Two regional training seminars, pilot projects, consultative services.

Participation Program
Annual Projects (approx.): $12,000
Statistics on science and technology.

Total projects costs	$ 86,000 per year
Total staff costs, estimated	409,000 per year
Total annual program, estimated	$495,000 per year
Total program, plus overhead, estimated	$813,000 per year

U.S. Participation in International S&T Cooperation

A Framework for Analysis

Mitchel B. Wallerstein

The decade of the 1980s has witnessed a renewed interest in international scientific cooperation and the forces that shape U.S. participation. Enhanced appreciation of science as a national resource, of the value of cost/task sharing in large or expensive projects, of technological advances in telecommunications and travel, and of constrained opportunities for younger scientists are some of the factors that have become central topics of international science and technology (S&T) policy discussions. At the same time, science and technology have become increasingly important as instruments of foreign policy.

U.S. policy on international S&T cooperation must take account of opposing and, often, irreconcilable pressures. On the one hand, the constraints on domestic resources and growing scientific excellence abroad suggest strongly the need for the U.S. to enter into cooperative arrangements with other technically advanced nations. Yet, on the other, foreign policy imperatives and concerns about the loss of proprietary information to potential competitors or security-sensitive information to potential adversaries have created new impetus in the United States for greater vigilance in the open interchange that characterizes the international S&T community.

THE SETTING AND OBJECTIVES OF S&T COOPERATION

International cooperation in science and technology encompasses a broad spectrum of activities ranging from informal exchanges or visits arranged privately by individuals to large multinational projects or programs funded and arranged either directly by governments or through international organizations on their behalf.

The form of cooperation best suited for any particular S&T initiative is determined by a wide range of factors, often varying according to the nature and historical traditions of the scientific field, prevailing economic and/or political constraints, and other factors. Among the considerations that are involved are the following: (1) the nature and frequency of the information to be exchanged, (2) the length of time for which cooperating scientific personnel must interact, (3) the extent to which the problem lends itself to a division of labor and the relative scientific strength of the cooperating partners, (4) the relative economic strength of the cooperating partners, (5) the type and cost of facilities involved, (6) the degree to which global coordination is required (e.g., the model of the International Geophysical Year), and (7) the extent to which national security or proprietary concerns or other sovereign prerogatives are involved.[1] The form of a particular cooperative activity evolves as the result of discussion, consultation, and the historical pattern of collaboration among interested parties.

The type of international cooperation favored in one discipline may be quite different from that favored by another. A survey of National Science Foundation (NSF) program managers found, for example, that certain modes of cooperation were cited with greater frequency in some disciplines than in others. The results of the survey are summarized in Table 1.

Scheinman[2] has noted that the overall record of international cooperation among technologically advanced countries appears to favor bilateral channels, especially when something more than the exchange of personnel and information is involved. On the other hand, multilateral channels seem to be favored for agreements emphasizing information exchange. This latter category also includes nongovernmental contacts such as those initiated through the International Council of Scientific Unions (ICSU) and its disciplinary member unions.

The motivations for intergovernmental cooperation are extremely diverse. On the most general level of national policy, international S&T cooperation is supported in pursuit of both symbolic and utilitarian goals. Symbolic goals are essentially political, involving considerations of prestige, political influence, propaganda, and national security, while utilitarian goals are usually focused on economic and/or technological objectives.[3] At a more functional policy level, international S&T cooperation in a particular field may be attractive for some or all of the following reasons:[4,5]

TABLE 1 Frequency With Which Modes of Cooperation With Western European Nations Are Cited by Various NSF Programs

	International Conferences	Focused Seminars	Short-Term Exchanges	Sabbaticals	Fellowships—Postdocs	Bilateral Research	Multinational—Continuing	Multinational—Temporary
Astronomical, atmospheric, earth, and ocean sciences	16	15	9	18	8	17	13	13
Applied sciences and research applications	20	12	12	4	11	25	5	2
Biological and behavioral sciences	11	10	10	13	10	11	5	6
Social sciences	0	12	10	6	0	10	8	7
Physics	12	12	11	14	7	6	6	6
Engineering	8	15	13	13	15	11	7	6
Materials research	3	5	10	11	8	8	3	3
Mathematics and computer science	10	10	7	10	9	6	5	2
Chemistry	4	6	8	10	9	7	4	2

SOURCE: NSF Professional Staff Questionnaire.

1. *Cost Sharing*—avoid unnecessary duplication of effort particularly in the case of research facilities or instrumentation requiring substantial amounts of capital.
2. *Concept Development*—formal cooperation can build on the invisible colleges of science to speed the identification and exploitation of new research approaches.
3. *Acceleration of New Technologies.*
4. *Enhancement of Scientific and Engineering Competence*—a particular concern at the end of World War II.
5. *Political Considerations*—S&T cooperation may provide an attractive means of projecting national influence or of encouraging other forms of contact between nations (e.g., the United States-People's Republic of China bilateral S&T agreements, Antarctica).

Clearly, U.S. policy has encompassed all of these objectives at various times, although the emphasis accorded to each has shifted over the years.

In the period immediately following World War II, a chief U.S. concern was the rebuilding of the European science apparatus which had been largely disrupted or destroyed. U.S. assistance was particularly important in some of the faster moving disciplines such as molecular biology and high energy physics. During the 1950s, the United States supported a number of initiatives to promote international S&T cooperation, some of which were intended further to promote the redevelopment of European scientific infrastructure and some to benefit the United States itself. These included U.S. support for the creation of the specialized technical agencies of the UN, such as the World Health Organization (WHO) and the UN Educational, Scientific, and Cultural Organization (UNESCO). Later in the decade, the United States was instrumental in an effort, launched through the NATO Science Committee, to establish an International Institute of Science and Technology.[6]

Perhaps the most enduring example of U.S. involvement in international S&T cooperation during this period was the organization in 1957-1958 of the ICSU-sponsored International Geophysical Year (IGY), involving representatives of 67 countries with worldwide networks or surveys in 14 scientific disciplines in all aspects of the earth's environment. The IGY opened up the Antarctic and initiated the space age. The organization of the IGY itself spawned new ways of conducting science for large-scale problem solving that had profound effects on the disciplines involved (e.g., oceanography) and on the manner in which individual scientists approached their fields. It introduced mechanisms for the orderly sharing of detailed observational data as a new dimension to the traditional sharing of scientific results through publication. It also generated new intellectual capital which, in turn, gave rise to additional cooperative research efforts (e.g., the Global Atmospheric Research Program, or GARP).

By the 1960s, European science had become largely self-sufficient, and the United States was experiencing a retrenchment in its own R&D budget. The result was that, for the first time, a substantial number of young American scientists were receiving *European* support for their work in European labs. With the dawning of the era of East-West detente in the late 1960s and early 1970s science and technology agreements became favored instruments of both symbolic and instrumental diplomacy. Conversely, the end of the detente era during the Ford administration witnessed the curtailment or cancellation of many of these same bilateral S&T arrangements.

The post-oil crisis (1973) "stagflation" that has afflicted the entire Organisation for Economic Co-operation and Development (OECD) community since the early 1970s has had a dampening effect on the willingness and capacity of the United States and other technically advanced countries to undertake new international S&T activities. One manifestation has been a changing demography in the academic job market, which has created a reluctance on the part of young American researchers to leave the country for extended periods to participate in scientific exchanges. The decline in the number of Ph.D.s undertaking foreign postdoctoral study in the period since 1971 is apparent in the data presented in Table 2.

U.S. policy since the mid-1970s regarding international S&T cooperation has remained at cross purposes. Europe and Japan are no longer "weak sisters" requiring U.S. capital and technical infusions; they are strong and sophisticated economic competitors. At the same time, growing alarm has been expressed regarding the potential loss of militarily sensitive scientific and technological information as a result of various international S&T contacts.[7] In many fields, this concern also involves the potential loss of proprietary data, due to the reduced time delay between basic research and commercial application.

Yet, there are also trends toward *increased* levels of cooperation. These have been particularly in evidence since the 1982 economic summit at Versailles, France, at which the heads of state agreed to study the most fruitful areas for collaboration in various scientific and technological areas. The subsequent report, produced under the direction of Jacques Attali of France, identified 17 specific cooperative projects involving various combinations of OECD countries; it re-

TABLE 2 Ph.D.s With Firm Commitment for Foreign Postdoctoral Study at Time of Degree Award, 1967 to 1979

	Total Number	Percent of All Ph.D.s	Number to Western Europe	Percent of All Ph.D.s
1967	249	1.4	191	1.0
1968	226	1.1	161	0.8
1969	271	1.2	174	0.8
1970	325	1.2	204	0.8
1971	430	1.5	267	1.0
1972	368	1.2	227	0.7
1973	255	0.9	145	0.5
1974	228	0.8	129	0.5
1975	250	0.9	150	0.5
1976	239	0.8	136	0.4
1977	201	0.7	119	0.4
1978	195	0.6	113	0.4
1979	236	0.8	139	0.4
TOTAL	3,473		2,155	

SOURCE: Office of Scientific and Engineering Personnel, National Research Council.

ceived formal approval at the 1983 economic summit at Williamsburg, Virginia. Since that time, multi-national working groups in each of the 17 areas have been functioning with varying degrees of success. Despite the lack of major accomplishments to announce at the most recent summit in London, England, all seven governments (plus the Commission of the European Economic Community) formally endorsed continuation of the exercise. There was even discussion of assigning the projects' steering committee, which consists of top level science advisors, a more prominent role in international affairs. This could involve a range of activities from giving collective advice to heads of government to becoming a channel for negotiating international agreements on major scientific facilities. If such a role were to materialize, the steering committee could well supplant the OECD as the principal international channel for science policy discussions.[8]

CURRENT FORMS OF U.S. INTERNATIONAL PARTICIPATION

To the extent that the Reagan administration has articulated an international S&T policy, it has attempted, where possible, to deemphasize the role of the federal government while placing increased reliance on private contacts through university and/or industrial firms. As the

1982 annual report of the Office of Science and Technology Policy stated,

> . . . international cooperation is not synonymous with Federally sponsored cooperation. American scientists and engineers cooperate in a great many international ventures—often through the universities or the industrial firms that employ them—in which the Federal Government acts, at most, as a facilitator.[9]

Other evidence suggests, however, that the U.S. government continues to maintain interest in cooperative activities (witness, for example, the recent U.S.-India bilateral S&T agreement). This is further demonstrated in the NSF FY 1984 budget for international cooperative scientific activities ($12.9 million), which represents a 30.3 percent increase over the FY 1983 budget for this category ($9.9 million).[10]

Intergovernmental Organizations

Many pressing global problems can be handled only by organizations with *global* representation. The United States and other nations that contribute substantial resources to international organizations such as UNESCO, WHO, or the International Oceanographic Commission (IOC) have found multinational channels useful as a means of promoting international cost burden sharing and of facilitating activities, individual scientific contacts, and access to research localities that, for political reasons, would not be feasible on a bilateral basis.[11] On the other hand, supranational organizations—UNESCO chief among them—have become increasingly politicized in recent years, often on issues having little to do with their stated mission and in a manner that is inimical both to U.S. interests and the general health of international science. Moreover, many of these organizations are characterized by large bureaucracies where progress occurs slowly and where resources may be used inefficiently.

Growing dissatisfaction with the operation of UNESCO was brought sharply into focus on December 28, 1983, when Secretary of State George P. Shultz informed the organization's director-general, Amadou Mahtar M'Bow, of the intention of the United States to withdraw effective at the end of 1984. In his letter, Secretary Shultz stated:

> For a number of years, as you know from statements we have made at the Executive Board and elsewhere, we [i.e., the United States] have been concerned that trends in the policy, ideological emphasis, budget, and management of UNESCO were detracting from the Organization's effectiveness. We believe these trends have led UNESCO away from the original principles of its constitution. We feel

> that they have served the political purposes of member states, rather than the international vocation of UNESCO.[12]

Both the Shultz letter and subsequent public statements by senior administration officials—including the President himself—left open the possibility that the United States would reverse its decision if certain changes were made in the tone and substance of UNESCO's work, and if the budgetary and management shortcomings were resolved.

Leaders of the U.S. science community met during the months following the announcement to consider what, if anything, could be done to encourage the administration not to implement its announced decision. While it was generally agreed that the science-related activities of UNESCO are *not* the primary source of the difficulties within the organization, it was also recognized that those supporting continued multilateral scientific cooperation have only limited influence on the larger political process and must therefore wait for the right target of opportunity before acting.

Whatever the ultimate outcome of the U.S. policy regarding UNESCO, it would appear unlikely for the foreseeable future that the United States will further expand the level of its multinational S&T participation, since it continues to maintain serious political reservations about the effective use of such resources. On the other hand, given the global, interconnected nature of many current S&T problems, the United States is equally unlikely to disengage further from the world research system.

Regional multilateral arrangements are another common channel for promoting S&T cooperation. The United States has been a strong supporter of the NATO Science Committee, which has promoted the advance of basic science through the mobility of scientific personnel, and of the Committee for Scientific and Technological Policy of the Organisation for Economic Co-operation and Development (OECD). In both cases, the principal functions are education and information exchange, which were the principal emphasis of U.S. multilateral S&T cooperation before 1973.[13,14] Also, in both cases U.S. participation contributes to its broader foreign policy agenda (national security in the former case and economic development in the latter).

The United States has, in addition, supported other types of multilateral cooperative arrangements that have circumvented some of the political, economic, and organizational problems on which multinational programs have often foundered. There is, for example, the unique joint sponsorship arrangement of the Global Atmospheric Research Program (GARP), supported both by the World Meteorological Organization (WMO) and by the International Council of Scientific Unions (ICSU). In this case, ICSU involvement provided scientific leadership, while the involvement of WMO offered some assurance of steady funding and global access. A similar arrangement exists today in the cooperative arrangement between ICSU and WHO for the World Climate Research Program. U.S. scientists have figured prominently in the development and implementation of both programs.

Bilateral Agreements

In 1982, the United States had approximately three dozen formal bilateral S&T agreements in force.[15] When these formal arrangements are combined with other bilateral mechanisms such as interacademy exchanges, joint commissions, and informal (National Science Foundation- or Agency for International Development-sponsored) arrangements and interagency memoranda of understanding, total U.S. bilateral S&T relationships number many hundreds. Certainly no form of cooperation is more explicitly political; agreements have sometimes been developed primarily in order to give visiting heads of state something to sign at the conclusion of a visit. On the other hand, some bilateral agreements tend to continue in effect long after the conditions that created the need for them have changed, because termination may be politically difficult. For example, the United States maintains a bilateral arrangement with Japan based largely on the technical and economic circumstances which existed at the end of World War II.

In most cases, the central function of bilateral arrangements is to serve as a symbolic means of winning or maintaining support with friendly governments. Moreover, the U.S. decision in the wake of the Soviet invasion of Afghanistan to scale back U.S.-Soviet bilateral S&T relations demonstrates that other types of symbolic messages also can be sent in this fashion.

Nongovernmental Organizations

Given the predominant values of science that transcend national identity—i.e., objectivity, neutrality, replicability, generation of new knowledge, etc.—it is not surprising that some of the more successful examples of international cooperation are nongovernmental in nature. The principal venue for nongovernmental S&T arrangements is ICSU, an autonomous federation consisting of 20 disciplinary scientific unions and 70 national member organizations (mostly academies of sciences and like institutions). ICSU was created in 1931 out of the International Research Council to reflect the growing importance of the scientific unions. Its dual national and scientific membership is unique within the international field. In addition, ICSU has provided an important infrastructure over the ensuing years for nongovernmental scientific cooperation, including organization of the aforementioned International Geophysical Year (IGY) and its successor programs: in space, Committee on Space Research (COSPAR); the oceans, Scientific Committee on Oceanic Research (SCOR); Antarctica, Scientific Committee on Antarctic Research (SCAR); and the biosphere, International Biological Program (IBP), to name a few.

The ICSU family of activities represents an important infrastructure for cooperation initiated and conducted directly by the scientific community. The U.S. membership in ICSU is exercised by the National Academy of Sciences (NAS) via a network of U.S. national committees (USNCs) located within the disciplinary units of the NRC and drawing on the participation and cooperation of a wide range of professional societies. Support for annual membership dues is sought from the federal government, and many of the U.S. contributions to international collaborative research programs occur with government support. ICSU is constrained both by administrative and funding limitations and is currently in the process of reexamining its role and functions. Nevertheless, its existence serves as an extremely important scientific counterbalance to the explicitly political types of bilateral cooperation.

Besides serving as the host institution for the USNCs of ICSU, the NAS—and its research arm, the National Research Council—also participate directly in international cooperative S&T activities through agreements with counterpart organizations in other countries. Among the types of agreements that the NAS may initiate are the following: (1) informal agreements with counterpart institutions aimed generally at fostering friendly relations and greater scientific interaction, (2) formal exchange agreements with counterpart institutions which are usually negotiated with or through government organizations, (3) agreements aimed at strengthening the capabilities of scientific organizations in developing countries, and (4) arrangements in which the Academy complex plays a role in government-to-government agreements. There are currently academies of science (or corresponding organizations) in over 70 countries, of which 20 are located in industrialized nations.

Mention also must be made in this context of the International Institute for Applied Systems Analysis (IIASA), which was created in 1972 (out of discussion initiated at the request of President Lyndon B. Johnson), as a new prototype for international cooperation on pressing global problems. Because the charter dictates that a *nongovernmental* organization must represent each member nation, the institute is ostensibly nonpolitical in nature. Nevertheless, due to a combination of internal and external factors, the U.S. government withdrew NSF funding in 1981. In the absence of U.S. financial support for its involvement, the National Academy of Sciences, which was the U.S. national member organization, resigned its membership. Subsequently, the American Academy of Arts and Sciences established a mechanism to support U.S. membership in IIASA, seeking funds from nongovernmental agencies in the United States. The decision to withdraw NSF support also has had negative ramifications beyond the context of IIASA. It has raised serious questions about the viability of nongovernmental organizations involved in international S&T cooperation that must depend, even indirectly, on government funding.

Industrial Cooperation

Another promising channel for future nongovernmental S&T cooperation is direct contacts between two or more industrial firms. While most arrangements of this sort focus on applied research and joint development, some basic scientific research also is supported. Among the major objectives of and motivations for industrial S&T cooperation are: (1) exchange of information to promote modernization and/or new product development, (2) pooling of technical talent and/or financial resources across national boundaries to facilitate projects that otherwise would be prohibitive, (3) conservation of resources to avoid unnecessary duplication and provide economies of scale, and (4) preservation of market share.[16]

The frequency of private-sector technical cooperation, while still relatively low, is increasing. A survey of announced private technical cooperation agreements conducted in 1980 found that at least 78 such contacts were made in that year, involving either research and development or collaboration on the development of new products or processes. The survey also revealed, however, that two-thirds of the agreements were in just two industries—electronics and aircraft. Cooperation agreements in other manufacturing technologies remain relatively rare.[17]

In a world inhabited increasingly by *transnational* private companies, cooperative S&T arrangements that benefit a private firm may not necessarily be viewed as advantageous by the host government.

The United States, for example, may intervene actively in private international agreements in cases involving (1) national security considerations, (2) antitrust considerations, or (3) questions of national industrial policy (e.g., protection or promotion of a failing industry).[18] Yet, despite the problems of control inherent in such private cooperation, a future increase in industrial contacts may reduce the need to build additional international S&T infrastructure at public expense.

Individual Cooperation

In the final analysis, the most basic and enduring channel of international S&T cooperation remains at the level of the individual scientist or engineer. There is a rich sociological literature on the so-called "invisible colleges" of science[19] that function informally through correspondence, telecommunications, and personal contacts and visits. Most would agree that this is the very lifeblood of scientific progress. On a more formal level, individual S&T cooperation takes place chiefly through short- or long-term academic exchanges and fellowships, student-teacher relationships, attendance at international conferences and meetings, joint authorship of scientific literature, and collaborative research projects. Data monitored by the NSF indicate a decline since the mid-1970s in U.S. foreign participation in international meetings and U.S. postdoctoral study abroad, and only very modest increases in the authorship levels of U.S. international cooperative research in the period between 1973 and 1980. (In fact, the United States and Japan continue to maintain the lowest levels of cooperative international authorship among the major OECD countries.)[20]

These trends may be explained in part by the increased costs of foreign travel at a time when travel budgets are no longer growing. For example, due to inflation and rising costs, most of the Fulbright awards made to U.S. scholars working in Western Europe in recent years have been only partial grants for periods of less than 9 months. In academic year 1982–1983, only 38 percent of the awards were for the full academic year; of this group, only 38 percent were fully funded. However, Fulbright scholars in *scientific* disciplines, who received 34 percent of the research awards made from 1978 to 1982, have been somewhat more successful than those in the humanities or social sciences in identifying supplemental sources of support.[21]

U.S. postdoctoral fellows cite a number of additional factors for not considering further study outside the United States; these are listed in Table 3. Among the most frequently mentioned are the inadequacy of funding, poor support by the hosts, and language problems. The lack

TABLE 3 Factors Inhibiting Effective Foreign Scientific Interchange by U.S. Postdoctoral Students[a]

Inadequate funding	27%
Poor administration or staff support by hosts	25%
Language problems	23%
Quality of foreign scholars	16%
Inadequate scholarly/scientific facilities	14%
Nationalism	9%
Inadequate personal facilities	9%

[a] Duplicate answers included in tabulation.

SOURCE: Ladd-Lipset (1977) data on foreign travel of scientific personnel.

of career advancement rewards also continues to be a factor in such decisions. Moreover, there has been mounting pressure on scientists and engineers working in research areas with potential national security or proprietary applications to be more circumspect in the open and immediate dissemination of state-of-the-art information.[22] Despite these pressures, the consensus—both within and outside of the government—is that individual scientific contacts and the dissemination of ideas and research results, all of which occur primarily within the academic context, must continue unimpeded if scientific and technological progress is to be maintained.[23]

ASSESSMENT OF COSTS, BENEFITS, AND EFFECTIVENESS

The historical record of U.S. participation in various forms of international cooperation in S&T reveals, in the aggregate, a pattern of steady and rather impressive expansion through the decades of the 1950s and 1960s with interruptions only in the 1930s and 1940s. The 1970s witnessed slowing growth and near-equilibrium, and the 1980s so far have seen somewhat erratic expansion and contraction. Certainly this pattern does not hold true to the same extent in all scientific fields. It is reflective, however, of the fact that, since the successful rebuilding of S&T infrastructure in Europe and Japan, U.S. international S&T policy has become much more complex and unpredictable, meaning that international cooperative agreements are now pursued as much for diplomatic, strategic, and economic reasons as for reasons of scientific priority. In fact, some argue that, particularly in the bilateral context, sound scientific design is sometimes sacrificed in the interests of political expediency.

One particular manifestation of this changed policy environment is the extent to which the proffering or withdrawal of S&T cooperative agreements is employed by the United States as a direct instrument of diplomacy. Examples abound of the use of science and technology as positive or negative reinforcement for the policies of another nation. What is new about this situation is the increasing frequency with which the realm of science has come to be viewed as a fundamental component of U.S. foreign policy. This may be explained, in part, by the fact that access to frontier S&T is greatly desired worldwide. Greater use of S&T as instruments of foreign policy may also be understood, however, to reflect the simple fact that there are often constraints on other traditional sources of foreign policy leverage (e.g., capital, food, or military assistance).

This emerging pattern of increased use of S&T as elements of foreign policy raises two important and interrelated questions: (1) are S&T effective as instruments of policy?, and (2) is involvement in the political arena good for the health of science and technology? Clearly, as a symbolic action, the development of a new cooperative initiative is highly effective for public relations purposes. Witness, for example, the high degree of publicity that surrounded the United States-People's Republic of China S&T agreement during the Carter years. But have such arrangements succeeded in influencing the foreign (or domestic) policies of other nations? While there is little doubt that S&T agreements have helped on some occasions to move relations onto a more positive basis, and on others to signal U.S. displeasure regarding certain behavior, there would appear to be little conclusive evidence that the signing or termination of an agreement has been very influential in persuading another nation to pursue or desist from a particular policy position.

With regard to the health of S&T, we have already made note of the fact that cooperative S&T projects are sometimes designed more according to the availability of funding and political support than on the basis of scientific priority. Mention also has been made of the growing preoccupation with national security and proprietary considerations, resulting in some efforts to "close down" international scientific communications. But, besides the problem of maintaining free and open channels of communication among scientists, there is also the problem of the apparent mismatch between the requirements of diplomacy and the process of scientific inquiry. Sound cooperative projects do not always materialize at politically opportune moments. Moreover, because the pace of scientific research must, of necessity, be slow and methodical, results cannot always be provided within a short-term time frame. In fact, high-quality S&T cooperation frequently requires sustained multiyear funding in order to achieve anticipated outcomes.

Thus, it must be recognized that certain tensions or mismatches do exist between the needs of science and the exigencies of foreign policy. While these conflicts are probably inevitable and not altogether counterproductive, they do raise profound questions about the future scope and direction of S&T cooperation.

There are, in addition, other types of pressures or conflicts extant within the U.S. S&T policy environment. For example, many analysts[24] have noted the imbalances that exist between the priorities of the mission-oriented agencies (e.g., the National Aeronautics and Space Administration, the Department of Energy, etc.) and the objectives and competencies of the Department of State. While the State Department maintains a comprehensive view of the U.S. role and interests in the international context, it is poorly equipped to provide the same high level of staff competence and mission focus on S&T fields as other line agencies. This problem is mitigated to some extent by the existence of the Office of Science and Technology Policy within the White House. But, in some respects, the lack of effective State Department involvement relegates the formulation of international S&T policy to an ad hoc "turf battle" between the mission agencies.

Less significant but nevertheless important are pressures that emanate from within the scientific community itself. Given both their access to the highest levels of government decision making and their need for government funding, scientists often function as formal or informal pressure groups for particular projects. On some occasions, groups of scientists within a discipline are able to bring pressure on intergovernmental or nongovernmental organizations to support a certain type of cooperation for which they themselves may be among the beneficiaries. Governments besieged by multiple competing demands for scarce resources have sometimes viewed the impassioned exhortations of the scientific community for additional research support not so much as "common good" but as a form of "special pleading" from yet one more interest group.

Costs and Benefits[25]

The importance of achieving "critical mass"—as measured in terms of capital, human expertise, and facilities—in an area of scientific endeavor stands out as a major benefit of cooperation. The synergistic economic effect of multiple funding for a particular line of research is obvious, but collaboration in fields such as environmental science or geophysics also can facilitate the coordination of numerous modest projects into a major global program of lasting significance. By the same token, agreement on cooperative research permits the pooling of research talent and/or facilities to produce results beyond the capabilities of any one country or university and avoids needless duplication of effort. The sharing of costs for construction of facilities becomes especially critical for "Big Science" projects. Significant cooperation often brings with it, too, a higher level of visibility to areas of scientific inquiry that may lead to improved future funding prospects. (There is a danger, however, that the greater visibility and appeal of "Big Science" projects may have a deleterious effect on the health of smaller-scale scientific cooperation.) Finally, higher levels of activity in a given field also increase the chances of "spin-off" research initiatives' yielding unexpected breakthroughs.

The opportunity to interact and exchange ideas is in itself a benefit of international science, because it expands the familiarity of U.S. personnel with the work of foreign colleagues (and, of course, vice versa). This, in turn, increases the likelihood of future cooperative relationships. The sharing of new or modified approaches is the foundation of scientific intercourse, and the awareness that other groups in other countries are working on the same or similar approaches can also prove to be a powerful motivating factor governing the pace of research. Finally, the knowledge that a particular approach is being pursued with success elsewhere may lend legitimacy and influence to project proposals. Witness, for example, the redirection of the U.S. fusion program towards the Tokamak concept after the exchange of information with Soviet scientists.

Many of the costs of cooperation are mirror images of the benefits. For example, there are opportunity costs involved in committing personnel and equipment to a joint research project when these resources might have been assigned to other tasks. Similarly, there are what might be called "development" costs associated with sharing information and/or ideas produced previously under other auspices and, presumably, other financing. In fact, part of the motivation for the recent attempts to stem the flow of unwanted technology transfer in the United States has been the concern over the lack of compensation for the sizable capital and time investment involved in developing the S&T information supposedly being "lost."

Little need be said about the direct costs of participating in international S&T projects, which involve primarily personnel, facilities, and equipment. It should be noted, however, that it is often not so much the capital outlay itself which is viewed as a liability as it is the loss of *control* over R&D resources. Such concern becomes paramount in cases where resources are channeled through or controlled by an intergovernmental or nongovernmental organization. Recently, the control issue has been exacerbated by the increasing politicization of many intergovernmental organizations dealing with science and technology (e.g., UNESCO). The United States, like many other countries, has little desire to make large contributions for dues or for special projects only to see the organization engage in activities or rhetorical debates inimical to U.S. interests.

The problems of dealing through intergovernmental organizations raise yet another type of cost, the principle of "juste retour,"[26] referring to the expectation that each participating nation will get a share of the research, engineering, and equipment supply contracts in proportion to its financial contribution. As a result, the efficiency of sound management practices often must be sacrificed in favor of greater equity of distribution. Euratom, ELDO, and INTELSAT all have been affected to varying degrees by this problem.

Finally, there are the inevitable internal bureaucratic costs of undertaking cooperative projects. Unless such collaboration is kept very narrowly focused, it tends almost inevitably to overlap agency jurisdictions. In those cases where an agency's participation in a cooperative venture requires that it transfer budgetary authority or personnel to an international organization or to another agency of the U.S. government, the inherent tendency to guard bureaucratic "turf" may have negative ramifications for the project.[27]

There are, of course, no universally applicable guidelines for successful international S&T cooperation. Much depends on the specific circumstances (and previous history) of the initiative and, frequently, on the presence or absence of a few charismatic individuals who can provide initial and continuing leadership. Some of the more significant background conditions likely to increase the chances of successful cooperation were set forth in a 1981 study by the OECD.[28] These are summarized below.

- Intergovernmental cooperation must be based upon an awareness of the political context, and the further the program moves toward applied research, the more precise the political implications must be.
- It is important that there should be similarity between partners, both in terms of scientific and technical development, and economic development.
- Aims of the joint action must be defined clearly at the outset.
- A general preparatory mechanism for contact and discussion is necessary to launch, define, and mount the joint effort.
- A detailed cost-benefit analysis of various potential institutional frameworks should be conducted.

- Direct cooperation between national establishments—or use of existing international organizations—is generally preferable to the creation of a new international body.
- A balance between equity (returns in relation to investment) and efficiency (entrusting work to those more competent to perform it) must be reached.
- Adequate mechanisms for supervision and responsibility in monitoring and management must be provided.
- The international program should not compete with national programs—it should complement them.
- Red tape must be minimized and the delegation of responsibilities maximized.
- Budgets should extend over a number of years to ensure financial stability.

It is significant that these OECD guidelines fail to address directly what many would consider the most essential criteria for effective cooperation: namely, the need to take account of that which promotes the health and advancement of science in terms of the allocation of limited resources and the design of cooperative arrangements. As suggested in the preceding analysis, this prescription represents a not insignificant task. Yet, given the changing conditions and new challenges facing the global community, the search for new, more effective modes of international cooperation must become a matter of high priority for the science and engineering establishment both in the United States and worldwide.

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Problems in the U.S. Government Organization and Policy Process for International Cooperation in Science and Technology

Eugene B. Skolnikoff

The U.S. government supports international cooperation in science and technology through a number of different mechanisms and to serve a variety of national goals. Almost every agency of the federal government is involved to some extent, and cooperation takes place through bilateral, multilateral, and private-sector channels. No precise measure of the funding dedicated to international cooperation is available, but most of the relevant programs are described in an annual report to the Congress colloquially known as the Title V report.[1]

It is not an overly impressive document, notwithstanding its bulk; the list of activities appears substantial only until one recollects that this represents the international dimension of a federal research and development (R&D) budget of well over $40 billion. Then, it seems minor indeed, to which most of those who have been engaged in attempting to promote international cooperation in science and technology from inside the government can quickly attest. In the abstract, one would assume that the shared interest in R&D progress among friendly and even not so friendly countries, the global nature of many problems, the wide diffusion of technological competence, the importance of building science and technology in developing countries, the budgetary pressures all are experiencing, let alone the political interests that can be served, would all lead to substantial pressure for increased cooperation. In practice, of course, other pressures—economic nationalism, domestic institutional interests, concern over technological leakage, bureaucratic difficulties, ignorance of developments overseas, a commitment to leave R&D to the private sector and the general domestic orientation of the U.S. government (of which more below)—conspire to keep the number and scale of government-supported international programs a quite minor proportion of total R&D support.

It was not always so. Even though international cooperation was always a relatively small part of the budget, the present situation is in fact poorer than in earlier postwar years. Following World War II, and particularly after the Marshall Plan and the onset of the Cold War, there was a substantial U.S. interest in science and technology cooperation with Western industrial countries. Research was supported directly by U.S. agencies in Europe, and the climate was generally supportive for expansion of cooperation wherever possible. A major program of cooperation was begun informally with Japan in the late 1950s, and formally in 1961. The National Aeronautics and Space Administration (NASA) legislation, passed in 1958, explicitly called for an international approach, as had the National Science Foundation (NSF) legislation in 1950. Early objectives in NATO included major interest in joint research and production, and the NATO Science Committee was started in 1957 with grand ideas of spurring cooperative R&D. Even the Organisation for Economic Co-operation and Development (OECD), when it was reconstituted out of the former Marshall Plan, included science policy cooperation among member countries as an important segment.

But the climate substantially changed. Absolute resources going for international cooperation in science and technology may be larger today, but relative to national budgets, the relative amount is surely much lower. Certainly, the atmosphere in which cooperation must be developed and funded is less supportive, notwithstanding the discussion at the last three summits about international cooperation. (Perhaps the formal agreement at the Williamsburg summit will spur a change in attitude, but it is too early to tell.)

From economic, budgetary, political, and scientific perspectives, this is unfortunate. Public-sector goals in science and technology could benefit from a different climate of receptivity toward international cooperation, and certainly this nation's objectives in foreign affairs and in technical assistance would benefit from much greater ability to tap American scientific and technological resources.

Among the several reasons for the relative lack of support for international cooperation is one "family" of reasons that has received relatively little attention or analysis. That is the organization of the U.S. government for policymaking and funding of international cooperation in science and technology. In fact, the particular structure of the U.S. government and the government's budgetary process have a great deal to do with the difficulty of expanding such programs even under supportive administrations and much to do with the ease of cutting them back in antagonistic or disinterested administrations. The lack of clear understanding of this aspect of the subject, though by no means the only critical element, nevertheless can frustrate efforts to build international cooperation even when the political will exists to do so. And it certainly goes a long way to explain why more projects and possibilities for international cooperation do not arise spontaneously, whatever the interest of a particular administration.

Astonishing as it may be, the U.S. government has no clear governmental instrument for international cooperation, and in fact some agencies are legally barred from using appropriated funds for other than "domestic" R&D objectives. Individual departments and agencies must carry out their own programs of cooperation as part of regular budgets, with little or no recognition of the problems and disincentives thus created. Difficult as it is for cooperation on projects of clear scientific merit and interest, proposals with mixed scientific and political objectives have no natural home or funding resource. We will attempt to explore and explain this situation.

THE ISSUE

The U.S. government's purpose in supporting international cooperation in science and technology is exactly the same as that for supporting science and technology more generally (or of any other federal activity, for that matter): to contribute to the nation's domestic and international goals. These goals have to be translated into specific policies, of course, and, in practice, into concrete programs and budgets. From the perspective of the government bureaucracy, this process now becomes a policy management issue: how best to formulate programs, compare them with each other in relation to the national purposes they are to serve, budget for them appropriately, and ensure effective implementation and evaluation. These necessary management objectives turn out, given present structure and practices, to discourage proposals for international cooperation, or to bias the system against them once proposed. Ironically, we are denying ourselves substantial use of science and technology in the service of national interests in the international arena, in the laudable effort to maintain detailed policy and management control.

To examine this in greater detail, it is best to first separate international science and technology activities into three rough categories, recognizing inevitable overlap, for the issues are somewhat different for each.

International Cooperation Directly Supporting U.S. "Domestic" R&D Objectives

In this category are those programs or activities that arise directly from the R&D goals of the U.S. government. Examples are:

- cooperation with, and occasional support of, foreign scientists or institutions in pursuit of common scientific objectives when justified on competitive assessments of scientific quality
- programs carried out internationally because of the requirements of the subject, such as in oceanography, geophysics, or global climate;
- participation in internationally organized research endeavors, such as the International Geophysical Year or the Global Atmospheric Research Project; and
- comparative studies or conferences intended to improve U.S. efforts by examination of policies or programs of other countries (e.g., environmental standards, use of health care technology).

International Cooperation Carried Out for Mixed Foreign Policy and Scientific Purposes

In this category are those programs or activities that have an important foreign policy component as part of their motivation.[2] Examples are:

- dedicated programs of bilateral cooperation with other countries that are established to serve one or several foreign policy objectives with those countries (i.e., the programs with the USSR, Poland, China, and France are illustrations; the Chinese program overlaps with the development assistance category as well);
- activities with, or in, other countries that may not be part of a dedicated program with that country, but are at least partially justified by foreign policy interests (e.g., possible desalination projects in

the Middle East, involvement of local oceanographic institutions in U.S. expeditions);

- application of U.S. science and technology capabilities for U.S. policy purposes (such as foreign participation in Landsat, use of U.S. technology abroad for mapping and oil exploration, or commitment of domestic R&D resources to tackle a problem of particular interest to another country);
- programs to encourage expansion of foreign R&D, or refocusing of foreign R&D on objectives the United States sees as priority problems (e.g., efforts to stimulate energy-related R&D through the International Energy Agency (IEA), or some aspects of the Japanese cooperative program).

Science and Technology Cooperation Designed to Serve International Development Objectives

This category, closely related to the previous ones, involves those activities particularly geared to the development assistance objectives of the United States and to the problems of developing countries across the range from the poorest to those now considered "middle income." The justification for separation from other foreign policy interests is simply the present magnitude and likely future significance of this category to the United States. In addition, the different policy and funding structure in the development assistance area makes the issues to be dealt with substantially distinct. Examples are:

- programs of cooperation between U.S. agencies, or U.S.-funded institutions and those in less-developed countries (LDCs) on development problems, sometimes in the context of dedicated bilateral agreements, other times on an individual project basis;
- support of R&D in institutions outside the United States on development problems;
- commitment of R&D resources in the United States to work on development problems, varying from full commitment of some resources to partial modification of domestically oriented programs to make them more relevant to development applications;
- application of U.S. science and technology capabilities to development needs abroad, such as resource exploration, Landsat imagery, communications technology; and
- participation in international science and technology programs (United Nations and others) concerned with development.

This category will not be considered in detail in this paper as it is largely outside the focus of cooperation among OECD countries.

POLICY MANAGEMENT ISSUES

A number of policy management issues arise in the government's sponsorship of international cooperative activities in the first two categories that have become serious disincentives to elective program development. We can take up the categories in turn.

International Cooperation Directly Supporting U.S. "Domestic" R&D Objectives

This category of activities poses the least difficult conceptual management issues within the government, since the programs presumably must and in principle can compete for funds within agency budgets and objectives. Criteria are clear, or at least no less clear than for R&D in general, and it is evident what programs new proposals are to be compared against.

But there are important policy process issues here that serve to create major barriers to active development of international cooperation. These have to do with the detailed processes by which projects are proposed and funded, and the general encouragement (or lack of it) of an international perspective in government R&D programs. The two are related.

The dominant domestic orientation of the American R&D enterprise is often a surprise not only to scientists in other countries, but also to Americans used to the view that science is basically an international enterprise. Though science is nonnational in its substance, nations do support science and technology for national purposes, and the institutions of government providing support are necessarily oriented to national goals. In the United States, the development of governmental institutions has historical, cultural, geographic, and political roots that result in a policy process that weights domestic interests and concerns to a much greater extent than is prevalent in most other countries. The separation of powers between the executive branch and the Congress is a major factor in continuing this dominance of domestic interests. Moreover, the very scale of science and technology in the United States, coupled with the geographic isolation of the country, has tended to make scientists and engineers as a whole less knowledgeable about and less interested in what is happening outside the country.

The result is a policy and budget process geared so automatically to domestic use of funds that necessary adjustments for international projects, e.g., extra initial costs or funds for needed travel, are almost always ad hoc and usually viewed with skepticism. Nor is there a general climate in the government that recognizes the value to the United States of international cooperation, nor widespread interest and pressure from the scientific community at large advocating more international cooperation as a major policy need. It is anomalous in an era in which high-quality R&D capability exists (and is growing) in many countries that share U.S. interests, in which the problems facing these societies are increasingly common and intertwined with those of the United States, and in which the costs of R&D increase so as to limit the ability of any one country, even the United States, to seek answers entirely on its own, that so little of an international perspective is in evidence.

To develop that perspective, to take more advantage of the R&D benefits of international cooperation, and to realize the potential value to the United States of an international approach to the problems that loom so large in all societies will require more than a simple policy decision. Agencies, and particularly the lower levels of R&D management, would have to be sure not only that there is high-level executive branch and congressional interest in developing international activities that support the agencies' R&D objectives, but also that international programs, if competitive, would be welcomed in their overall program and that the likely greater uncertainties encountered in evaluation of new proposals would be sympathetically taken into account.

There would also have to follow some changes in the funding process that recognized that international projects cannot be treated simply as any typical proposal that is wholly domestic. Up-front funding may be necessary to explore opportunities and to allow initial development of proposals that may be harder to formulate because of differing research styles or institutional practices. Some risks may have to be taken for situations in which there could be serious costs if a jointly developed proposal is ultimately rejected. Recognition of the importance of being a reliable partner may also sometimes lead to longer commitment of funds than is typical for an agency. In some cases, funding may be necessary for higher infrastructure and travel costs.

Those extra funds have always been difficult to appropriate, and in particularly tight budgets they appear as direct reductions in domestic research funds, and thus inevitably contentious. The effect of the recent distribution of the NSF's international budget among research divisions will for that reason certainly have a chilling effect on international cooperation, even when international projects could in principle be fully competitive scientifically.

It is also worthwhile noting not only the difficulty but also the importance of making the "domestic" agencies of the U.S. government conscious of the international framework in which R&D is actually embedded. The potential practical payoffs are obvious: U.S. R&D can benefit from work in other countries, much more of which is now equal to U.S. R&D in quality, and more frequently there will be parallel work of direct relevance to U.S. R&D objectives and increasing opportunities for cost sharing or for faster progress toward R&D goals.

There is another, perhaps more important but unfortunately only philosophical, reason: the fact that the results of American R&D directly and indirectly affect people in all countries. They have no voice in setting R&D objectives in the United States even though they have an interest in the outcomes of the world's largest R&D enterprise, nor can any process be imagined in the near future (at least) that could provide such a voice. But that only emphasizes the desirability of developing over time much greater sensitivity in the United States to the international nature of the R&D enterprise and to the societal effects, not limited by national borders, it engenders. Rarely is any thought given, and certainly only rarely in an organized, conscious way in the government, to the international effects of the R&D being supported. The conscious encouragement of greater involvement in international programs and cooperation by U.S. domestically oriented agencies can, in the long run, serve to increase understanding of the international dimensions of everything the United States does in science and technology.

Of course, all the obstacles do not reside within the government, though the process difficulties within government do have their resonance in the scientific community. Realization of the difficulties in funding international cooperation or experience in trying to satisfy the difficulties is often an effective disincentive for scientists to invest the time required to bring cooperative projects to the point at which they could be considered in the research competition. In many cases, of course, the opportunities and appropriateness, because of special equipment, skills, or the nature of the subject, make the effort to overcome the difficulties worth the candle. But, in marginal or less clear cases, the disincentives loom large.

Aside from the difficulties inherent in obtaining funding, other factors serve as disincentives. The time delays necessarily involved; the extra travel, language, and cultural obstacles to intimate interaction; and the different national patterns of allocation of research funds (which can result, for example, in disparities of funding and uncertainties of the results of priority ranking) also are important. Moreover, scientists are not immune from national biases, notwithstanding the nonnational basis of scientific knowledge. Particularly in the United States, many scientists think little and know less about the details of work in other countries and have little interest in international cooperation. Others view international cooperation as inimical to the competitive race for national prestige and preeminence and are little inclined to collaborate unless absolutely necessary.

And, of course, the growing national concern with the possible economic and security costs of transfer of technology has served to put a further damper on official interest in international cooperation. Though that does not affect many scientific fields, it certainly is relevant to those, such as electronics and biotechnology, in which the distance between the laboratory and production is shrinking. The concern, still largely focused on security, will almost certainly turn increasingly to economic issues. Growing pressures for "technological protectionism" cannot help but prove to be a deterrent to international scientific cooperation.

Thus, impediments and disincentives, even for projects entirely justified scientifically, can be substantial. These arise from the general domestic orientation of the U.S. government and a policy and funding process that provides little recognition of the special requirements for organizing and implementing international cooperative projects. Not all possible international projects *should* be supported, of course, but the growing importance of such cooperation to the United States, as well as to others, dictates greater efforts to modify the existing climate, and to make the governmental process more flexible and responsive.

International Science and Technology Cooperation Carried Out for Mixed Foreign Policy and Scientific Purposes

Though seemingly less relevant to cooperation among OECD countries, it is nevertheless true that some cooperative programs do (and should) have motivations that go beyond purely scientific purposes. The United States has umbrella agreements for cooperation with Japan and France and other nonspecific agreements in various delineated fields, for example, or those with particular departments in other

OECD countries. Some OECD countries, in addition, are not in the front rank scientifically, so that cooperation with them must be justified, if at all, on foreign policy as well as scientific grounds.

The question here is not *whether*, but *how* to use science and technology in support of international goals. Clearly, international activities in science and technology can serve a variety of objectives in addition to R&D goals, including contributing to U.S. political and economic interests with other countries, attracting high-level attention to particular issues, creating advantages for American industry in foreign countries, gaining knowledge of scientific and technological progress in other countries, and stimulating work on common or global problems. Presidents, secretaries of state, and others have capitalized on the nation's strength in science and technology for cooperation designed to achieve more than scientific purposes and will continue to want to do so. That is appropriate, for national goals can be served by sensible use of all resources, as long as it is done responsibly and without damage to the primary mission of those resources.

The most difficult of the issues raised in these cases in the policy process, and the ones that are at the heart of the problems of management of international science and technology activities, are those associated with funding. They are central to the goal of responsible management and deployment of public funds, and central to the ability of the government to use its scientific and technological resources effectively for a variety of national objectives.

The major problem is that the international programs referred to here cannot be fully competitive on scientific grounds with alternative domestic programs (if they were they would raise no special conceptual problems, as programs in the first category), and even when they may eventually be able to be competitive, the advance planning and commitment process required to initiate a formal international or bilateral agreement is not compatible with the normal competitive budget process. Alternative budgetary processes and in some cases segregated funding are thus unavoidable.

There are several alternative budgetary mechanisms possible, none of them fully satisfactory nor mutually exclusive. They include: funding of international activities from regular appropriated R&D funds; developing line items within domestic agencies administered either by a technical division or by an international programs office; seeking dedicated funds in the Department of State to be transferred to the operating agencies to fund these activities; seeking dedicated funds in another agency, such as the NSF, for transfer as appropriate; or creating a new agency expressly for this task. A different technique of one-shot endowment for a "binational foundation" is also possible and has been employed in the past, notably in the case of Israel. Each has its advantages and disadvantages.

Relying on appropriated agency R&D funds when mixed foreign policy and scientific goals are involved has several problems: establishing objective criteria for comparing the foreign policy interest of alternative proposals, determining the weight that should be given to those interests in comparison with scientific goals, providing adequate means for representing those interests in the budget process, and absorbing the implicit reduction in funds available for the domestic objectives of the agency (especially acute if funds must be segregated in advance to protect against later rejection). The programs, however, are more likely, by comparison with processes that involve nontechnical offices, to be of high quality since the technical people most knowledgeable are those most heavily involved, and the scientific aspects would be evaluated by the normal process.

Developing a separate line-item budget within agencies administered by the technical divisions or the international office (or both) avoids the problem of reducing funds for "domestic" R&D objectives (assuming no larger trade-off in the agencies' overall budgets), but raises more starkly the problem of justification of funds and effective program evaluation. This technique can lead to unjustified continuation of funding once started simply from the normal inertia of budgets, and can reduce the pressure for scientific justification since the funds are not subject to as rigorous scientific competition. In addition, the international offices, if they administer the funds, may develop a vested interest in the programs which may not adequately reflect either overall U.S. foreign policy interests or the scientific opportunities. Line items for programs intended to serve, in part, foreign policy interests raise directly the problem of how funds and programs are compared across agency lines, especially since the normal budget process within agencies and with the Congress involves many other considerations.

On the other hand, both line items and use of regular R&D funds within agency budgets give the agencies a stake in international activities; force them to have to evaluate, advocate, and defend the programs as their own; require commitment to use of resources for international purposes; and allow the development of permanent staff assignments as opposed simply to carrying out programs as a "service" to other agencies.

The alternative of establishing funds in the Department of State to support international scientific and technological activities of the agencies has several serious barriers, though it appears attractive in the abstract as a way of forcing projects to compete within a defined budget. One barrier is simply the political reality of expecting the Department of State to be able to obtain funds of any scale for this purpose (opposition would be substantial in both the executive branch and the Congress). Another is the separation of the source of funds from the scientific and technological resources, coupled with the Department of State's inherent difficulty in identifying adequately the opportunities in science and technology across the government and in developing internal competence in science and technology. In addition, many activities should not be discrete separate programs, but part of larger efforts. If most international funds had to come from the Department of State, the bureaucratic burden for allocation and implementation would be enormous and probably intolerable. Moreover, this route is not likely to develop the desired commitment and competence in the agencies.

Establishment of dedicated funds in another agency, such as the NSF, has some of the same problems as a State Department fund, except that it has proven more feasible to appropriate money to the NSF for international programs, and NSF's internal competence in science and technology could make it easier to work with the technical programs of other agencies. As is evident from past use of NSF in this way, however, an agency finds it difficult to accommodate substantial funds that, as a matter of course, are only to be justified and spent by others. There has always been difficulty even in NSF funding of National Academy of Sciences international programs over which NSF has had little detailed control. It also puts NSF in the middle between domestic and international agencies with little stake of its own.

A separate agency created expressly for international cooperation in science and technology would be a most interesting innovation, but has little political reality in the near future. Though it would have some of the same problems enumerated above, its dedicated mission would minimize them. Moreover, it would have the capability of overseeing a "cross-agency" budget that would make possible responsible comparison of projects and budget management. And, it would provide a focused instrument for international cooperation now lacking in the U.S. government. Such an agency was proposed (Institute for Scientific and Technological Cooperation, or ISTC) as part of a foreign aid reorganization in the last administration and was authorized but not funded by the Congress. It is unlikely to reappear again for some time.

The binational foundation approach has considerable appeal for a limited number of countries as a result of its permanent basis that does not require annual appropriations or detailed oversight. By definition, it is not available for short-term foreign policy purposes though its existence and successful operation can obviously contribute to relationships. Its independence is an asset, but by the same token, it is external to U.S. departments and agencies and not likely over time to stimulate international interests within those agencies, or see its mission as integration of U.S. scientific and technological capacity with U.S. international interests. Finally, its independent status makes program review or modification difficult once a direction is set.

Though all of the alternatives have their strengths and weaknesses, it seems inescapable for now that for the *bulk* of international science and technology activities justified in part on foreign policy grounds, it is the resources of the agencies themselves, whether in an "international" budget or as part of regular programs, that will have to be relied upon. The other choices are simply not commensurate with the nature and scale of the overall objective though all mechanisms are, and ought to be, used to some extent.

This conclusion that the bulk of the resources must come from the agencies, however, requires coming to grips with the difficulties associated with that route. Primarily, those difficulties have to do with evaluation and choice when a foreign policy motivation is involved. Who is responsible for representing and/or qualified to represent the foreign policy interest? How much should it weigh against scientific evaluation? How can activities with different countries, different fields, and different agencies be compared? What can provide the discipline that is required to force hard choices? How objective can foreign policy criteria be in any case?

An argument can be made that almost any science and technology interaction with a country of interest is "good." Traditionally, the Department of State has tended to be rather uncritical in its support of international science and technology activities of other agencies within broad foreign policy constraints. But that is inadequate, if it ever was otherwise, in a period of growing interest in more effective use of U.S. science and technology capacity internationally. Even if funding constraints were not as serious as they are today, responsible use of public funds and resources would require more appropriate discipline.

In thinking about various alternative mechanisms, it is important to realize that the international activities that are actually relevant to this analysis are only those that fall marginally below the cutoff point on an agency's scientific quality ranking of research projects (leaving aside, for the moment, the question of how international projects can be developed to the point of being competitively ranked). That is, proposals above the cutoff can be funded whatever the foreign policy interest because of their inherent scientific interest to the agency. Proposals that fall near the bottom of the ranking are of little scientific interest to an agency and should proceed *only* if there is a special foreign policy interest in having them implemented. In that case, external (to the agency) funding is clearly appropriate and, in fact, essential. Only those that are marginal in an agency ranking—below but near the cutoff—are of interest, for they have reasonable scientific merit and agency engagement.

This logic leads to the suggestion that it should be possible to rank international science and technology programs across departments and agencies according to foreign policy interest. Such a ranking would be compared with the independent ranking within departments and agencies based on agency criteria. Projects that are marginal on an agency ranking, but high on foreign policy ranking, would be given an extra boost. Those marginal within the agency but low on the foreign policy ranking would be dropped, while those low in agency ranking, but high on foreign policy, would proceed only with funding provided by the Department of State or other external source. Those marginal on both scales might deserve further examination.

Such a cross-department ranking makes sense in theory, but in practice how can it be done with competence and credibility? A separate agency for international science and technology cooperation mentioned earlier could have been the chosen instrument, but the attempt to create that agency did not succeed. The State Department is unlikely to be able to carry out such a ranking with sufficient support from technical agencies, or with adequate authority to implement the results. A possibility is an interagency working group, chaired by the Department of State, that could provide the locus for a governmentwide ranking. Or, the Office of Management and Budget (OMB) or the Office of Science and Technology Policy (OSTP) could chair the group to provide more objective leadership.

Whatever mechanism is used for "managing" agency budgets for international cooperation, that will not be enough. The need for planning flexibility, especially for broad programs of cooperation of high political value and White House interest, such as with China and the Soviet Union, and the need for initial funds to define and develop projects dictate a requirement for some segregated (noncompetitive) funds able to be used for new international initiatives. The amounts can be reasonably limited on the assumption that programs once established should move into a competitive process of some kind as rapidly as possible. Under that assumption, the Department of State could be the logical repository of such segregated funds; more realistically, they should be line items in the appropriate domestic agency budgets and/or dedicated international funds in the NSF.

CODA

The analysis of the problem seems clear, but an effective institutional mechanism and appropriate policies are not easy to formulate within the U.S. government structure. Something must be done. The U.S. government is simply poorly positioned to use science and technology in support of its international objectives, especially when an unambiguous scientific justification is not possible. Even when it is, the United States is often muscle-bound in its structure and process in providing incentives or support for international cooperation that is in the national interest. Though there are many explanations for this situation, the fact of the matter is that the changing nature of the problems the nation and the world face, the diffusion of scientific competence, and the economic pressures on Western societies make it essential that ways be found to spur rather than discourage international cooperation in science and technology.

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U.S.-European Cooperation in Space Science

A 25-Year Perspective

John M. Logsdon

In the 25 years that the United States has had a government space program, international cooperation has been one of its major themes; an objective of the National Aeronautics and Space Act of 1958, which was the charter for the civilian space program and which established the National Aeronautics and Space Administration (NASA), was "cooperation by the United States with other nations and groups of nations in work done pursuant to the Act and in the peaceful applications thereof."[1] Armed with this legislative mandate, with presidential and congressional support for a U.S. civilian space program that emphasized openness and scientific objectives, and with already existing patterns of cooperation in space science, NASA has since its inception conducted an active program of international partnership.

In space perhaps more than in most areas of international science, it has been the policies and initiatives of a government agency and its top officials, rather than those of the scientific and technical community, which have established the U.S. attitude toward cooperative undertakings. Although NASA's international programs have involved the Soviet Union, Canada, Japan, and various developing countries, its primary cooperative partner has been Europe—both individual European countries and the various European space organizations that have existed over the past two decades. Table 1 suggests the dominance of U.S.-European interactions in the overall record of NASA's most important cooperative programs.

TABLE 1 Patterns of International Cooperation, 1958–1983[a]

	Cooperative Spacecraft Projects	Experiments With Foreign Principal Investigators
Total, Europe	33	52
European Space Agency	8	1
France	2	17
Federal Republic of Germany	7	11
United Kingdom	7	18
Italy	6	1
Netherlands	2	3
Other	1	1
TOTAL, All countries	38	73

[a] Includes past and currently approved cooperative projects.

SOURCE: *NASA 25 Years of NASA International Programs*, January 1983.

The U.S.-European partnership in space science has been on the whole remarkably successful, both in terms of cooperation between the United States and individual European countries and between the United States and Europe's multilateral space science agencies, the European Space Research Organization (ESRO) and its successor, the European Space Agency (ESA). Projects such as Ariel (United States-United Kingdom), Helios (United States-Federal Republic of Germany), Infra-Red Astronomy Satellite (United States-United Kingdom-the Netherlands), International Ultraviolet Explorer (United States-United Kingdom-European Space Agency), and International Sun-Earth Explorer (United States-European Space Agency) are just a few of the major scientific undertakings which have benefited from U.S.-European collaboration. This record of success must be kept in mind in evaluating any past and current stresses in the cooperative relationship.

As the U.S. space program enters its second quarter century, there are significant changes in U.S.-European cooperation; the major reasons for these changes include: the increased maturity and level of space capability that Europe is bringing to the partnership; the consequent addition of a competitive dimension, both in scientific and economic terms, to the relationship; the increasing cost of space science missions; and the relative scarcity of financial resources available on both sides of the Atlantic for space science.

Last fall saw the first flight of Spacelab, an orbital facility for manned scientific experimentation that was developed by Europe at a cost of approximately $1 billion; Spacelab is designed for use with only the U.S. space shuttle and reflects the intimate character of continuing U.S.-

European collaboration. At the same time, Europe has developed its own launch capability in the Ariane series of expendable boosters and is using that autonomous capability not only to launch its own spacecraft but also to compete with the space shuttle for other launch contracts. European countries are also developing satellites for earth observation and communications and exploring the potential of space manufacturing, with the objective of competing with the United States for economic payoffs from space.

Further scientific cooperation in space between the United States and Europe will occur in this mixed context of collaboration and competition. The state of that cooperation is vigorous, as both the United States and Europe continue the fascinating adventure of exploring the nature of the solar system and the cosmos that is made possible by space technology.

ORIGINS OF U.S. COOPERATIVE PROGRAMS

As the late Homer Newell, one of the U.S. pioneers in space science and an early and strong advocate of international cooperation in space, has noted, "With roots in the International Geophysical Year, which had already generated a lively interest in the potential of satellites for scientific research, one might argue that the appearance of an international component in the NASA space science program was inevitable."[2] The International Geophysical Year (IGY), organized under the sponsorship of the International Council of Scientific Unions (ICSU), was an 18-month (July 1957–December 1958) effort involving 66 countries, some 60,000 scientists, and the expenditure of hundreds of millions of dollars; both the Soviet Union and the United States agreed in 1955 to launch scientific satellites as part of IGY activities.

There was in place at the very start of the space age, therefore, a nascent international community of scientists who saw space technology as providing exciting opportunities for extending and expanding their investigations. This community was quick to press NASA to keep its program open to international involvement. This pressure was congenial, since one reason that the United States had decided to house its major space activities in a separate, civilian government agency was to present to the world an image of peaceful intent and open style; this was in deliberate contrast to Soviet space activities, which were controlled by the military services and conducted with great secrecy.

There were those in 1958 who argued that the U.S. space program should be under military control and not opened to international cooperation because "the tools of space research—rockets, radio, radar, guidance, stabilization—were all common to both the military and to science. Even the scientific objectives . . . were of interest and possible value to the military."[3] Added to this "dual use" character of space technology and some areas of space science was the role of space achievement as an area for superpower political competition, particularly after the United States launched the Apollo program in 1961.

The scientific activity involving the use of space systems took place in a highly charged political and military environment. By carefully defining the conditions under which cooperative activities would be initiated and carried out, NASA was able to conduct an international program that has been relatively free from distortion for political purposes and from limitations because of military sensitivities. Even so, with respect to space cooperation "a clear duality dogs both the history and the prospects of international partnerships."[4]

NASA GUIDELINES AND OBJECTIVES FOR INTERNATIONAL COOPERATION

When NASA announced to the ICSU's Committee on Space Research (COSPAR) in March 1959 that it would assist COSPAR members in launching scientific experiments and satellites, the agency had already under development a set of policy guidelines for such cooperation. Those guidelines have survived periodic reexamination and remain in force today. They reflect "conservative values"[5] with respect to the conditions under which cooperation is desirable; shaping those values were both the recognition of the political significance of space activities and the strong personalities of such individuals as Newell and Arnold Frutkin, who directed NASA's international program from the agency's earliest months until the mid-1970s.

The essential features of NASA guidelines are:

- Cooperation is on a project-by-project basis, not on a program or other open-ended arrangement.
- Each project must be of mutual interest and have clear scientific value.
- Technical agreement is necessary before political commitment.
- Each side bears full financial responsibility for its share of the project.
- Each side must have the technical and managerial capabilities to carry out its share of the project; NASA does not provide substantial technical assistance to its partners, and little or no U.S. technology is transferred.
- Scientific results are made publicly available.[6]

A key feature of NASA's cooperative efforts is that "while NASA has international programs, it does not fund *an* international program." Rather, "funding for international projects must come out of the NASA program offices," and "for an international approach to a project to be undertaken it must not only contribute to achieving the goals of the interested program office, but it must be considered to be among the best approaches to achieving those goals."[7] This emphasis on technical soundness and scientific merit has been a consistent feature of the U.S.-European cooperation over the past 25 years, whatever other objectives are sought through such cooperation. As one perceptive analysis notes, "although NASA recognizes possible political benefits from achieving utilitarian goals, NASA's cooperative programs are justified almost entirely on technical and scientific grounds, both within and outside" the agency.[8]

The objectives of NASA's international programs can be grouped as follows.

Scientific/Technical

- "Increasing brainpower working on significant problems and expanding scientific horizons by making space an attractive field for research."[9]
- Shaping the development of foreign space programs to be compatible with the U.S. effort "by offering attractive opportunities to 'do it our way'."[10]
- Through such influence, limiting funds available in other countries for space activities that are competitive or less compatible with U.S. interests.
- Obtaining unique or superior experiments from non-U.S. investigators.
- Obtaining coordinated or simultaneous observations from multiple investigators.
- Increasingly making available opportunities for U.S. scientists to participate in the space science missions of other countries or regions.

Economic

- "By sharing leadership for exploring the heavens with other qualified space-faring nations, NASA stretches its own resources and is free to pursue projects which, in the absence of such sharing and cooperation, might not be initiated"[11]; NASA estimates getting over $2 billion in cost savings and contributions from its cooperative programs over the past 25 years.[12]

- "Improving the balance of trade through creating new markets for U.S. aerospace products."[13]

Political

- Creating a positive image of the United States; "the U.S. program of cooperation in space reaches a scientific, technical, and official elite in the struggle for minds."[14]
- Encouraging European unity; the U.S. space program "lends itself admirably to cooperation with multilateral institutions in Europe."[15]
- Reinforcing the image of U.S. openness in contrast to the secrecy of the Soviet space program; "when NASA was organized . . . the keystone of Government space policy was to give dramatic substance to the claim of openness—and, at the same time, to seek credibility for the nation's assertion that it entered space for peaceful, scientific purposes. This was done . . . most importantly, by inviting foreign scientists to participate extensively and substantively in space projects themselves."[16]
- Using space technology as a tool of diplomacy to serve broader foreign policy objectives.

While the priority given to these various objectives has varied over time and mission opportunity, at the core has been a policy that permitted this country's closest allies to become involved in the U.S. space effort. Indeed, some have criticized NASA for making possible such participation, at minimal cost, in an effort paid for almost entirely by U.S. taxpayers; "benefit, know how and opportunity were shared to an extent that was entirely unprecedented where an advanced technology was involved, particularly one with such strong national security implications."[17]

EVOLUTION OF U.S.-EUROPEAN COOPERATION IN SPACE SCIENCE

During the "golden age" of the U.S. space program, from the beginning of the Apollo buildup in 1961 through its peak in the 1965–1966 period, NASA's international activities grew rapidly along with the rest of the agency's efforts. Before the first Apollo 11 moon landing in July 1969, nine European spacecraft had been launched by the United States, and substantial momentum had built behind European involvement with the United States in space experimentation. This momentum has carried through to the current day, but, as one top-level participant has commented, "when resources abound and opportunities are plentiful, a cooperative attitude abounds. . . . When the resources and opportunities shrink, . . . altruism takes a back seat and . . . scientists take a more selfish view of cooperation."[18]

Several factors have influenced the evolution of U.S.-European space cooperation in the 1970–1983 period. In no particular order of importance they are:

1. A shrinkage in the NASA budget overall in the post-Apollo era; the space science budget came under particular pressure as the share of overall resources going to shuttle development increased. This meant fewer science missions and more competition among U.S. scientists to get their experiments on the missions which were approved.
2. A broadening of NASA's international program to encourage European participation, not only in science missions, but also in developing large space systems including manned space flight elements.
3. The evolution of the 11-member European Space Agency (ESA), founded in 1975, into an effective entity that has carried out a successful science program of its own and has managed several space applications projects and two major hardware development programs, Spacelab and Ariane. The national space programs of France, Germany, Italy, the Netherlands, and the United Kingdom, each with differing emphases, are also vigorous.
4. More recently, growing concern in the United States that cooperative undertakings in space, including space science, could serve as vehicles for unwanted transfer of militarily or economically sensitive U.S. technology to other countries.

While Europe has continued to cooperate with the United States, it has also become a formidable competitor in various categories of space applications and in some fields of space science. Europe is now a very capable actor in space, and it could become more difficult for the United States to develop cooperative projects on its preferred terms. While the United States remains the partner of choice for ESA and individual European countries, existing and potential cooperation with the Soviet Union and Japan provides an alternative. There is now the possibility of a global division of labor and cost in space science, and this makes the task of planning and getting agreement for major space science projects both challenging and full of opportunities.

There has been over time an undercurrent of ambivalence among U.S. space scientists and NASA managers about European involvement in NASA missions, whatever the stated policy. For one thing, "always the U.S. side was slightly constrained by fear that foreign collaborators

. . . might not fulfill their commitments." This concern has diminished over time; "in the few cases where serious delays occurred, as in the Solar Polar project, it was more often the United States that was responsible. . . . Had NASA personnel not been susceptible to the then universal belief that other nations necessarily lagged behind the United States in technological capability, the policy of collaboration in space matters could almost certainly have been even more rewarding."[19] For another, when foreign experiments have been selected by NASA, some U.S. scientists have raised the question of whether the foreign experiment was really selected over a competing U.S. experiment based on merit or whether it was selected because it would be provided to NASA free of charge.[20] Another reservation with respect to foreign participation has been that "by selecting a high-technology experiment, the United States encourages development of the industrial base in the foreign country which will contribute to a decreased United States competitive position in world trade."[21] Yet another concern is that management of a U.S. space science project is greatly complicated by the need to integrate the experiments or other contributions from a foreign partner.

While growing European capability has muted concern about the first of these factors, it has also created a healthy competition among all space scientists for access to orbit and beyond for their experiments. While European scientists have always been able to propose experiments on U.S. missions, U.S. scientists are only now gaining a reciprocal opportunity to serve as principal investigators for experiments on ESA missions.

A major attempt to engage Europe with NASA's technology development efforts took place in the 1969–1973 period, as NASA itself sought to gain presidential and congressional approval of an ambitious post-Apollo program of manned space flight. The negotiations on European participation in the post-Apollo manned program were much more political in character than prior (and subsequent) negotiations on cooperative undertakings in space science. This post-Apollo experience, perhaps justifiably, has left a lingering "bad taste" in Europe. NASA's objective was "to stimulate Europeans to rethink their present limited space objectives, to help them avoid wasting resources on obsolescent developments (this was a reference to European plans to develop an independent launch capability) and eventually to establish more considerable prospects for future international collaboration on major space projects."[22]

A basic problem in this case was that NASA could not deliver on what it was promoting in Europe. NASA's post-Apollo ambitions included a space station and a fully reusable space shuttle and the agency continued to solicit European involvement in these programs even when their approval by the President was very uncertain. Indeed, within the United States NASA tried to use the prospect of cost sharing with Europe as a selling point for approval of these programs. When only the space shuttle remained as a potential program, NASA encouraged Europe to consider developing both components of the shuttle orbiter and a separate major project, a reusable orbital transfer vehicle called a "space tug." However, NASA was forced to withdraw these offers at the last minute when the Air Force, whose support was needed for shuttle approval, objected to European development of essential elements of the Space Transportation System; when concerns regarding excessive transfer of propulsion technology were raised; and when some in NASA became concerned about the safety implications of placing a cryogenically fueled tug in the shuttle payload bay. Finally, NASA offered Europe the comparatively simple and less expensive task of developing a "research and applications module" to fit into the shuttle payload bay; this is what became the Spacelab project.

By this time, Europeans were rather skeptical with respect to NASA overtures, but they (particularly Germany) had also become so eager to embark on manned flight activities that they agreed to develop the Spacelab system under what in hindsight have been seen as unfavorable terms; the first set of flight hardware, developed with European funds, was to be transferred to NASA, and after an initial joint NASA-ESA mission that included flying a European payload specialist, Europe was to pay for future shuttle-Spacelab flights. NASA agreed to buy a second set of flight hardware from Europe, but "a significant segment of the European space community believes that the United States is getting the lion's share of the benefits from Spacelab."[23]

European space officials have described themselves as "stupid" in accepting the U.S. terms for involvement in its post-Apollo program and believe that such acceptance stemmed from lack of confidence in European capabilities and from a belief that only through cooperation with the United States could those capabilities be improved. Now, having brought both Spacelab and Ariane to success, Europe has much more confidence in its ability to chart its own future in space and it will be a more demanding participant in negotiations with the United States over cooperative ventures.[24]

European confidence in the United States as a cooperative partner was shaken in the spring of 1981 when the United States announced, without prior consultation with its European partners, that it was canceling a U.S. spacecraft that was part of a two-spacecraft International Solar Polar Mission (ISPM). This withdrawal caused vigorous protests from not only European space officials but also representatives of foreign ministries.[25] In this case, "NASA's success in international participation became a political liability"[26]; NASA was forced to reduce funding in a major space science mission, and all three existing large missions—the Space Telescope, the Galileo mission to Jupiter, and the Solar Polar mission—had major European involvement.

There is general agreement that the ISPM affair was handled clumsily, and both the United States and Europe have moved beyond it, although European officials are not beyond using U.S. guilt over the incident as a bargaining chip in U.S.-European negotiations on future collaboration.

In summary, U.S.-European cooperation in space has become a much more complex enterprise in the last 10 years as both U.S. and European space efforts matured. While the balance sheet in that enterprise remains strongly on the positive side for all participants, competition and conflict have joined collaboration as hallmarks.

CURRENT ISSUES IN U.S.-EUROPEAN COOPERATION

The major U.S. science missions now approaching launch, the Space Telescope and the Galileo spacecraft to Jupiter, have major participation by Europeans, and there is every anticipation that there will be continuing cooperation as both the United States and Europe begin new missions. The following are some of the issues which will influence the development of that cooperation.

Closer Coordination and Collaboration in Planning and Conducting Space Science Efforts

The task of maximizing the scientific payoff from the resources available in the United States and Europe (and other countries) for space research is perhaps the key continuing issue in this area. The United States, ESA, and various European countries are all fully capable of undertaking major space science missions on their own, but with limited funds available on both sides of the Atlantic, there is a need to develop a coordinated approach to space science that recognizes the benefits of cooperation and the realities of competition. To date, it has primarily been government agency-to-government agency negotiations that have attempted to do this. There are regularly scheduled meetings between the heads of NASA and ESA and between the space science directors of those two agencies.

One of these NASA/ESA space science planning meetings occurred in June 1983, and the issues addressed exemplify the problems and potential of a coordinated approach to future space science undertakings.[27] Three areas of cooperation were discussed:

- infrared astronomy
- solar terrestrial research
- planetary exploration

In the first of these areas, in essence the United States and ESA "agreed to disagree." The issue under discussion was the next step beyond the highly successful U.S.-Dutch-British Infrared Astronomical Satellite (IRAS) launched in early 1983. Both the United States and ESA have developed future mission concepts, and the two approaches are not compatible. The meeting noted both "NASA's strong interest in collaborating to develop a single major international infrared space telescope facility" (presumably based on the U.S. mission concept) and "the firm commitment of ESA" to its mission. Recognizing that "the differences in orbit and launch vehicle restrict any major hardware collaboration," NASA and ESA agreed to coordinate the planning for the separate missions to maximize their complementarity and overall scientific return, but also for the time being abandoned any hope of a joint mission.

By contrast, an examination of the large number of missions under study in the United States, Europe, and Japan in the area of solar terrestrial physics identified "considerable merit in considering a joint . . . mission"; NASA and ESA established a working group, which will also include Japan, to "look for joint missions which can satisfy the main scientific requirements in a cost-effective way." Similarly, NASA and ESA agreed in the planetary exploration area "to identify mutually beneficial opportunities for cooperative missions." In particular, the two agencies are to study a joint Saturn-Titan probe mission for a 1992 launch. Planetary exploration is one of the areas of international scientific cooperation agreed on at the recent series of summit meetings and is also the focus of attention of a National Academy of Sciences/European Science Foundation working group. A cooperative Saturn-Titan mission, if feasible, would thus be politically as well as technically significant.

Another example of the benefits of a coordinated approach to mission planning in a particular area of science is found in U.S.-German interaction in x-ray astronomy. A large community of investigators has developed to use the data produced by NASA's High Energy

Astronomical Observatory. However, there would be a data gap of a number of years before the next mission in x-ray astronomy, were it not for the existence of a German project called *Roentgensatellit* (ROSAT). The United States and Germany in 1982 signed a Memorandum of Understanding for close collaboration in this mission, thus ensuring continuity in the field for U.S. as well as European scientists.[28]

There is a growing need for the United States, Europe, Japan, Canada, and perhaps eventually the Soviet Union and other space-capable states to work together in space science, from the early stages of developing a mission concept to the joint funding and conduct of various missions. Because of its dominant position in free-world space activities, the United States in the past has been largely able to shape such collaboration to its own objectives. This situation no longer obtains, and there could be a difficult period of adjustment for this country as the new reality of partnership among relative equals becomes the standard pattern. It may prove advantageous for NASA to engage the U.S. scientific community more intimately in developing its international programs; this could minimize international misunderstandings and perhaps blunt nonproductive and expensive competition. In space science, as in many other areas, the United States is adjusting to the recognition that it cannot be first in everything.

Involvement of Non-NASA Scientists in Shaping International Cooperation

"At present, ideas for joint international endeavors are primarily developed at formal meetings between representatives of the various governments. . . . There is a need for a more effective forum which would enable space scientists and managers to exchange ideas informally."[29] While NASA plans its science programs in close consultation with the external science community, including the Space Science Board (SSB) of the National Academy of Sciences, there is little tradition of SSB involvement in international space science matters. The National Academy of Sciences is the U.S. member in COSPAR, but that forum has little apparent influence on national space programs. Of course, informal interaction among space scientists in various countries interested in similar scientific problems is a major source of project proposals both in the United States and within Europe.

The nearest European equivalent to the SSB is the Space Science Committee (SSC) of the European Science Foundation. This committee has a small budget and has not developed close ties with the ESA. Nevertheless, the SSB and SSC have held joint workshops in 1976, 1978, and 1983, and there is some consideration being given to establishing standing SSB-SSC working groups in selected areas of space science.

In a separate development, at the initiative of the heads of the European Science Foundation and the National Academy of Sciences a joint SSB-SSC working group on planetary exploration has been established. The U.S. side of this group is composed mainly of individual scientists who are closely related to NASA's Solar System Exploration Committee.

All of these developments may represent initial steps in opening up the process of planning U.S.-European cooperation in space science to more structured participation of nongovernment scientists. As scientific competition among those working in space becomes increasingly international, such involvement may be required to reach agreement on how to coordinate or cooperate in research on major scientific problems.

Access for U.S. Experimenters to European Science Missions

If Europe is to approach parity in influencing the direction of progress in various areas of space science, there must also be a mutuality of opportunity for U.S. and European scientists to participate in the resulting activities. NASA has from the start opened its "Announcements of Opportunity" to all free-world scientists, but ESA and individual European countries have limited access to their scientific missions to European scientists, at least as principal investigators. This policy may have been defensible as a means of developing a European space science community, but NASA is now demanding reciprocity of access. Germany has already indicated its willingness to comply. For the ESA mission to Halley's Comet, *Giotto*, 9 of the 10 experiments have U.S. coinvestigators (a total of 33 individuals); ESA has agreed in principle to open up its future missions to U.S. principal investigators, and a NASA/ESA committee is now studying how best to implement that agreement.

Increasing Militarization of Space Activities

Space technology had its origin in military missile and satellite programs, and there has been continuing attention to ensuring that the international programs of NASA do not provide access to militarily sensitive technology. Now the major U.S. launch system is the space shuttle, which is a national capability used for NASA, DOD, and non-U.S. missions. In this context, "classified operations will be a necessity and are bound to lead to a more restrictive atmosphere, less conducive to international cooperation; tending to lead in the same direction . . . are developments in detector technology and in active atmospheric-magnetospheric experimentation."[30]

It is well beyond the scope of this paper to discuss the increasing military interest in various uses of space technology, but if the DOD budget for space, which is already larger than NASA's, continues to grow, there is likely to be an impact on international space activity. One possibility is increased international cooperation on defense applications of space among the United States and its NATO allies. Other areas of scientific collaboration have been able to coexist with military interest in the same scientific area and its underpinning technologies, and this duality has been present in space from the beginning; nevertheless, the changing context of space activity must be of concern to those interested in promoting open international cooperation in space science. In particular, several members of ESA are neutral states that could object to being involved in cooperative activities with the United States which had any hint of military overtones.

Impact of Space Shuttle on Scientific Cooperation

The space shuttle is an extremely capable launch system and short-term orbital platform. It offers scientists a much different environment than previously available in which to design and operate their experiments; there is even the chance to accompany them into orbit. Europe has recognized the shuttle's potential and is designing systems for its own and cooperative space activities which can only be used with the shuttle. These include Spacelab, of course, and an ESA-developed unmanned free-flying platform called *Eureca*, scheduled for a 1987 launch. As the shuttle, Spacelab, and other systems become more familiar to scientists, there will emerge innovative ways to take advantage of these new capabilities.

However, U.S. and European scientists will also share a common problem as they plan their missions for the Space Transportation System; because it is a manned system, the requirements for qualifying payloads to go aboard it and for supporting those payloads with documentation are both demanding and expensive, especially in comparison to similar requirements for unmanned launches. When European scientists began to plan for the use of Spacelab, for example, they "were really shocked by the requirements for testing and documentation and the associated cost of those requirements."[31] Europe is continuing to find it difficult to afford to use elements of the Spacelab system for its experiments; the result is that "continuous use of Spacelab by those who built and financed it is not likely."[32] Whether the shuttle will prove to be a crucial asset for those planning future science missions or a source of costs which limit the number of missions that are affordable is yet to be determined, but the impact of the shuttle is of crucial importance to U.S. and European space scientists alike.

Possible U.S.-European Collaboration on Space Station

Just as U.S.-European interaction over a European role in NASA's major post-Apollo programs has colored the whole of trans-Atlantic cooperation in space over the past decade, so may the outcome of the initial interactions over European participation in NASA's proposed space station program affect the overall prospects for European-U.S. collaboration over the next decade or more. This impact could have several dimensions. Europe has been following NASA's planning for the space station quite closely and has carried out parallel studies of options for European participation; in essence, NASA and ESA are already travelling together down a path that could lead to a major European role in an evolving station effort. This early and close involvement is quite different from what occurred in the post-Apollo period and signifies how closely the U.S. and European outlooks on space have become interwoven.

If, after this start, something intervened to make large-scale collaboration on station development impossible, there would certainly be a ripple effect on other areas of cooperation. On the other hand, a joint decision to move ahead with significant collaboration on the space station would cement the increasingly intimate relationship between the planning and conduct of U.S. and European space activities. While there would still be both economic competition and rivalry over scientific achievement, they would occur within a broader cooperative framework.

One rationale for developing a space station and associated infrastructure is to create a research facility in earth orbit. Just as the existence of the space shuttle and Spacelab will define the conditions for many space science missions in the coming decade, so would the availability of permanent orbital facilities condition the conduct of space science in the 1990s. Thus it is important to the space science community that any space station that is developed be a congenial base for its experiments, and pressure from U.S. and European space scientists will be important in ensuring that such is the case.

CONCLUSION

Kenneth Pedersen, current NASA Director of International Affairs, has commented that "international space cooperation is not a charitable enterprise; countries cooperate because they judge it in their interest to do so."[33] This observation can be extended to the level of individual space scientists; in the 25 years since scientific experiments in outer space became feasible, U.S. and European scientists have found it increasingly in their individual and mutual self-interests to carry out much of their activity on a cooperative basis. NASA's policies have encouraged and facilitated such cooperation; one result has been the nurturing of a vigorous space science community in Europe as well as in the United States.

That community today recognizes the high stakes involved in maintaining effective communication and cooperation across national borders; this appears the only way for space science to thrive. The simple missions have already been flown, resources for space science are scarce, and a coordinated approach to the planning, funding, and conduct of complex science missions makes eminent sense. New ways to allow space scientists to join with the government organizations through which they function in a collaborative enterprise of cosmic discovery may be needed, but in general the outlook for international space science in the coming decades is one of great promise and excitement.

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U.S. Participation at CERN
A Model for International Cooperation in Science and Technology

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Clemens A. Heusch

INTRODUCTION

On the slightly sloping plains between the southwest end of Lake Geneva and the steep southern flank of the Jura Mountains, a vast complex of architecturally confused and confusing surface structures makes up that part of the European Laboratory for Particle Physics that is visible to the casual visitor. A tightly interlaced network of beam tunnels and accelerating and detection equipment is almost entirely hidden from view, much of it subterranean, all of it fed from one initial source of positively charged hydrogen nuclei ("protons"), all of it masterminded by one precisely linked network of computers. The protons, on their way from initial liberation out of a hydrogen plasma to eventual collision with a stationary target at an energy equivalent to 500 times their mass, or to final annihilation upon encountering head-to-head an antiparticle of equal but opposite momentum, will pass the border between French and Swiss territory some 100,000 times. This is the border across which Voltaire withdrew when his free-thinking ways made him suspect to the rightist French monarchical establishment, the border which has guarded covetously held freedoms and prejudices between different political and economic systems over centuries. For the 10^{11} protons contained in every burst of accelerated beam, and for the 6,000 scientists, engineers, technicians, and support personnel implementing a large number of research projects on this site, the frontier does not exist—even while customs officials ferret through automobile trunks at the official border post of the Route Nationale Lyon-Geneva just outside the laboratory fences.

The vast laboratory that geographically straddles the République de Genève and the French Département d'Ain was formally established by an intergovernmental treaty of 11 European nations in early 1952. Dedicated to the pursuit of fundamental research in particle physics, and financed on a level beyond the means attainable by most individual countries, the organizational entity created at that time was given the name Conseil Européen pour la Recherche Nucléaire (CERN). Although the laboratory's mission is better reflected, in today's context, by the nomenclature the present directorate prefers also for political reasons—European Laboratory for Particle Physics—the acronym of the initial organization, CERN, gives the laboratory its name to this day. More importantly, CERN is the single most successful international organization that has sprung out of the misery of postwar European political, social, and cultural conditions. It may be one of the very few international organizations ever created that have fulfilled their mission, almost invariably high-minded, to the expectation of their initiators.

Geneva is home to a number of organizations whose multifaceted international missions and precariously balanced constitutions permit only limited success; others flounder from crisis to crisis, from bilious infighting to sullen compromise. At CERN, on the other hand, preoccupations and highlights concern the successful operation of a major new accelerator or beamline, a tantalizing new experimental result, or a splendid new discovery. The epochal achievements of two large experimental teams that, this year, discovered field quanta akin to the massless photon, but a hundred times more massive than the hydrogen nucleus, had no national origin and found no nationalistic overtone—it was an achievement of the first order produced by teams of scientists from all across Europe, and the entire laboratory appeared to share in the pride the discovery generated. The author list of the scholarly publications following from this work also contains U.S. scientists, reflecting both institutional participation and individual visitors.

What makes particle physics a field where international cooperation appears to generate success?

HIGH-ENERGY PARTICLE PHYSICS: FEATURES OF A DISCIPLINE

Particle physics is the discipline that deals, by all means accessible, with the physical world at its most fundamental level—that is, with the most elementary constituents of our universe and with the forces that govern their appearance and their interactions. Originally devoid of all practical implications, the philosophical quest for an understanding of these phenomena has occupied fertile minds from antiquity to the present day: diffuse threads link Democritos' postulate of the existence of an α-τομοσ (=atomic, i.e., indivisible state of matter) to medieval alchemists and to nineteenth-century chemists, whose observations first indicated a precise number of basic constituents of, say, a liter of water. Their ατομοι were water molecules.

The vast explosion of scientific knowledge that has characterized the most recent hundred years has, as its principal landmarks, discoveries that more and more precisely defined notions of what would describe "particle" behavior in successive generations: Maxwell's theory of electromagnetism, Roentgen's discovery of X rays, Einstein's theory of blackbody radiation, Bohr's model of the atom, and finally the tidal wave of quantum mechanics, both classical and relativistic, the emergence of particulate electrons, photons, neutrons, of antimatter, and of massive particles ("pions") that appeared to carry the force between atomic "nuclei," the dense insides of the atoms that make up yesterday's ατομοι, the molecules of the chemist.

If there are two discoveries that have set the scene for today's appearance of the discipline of particle physics, they are, first, Einstein's 1905 postulate that energy and mass are equivalent ($E = mc^2$), with its later corollary that a particle of a given energy is describable in terms of a wave characterized by a fixed frequency of oscillation, or a wavelength inversely proportional to that energy; and second, on a different level, Hahn's and Strassmann's 1939 discovery that a heavy atomic nucleus, e.g., certain isotopes of uranium, can be split in such a way that neutrons emerging from the break-up process can initiate further such splittings, leading to a chain reaction. The first of these observations has been leading us to understand that, to study successively smaller substructures of matter, at levels way below the atoms of 1905 or the nuclei of 1938, we have to go to smaller and smaller wavelengths of the "light" that we use to illuminate them, and therefore to higher and higher energies for the particles that make up these beams. The second occurrence has forced us to realize that an illusion held dear by modern-day scientists—the illusion that, unlike the medieval alchemist whose livelihood was provided by some lord who really expected his hired sage to turn tin into gold or carbon into diamonds, our latter-day civilization permits them to pursue knowledge for its own sake in suitably equipped and comfortably soundproofed ivory towers—is at best a dangerous one: a mere 6 years after Hahn's and Strassmann's discovery, a technology based on their laboratory observation put an abrupt end to what remained of World War II and to the cities of Hiroshima and Nagasaki.

Particle physics in its present form is shaped by these two events. How?

The distances over which we observe elementary particle structure and interactions today have decreased from the 10^{-8} cm of typical atomic structure to some 10^{-16} cm. This means that the energies needed for particle beams that will probe subnuclear interactions as we study them today are some 10^{8} times higher than energies typical of atomic phenomena. This translates into a need for great technical efforts. We can illustrate this by a look at particle accelerators at the cutting edge of our science. Take, as examples, the CalTech Electron Synchrotron, which helped accumulate vital data on nucleonic structure between 1955 and 1970: at a final energy of 1.5 GeV,[1] it accelerated electrons so that photons could probe nucleons to distances a few times 10^{-14} cm; it fitted comfortably into a single hall on the small Pasadena campus, and was well supported by a crew of eight operators and technicians, with annual operating costs of about $0.5 million. Between accelerating cycles, its energy was stored in a large steel flywheel. The bill paid to the local power company was negligible.

The synchrotron that will accelerate electrons to an energy of some 50 GeV as a first stage (later to be raised to 100 GeV) and their antiparticles to an equal but opposite momentum,[2] to be built by CERN for initial operation in 1988, needs a subterranean tunnel of roughly circular shape, and of a total length of some 26.7 km. Its building costs will be some $400 million,[3] the permanent support staff will number some 800 people, and the electrical power bill alone will amount to an annual $20 million.[4] This accelerator, suitably called LEP (Large Electron-Positron [collider]), will probe the so-called Weak Nuclear Force (the force responsible for β-radioactivity in nuclei) at distances below 10^{-16} cm, just as the CalTech Synchrotron probed the strong nuclear force at 10^{-13} cm. Just as there were four experimental setups serving four teams of experimental physicists at CalTech, doing different but related experiments, so we expect to have four experimental setups providing four related experimental goals for four teams of scientists at LEP.

This is where the parallel becomes skew: The teams at CalTech consisted of, typically, a faculty member and a couple of graduate students; at LEP, the teams will consist of between 200 and 400 scientists each, with more senior researchers and professors than research fellows or graduate students. At CalTech, the beamtime was casually divided between the people interested, who could be summoned at all hours from their nearby houses for emergency discussions or fixups of apparatus; at

LEP, people will fly in for shifts arranged months ahead of time, from home bases hundreds or thousands of miles away. At CalTech, preparation of an experiment took from 3 months to a year; at LEP, the minimum time deemed reasonable for full preparation of a major experiment is approximately 6 years. At CalTech, funding for the individual experiments was informally arranged within the laboratory and almost automatically subscribed by the U.S. Atomic Energy Commission (which at that time funded about 90 percent of particle physics research in the United States); at LEP it takes deliberations involving representatives of 12 national governments to finance any of the four experiments. Across the changes illustrated by the two examples given, these changing features as well as those that have remained constant make up the very special features of particle physics that make it a natural for international collaboration:

- The problems pursued are of a truly fundamental nature. There is no dissension concerning the basic importance of our understanding of the most elementary constituents and forces of nature. The field is not subject to scientific or cultural or economic "fashion."
- The aims of particle physics are deeply cultural. They are, as of themselves, remote from the interests of military use or economic gain. This is not to say that secondary effects may not be interesting to both of these pursuits, but the second of the shaping events mentioned above has engendered a strong tradition among scientists that keeps them well separated from all military or even traditional commercial interests.
- Fundamentality as well as remoteness from competitive power structures permits and encourages openness. All research done at all high-energy particle accelerators the world over is unclassified, readily published, easily communicated among colleagues, and accessible to all interested.
- Easy communication encourages competitiveness on an international basis: new theories or speculations that suggest novel experiments are immediately known worldwide. Many scientists may wish to pursue an almost identical problem, maybe even with almost identical means.
- Undeniably, there is a prestige or "flagship" aspect to the support of elementary particle physics. All great cultural and economic powers support this field despite its remoteness from practical use and notwithstanding the very considerable economic means needed. Sometimes, this happens in the face of dire demands from other national needs that may appear much more pressing—the recent Chinese efforts to establish a new accelerator laboratory, initiated by Chou En-lai and emphasized by his successors, may serve as an example.

- The ever-increasing size and cost of elementary particle experimentation has forced a sharing of resources and of responsibilities. When CERN was founded, national accelerator laboratories flourished in France, England, and Italy; Germany was starting her own. Today in Western Europe, only Germany maintains a vigorous national facility of her own, and even that is attempting to widen its appeal to all interested parties from Europe, Asia, and the Americas.
- Through all the vagaries of the Cold War and the economic straits of the past 30 years, scientific contacts among particle physicists from all nations involved in this pursuit have been unbroken. This has been true despite the most trying aspects of strategic, economic, and civil rights disputes.

All of these points may indicate why elementary particle physics is a special field that profits from the most unrestricted international collaboration—and has done so traditionally. It may not be a coincidence that, even in a historical context, an arch-internationalist nation like Italy, spreading its people over the globe, has done extremely well in particle physics—*vide* Fermi, Segrè, Amaldi, Piccioni, Wick, Cabibbo, Regge, and many others, disproportionately so when compared with other, more chauvinistic nations that tend to try and go it alone, albeit with much superior means.

It may not be too astonishing then that the team of scientists that discovered the $W^{\pm}$ and the Z^0 bosons at CERN contains 150 scientists from a score of nations, headed by an Italian who also holds a professorship at Harvard, and that the apparatus it used was financed by a dozen European governments.

CERN: FEATURES OF A LABORATORY

CERN owes its origins to a confluence of efforts by various individuals and institutions whose original aim was the establishment of a "Centre Européen de la Culture" including specialized institutes.[5] Formally, it took a UNESCO initiative that encouraged European governments to pool their resources for the purpose of doing nuclear research on a level that would permit smaller, less pecunious nations to participate in these activities. The structure that has grown from the 1952 convocation is a most impressive one, as we will see below. Its true measure of success may be most apparent when compared with the fate of its much more official, much better financed sister organization EURATOM; this latter one, established in parallel with the European Common Market for the purpose of furthering cooperation toward the exploration and realization of economically interesting nuclear physics applications, has had a hard time rising from political and economic, nationalistic and factional controversy, and has since been formally integrated into the European Community.

CERN today has 13 member states who participate in the running and the financing of the laboratory according to a convention and a financial protocol signed in 1953; it has been amended several times since without changing the basic spirit or setup. Article I creates the organization with its seat in Geneva; significantly, Article II immediately states that "the organization shall provide for collaboration among European states in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The organization shall have no concern with work for military requirements, and the results of its experimental and theoretical work shall be published or otherwise made generally available."

CERN's mission has been principally the design, building, and operation of particle accelerators capable of realizing these research aims, the execution of major experimental programs on elementary particle research topics, and the assembling of a team of theoretical physicists capable of stimulating and interpreting experimental work. The laboratory today operates a proton synchrotron (PS) with an energy of 26 GeV (since 1959) and a proton synchrotron (SPS) that reaches 450 GeV (1976); these have recently been modified to also accelerate antiprotons in the opposite direction, so as to make collisions of protons and antiprotons traveling at equal but opposite velocities possible ($\bar{p}p$ Collider); it also operates the Intersecting Storage Rings (ISR), which collide protons traveling in two interlaced rings almost head-on. For many years, starting in 1957, there was also a vigorous medium energy program centered on the SC (Synchro-cyclotron), which accelerated protons to 0.6 GeV. Much of the present CERN activity is directed toward the design and operation of the LEP project discussed in the previous section—the first excursion of CERN into the realm of electron machines, hitherto dominated by the Stanford Linear Accelerator Center (SLAC) in California and the German Electron Synchrotron Laboratory (DESY) in Hamburg.[o]

Among these projects, two do not at present have an equivalent in the United States, the ISR and the $\bar{p}p$ Collider. The antiprotons that feed the Collider can also be decelerated to permit low-energy $\bar{p}p$ (proton-antiproton) interactions in the Low Energy Antiproton Ring (LEAR), another unique facility. The huge LEP project, on the other hand, will have a U.S. competitor, the Stanford Linear Collider (SLC), for its first (50 GeV) phase; but machine parameters and readiness of access make for differences that will still attract powerful U.S. interests to LEP; on the whole, SLC and LEP should be seen as complementary facilities.

CERN's organizational structure, owing to the multinational support it enjoys, differs considerably from that of American laboratories: its governing body is the Council. Each member state has two delegates in the Council, usually one scientist and one representative of its government. The Council determines the outlines of the scientific policies and its relations with the member states. It has to pass the CERN budget, supervises all financial, legal, and personnel matters, and appoints the director-general.

The Scientific Policy Committee, consisting of scientists without regard to their national origin, advises the Council on scientific matters and on their importance for the CERN program. Its membership includes the chairmen of the experimental committees that are responsible for the examination of experiment proposals submitted to the laboratory. Experiments are approved or disapproved, upon the recommendation of the appropriate experiment committee (of which there is one for each large accelerator) by the Research Board. This board, chaired by the director-general and also containing CERN's research directors and scientific divisional leaders, carries ultimate responsibility for definition and realization of the experimental program of the laboratory.

The CERN management is headed by the director-general, whose term of office usually extends over 5 years. The director-general is a scientist who has considerable executive privileges, but usually comes from outside the laboratory and usually returns to a position outside the laboratory after his term. There has been only one extension of the term of office of a director-general. The director-general need not come from a member state.

The distribution in national origins of CERN scientific personnel, coming mostly but not exclusively from member states, is not necessarily representative of the importance of their home countries in CERN support. Out of a total of some 6,000 people working at the laboratory, some 3,500 are full-time employees (the top echelons of which enjoy diplomatic status, on a par with the leading employees of other international organizations); the remainder are fellows, visitors, or people working at CERN for outside laboratories.

The financial resources needed for the operation of CERN are determined by a standing committee, the Finance Committee, and then are agreed upon by the Council every year; a 5-year projection of expenditures is passed by the Council, providing for due notice to national governments. The member states contribute to the CERN budget in proportion to their GNP of the past 3 years, with the proviso that no nation shall contribute more than 25 percent of the total budget. At present, the 674 million Swiss francs ($320 million) annual operating budget is subscribed 25 percent by Germany, 21.7 percent by France, etc., down to 0.36 percent by Greece.

Certain decisions, such as the LEP construction, have to be supported and subscribed to by unanimous vote of the CERN Council. This gives unusual weight to the small nations and acts as a safeguard against the domination of the fate of the organization by the large contributors. The recent agreement to establish LEP was preceded by endless negotiations. A special convention saw only two-thirds of the member states in favor of LEP. It took special negotiations by the Council to mute the preoccupations of several countries and reach unanimity.

Given the above organizational features of CERN, what makes it the success it has been? It should first of all be remembered that the discipline itself sets the tone of the activities (see section above). But in practice, here are patterns that have evolved over the years which must be counted important:

- Experimental teams, large or small, very rarely if ever are composed of people from one member state only. Most collaborations have multinational membership.
- CERN management has never been shy about imposing organizational conditions on experiment proponents, including the recommendation that teams from other (usually less well supported) nations be absorbed into a collaboration. This has, notwithstanding its interference in the internal workings of scientific teams, ensured that strong and well-funded nations would not dominate the scene.
- There is no history of national rivalries, of chauvinism among CERN teams; competition for support means, for beamtime, or for approval of an experiment is tough, sometimes even vicious, but always directed at the task at hand.
- In its decision-making process, CERN management has invariably been mindful of the societal impact of the laboratory. This has sometimes led to the support of programs the principal distinction of which appeared to be that they would feed a large number of physicists, rather than maximum scientific merit.
- CERN has consistently opened its door to outsiders: Although scientists from nonmember countries do not share in all the privileges of their European colleagues, U.S. participation has been significant and steady; Russian and Chinese scientists have collaborated directly at CERN or from their home institutions; so have people from many other

nations. There has been a consistent pattern of helpfulness toward countries whose scientists had political or economic problems of collaboration.

- CERN's stable finances have permitted it to do things well, i.e., to devote the necessary resources to the building and maintenance of machines, beamlines, and detectors. Few if any scientists there have had to operate under the constraint, only too well known in the United States, to cut corners whenever possible, to take inordinate risks, to compromise quality.
- CERN's facilities have been designed and built by well-paid engineers—more or less like NASA, which cannot afford technical failures. A U.S. tendency to have research physicists act as amateur machine builders has been avoided.
- The ensuing high quality of machine building has paid off handsomely: only by the high standards of magnet and vacuum chamber construction can the success of converting the SPS accelerator into a colliding $\bar{p}p$ machine be explained.
- CERN realized early on that the presence of a strong theory group is of great benefit to a laboratory based on accelerator work. Today, a senior staff position with the CERN Theory Division can compete for talent with a professorship at Europe's most prestigious universities. Temporary positions, too, are made unusually attractive. Visitors come in hordes. As a result, much excellent theoretical work is done at CERN. U.S. accelerator laboratories rarely if ever have been able to compete for theoretical talent on this scale.
- There has been an explicit policy to bring European industry into close contact with the laboratory. Unlike a tendency well entrenched in the United States, there has not been a trend to build magnets more cheaply on site, to build klystrons or power supplies in competition with industry: Orders have been passed out to industry, sometimes along with necessary expertise. This policy, well balanced over the member states, has made powerful friends for CERN.
- The laboratory management has made consistent efforts to make not only governments, but also a wide public understand its efforts. The popular brochures put out by CERN are exemplary in content and presentation.

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Clearly, there is a distaff side to the heavily organized, painstakingly defined structure of CERN. On balance, however, the laboratory is liberal in its approach and its practices, elitist in its aims. Therein lies its key to success.

Thus, an elitist institution can also afford to attract some of the most fertile brains in instrumentation and engineering physics. The laboratory has derived immense benefit from the presence on its staff of such inventive people as Simon van der Meer, developer of stochastic cooling and of the neutrino "horn of plenty" (without which high-energy neutrino experimentation would be unthinkable)—whom Victor Weisskopf, director-general during the 1960s, gratefully calls the "Maxwell Daemon of the 20th century"; as Georges Charpak, the yardstick of detector specialists; as Kjell Johnson and Wolfgang Schnell, builders of accelerators that so far surpassed their specifications as to permit their use for projects far beyond their original mission; and many others, whose ingenuity, in the United States, would likely have found proper recognition only in industry.

CERN: A LABORATORY WITH U.S. ROOTS

Historically, Western European and U.S. science are so tightly interwoven that it would be wiser to speak of roots common to all than of specific national godfatherhood to a great scientific enterprise. Still, it is not just for the present argument's sake that we recognize typically American features—features that would not follow from European traditions—in the structure as well as the practices of CERN.

The roots of CERN science may have little that's American in them, but the great exodus of top European scientists during the Nazi and postwar eras exposed these people to a spirit of pioneering attitudes, of speculative approaches to the problems of the classical sciences, of a lack of respect for passed-down structures of academic life that were to be seminal to European science at the postwar stage. In this sense, it was not only the official UNESCO appeal (influenced in no small measure by the insightful suggestions of I. I. Rabi, the noted Columbia University physicist) that led to the original CERN convention and, by shaking European nations out of national patterns of academic activity, brought a transatlantic breeze into action; but also the attitudes acquired by formerly European scientists who now came back to help establish the new research complex that put a decisively American brand onto a wide range of CERN features. The laboratory may, in its infancy, not have had much of a personality of its own, when Felix Bloch—born in Switzerland, later at Stanford—became its first director-general. The truly formative years of CERN were those when the first important experiments were done—and there again American influence is considerable: The Ford Foundation had provided a generous grant to help CERN attract visiting talent, and American researchers were more than happy to respond to the beckoning from the Alps, for sabbaticals or leaves from their normal duties. The justly famed series of experiments that measured, to ever greater precision, the magnetic moment of the muon, and thereby provided an ever more impressive confirmation of the theory of quantum electrodynamics, had people like Garwin, Lederman, and Telegdi among its initial contributors. On a technical basis, too, U.S. influence was seminal: Courant and his colleagues from the Brookhaven National Laboratory (BNL) suggested to the CERN engineers the adoption of the strong-focusing technique for accelerator construction.

Maybe the most formative period was that of Victor Weisskopf's term as director-general (1961–65), during which CERN became a full competitor to its then U.S. equivalent, BNL. Weisskopf brought to his task an inimitable mix of Old Vienna charm, of the prestige associated with his pioneering work on quantum mechanics with Pauli and others, and of the teamwork know-how he had acquired during his service in wartime Los Alamos. A man of deep culture, he personified the best of both the European and the U.S. traditions: The first made him universally accepted among European colleagues as well as government representatives; the second gave him both the confidence and the know-how to assemble and direct a large team of scientists in such a way as to make the physics result the principal issue. He adopted—consciously or subconsciously—the charismatic leadership style that had been so effectively developed at Los Alamos by Oppenheimer. But unlike the latter, he did not have to live to question the fruit of his labors: To this day, Weisskopf is a popular lecturer and valued counsel around CERN, just as his voice was heard and respected for many years as the chairman of the High Energy Physics Advisory Panel (HEPAP), an advisory panel of the U.S. government, upon his return to the United States.

Weisskopf's activities included attracting top U.S. scientists with European backgrounds to CERN; by inviting Giuseppe Cocconi and Jack Steinberger to join the new laboratory, he again imported U.S. know-how and U.S. attitudes, albeit in European skins. Into his period fall two other important developments, one positive and one less successful: On the positive side, CERN developed a neutrino beamline that was to compete with the U.S.'s Brookhaven Alternative Gradient Synchrotron (AGS) neutrino facility head-on, to find out whether speculations for two separate lepton families were correct or not. CERN lost the race, but its resulting commitments to neutrino physics were to lead to the first great CERN discovery: During the subsequent tenure of Bernard Gregory as director-general (1966–1970), the large bubble chamber

GARGAMELLE received the support that was to lead to the identification of weak neutral currents. On the negative side, we must count the invitation to an entire U.S. team of experimenters that attempted to do a major experiment at the CERN PS, using almost exclusively equipment built in the United States and transported to CERN, in a search for the relative parities of the sigma and lambda hyperons through spark chamber techniques. This concerted effort to do an entire project from the outside on a go-it-alone basis did not lead to success and would influence later attitudes toward experimental collaborations with nonmember states.

Also into this period falls the decision by Weisskopf to build the ISR, permitting high-energy protons to interact with others of equal but opposite momentum; parallel initiatives at BNL had been rejected. The technical success and experience thus gained permitted his successors Leon van Hove and John Adams, in 1978, to support the conversion of the SPS into a proton-antiproton collider, whose great later successes would otherwise be unthinkable.

The presence of U.S. physicists at CERN thereafter remained a persistent but ad personam feature for years, until, with the advent of the above-mentioned ISR in 1971, CERN had a unique facility at its disposal that had no equivalent in the United States. At that point, discussions between Bernard Gregory and Rodney Cool of Rockefeller University, who had spent repeated periods at CERN, led to the entry of U.S. teams into joint experimental ventures at the ISR. The pattern informally suggested by Gregory, never elevated into a fixed rule, implied that there should be at most 50-50 participation from the United States and that there should be a proportionate sharing of the costs of experimental equipment, but no charges for services, setup, or beamtime (as has been the case at other laboratories). The ensuing CERN-Columbia-Rockefeller collaboration has, with modifications, existed ever since. It was later joined by a Brookhaven-Yale-Syracuse contingent for another major ISR experiment series, whose head, W. Willis of Yale and Brookhaven, has since become a permanent CERN staff member and by a major search for high-mass states that might decay into $\mu^+\mu^-$ pairs, headed by S. Ting of MIT. In fact, in 1978, about 25 percent of all physicists working on experiments at the ISR came from U.S. laboratories. All of this happened simply by arrangement with the individual U.S. institutions, not by Council negotiations with U.S. government agencies.

The CERN Theory Division has similarly benefited from its frequent U.S. contacts and from the inclusion of European returnees from the United States among its staff. Much of European theory tradition tends to put great emphasis on axiomatic, "high-brow" aspects of the field. The irreverence typical of the American approach, which doesn't mind occasionally adopting a cheerfully "low-brow" stance, has had a salutary effect on particle theory through its influence at CERN.

PATTERNS OF U.S. COLLABORATION AT CERN: PROBLEMS AND BENEFITS

Activities of U.S. scientists at CERN are seen to fall, roughly, into these categories:

- Individuals who have been invited to CERN because of specific promise that their presence at Geneva would be a major asset to the laboratory. This may be on either a temporary or a permanent basis.
- Short-term visitors (usually for 1-year terms) on leave from their home institutions (often sabbatical leave); they may be partially or fully supported by CERN, or merely enjoy the courtesies accorded unpaid visitors. They may come to CERN to participate in a specific experiment or development project, to do theoretical work, or they may decide on-site which activity to join.
- Small (or even larger) groups from one or several U.S. institutions who come to CERN to collaborate on a given experiment they may have co-proposed. Their activities at CERN are supported by the U.S. funding agencies, mostly within the framework of normal university or laboratory funding. CERN may or may not subsidize their presence in Geneva, which is motivated by the availability of an attractive facility (beamline, detector). Such collaborations may last for 2–4 years, the typical duration of an experiment.
- Groups of U.S. scientists—usually entire university groups—who have been attracted to CERN by a unique possibility of experimentation—*vide* the arrival of stable groups from the United States with the advent of the ISR. Such groups have established a long-term presence at CERN; their funding comes from the Department of Energy (DOE) or the National Science Foundation (NSF) and is usually only indirectly helped by CERN. Their size may be small, as the Northwestern University group, or moderate, as the UCLA team at the ISR, or become quite massive (as the MIT team); they will *in praxi* be treated like a team from any member-state institution, as long as they provide their share of equipment and manpower for an enterprise.
- Lastly, there is an interesting and pervasive presence of U.S. scientists at CERN who are usually young, but past their first postdoctoral period. They are usually bright people who came to CERN for a year

(see above) after their Ph.D. completion, liked Europe or CERN or a specific group of congenial colleagues, and therefore decided to stay on. They are often supported on short-term contracts by member state laboratories and will often contrive to remain in Europe as long as possible. They are the wandering minstrels of modern-day physics, and upon returning finally to the United States bring a flair of European attitudes to their U.S. institutions. Some small fraction of these will wind up in permanent (mostly nonuniversity) positions in various European countries, where again their presence tends to add a refreshing note.

Remarkably, while all of these contracts and collaborative arrangements were made after a slowly emerging pattern, never to reach the level of a rigid set of rules, and often changed to suit specific circumstances, relations of the United States with certain other national high-energy physics communities were bound up in government-to-laboratory or government-to-government agreements, respectively. This is true of U.S.-Russian, U.S.-Chinese, and U.S.-Japanese agreements, setting down precise guidelines of collaboration, specifying the projects involved, the support to be granted by each side, etc. Similarly, protocols of cooperation exist between CERN and the Soviet Union and between CERN and China. CERN also formalized its relations with some nonmember states by appropriate exchanges of letters or of agreements of understanding, usually involving the Council.

CERN permits physicists from other East European states collaborative activities under its mantle agreement with the Dubna Laboratory in Russia. The fact that U.S. scientists have been granted access to CERN and—in varying degrees—to its resources, in the absence of any attempt at formalization, must be seen as a recognition not only of the high quality of U.S. high energy physics and of the special "godfather" role the U.S. originally played at CERN, but also as an expression of a special kinship between the communities of high energy physicists in the United States and in Western Europe. These communities are numerically remarkably well matched. Coincidentally, the informality of the process has been invariably useful to both sides.

In 1978, the European Committee for Future Accelerators (ECFA), an advisory body set up in 1963 by the director-general and the president of the SPC, which acts as an informal adviser to all of European high energy physics, and HEPAP asked a small working group of two U.S. and two European physicists to report on recent trends in U.S.-European "interregional activity" in high energy physics. After studying available data on the 5 preceding years, they reported that the use of European facilities by U.S. scientists and of U.S. facilities by their

European colleagues had been fairly well matched (to be specific, in 1978, 70 American physicists were engaged on CERN experiments, about 70 percent of these at the ISR). Contributions and benefits were seen to have been evenly matched.

Let us try to be more specific here, without attempting to become quantitative. What are the benefits accruing to the United States from its CERN connections?

- Providing access to unique facilities. As the demands on energy and intensity of beams rise, it becomes less advisable (or even feasible) to have parallel machine ventures in the U.S. and Europe. At present, the CERN $\bar{p}p$ Collider, ISR, and LEAR are facilities not available in the United States. Ready access to these machines for U.S. physicists is important for a balanced U.S. program in high energy physics. Conversely, Europe foresees no early availability of 1 TeV[7] fixed-target or collider facilities; as a result, CERN's European Muon Collaboration is the first European group that has contracted to take vital parts of their existing equipment to the United States. This will undoubtedly boost the activities of the Fermi National Accelerator Laboratory (FNAL) muon program. The trend will accelerate in the future (see next section).
- Sharing the cost of accelerator physics developments. In a routine way, U.S. laboratories and CERN share technological advances in accelerator physics—frequently aided by exchange visits of U.S. personnel at CERN and that of CERN staff at FNAL, Brookhaven, or SLAC. Developments of superconducting magnets, of beam cooling techniques,[8] of the study of beam instabilities, and of highly focusing particle optics may serve as examples. This practice more than doubles the means effectively available to U.S. accelerator laboratories for much-needed development work.
- Sharing the cost of detector development (and construction). Similarly, access to much European detector development—which is largely directed at, if not locally tied up with, CERN experimentation—is of great value to U.S. scientists. Much of the pervasively important wire chamber and drift chamber technology, to name just one example, came almost "free of charge" from CERN. The same can, to a lesser degree, be said of liquid argon calorimetry, ring-imaging Cherenkov counting, and other techniques. Again, close collaboration more than doubles effective U.S. resources.
- Sharing the cost of entire experimental projects. This is a concept that has been evolving from early ISR activity, where the MIT-led $\mu^+\mu^-$ experiment was actually performed on a shared-cost basis. With

the advent of complete computer links from CERN to U.S. home institutions and the implied possibility that much of the off-line (if not on-line) data analysis can be done in the United States, this mode is expected to evolve more fully.

- Participation of U.S. scientists in parallel or competing experimental projects. It has been a frequent occurrence that individual U.S. scientists on leave from their home institutions participate in CERN experiments that are close competitors of the projects they are involved in at home. This practice provides for a critical look at their own enterprise, a cross-check, and a sharing of experiences and of responses to problems typical of the specific field studied. Sometimes such activities may lead to a repeal rather than a verification of previous results. Both are obviously healthy.
- The spawning and support of industrial development. This is an area more consciously and vigorously pursued by CERN (and, for that matter, by DESY) than by U.S. laboratories: The highly political nature of the CERN Council makes the support of high-technology industries in the member states an important feature of CERN activities. The acceptance of the LEP project, with its $450 million price tag, was a controversial item for some time; remarkably, CERN put out a 33-page list of items expected to be developed and supplied by European industries, from "hi-tech" to civil engineering, complete with name and telephone extension of the CERN project engineer to be contacted for details. Interaction with CERN developments, frequently through U.S. scientists working there, but also by direct contacts, has heavily influenced the development (and sales) success of U.S. manufacturers of electronics and computing equipment.
- Providing a sales outlet and testing ground for U.S. electronics and computing manufacturers. The relatively foreseeable and solid funding of CERN experiments has been of considerable importance to a number of U.S. manufacturers—to name but a few, LeCroy Systems and Edgerton, Germeshausen, and Grier (EGG), in the fast electronics sector; Digital Equipment Corporation and Hewlett-Packard in the computing sector. It is no coincidence that these companies maintain their European headquarters in Geneva. (There is little if any reciprocity in this sector: European hi-tech manufacturers have made negligible inroads in the U.S. market.)
- Access to European scientific documentation and records. Although this may seem a minor point, sharing documentation resources well developed at CERN is an important help to the U.S. high-energy physics community. Europeans, with more of a sense of history

than most Americans, tend to record historical events more readily (an exhaustive history of CERN has been commissioned by outside sources).[9]

- Postdoctoral education for young U.S. physicists. Traditionally, CERN has been receptive to a number of the most promising U.S. Ph.D. graduates and has welcomed them as fully paid CERN research associates. Others have spent their initial postdoctoral period in French, English, or German laboratories, which made them, for long stretches, resident at CERN. Their exposure to a top-notch international research establishment has invariably enriched them—not only scientifically. A cultural broadening may be one of the most essential benefits U.S. scientists experience at CERN.
- "Continuing education" of senior scientists. The great frequency of shorter-term (up to 1 year) visits of U.S. physicists at CERN provides a very important outlet to our community: Easy communication on all levels—scientific, cultural, human—with a broad international spectrum of colleagues is a vital resource to many people on leave or on sabbatical from high-pressure laboratory or academic surroundings in the United States.

Maybe the most pervasive benefit of the CERN-U.S. connection, in a more general sense, is the realization by an important component of the academic elite in the United States that sharing on a broad basis without counting up each benefit, without weighing advantages and disadvantages, is both normal and healthy in international relations. Just as it is of lasting benefit for European-educated scientists to spend some time in the United States and acquire some of the disrespectful pioneering spirit that is so often the key to success in our discipline, it is refreshing for U.S. physicists at CERN to be exposed to European traditions and trends. It helps to remove vestiges of cultural isolationism still pervasive in some of our academic life.

Measured against the benefits, problems springing from U.S. involvement have been less prominent, but are changing as the volume grows. They are mostly generated by the operational mode necessitated by the intercontinental nature of collaborative ventures.

University (or national laboratory) groups are most effective when they can act cohesively. In experimental high-energy physics, this means that a group operating at an accelerator within easy driving distance of the home laboratory has a distinct advantage. Group interactions, vertical and horizontal, are a vital feature of a healthy research and teaching environment. Most university groups face the complication of long-distance travel to accelerator sites. Common seminars become hard to organize, student and shop supervision are more problematic, teaching schedules must be carefully arranged against experimental shifts; but still, by and large, the problems are manageable.

For intercontinental collaborations, practical problems of this nature can severely affect the cohesiveness of university or laboratory environments. If a U.S. group has an important involvement at CERN, a senior professor and three or four more junior people may have to spend most of their time in Europe. With this long-term absence of a major fraction of a high-energy physics group, the cohesiveness at the university level may be seriously disrupted. Inside the United States, daily telephone communication on leased lines can make up for some of this; but intercontinental interaction becomes difficult and costly. As a result, important aspects of group activities can seriously suffer: Normal teaching becomes impossible for long stretches; the vital interaction among senior physicists that shape the future program and present quality of the group suffers; graduate student, laboratory, and shop supervision become impossible. If a U.S. group contracts to furnish a certain fraction of equipment for a CERN experiment, it may not be reasonable to build it at the home institution and ship it to CERN. The home shop size may have to be reduced (and thereby suffer in quality and flexibility) to accommodate purchases abroad. Frequently, ISR participants from the United States have hired and fired research fellows (with U.S. funds, obviously) who never came to visit the home institution. Group identity becomes compromised—it might be just as well to directly fund foreign activities without going through a U.S. university (and thereby inflate the cost by the university overhead expenses).

In the same spirit, maintaining a group abroad is disproportionately expensive. Separation payment, travel expenses, and communication costs can eat up large fractions of a group's budget.

There may, on a purely financial level, also be the problem of creating a two-tiered pay scale. People working abroad pay no taxes. Young postdoctoral scientists on tax-free CERN fellowships may be remunerated as well as some U.S. professors after taxes and will therefore be bitterly disappointed when they come home to a meager U.S. postdoc stipend. CERN-based and FNAL-based researchers from the same U.S. institution may feel they belong to different societies.

To revert to the previously cited comparison with CalTech Synchrotron operations in 1965, it was easy to have a healthy, fruitful university atmosphere conducive to the education of young scientists when all were locally present day and night; it is not obvious how much of a university atmosphere and character can remain intact with intercontinental operations. This is the principal price we pay for all accruing benefits.

CHANGING BOUNDARY CONDITIONS: OUTLOOK

At present, we appear to be crossing a dividing line in the operational mode of high-energy physics operations. It may have been marked by the migration, in 1982, of an active major detector from the SPEAR facility at Stanford to the DORIS facility at Hamburg, Germany. Concurrently, the Crystal Ball Collaboration, which had operated this detector at SLAC, doubled in size, swelling its ranks with European collaborators. The detector, after being adapted to its new habitat, has been taking data since early this year.

The trend is motivated by the drying up of more and more beam "spigots" available to experimental groups of moderate size, the emergence of unique facilities abroad, and the determination of the international high-energy physics community to operate as free of national and regional bias as possible. U.S.-CERN relations are realigning themselves to this development.

If we look at the machine facilities presently available, or firmly approved for construction such that experimental planning is already under way, the message becomes clear: A few years from now, initial-state (i.e., machine) parameters for high-energy experimentation will be different in Europe, in the United States, and in Japan. In the United States, there will be 1,000-GeV fixed-target physics as well as 1 × 1-TeV $\bar{p}p$ collisions at the FNAL and 50 × 50-GeV e^+e^- annihilations at SLC, plus the remaining (and possibly upgraded) lower-energy facilities at Stanford, Cornell, Los Alamos, and BNL. CERN will have the $\bar{p}p$ Collider program, probably upgraded in luminosity, LEP, and the remaining SPS fixed-target program. Electron-proton (ep) physics will most probably be available at the HERA facility in Hamburg, Germany, where 30-GeV-electrons will meet head-on with 800-GeV protons; there will be 30 × 30-GeV e^+e^- interactions at the TRISTAN facility (Japan); possibly, the UNK facility (in the Soviet Union) will offer 3-TeV fixed-target physics.

CERN is attracting large contingents of U.S. physicists to its LEP program, since the SLC is slated for only one experimental region. (Also, LEP promises to have higher luminosity and, in its second phase, higher energy than the SLC, and thereby the prospect of investigating a wider variety of processes.) While, typically, DOE support for the CERN operations of U.S. groups has totaled some $0.5 million per year, this will rise to some $7–8 million per year with LEP operations. If we include the total support for U.S. high-energy physics groups operating abroad, this figure will approximately double and make up some 13 percent of the U.S. DOE university support volume by the agency. In fact, projected U.S. expenditures for one of the LEP detectors (L-3) are of the same order as the target cost of both detectors at the U.S. "competitor" installation, the SLC. Clearly, interregional operations in high-energy physics have become more than a fringe phenomenon; U.S. relations with Europe and Japan will have to be defined within our discipline. U.S.-CERN arrangements may have to be modified.

The International Committee on Future Accelerators (ICFA) has defined a set of guidelines for interregional collaboration in particle physics, which attempt to ensure access to all high-energy physics facilities to appropriately staffed and supported groups of scientists irrespective of their national origin. Scientific merit should be the principal criterion for acceptance of an experiment proposal; but local collaboration should be secured for any distant-based originator of a proposal, and ultimate control rests with the host institution.

Given the great success of informal U.S.-CERN exchanges in the past, it must be our goal to keep formal arrangements at a minimum level. Still, the sheer volume of U.S. interest in CERN has led to some unprecedented changes. Frequent contacts between CERN management and the DOE High Energy Physics (HEP) Office culminated in the exchange of formal letters between the present CERN director-general, Herwig Schopper, and the director of the DOE-HEP Office, James Leiss, affirming the ground rules for U.S.-CERN relations; and a U.S. representative was made a member of the selection committee for LEP experiments (R. Taylor of SLAC).

The recent decision not to pursue the construction of a high-luminosity, high-energy (400 + 400-GeV) $\bar{p}p$ Collider in the United States has contributed to the concern that U.S. participation at CERN will be much stronger than CERN member-state participation at U.S. facilities. HERA and TRISTAN construction will add to the trend of U.S. scientists' participating in experiments abroad. The worry that this will lead to a massive spending of U.S. high-energy physics funds abroad, to the detriment of the national laboratories, must be seen in context:

- Insufficient coordination and subcritical funding of U.S. facilities and facility development are largely the basis of this imbalance.
- While reciprocity is a laudable objective in interregional cooperation, it is not at all compelling that such balance would have to be

established over a short period of time; rather, arrangements for U.S. support of, and interest in, CERN facilities might well be coupled with CERN participation in the preparatory work for the very large $\bar{p}p$ Collider recommended by the 1983 HEPAP subpanel.

- Major U.S. use of LEP (as well as HERA and TRISTAN) means that the great investments made by the countries subscribing to their construction and operating costs directly benefit the United States; the arrangement remains economically advantageous.
- Essentially all other benefits of U.S. CERN participation, specifically those to U.S. electronics and computer manufacturers, remain valid.

As we embark on a period where international coordination becomes more prominent, we have to strive for greater continuity in our high-energy physics program. The stable growth of the European program is not in the least due to the long-range planning prevalent in European countries. (In Germany, e.g., even individual university groups are funded for 3-year periods, and long-range projections are written into national budgetary legislation.) Lackadaisical support for our own facilities and abrupt termination of half-finished projects, as well as the unpredictability of the funding for our university program on a yearly basis, put us at a severe disadvantage when it comes to coordination with international research activities. The longer time range over which a major experimental effort will span—say, 8–12 years for an LEP experiment, from proposal to the completion of the initially foreseen program—alone mandates greater long-term stability for our program.

CONCLUSIONS

When the European Laboratory for Particle Physics started operations in the late 1950s, benevolent U.S. assistance helped to set a pattern of successful operation. A tradition of informal U.S. presence at CERN built up over the years, thus opening up the physical and cultural resources of this uniquely successful laboratory to American scientists on a mutually beneficial basis.

As individual machines grew ever more costly to build and operate, CERN facilities started to include some that were otherwise unavailable to U.S. scientists. Still informally arranged, participation by entire U.S. teams became an accepted feature at CERN.

A continuing trend toward contraction to a smaller number of high-powered, high-cost facilities can be partially offset by the practices thus evolved, to permit joint usage of major facilities at CERN and in the

United States (as elsewhere) to scientists from both sides of the Atlantic. It will be desirable to keep U.S.-CERN relations as informal and, therefore, as flexible as possible. This will be helped by better long-range planning and a willingness to assume longer-range commitments by our government. University groups will have to restructure their activities to permit far-off operations without an interruption of their classical mission, the "unity of teaching and research." Funding agencies and parliaments on both sides of the Atlantic will have to show flexibility and imagination; they will have to resist the temptation of trying to write narrow balance sheets.

Properly administered, the U.S. presence at CERN will increasingly mean a vast widening of our technological and scientific horizon; cultural and economic benefits will combine to ensure continued and increasing success of this collaboration.

On a more general level, a broadening of the horizons of U.S. and European scientists may provide for the most lasting advantages to be realized. Just as CERN's impact in Europe has been largely due to its proven history of a most successful enterprise in international relations, U.S. relations with CERN may yet set a pattern for fruitful interactions of American economic and scientific power with other nations.

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NOTES

1. 1 GeV = 10^9 electron volts; the mass of the proton corresponds to approximately 1 GeV.
2. For high energies, we can use momentum and energy as though they were quantitatively the same. But the definition of momentum contains the direction of motion; energy does not.
3. To be precise, 910 million in 1981 Swiss francs, 1,017 in 1983 currency equivalent. Experimental equipment is not included in these figures.
4. This includes the power bill for the preaccelerators feeding particles into LEP.
5. For historical accounts, see: L. Kowarski, An Account of the Origin and Beginning of CERN (CERN 61-10, 1961), and D. Pestre, Eléments sur la Préhistoire du CERN (CHS-2, 1983).

6. DESY is a German national laboratory that is currently attracting a large number of foreign, including U.S., scientists to its program; it operates e^+e^- storage rings roughly equivalent to the PEP and SPEAR positron-electron colliders at SLAC.
7. 1 TeV = 10^{12} electron volts.
8. Cooling here means the compression of phase space, permitting the accumulation and acceleration of large amounts of particles like positrons and antiprotons.
9. Note, however, that the American Institute of Physics (AIP) maintains very useful archives and similarly sponsors historical studies.

The Global Atmospheric Research Program

John S. Perry

INTRODUCTION

In 1979 and 1980, our earth's atmosphere received its first truly complete physical examination. Aircraft cruised over the broad expanses of the Pacific, Atlantic, and Indian oceans, releasing parachute-borne instruments to sense the atmosphere's structure. A fleet of more than 50 ships stationed themselves around the equatorial oceans to release additional instruments and obtain oceanographic observations. Hundreds of drifting buoys were deployed in the vast reaches of the southern oceans. A flock of balloons floated through the lower stratosphere transmitting observations of temperature and wind to orbiting satellites aloft. Commercial aircraft similarly transmitted observations through satellites to a network of ground processing centers. From space, two polar-orbiting and five geostationary satellites kept the globe under surveillance. The routine operational weather services of the world went into high gear, and special care was taken to transmit every possible observation to data-processing centers and archives. Today, some 5 years later, the body of data collected in this Global Weather Experiment—the centerpiece of the Global Atmospheric Research Program (GARP)—has been processed and analyzed through an internationally organized network of centers and is being intensively exploited by the world's research community to unlock the secrets of weather and climate.

The execution of this massive data-gathering program was a remarkable achievement. Moreover, its conception and planning represented an even more remarkable interplay between science and politics on a global scale. To understand how the Global Weather Experiment came to pass, one should consider the development of its parent program—GARP—in the context of the history of international cooperation in the atmospheric sciences.

BACKGROUND

Of all scientific endeavors, those dealing with weather and climate are surely the most international in character. Air flows freely over political boundaries. The same storm may bring rain to London and snow to Stockholm. The hurricane that ravages Cuba today may irrigate Mexico tomorrow. Even the climate of Siberia is moderated by the distant but vast ocean. Thus, exchange of weather information between nations goes back many centuries to the circulation of ships' logs between mariners.[1] However, it was only in 1872 that a formal international system for data exchange was organized with the formation of the International Meteorological Organization (IMO). Following World War I, the International Commission for Air Navigation took an interest in the exchange of aviation weather data, and the International Union of Geodesy and Geophysics, a nongovernmental member of the International Council of Scientific Unions (ICSU), concerned itself with meteorological research. After World War II, the IMO's functions were inherited by the World Meterological Organization (WMO), an intergovernmental specialized agency of the United Nations (UN).

The point of the above chronology is simply to emphasize that an active and effective infrastructure for international activities in the atmospheric sciences has existed for a longer time than have many of the world's nations. While the Global Atmospheric Research Program eventually became grafted onto this infrastructure, its genesis lay in a unique convergence of scientific and political circumstances.[2] In the period around 1960, many circumstances favored major forward steps in meterology. Advances were being made in the design of mathematical models of the atmosphere, and electronic computers were becoming sufficiently powerful to implement these models. The launch of Sputnik in 1957 and its many successors had demonstrated that the earth could be observed in its entirety from space at feasible cost. At the same time, the postwar hopes for a world of peace and universal cooperation were being dashed by the emergence of the Cold War. On assuming the presidency in 1961, John F. Kennedy faced a world rapidly solidifying into two hostile camps—the first brick in the Berlin Wall was laid in August of that year. Moreover, the opposing camp was demonstrating impressive capabilities in the prime technology of the age: The first man in space in April 1961 was a Russian.

In these circumstances, the new President was naturally motivated to open channels of communication in science and technology with other countries, especially the Soviet Union, in the hope that advances in science—particularly in the mastery of space—could be turned to peaceful ends. Explorations were initiated in the U.S. scientific community to uncover areas in which international scientific activities could serve these objectives. As suggested above, it was almost inevitable that meteorology would be seized upon as a most likely candidate because of its long record of success in the international arena and the emergence of exciting scientific opportunities. Complex discussion in the U.S. scientific community and government led to insertion of a single sentence into President Kennedy's September 1961 address to the United Nations on "the peaceful uses of space" appealing for "further cooperative efforts between all nations in weather prediction and eventually in weather control." This impetus, in turn, led to the adoption of UN resolutions in 1961 and 1962 calling on member states, WMO, and ICSO to develop plans for expanded programs in meteorological services and research, with particular emphasis on the peaceful uses of space technology.[3]

PROGRAM DEVELOPMENT

These resolutions set in motion a lengthy period of exploration and planning both within the United States and in the international community. The Panel on International Meteorological Cooperation was formed by the National Research Council's Committee on Atmospheric Sciences (1966), and a similar international group was established under ICSU auspices. In early discussions, a wide variety of topics for international cooperation under the UN's broad charge was discussed.[4] However, attention rapidly focused on a single problem, the large-scale motions of the atmosphere and their relationship to weather and climate.

On this topic, all the streams of motivation that had led to Kennedy's call to action strongly converged. Numerical models of the atmosphere were already being employed in routine weather prediction and were evolving into tools for the study of global climate. Research had shown that, while there existed a clearcut limit to detailed predictability of weather systems, this limit lay well beyond the realized capabilities of the weather services. The primary barrier to extending the range of prediction was the difficulty of determining with sufficient accuracy and detail the initial state of the entire global atmosphere. With an adequate research data set, it would be possible to distinguish between prediction errors induced by scanty data and those arising from imperfections in the models, and meaningful research could be performed. This would pave the way for better operational forecasts employing improved models and an efficient global observing system. Moreover, observations from space provided a new means for obtaining the complete worldwide observations needed to carry out meaningful research in this area. Finally, it was evident that such a global data set could be obtained only through close cooperation among all nations—including the Soviet Union—thus addressing the political goals of the Kennedy initiative.

With the central goal of the program defined, there remained the establishment of an institutional framework to support its implementation. Here, many competing interests and allegiances had to be reconciled. It was clear that a program to observe the entire planet would require significant resources and that these resources could be supplied only by the governments of the world. It was equally clear, however, that a simple hardware-oriented data-gathering exercise would fail to build the intellectual bridges between scientific communities that were so urgently desired. A complex partnership thus evolved, the advantages of which will be discussed more fully later on.

Two major and closely linked programs were developed. The first, the World Weather Watch, was to be organized by the intergovernmental WMO. This promised near-term improvements in the world's operational weather observing and forecasting systems by providing coordination of national efforts and infusions of technology and training from the developed to the developing countries. A parallel Global Atmospheric Research Program held out hope for the future. This program would be organized jointly by both WMO and ICSU in order to draw on both the needed physical resources that governments can provide and the intellectual inputs of the nongovernmental scientific community. For this latter effort, a unique planning and management structure was developed, centered on an independent Joint Organizing Committee (JOC) of distinguished scientists reporting directly to the executive bodies of the sponsor organizations and an equally independent Joint Planning Staff (JPS) reporting only to the JOC. This central structure was provided with significant funds of its own that it could use with minimal bureaucratic inertia and constraint. Supporting national committees were established in many countries, notably the United States, and made important contributions to the program's development.[5] By 1968, this structure was complete, and the detailed planning of GARP began.

IMPLEMENTATION

The remainder of the history of GARP is best told in terms of its achievements.[6-8] In 1974, the GARP Atlantic Tropical Experiment was conducted in the equatorial Atlantic off the coast of Senegal. Scientifically, this experiment addressed the problems of the tropical atmosphere and ocean and their interaction with the global circulation. Politically and organizationally, it served to test the previously untried notion that scientists, technicians, and support personnel of many nations could work intimately and effectively on a common goal in the stressful circumstances of a major field program. Both objectives were achieved with remarkable success. Other preparatory, process-oriented experiments were also launched in the ensuing years, such as the Air Mass Transformation Experiment (AMTEX), organized largely under Japanese leadership in the western Pacific.

Meanwhile, planning for the Global Experiment continued. The details of its observing program are largely irrelevant to the present discussion. In essence, it sought to obtain accurate observations of the atmosphere and the underlying surface with a resolution in space and time that numerical experiments had indicated would be adequate for effective weather prediction research. These stringent requirements demanded not only global satellite data, but also in situ measurements over the tropics and the oceans. Assembly of the many observing systems that might be contributed by many countries was a complex and challenging task. Moreover, regional programs such as the Monsoon Experiment (MONEX) arose to take advantage of the observational network of the Global Experiment. It is not surprising that the Global Experiment, first proposed for 1972, was postponed many times because of problems in one or another observing system.

Throughout, the JOC set scientific objectives and priorities and served both as a court of mediation and as a court of last appeal seeking to maintain a program that would be both scientifically meaningful and operationally achievable. JOC's success in this difficult endeavor is evidenced not only by the execution of the largest international scientific field program to date, but also in the continued vitality of the worldwide research effort based on the GARP experiments.

IMPLICATIONS

What lessons may be drawn for the design of international scientific efforts from the history of GARP, and what guidelines may be deduced for U.S. involvement in such activities? First of all, I believe we must recognize clearly that many aspects of GARP were unique to their time and are unlikely to be repeated. GARP arose in the postwar, post-Sputnik era when a unique convergence of scientific optimism, technological opportunities and Cold War tensions obtained. The linkages between nations, including those in science, had been disrupted by war, and there was a widespread yearning to reestablish them. The desire to penetrate the Iron Curtain led to strong and continuing political support for the program in the United States. This strong political support was reiterated time and time again not only by the nations assembled in the WMO but also by each successive U.S. president. This continued backing, and—even more remarkably—the continuing provision of funds by successive U.S. congresses, may demonstrate a fairly stable constituency for international cooperative scientific activities.

Other factors that contributed to the success of GARP are to some extent unique to the atmospheric sciences. As we have noted above, meteorology has an unequaled history of effective international collaboration. Moreover, most individual meteorologists have at one time or another performed the exercise of plotting data from around the world on a world map in order to develop analyses and forecasts. In this process, they are vividly reminded that none of their work would be possible without the cooperation of thousands of meteorologists and technicians in all countries of the world. Thus, meteorologists are preconditioned to take for granted the necessity of and the feasibility of worldwide cooperation toward common goals. Reflecting the nature of the discipline and the psychology of its practitioners, WMO is generally recognized to be the most efficient and least political of the UN specialized agencies and is served by an exceptionally capable Secretariat. Thus, international activities in the atmosphere can lean upon a unique sociological and institutional infrastructure possessed by no other discipline.[9]

Other factors underlying the success of GARP, however, may be more widely applicable to programs in other fields.

A distinctive feature of GARP was its implementation through a novel partnership between an intergovernmental organization, the WMO, and a nongovernmental organization, ICSU. Each type of international mechanism has distinct assets and liabilities. Governments levy taxes, control access to their territories, protect the security and welfare of their citizens, and—somewhere in the lower reaches of their list of priorities—provide most of the resources to support basic science; it is hard to do anything concrete in the real world of science without bringing in governments. Bringing in governments, however, inescapably brings in foreign ministries, national politics, territorial squabbles, and a host of other issues and institutions extraneous to the scientific tasks at hand. Moreover, governments are by their nature complex and multicellular political-bureaucratic organisms; each of their component agencies has its own political linkages, territorial imperatives, and supporting constituencies. The specialized intergovernmental organizations deal with their national member countries primarily through the specialized governmental agencies of these nations. Thus, the Food and Agriculture Organization's communications channels run primarily through the food and agriculture ministries of governments; the WMO sees the world through the national meteorological services, and so on. A scientific program implemented exclusively through an intergovernmental organization will therefore inevitably be molded by the interests of the organization's constituent national bureaucracies. Moreover, the members of these bureaucracies will usually play a disproportionate personal role in the program. For example, in WMO-organized activities, scientists associated with the meteorological services are notably more numerous than academics.

The nongovernmental organizations are to a great extent mirror images of their intergovernmental colleagues. Typically, they have slender resources and minuscule staffs—indeed little physical existence at all. Their constituencies, however, cross both national and bureaucratic lines. On any particular scientific problem, they can entrain quite directly the worldwide network of interested and expert individual scientists who, in the end, must do the work. For example, the framework of the composite observing system for the Global Weather Experiment was largely designed by ISCU's Committee on Space Research (COSPAR).

It is important to recognize that the WMO-ICSU agreement on GARP that created the JOC and the JPS essentially created a *new international organization* with interesting, and perhaps unique, capabilities that simultaneously combined the assets and minimized the liabilities of the two types of organization. Responsible not directly to individual governments, but to organizations representing global constituencies, the JOC could define GARP's goals with considerable independence, guided primarily by scientific imperatives. Through these scientific plans, it could focus the resources of governments as could no private club of scientists. However, the JOC could also call on individual scientists to participate in its work without much regard for their national or organizational affiliation. The JOC had a staff and resources that were modest on the scale of intergovernmental organizations, but substantially greater than those enjoyed by typical nongovernmental associations. Moreover, the JPS used the efficient infrastructure of the WMO Secretariat, while avoiding many of its administrative constraints. This ad hoc hybrid organization proved immensely effective and served as a model for the current WMO-ICSU World Climate Research Program and its ICSU—UNESCO oceanographic component.

The programmatic setting of GARP was adroitly conceived to pair a scientific program of fundamental research justified by rather esoteric intellectual concepts with an operationally oriented program of services and development assistance that offered short-term practical advantages to all countries The linkages between the hoped-for results of the research effort and the clearly apparent needs of the operational program were continually made explicit. Indeed, the terminal event of GARP will be a conference in 1985 specifically designed to draw from the research community the conclusions important for the design of future operational weather systems. The linkage between research and operational needs, and the parallel linkage between the scientific community and governmentally provided resources, promoted a widespread perception of mutual benefits in the program. Developing nations, even those with minimal scientific research establishments, could readily perceive the benefits of improved weather services. Moreover, the existence of a world weather program offered a channel for technical assistance and training that was of great appeal. Participating scientists saw a means not only of attaining their individual scientific objectives and of communicating with their colleagues in other countries, but also of legitimizing their own aspirations in the eyes of their nations' research establishments. The GARP label on a scientific proposal may not have been equivalent to a blank check, but it certainly buttressed strongly the efforts of scientists in many countries to obtain resources from their governments.

The most important factor, however, underlying the longevity and achievements of GARP was the steadfast maintenance of its scientific integrity. Although its genesis was largely political, it rapidly acquired a sound scientific basis through the efforts of Jule Charney, Edward Lorenz, and many others. An impeccable and widely accepted body of scientific research demonstrated unequivocally that improved numerical models of the atmosphere and ocean would indeed lead to better weather forecasts and enhanced ability to deal with the problems of natural and manmade climate variations. The innovative institutional arrangements set up under WMO and ICSU permitted the clarity and sharpness of focus on these objectives to be maintained throughout the long life of GARP. The JOC was not only independent in theory, it was provided with the resources in terms of money and staff to exercise effectively that independence. In essence, the nations of the world committed themselves individually and collectively to do something called

"GARP," and delegated to the JOC virtually unlimited authority to define its objectives and to design its execution.

Time and again in GARP's long gestation period, the JOC was faced with temptations to accept convenient shortcuts and compromises that might have undermined the program's integrity. Each time, these temptations were decisively rejected. The JOC decided, for example, that a GARP Atlantic Tropical Experiment (GATE) program without a satellite would not be meaningful, and by a miracle of leadership and improvisation, the United States came up with a satellite in the nick of time. The JOC decided that a global experiment without atmospheric soundings in the tropics would not be meaningful, and a patchwork quilt of aircraft and ship programs was evolved to replace the neat and glamorous technical solution of a carrier balloon system that had failed to materialize. A global experiment with only four geostationary satellites instead of five could have been organized with far less East-West wrangling, but the JOC stuck to its guns and the gap left by delays in a Soviet satellite was eventually filled by a U.S. contribution. GARP demonstrated that an international scientific program can maintain the integrity of its scientific goals over years and decades.

THE U.S. ROLE

As the capsule history above indicates, the U.S. role in the development of GARP was crucial in almost every respect. The original impetus to the program was provided by U.S. leadership from the very top. Our steadfast political support set an example for other countries to keep the program going both through the sponsoring international bodies and through their own programs. Our physical resources in terms of money, technical and logistic capabilities, and scientific talent played a vital role. We contributed large sums to the international planning activities; we provided unique observing systems such as satellites, aircraft, and airborne electronics, and we seconded many scientists to international planning activities and field programs. Most significantly, however, the intellectual contributions of the U.S. community, which through most of the planning period was clearly preeminent in the world, shaped the program and lent it the scientific integrity and authority noted above. The magnitude of the U.S. contribution is difficult to assess quantitatively, in part because of the intermingling of research and operational activities. Over the lifetime of the program, total expenditures by all participating countries were probably on the order of $500 million, with the U.S. providing about $100 million of that sum.

BENEFITS TO THE UNITED STATES

Did the United States accrue benefits commensurate with these outlays? The benefits are even more difficult to assess quantitatively than are the inputs contributed, but the existence of benefits is not in doubt. In common with other nations, we acquired access to unique data sets, including not only complete collections of global observations, but also specialized data on regional phenomena such as the Asian monsoon and the details of air flow over mountain masses. These could have been obtained in no other way than through an international collaborative program, for the real estate of the globe is after all managed by some hundreds of sovereign nations. Access to that real estate, the atmosphere above it, and the ocean bordering it for the purposes of science therefore requires the cooperation of those nations. If our scientists are to address global geophysical problems at all, they must address them in an international context.

We also obtained ideas from afar and thereby enriched our own national scientific life. Although the U.S. scientific community is massive and affluent, it has no monopoly on talent and imagination. Throughout the history of GARP, major intellectual contributions were made by scientists from other countries. Indeed, for most of the program's life, Sweden and Canada provided the leaders of the JOC, and Argentina and Sweden were the chiefs of the multinational JPS. Ideas initiated in the United States time after time migrated into the international planning forums, were reshaped by many hands, and returned in a greatly improved form. The international machinery offers an opportunity for independent review and improved conceptualization of scientific ideas that is often difficult to obtain within the political and institutional framework of an individual country.

One must recognize also that other countries mobilized through GARP contributed very significant resources to the program's implementation that in total outweighed our own. For example, the Soviet Union contributed 10 oceanographic ships to the Global Experiment, and we enjoy access to their results. The Air Mass Transformation Experiment (AMTEX) and the recently concluded Alpine Experiment (ALPEX) were primarily led, funded, and implemented by other countries. The United States played a minor role in the support of these efforts, but was able to draw fully on their observational and scientific results. International programs can provide highly significant leverage for our investments in science.

There are also other intangible benefits accruing to U.S. science from such international activities. GARP drew together the meteorological and oceanographic communities throughout the world, not the least in the United States. This rapprochement not only fostered a wide range of research in ocean physics relevant to atmospheric problems, but also slowly worked a sociological evolution in the oceanographic community. Oceanographers began to think in the larger context long familiar to meterologists and developed an increased appetite for and competence in cooperative programs. For their part, meteorologists began to acquire an understanding of the ocean's challenging complexity. This joint understanding was an essential foundation for the development of meaningful research on the long-term problems of climate, where ocean and atmosphere are inextricably linked. GARP also demonstrated that "Big Science" could not only be good science, but moreover could offer exciting opportunities and rewards for individual scientists. GARP made the organization of subsequent large-scale interdisciplinary programs in the environmental sciences infinitely easier. Thus, not only the end results of international activities, but also their process benefit the participating nations.

The inertia of an international program, once established, tends to lend a highly desirable stability to the contributing programs of individual nations. In the United States, for example, a network of interagency planning offices and agency focal points, each equipped with a budget line, gave an enviable stability to GARP-related research over better than a decade. GARP served as a flywheel on the often erratic engine of government support for atmospheric sciences.

The international process also gives us a better understanding of the real scientific capabilities, limitations, and attitudes of other countries' scientific establishments. The value of this understanding is hard to quantify, but in a world of competing nations, it must have some worth.

Finally, GARP really did achieve its objective, the improvement of weather forecasts. Operational predictions made by the world's weather centers are now genuinely useful out to 5 or 6 days. We—the nations of the globe—took on a job that could only be done in concert, and we did it.

PAST LESSONS AND FUTURE HOPES

In summary, then, it appears that a number of useful lessons may be drawn from the GARP experience. First of all, it demonstrated that science in an international setting can do a number of unique and valuable things not readily achievable through other mechanisms of the human endeavor. It showed that the scientific goals and the political goals of international activities are not necessarily incompatible and, indeed, may be mutually supportive. Not only the concrete outputs of international science, but also the process of international science has benefits to the participating countries.

It seems that three prerequisites must obtain for a successful international scientific program:

1. There must be a strong political support by the participating governments that must legitimize the program and provide its resources. This support can be mobilized only on the basis of a commonality of political objectives and a shared perception of benefits. The objectives and structure of international programs must be carefully tailored to enlist this support.
2. There must be an adequate infrastructure of institutions, communities, networks, and interests that allows access to both the governmental and nongovernmental scientific communities. Such an infrastructure can best be based on existing, successful structures that have well-established constituencies and well-supported ongoing activities. However, specialized ad hoc hybrid arrangements that provide considerable scientific sovereignty have great advantages.
3. Above all, there must be valid scientific goals, recognized and supported by all participating countries and scientific constituencies. A program pursued only for political or institutional ends will in the end achieve no ends at all.

Could a program such as GARP evolve in present circumstances and carry on with comparable success into the twenty-first century? One must admit that many circumstances today are far different from those of the 1960s. International cooperation is no longer a novelty. Indeed, our problem may be to use more effectively the international linkages we have rather than to create new ones. Technology is now all-pervasive, and our greatest problem is the unglamorous maintenance of what we have rather than the launching of daring new ventures. The parameters of our relationships with the Soviet Union and its allies are much better defined now than in the 1960s. Again, the problem is one of prudent management and maintenance rather than trailblazing.

Thus, more than ever before, international programs pursued solely for the purpose of doing something international seem both sterile and redundant. Nevertheless, the potential benefits of international activities to the United States remain great. The challenge for the future, then, is to identify clearly and to define rigorously those scientific problems whose resolution will inescapably depend on organized cooperation between the scientific communities and governments of the world.

As the human race as a whole presses ever more strongly on the resources of our finite globe, more and more such problems will undoubtedly emerge and will not only benefit from, but indeed will demand coordinated attention by the scientific communities of all countries. For the United States, the type of international cooperative activity exemplified by GARP may prove to be an indispensable tool for our own survival.

ACKNOWLEDGMENTS

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Deep Sea Drilling

The International Phase

G. Ross Heath

The International Phase of Ocean Drilling (IPOD) is a cooperative program of the United States, France, the Federal Republic of Germany, Japan, and the United Kingdom to investigate the geology and geophysics of the deep ocean basins by means of advanced drilling technology. The field studies have been carried out from a specially configured drilling ship, the *Glomar Challenger*, owned and operated by Global Marine, Inc., under contract to Scripps Institution of Oceanography of the University of California, San Diego.

This review focuses on the development of the drilling program and its international aspects. The scientific results are well documented in the Initial Reports of the Deep Sea Drilling Project and in the scientific literature.

HISTORY OF THE PROGRAM

Development of a U.S. Drilling Program

Van Andel (1968) has reviewed the history of ocean drilling prior to the launching of *Challenger*. The first part of this section draws heavily on his review.

Project Mohole, proposed in the late 1950s, was the first serious attempt to use advanced drilling technology to penetrate the deep sea floor. This National Science Foundation (NSF)-supported project used the barge CUSS-1, equipped with a large drilling rig, to drill 10 experimental holes in water depths of up to 3,600 m off San Diego and western Mexico. These tests demonstrated the ability to recover sediments and volcanic rock, as well as the feasibility of dynamic positioning of the ship, an essential requirement where the water is too deep for the use of anchors. Project Mohole then foundered as the estimated costs to construct the large, self-propelled platform required to meet the goal of drilling through the earth's crust to sample the mantle rose to unacceptable levels.

At the same time, however, marine geologists interested in sampling only the sediments and the surface of volcanic basement realized that the use of existing drilling equipment and techniques on a relatively mobile ship could meet their needs. Even a relatively modest program was beyond the capability of any one oceanographic institution at that time, however, so some form of multiinstitutional management was required.

The first such organization, created in 1962, was the LOCO ("long core") committee made up of two representatives each from the Institute of Marine Sciences of the University of Miami, Lamont Geological Observatory of Columbia University, Princeton University, Scripps Institution of Oceanography of the University of California, and Woods Hole Oceanographic Institution. This committee could not agree on the charter for a nonprofit corporation to manage a drilling program. Lamont, Woods Hole, and Scripps then formed such a corporation (CORE), which submitted a proposal for a drilling program. LOCO did not endorse their proposal, which was not funded. Both LOCO and CORE then faded away.

In 1964, scientists from Miami, Lamont, Woods Hole, and Scripps signed a formal agreement creating JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling) to plan and propose drilling programs, and to designate one of its members to act as operating institution and to be responsible to the funding agency for management. This structure was tested in 1965 when Lamont successfully managed a drilling program on the Blake Plateau, off the southeastern United States, which made use of the D/V *Caldrill*.

In January 1967, Scripps, as the operating institution for JOIDES, signed a contract with NSF to manage the first 18 months of the Deep Sea Drilling Project (DSDP). The D/V *Glomar Challenger* was built especially for this task and began operations in mid-1968. Subsequent extensions and renewals of the Scripps-NSF contract kept *Challenger* at sea until the fall of 1983, when this phase of ocean drilling came to an end.

Although the scientific operation of the drilling ship has changed little over the years, major changes in support and scientific oversight have occurred. From the U.S. side, six additional institutional members have been added to the original JOIDES four: the University of Washington in 1968, the University of Hawaii, Oregon State University, the University of Rhode Island, and Texas A&M University in 1975, and the University of Texas at Austin in 1982. In addition, in 1976, the U.S. institutions formed JOI (Joint Oceanographic Institutions, Inc.), a nonprofit corporation. JOI took over from Scripps the management of the JOIDES scientific advisory structure in 1978 and U.S. site surveys in 1978, thereby resolving a potential conflict of interest between Scripps' role as both the science operator and the contractor responsible for the scientific advice to the operator.

It is clear that the development of the U.S. drilling program was marked by false starts and years of complex negotiations. Even though the scientific goals were widely accepted and the technology was within reach, the self-education of a research community not used to large-scale cooperative research, and the resolution of difficulties introduced by a number of strong personalities at the various institutions took years to achieve. It is doubtful whether the level of cooperation required to launch the DSDP could have been achieved simultaneously at both the national and international levels.

The International Phase of Ocean Drilling

From the very beginning of the DSDP, JOIDES has drawn heavily on the non-U.S. scientific community to participate in the advisory panel discussions that determined the drilling targets. Likewise, non-U.S. participants were prominent in most shipboard scientific parties; for legs 1 through 44 (the U.S.-funded phase of the program) from 1968 to 1975, 141 of 448 shipboard scientists (more than 30 percent) were from other countries.

Thus, by the early 1970s a large community of marine earth scientists from 15 countries outside the United States was well aware of the scientific value of the DSDP, the way it operated and was managed, and the nature of its support.

When it became clear that the United States would have difficulty in providing full funding for the program beyond 1975, these non-U.S. scientists formed a series of knowledgeable pools of expertise able to advise their governments when the United States sought their active participation in the program. As a result, between January 1974 and November 1975, five non-U.S. members joined JOIDES to create the International Phase of Ocean Drilling (IPOD). In each case, negotiations were carried out on a bilateral basis between the NSF and a designated national representative.

USSR. The Soviet participation in JOIDES was formalized by the 1972 U.S.-USSR World Ocean Agreement and Science and Technology Agreement, signed during the Nixon-Kissinger visit to Moscow in 1972. Discussions and letters during the latter part of 1972 and during 1973 led to the signing of a formal Memorandum of Understanding between NSF and the USSR Academy of Sciences in February 1974. The Memorandum, effective January 1, 1974, was for a period of 5 years and was renewed for 9 months (plus close-out costs for FY 1980) in 1979. Subsequent Soviet participation in the program was inhibited by restrictions imposed by the Carter administration following the invasion of Afghanistan and was finally terminated by the Reagan administration's 1982 decision not to renew the U.S.-USSR Science and Technology Agreement.

Federal Republic of Germany (FRG). Negotiations between NSF and its FRG counterpart, the Deutsche Forschungsgemeinschaft (DFG), led to the signing of a 2-year Memorandum of Understanding in July 1974. The Memorandum, effective January 1, 1974, designated the Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) as the FRG member of JOIDES. The following 3-year Memorandum was signed by the BGR and has been renewed by amendment for three additional 2-year periods.

Japan. In June 1975 NSF signed a Memorandum of Understanding with the Ocean Research Institute (ORI) of the University of Tokyo, by which Japan became a member of JOIDES in August 1975. The initial Memorandum was open ended. A new Memorandum for 1979–1980 was signed when the contribution was increased. This has subsequently been extended by amendment for two additional 2-year periods. Even though ORI is the official Japanese signatory, the funding agency (MONBUSHO) has been an attentive observer during the NSF-ORI negotiations.

United Kingdom. Following the signing of a Memorandum of Understanding between NSF and the Natural Environmental Research Council (NERC) in September 1975, the United Kingdom became a member of JOIDES on October 1, 1975. The initial Memorandum covered 3 years and has been extended to the end of IPOD by three subsequent amendments.

France. France became a member of JOIDES effective November 1, 1975, following the signing of a Memorandum of Understanding between NSF and the Centre National pour l'Exploitation des Oceans (CNEXO). The initial 3-year Memorandum has been extended by three amendments that parallel the FRG and U.K. agreements.

Each of the Memorandums provided the non-U.S. signatory with a number of benefits: membership in the JOIDES Executive and Planning Committees, participation in JOIDES advisory committees, the designation of shipboard scientists, and full access to data and samples. In return, the United States has received annual contributions, initially of $1 million per country per year, increasing to $1.25 million in 1980–1981 and to $2 million per year in 1982–1983.

DISCUSSION

There is virtually unanimous agreement that the DSDP-IPOD drilling program has been an outstanding scientific success. The strong endorsement by the community and National Science Board of a new Ocean Drilling Program, to make use of a larger ship, is a measure of this success. The willingness of non-U.S. JOIDES members to speak in favor of the program and to contribute to IPOD (roughly $50.6 million of $220.6 million through FY 1983) has certainly enhanced the credibility of the scientific arguments.

Benefits

IPOD has allowed the United States access to the best scientists and ideas in the member countries. Background scientific syntheses, site surveys using geophysical techniques not available in U.S. oceanographic institutions, and postcruise analyses of core material, all at no cost to the project, have greatly augmented U.S. contributions and have led to more effective use of the drilling ship. Less tangible, but no less valuable, are the personal relationships developed at sea and ashore between U.S. and non-U.S. scientific participants. These contacts have led to innumerable sabbaticals and study leaves with their inevitable intellectual synergism.

The non-U.S. participants, on the other hand, have gained access to a state-of-the-art scientific tool that they could have afforded with great difficulty, if at all, on their own. They have been able to propose scientific targets and see them drilled as easily as have their U.S. colleagues. The impact of IPOD can be gauged by the number of non-U.S. IPOD scientists participating in *Challenger* cruises. Prior to 1975, 63 scientists from the five partner countries had participated in 44 legs, an average of 1.4 per leg. Subsequently, 272 scientists have participated in legs 45 to 91, for an average of 5.8 per leg. Not only has this created a large pool of earth scientists favorably inclined to international cooperation, but it has also fostered a level of internal cooperation within member countries that did not exist before.

Costs

The formal obligations recognized in the Memorandums of Understanding have resulted in some dampening of the less formal modus operandi of the U.S.-only drilling program. "Targets of opportunity" (often indistinguishable from personal projects of chief scientists or panel chairmen) are drilled much less frequently now than they were early in the program. To some extent, such formalization of the planning process was inevitable as the program matured, but the creation of IPOD accelerated the process. Whether this is good or bad is debatable!

A clear victim of IPOD has been the community of interested scientists whose countries could not afford, or did not choose, to pay the entry price to IPOD. Prior to IPOD (legs 1–44), 78 scientists from such countries sailed on *Challenger* (1.8 per leg). Subsequently, for legs 45 to 91, the number has dropped to 32 (0.7 per leg). One can argue that this is fair—those who pay should benefit. The opposite argument—that a scientific community as small as marine geology and geophysics cannot afford to exclude so many of its peers—has equal merit. The formation of consortia to participate in the new Ocean Drilling Program and the availability of more scientific berths on *Challenger*'s replacement should alleviate this problem in the future.

Why IPOD?

Even though the scientific benefits of international cooperation have been substantial, it is clear that IPOD came into existence primarily because the U.S. program faced serious funding problems. Whether, in the absence of such a need, the program would continue or an analogous one could be created is debatable. Individual U.S. scientists pay a price for IPOD through reduced numbers of berths on the *Challenger* and fewer U.S.-designated drill sites. Whether the intellectual benefits of international cooperation offset or are perceived to offset these costs is unknown and may be unknowable (since the control situation does not exist).

Adequacy of Agreements

The creation of IPOD through a series of bilateral agreements, rather than a multilateral agreement or treaty, has proven to be remarkably successful. For example:

- It has allowed for the Soviet dropout with minimal disadvantage for the other partners.
- It has allowed wording in individual Memorandums to be tailored to home audiences (for improved salability) without compromising the basic scientific and organizational goals.
- It has allowed NSF to deal with an extremely diverse suite of organizations. For comparison, the equivalent diversity within the United States would require an organization to negotiate bilaterals with the National Science Foundation (the analog of DFG and NERC), the National Oceanic and Atmospheric Administration (the analog of CNEXO), the U.S. Geological Survey (the analog of BGR), the National Academy of Sciences (the analog of the USSR Academy), and a research institute at a major university (the analog of ORI, at the University of Tokyo).
- It has allowed NSF to deal with the vicissitudes of each country's national budget cycle on a case-by-case basis.
- And, perhaps most importantly, it has kept active scientists on both sides very close to the negotiations. As a result, virtually all U.S. and non-U.S. scientists perceive that IPOD works for them, rather than the reverse.

There is little doubt that NSF's job would be easier if all bilaterals were identical, particularly with regard to funding cycles. The lack of such uniformity seems a small price to pay for a productive program, however.

Operational and Scientific Interactions

The Memorandums of Understanding created a legal framework for IPOD, but the successful execution of the program has depended largely on JOIDES. Several factors account for JOIDES's remarkable success.

1. The basic structure is sound. The hierarchy of problem-oriented panels reporting to a Planning Committee of experienced scientists who make the operational decisions and who in turn report to an Executive Committee of institutional heads who make policy decisions has proven able to handle almost any scientific, technical, or policy problem.

2. Institutional nominations, particularly to the Planning Committee, have consistently allowed effective, senior, active scientists from each country to make the scientific decisions. These people care about the program and have done the hard work required to make it function and to justify and defend it before their peers and the funding agencies.

3. Both U.S. and non-U.S. members have consistently sent senior scientific administrators to Executive Committee meetings. These individuals have had the authority to make major commitments on behalf of their institutions and countries. They have been able to resolve many policy issues without having to seek approval from their parent organizations. The long tenure of several key Executive Committee members, notably Jacques Debyser from France and Nori Nasu from Japan, have given the committee a corporate memory and developed a level of mutual trust among its members that have allowed it to resolve nationally sensitive issues expeditiously and without rancor. The creative tension between the more conservative Executive Committee and the less inhibited Planning Committee has been particularly useful in exposing all aspects of many thorny problems to vigorous debate.

THE FUTURE

The proposed new Ocean Drilling Program (ODP), a 10-year plan for scientific ocean drilling from a larger and more sophisticated ship, will again require international support for its long-term success. The United States is planning to fund the preparation of the ship over a 1-year hiatus in drilling during FY 1984 and probably can fund the initiation of drilling in FY 1985. During this initial period, NSF will have to move rapidly to negotiate bilaterals, not only with the four currently active IPOD partners, but with one or two new members (perhaps consortia). The long-term U.S. commitment, in principle, to the ODP, which never existed for IPOD, should facilitate international agreements.

CONCLUSION

The creation of IPOD was enormously simplified by the existence of a successful drilling program (DSDP). This allowed non-U.S. members to "buy into" a technically proven and scientifically productive program with minimal risk. The existence of a large community of interested, knowledgeable scientists in each prospective member country provided the funding agencies with a ready source of information on the value of the program. Finally, in the case of the USSR, the existence of very-high-level diplomatic agreements on marine science provided an umbrella for the bilateral negotiations. Subsequent events have shown, however, that the removal of such umbrellas can be as destructive to scientific cooperation at the operational level as their creation is constructive.

The creation of IPOD may have been possible in the absence of either an established U.S. program or strong national scientific lobbies. It would almost certainly have been impossible in the absence of both.

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Graduate Student and Postdoctoral International Exchanges of U.S. Scientists

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Philip W. Hemily

INTRODUCTION

The year is 1927. Picture a recent doctoral graduate arriving in Copenhagen, taking the tram to the Niels Bohr Institute, ringing the bell, announcing "I am Isidor Rabi. I have come here to do research." He was, of course, welcomed to join the bright, exciting group of young scientists working in close collaboration in this world-famous international setting. This was a major benchmark in his emerging illustrious career as a teacher and researcher at the frontiers of physics and as a public servant at the national and international levels—adviser to presidents, governmental agencies, and the Congress, promoter and spirit behind the NATO science program, the Atoms for Peace program, the establishment of the International Atomic Energy Agency (IAEA), and so many other activities of benefit to this nation and the world scientific community.

During the first three decades of this century, it was pretty much taken for granted that bright promising American scientists like young Rabi would seek out and participate in Western European research activities through doctoral and postdoctoral training. This was the time when the Solvay conferences and other colloquia in a broad range of fields were evolving; when the center of the scientific universe was a select group of universities and research institutes in Western Europe; when this network was being extended to a few promising centers in North America. It was a time of ferment, excitement, and evolution within a scientific community without national frontiers. Totalitarian regimes in Europe subsequently led to an influx of scientific leaders to the United States; World War II provided a great impetus for further advances in science and technology. The center of the scientific universe shifted more and more to North America. Still, the traditions and values of the great centers of training and research in Western Europe remained attractive to young American scientists in the postwar years. And U.S. governmental agencies, particularly those concerned with defense and health matters, supported the research and training of European scientists. The International Scientific Unions were strengthened and provided increased leadership in organizing and managing cooperative international research programs. New governmental institutions and associations were established: the Organisation for Economic Co-operation and Development (OECD), the North Atlantic Treaty Organization (NATO), and the European Communities, providing a basis for a broadened international community of scientists that today encompasses the advanced countries of North America, Europe, and the Far East.

For any given country, the interdependence between the domestic elements and particularly the foreign elements of the scientific community is critical. The capacity of its graduate and postdoctoral scientists and engineers to benefit from lively cooperative and competitive cross-country interaction is dependent on the competence of the domestic research and training system that has earlier shaped them. And, at the same time, the dynamism of that system continually draws on feedback from its own scientific "returnees" and on interaction with the foreign fellows in its own laboratories.

Lively reciprocity is a key factor in the exchange. But, over the past quarter century a number of inhibiting factors have appeared on the U.S. scene that discourage international mobility—in contrast to that first half of the century when the United States drew heavily on the Western European scientific community. It is a truism to say that, with the world scientific and technological community based on widespread interactions, we cannot afford to draw away from stimulating and supporting our graduate and postdoctoral scientists to initiate careers abroad. Enhanced by the challenges of working with foreign colleagues, these people are prime candidates for leadership in our academic, governmental, and industrial institutions.

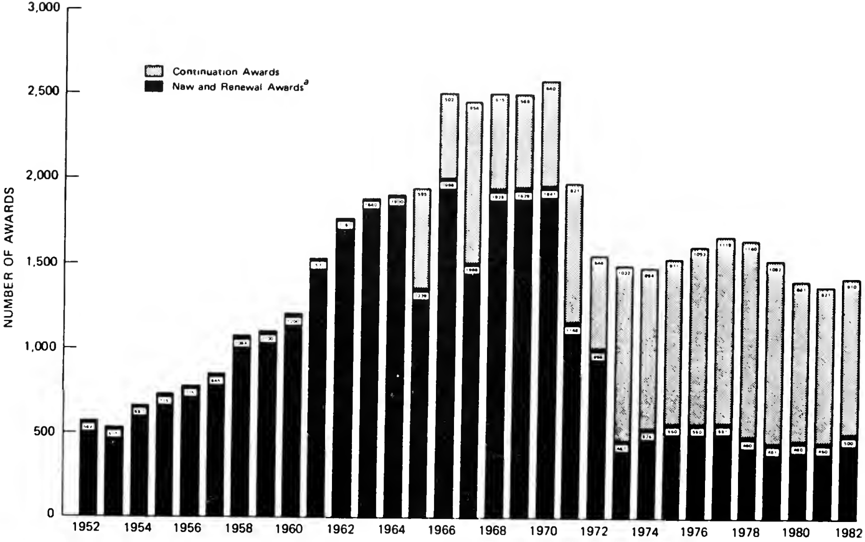
Within this perspective we shall trace through some of the factors influencing U.S. graduate student and postdoctoral exchanges in the natural sciences during the past 30 years. Particular attention will be given to National Science Foundation (NSF) programs and the Fulbright Senior Scholar Program, as well as to activities sponsored by the NATO Science Committee in order to highlight trends, benefits, and needs. We shall examine the international aspects of graduate and postdoctoral fellowship developments as well as short-term tutorial schemes and collaborative research activities involving young scientists. This will be followed by some general considerations on international mobility of young scientists and engineers. The emphasis here, as in preceding decades, will be on the person-to-person contact established in the researcher's early years. The enduring relationships developed by researchers in their early years, moreover, provide the basis for effective participation in all other modes of fruitful international science and technology cooperation during ensuing years.

FELLOWSHIP PROGRAMS

NSF Graduate Fellowships

One of the first major programs implemented by the newly established NSF in 1952 was the graduate fellowship program for predoctoral-level science students. This program experienced a range of pressures in the ensuing 30 years, but has consistently provided some 450–550 new awards each year. A near doubling of these awards (including renewals) was experienced during the 1960–1970 period under the influence of the post-Sputnik increase in foundation budgets. Thus, total annual awards, including continuation awards, grew to the 2,500 level by the year 1970, tapering off to the current 1,400 level.

From the beginning, a small number of NSF graduate fellows chose quite readily to study in centers of excellence abroad, mainly in the United Kingdom, France, Germany, and Canada. Figure 1 and Table 1 show that there were from 20 to 50 such fellows per year in foreign institutions throughout the first 20 years of the graduate fellowship program, or from 1.5 percent to 5 percent of all fellows. Data from NSF Annual Reports present an unexplained aberration in 1956 with 95 (8.4 percent) of fellows going to foreign institutions. The numbers of fellows attending foreign institutions fell off significantly beginning in 1974 to a large extent because of the discouraging restrictive rule requiring special justification for tenure in foreign institutions—a restriction brought on by Congress's concern, at the time, with a weakening dollar and gold outflow. Then, in 1981, this fellowship program, as well as all science education activities of the foundation, was doomed to cancellation through the policy of the administration at that time. The graduate fellowship program was, however, maintained through the concern of the Congress. At the same time, other



^a Prior to 1973, black represents New and Renewal Awards combined; beginning with 1973, black represents only New Awards (Renewal Awards were made on the basis of NRC recommendations; Continuation Awards are made upon certification of satisfactory progress by the fellowship institution).

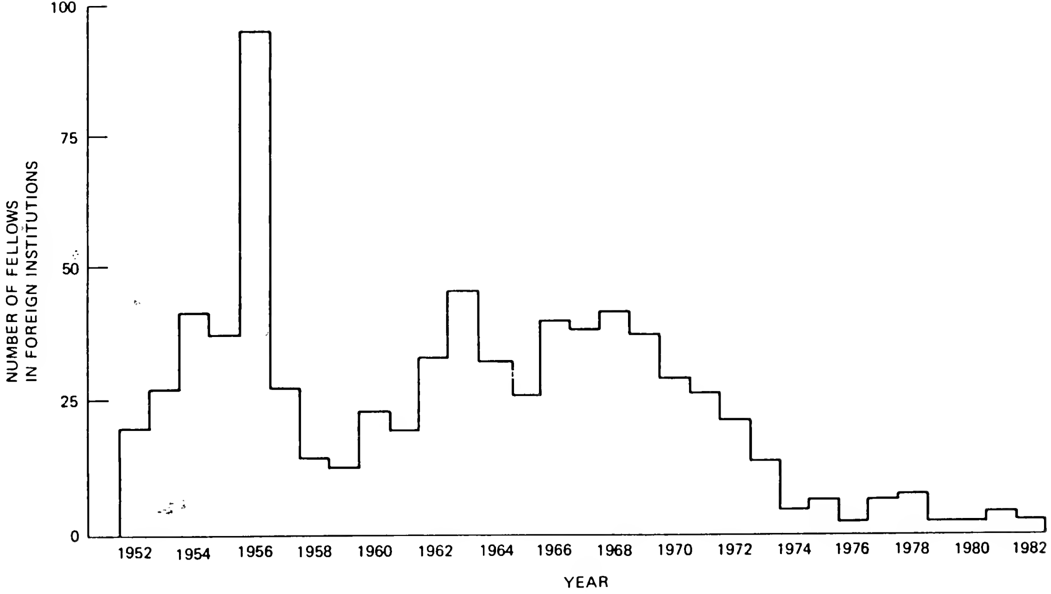


FIGURE 1 NSF Graduate Fellowship Program Awards, 1952-1982, and international participation in the program.

TABLE 1 NSF Graduate Fellowship Program, 1952-1982

Year	Total Awards Offered (No.)[a]	Grad. Fellows in Schools (No.)[b]	Grad. Fellows in Foreign Inst. (No.)[b]	Grad. Fellows in Foreign Inst. (%)
1952	569	575	20	3.5
1953	514	680	26	3.8
1954	657	913	42	4.6
1955	715	914	37	4.1
1956	773	1,133	95	8.4
1957	849	958	27	2.8
1958	1,081	939	15	1.6
1959	1,100	1,100	13	1.2
1960	1,200	1,198	24	2.0
1961	1,537	1,443	20	1.4
1962	1,760	1,761	34	1.9
1963	1,880	1,880	47	2.5
1964	1,900	1,900	33	1.7
1965	1,934	1,934	27	1.4
1966	2,500	2,500	40	1.6
1967	2,450	2,450	39	1.6
1968	2,500	2,500	42	1.7
1969	2,498	2,500	38	1.5
1970	2,581	2,582	30	1.2
1971	1,969	1,972	27	1.4
1972	1,738	1,550	22	1.4
1973	1,489	994	14	1.4
1974	1,479	581	5	0.9
1975	1,521	576	7	1.2
1976	1,603	550	3	0.6
1977	1,670	550	7	1.3
1978	1,630	490	8	1.6
1979	1,513	451	3	0.7
1980	1,401	463	3	0.6
1981	1,371	450	5	1.1
1982	1,410	500	4	0.8
1983		450	4	

[a] NSF Graduate Fellowship Program Table 1: New Applicants, New Awards, Success Rate of New Applicants—Total Awards Offered and Total Obligations by Year, 1952-1982, from NSF staff, June 1983.

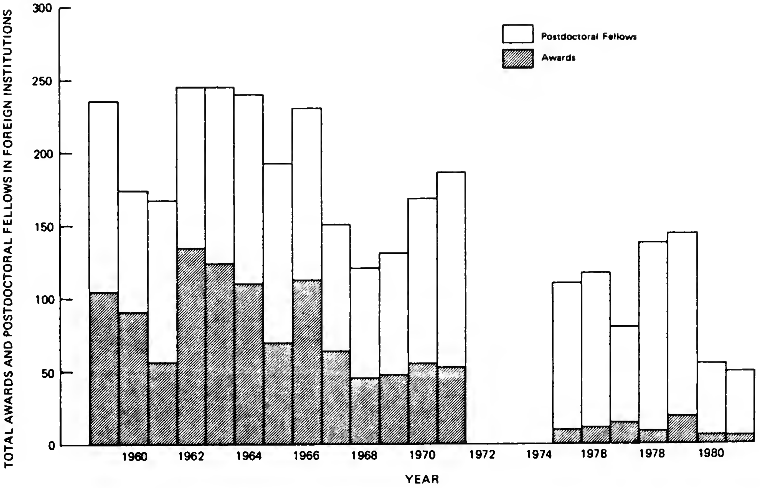
[b] Annual Report Listings: Institutions chosen by Fellowship Awardees. (Related to New Awardees as of 1973; 1983 data from award announcement.)

problems were developing with mobility of scientists and engineers in general. These are noted below under the discussion on international mobility. In any case, the numbers of fellows seeking study in foreign institutions is today at its lowest level in history—far less than 1 percent of awards.

Postdoctoral Fellowships

NSF Postdoctoral Fellowships. For young scientists primarily motivated toward academic and research careers at the frontiers of knowledge, postdoctoral fellowships and research associations in centers of excellence are a logical next step after completing their doctorates. Such movement to European centers was very much the case for young Americans in the decades prior to World War II, and this lively mobility continued in the 1950s, facilitated by the GI Bill, and Fulbright grants, as well as invaluable support from private foundations. However, it took the Sputnik tremor to move NSF into supporting a significant and highly effective postdoctoral program beginning in the 1958–1959 academic year. Some 120–245 NSF postdoctoral grants were awarded per year in the ensuing 13 years to 1971, with between one-third and three-fifths of these fellows pursuing training and advanced research in foreign institutions, primarily in Western Europe (see Figure 2 and Table 2). These were the halcyon days of U.S. science and technology. Advancements in space, medicine, communications, security, and most fields were increasingly centered around U.S. institutions and the leadership of U.S. engineers and managers of technology. We should recall the so-called "technology gap" of the late 1960s and the concern of our European and Japanese colleagues that they might never catch up. Still, the traditional and newly emerging intellectual centers of scientific excellence in Europe and Japan were readily recognized and sought out by leading American scientists and postdoctoral fellows.

But, for a complex of reasons—perhaps an exaggerated sense of confidence and self-sufficiency as well as serious questioning of the NSF role in supporting science education, and, furthermore, expectations that other sources might fill the gap—the NSF ended its broad postdoctoral fellowship program in 1972. The foundation then went through a mixed period (1975–1981) of supporting much smaller specialized postdoctoral fellowship programs designated as related to "energy," "national needs," or simply as "postdoctoral." The percentage of persons attending foreign institutions was much smaller. Since FY 1982 this program has been at zero level. It should be noted that a modest specialized exchange program of postdoctoral and senior-level scientists (10–15 each way) has been supported since 1970 under a U.S.-France Bilateral Agreement. More recently, even more restricted research (postdoctoral) fellowship programs have been initiated in the fields of plant biology and mathematical sciences, the latter restricted to U.S. institutions. This history certainly raises questions concerning



SOURCE: NSF Annual Reports.

FIGURE 2 Total awards and postdoctoral fellows in foreign institutions for NSF Postdoctoral Fellowship Program, 1959–1982.

TABLE 2 NSF Postdoctoral Fellowship Program, 1959–1982

Year	Postdoctoral Awards (No.)[a]	Postdoctoral Fellows in Foreign Inst. (No.)[a]	Postdoctoral Fellows Foreign Inst. (%)
1959[b]	233	102	44
1960	173	90	52
1961	168	56	53
1962	245	134	55
1963[c]	245	124	51
1964	240	110	46
1965	191	70	37
1966[d]	230	111	48
1967	150	63	42
1968	120	45	38
1969	130	47	36
1970[e]	169	54	32
1971	185	52	28
1972[f]			
1973			
1974[g]			
1975[h]	110	9	8
1976	118	10	8
1977[i]	80	12	15
1978	138	7	5
1979	144	18	13
1980	54	4	7
1981	50	4	8
1982[j]			

[a] Annual Report Listings: chosen by Fellowship Awardees.

[b] Initiation of postdoctoral program as well as cooperative graduate fellowships, senior postdoctoral fellowships, faculty fellowships, summer fellowships.

[c] Initiation of senior foreign scientists program.

[d] Termination of senior foreign scientists program.

[e] Establishment of U.S.-France (NSF-CNRS) Exchange of Scientists Program which has supported 10–15 postdoctoral/senior scientists exchanges (each way) per year.

[f] Termination of postdoctoral fellowships, senior postdoctoral fellowships, science faculty fellowships, summer fellowships.

[g] Faculty science program.

[h] Initiation of energy-related traineeships postdoctoral energy-related fellowships.

[i] Transformation to national needs, postdoctoral. Initiation of minority graduate programs.

[j] Termination of postdoctoral fellowships.

the objectives, continuity, and credibility of policies for the support of American postdoctoral researchers.[1]

Fulbright Senior Scholar Program (1978–1982). The Fulbright program is funded and administered by the U.S. Information Agency (USIA).[2] Most countries of Western Europe, including Germany, France, Italy, the Netherlands, and the United Kingdom, also make substantial contributions to the funding of the program. The number of grants and the fields in which they are offered are determined by the binational Fulbright Commission or U.S. embassy in each participating country. Each spring the Council for International Exchange of Scholars (CIES) announces approximately 650 awards for American scholars to lecture or conduct research in more than 100 countries, including 19 in Western Europe.

Of the 1,170 Fulbright awards made in all fields to American scholars going to Western Europe over the past 5 years, 722 were for lecturing and 448 for research. In the lecturing category, only 82, or 11 percent, were specialists in science and technology. However, in the research category, where awards are usually open to scholars in any field, 164, or 34 percent, of the awards made in the past 5 years were in the sciences. Of the 246 scientists who received lecturing or research awards to Western Europe, the largest cohort was in engineering, which had 53 grantees, followed by chemistry with 45, and physics with 34. The 114 remaining grantees were distributed among the life sciences, astronomy, computer science, food technology, geology, and mathematics. In summary, there have been on the average over

TABLE 3 Distribution of American Scientists and Engineers Under Fulbright Awards in Western Europe, 1978–1982

	1978		1979		1980		1981		1982		Total	
	Lect	Res	Lect	Res	Lect	Res	Lect	Res	Lect	Res	Lect	Res
Astronomy		1								1		2
Chemistry	3	8	2	4	3	6	3	4	3	10	14	32
Computer Science	2			1	1			1	1	1	4	3
Engineering	8	5	7	3	6	3	3	9	2	7	26	27
Food Technology									1		1	
Geology		1					1	5	2	1	3	7
History of Science				1						1		2
Life-Animal	2	2		2	1	6	2		1		6	10
Life-Botany	1	3		2	1	1		1	2	5	4	12
Life-Cell	1	3	1	3	1	2	1	1		6	4	15
Life-Medical	2	2	3	1		5	1	3		6	6	17
Mathematics	3	1	2	2	1	1	1	1	2	3	9	8
Physics	3	3		7		3	1	3	1	13	5	29
Total Science and Engineering	25	29	15	26	14	27	13	28	15	54	82	164
Total Other Fields	119	50	121	50	145	51	148	66	107	67	640	284
Grand Totals	144	79	136	76	159	78	161	94	122	121	722	448

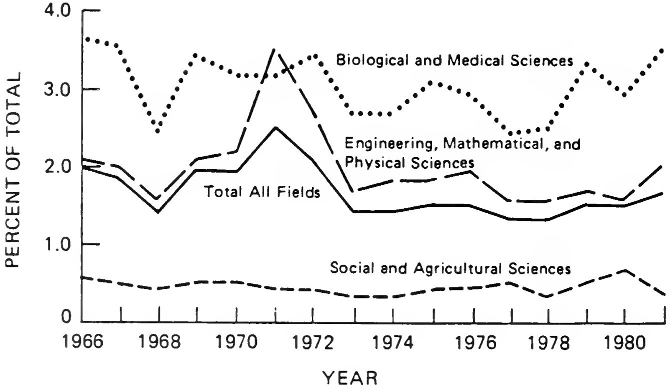
SOURCE: Council for International Exchange of Scholars (1983).

the past 5 years 49 American Fulbright grantees per year to Western Europe: 16 at the lecture level and 33 as researchers. Table 3 portrays the distribution of American scientists and engineers under Fulbright awards in Western Europe by year (1978–1982) and by discipline.

Because of inflation and rising costs, most of the Fulbright awards made to U.S. scholars in all fields to Western Europe in recent years have been partial grants for periods of less than 9 months. In the past, most Fulbright grantees have been able to make up the difference between the amount of the Fulbright award and their expenses abroad through sabbatical leave pay or with support provided by their host institution. However, the uncertain economic climate in the United States has meant that fewer American colleges and universities can supplement Fulbright awards through sabbatical pay. As a consequence, many American scholars are being forced to limit their stays in Western Europe to a few months. It appears, however, that more science than nonscience applicants are able to supplement awards.

Trends in Postdoctoral Appointments Abroad for Doctoral Scientists and Engineers From U.S. Universities. If we wish to assess in more detail the movement of postdoctoral fellows from the United States to other countries, we must distinguish between two classes of postdoctoral foreign research experiences: those of new postdoctoral scientists, and those of a larger, older group extending into sabbatical/senior scientist research-teaching appointments abroad.

With respect to new postdoctoral scientists, we have some quantitative information gathered by the National Research Council (NRC) on those new Ph.D.s from U.S. universities who have indicated firm commitments for postdoctoral study abroad. One should be cautious of using these numbers, which indicate the trends of new postdoctoral scientists' research plans, as indicators of the actual total numbers of postdoctoral scientists. The actual total may be perhaps twice as high during certain earlier periods for three reasons.[3] First, in any given year many prospective Ph.D.s, who have no firm foreign commitment when they receive the NRC questionnaire, secure such appointments later on. (The NRC survey has observed that less than half (46 percent of a sample of 441 individuals who held postdoctoral appointments abroad during the period 1970–1976 had had firm plans for foreign postdoctoral study at the time of the Ph.D. The remaining 54 percent had had other plans at that time.) Second, in any given year, a number of Ph.D.s who were awarded the degree 2 to 5 or more years earlier (and who do not figure in the data) take up postdoctoral positions abroad. Third, the NRC data do not include medical doctorates who in years past (particularly the 1960s) entered into foreign basic



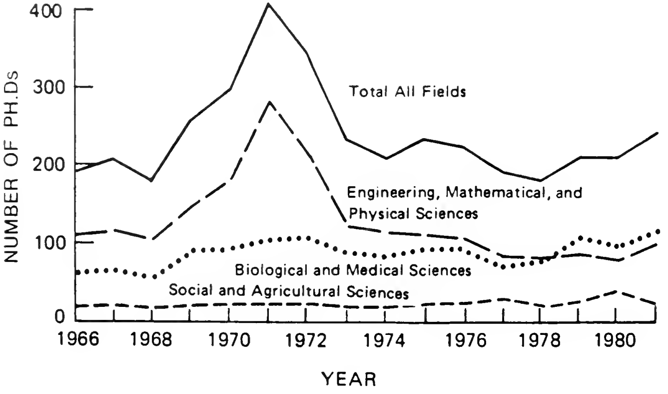


FIGURE 3 Number and percent of U.S. Ph.D.s in science and engineering with firm commitments for postdoctoral study abroad.

research experiences in significant numbers. The data are sketchy, although there appear to have been in the order of 50–100 M.D. basic researchers in the 1960s, tapering off to essentially zero at the present time.

The available data on trends in overseas postdoctoral posts must be scrutinized both for what they show and do not show. Reports and presentations frequently use the peak year of 1971 as a base, implying thus a 50 percent decline in the number of new Ph.D.s accepting foreign posts in ensuing years.[4-6] Using estimates of probable distribution of fellows for 1966, 1967, and 1968, Charles Kidd shows that the number of new science and engineering Ph.D.s with postdoctoral appointments abroad may, with fluctuations, be more or less constant when viewed not from this peak period, but over the longer span of years preceding and following 1970–1972.[7] Trends over the 1966–1981 period are portrayed in Figure 3 and Table 4. More importantly, Kidd points out that this relatively constant level conceals *increases* of about 20 percent in the biological and medical sciences that are offset by *declines* of about 20 percent in the physical sciences and engineering.

In examining possible causes of the 1970–1972 peak, Kidd refers to the motives, perceptions, and aspirations of new Ph.D.s, particularly those in physical science and engineering, when they received their U.S. degrees more than a decade ago. Significant factors turning their plans toward overseas posts were the sharp decline in federal research funds available per full-time equivalent scientist and engineer as well as the growing scarcity of tenured faculty positions. At the same time during the early 1970s, there was a pull from Western European research institutions to invite U.S. physical scientists and engineers to take up postdoctoral research appointments; this situation changed significantly by the end of the 1970s. In contrast to this experience in the physical sciences, Kidd shows that there was virtually no peak in the life sciences during the 1970–1972 period (Figure 3).

As already noted, the number of new Ph.D.s reporting firm commitments for study abroad is an indication of trends, but may be, in fact, about one-half of actual postdoctoral appointments abroad. Figure 4 shows that the percent of prior year's Ph.D.s in science and engineering who actually took up postdoctoral appointments abroad declined from an order of 5 percent in 1972 to around 2.3 percent in 1976.

In contrast to this rough picture of trends in new Ph.D.s (and M.D.s) taking up foreign appointments leveling down to an order of 2 percent at the current period, there is certainly a much larger older group (postdoctoral scientists/senior scientists/persons on sabbaticals) that one must consider in assessing trends of postdoctoral inter-

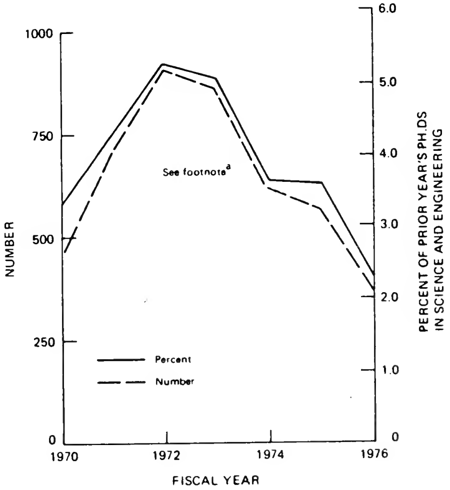
TABLE 4 Ph.D.s in Science and Engineering Awarded to U.S. Citizens and Holders of Permanent Visas by Fields and With Firm Commitments for Postdoctoral Study Abroad, 1966–1981 (Data for Figure 3)

	S&E Total (No.)[a]	S&E Abroad Total (No.)[b]	S&E Abroad (%)	EMS Total (No.)[a]	EMS Abroad Total (No.)[b]	EMS Abroad (%)	BMS Total (No.)[a]	BMS Abroad Total (No.)[b]	BMS Abroad (%)	SO/AG Total (A)	SO/AG Abroad Total (B)	SO/AG Abroad (%)
1966[c]	9,566	192	2.0	5,104	109	2.1	1,792	67	3.7	2,670	16	0.6
1967[c]	11,063	207	1.8	5,888	118	2.0	2,026	72	3.6	3,149	17	0.5
1968[c]	12,397	179	1.4	6,429	102	1.6	2,436	62	2.5	3,532	15	0.4
1969	13,846	261	1.9	7,102	149	2.1	2,712	92	3.4	4,032	20	0.5
1970	15,545	298	1.9	7,927	178	2.2	2,975	96	3.2	4,643	24	0.5
1971	16,588	409	2.5	8,042	281	3.5	3,263	105	3.2	5,283	23	0.4
1972	16,532	347	2.1	7,789	213	2.7	3,216	110	3.4	5,527	24	0.4
1973	16,246	232	1.4	7,233	124	1.7	3,258	88	2.7	5,755	20	0.3
1974	14,840	213	1.4	6,314	115	1.8	2,957	80	2.7	5,569	18	0.3
1975	15,261	232	1.5	6,140	112	1.8	3,100	96	3.1	6,021	24	0.4
1976	14,851	225	1.5	5,682	108	1.9	3,160	92	2.9	6,009	25	0.4
1977	14,387	188	1.3	5,410	84	1.6	3,071	74	2.4	5,906	30	0.5
1978	14,056	177	1.3	5,043	81	1.6	3,134	79	2.5	5,879	17	0.3
1979	14,184	212	1.5	5,164	88	1.7	3,262	108	3.3	5,778	26	0.5
1980	14,241	213	1.5	4,790	77	1.6	3,430	98	2.9	5,804	38	0.7
1981	14,141	242	1.7	4,758	98	2.0	3,416	118	3.5	5,968	26	0.4

[a] Science and Engineering Doctorates 1960–1981, NSF Special Report, NSF 83-309, pp. 28–39. *EMS*: Eng., Math., Earth, Physical. *BMS*: Biological (N.B. NAS/NRC data approx. 10 percent greater than NSF data due to inclusion of Pub. Health, Vet. Med., Nursing, etc.) *SO/AG*: Social, Ag., Psycho.

[b] Summary Report 1979, Doctorate Recipients from U.S. Universities, NAS/NRC 1980, p. 13

[c] Figures for postdocs abroad by field for 1966, 1967, 1968 estimated by assuming that the percentage distribution by field was the same as 1969 (from C. Kidd, 1983).



Trend in Number[a] of Doctoral Scientists and Engineers with Postdoctoral Appointment Abroad, 1970-1976

[a] The above chart is presented only to show the trend in number of doctoral scientists holding postdoctoral appointments abroad. The actual numerical level is considered to be an underestimate because it is based on a survey question that had 24.3% item non-response, however, this bias is partially offset by the relatively high response rate of Ph.Ds who had firm plans for postdoctoral study abroad at time of Ph.D.

SOURCE: National Research Council (1978).

FIGURE 4 Actual postdoctural study abroad.

TRENDS IN POSTDOCTORAL STUDY ABROAD, 1970-1976

(U.S. citizens and foreign citizens with permanent visas)

- The peak year for postdoctoral study abroad was 1972 followed by a continuous drop in number through 1976, a 59% drop in a four year period.
- The peak year for postdoctoral study abroad, 1972, not surprisingly, followed the 1971 peak year in number of Ph.Ds in science and engineering.
- The number of doctoral scientists holding foreign postdoctoral appointments is not a constant proportion of the number of Ph.Ds in the prior year. Trends in number of Ph.Ds awarded are amplified in the following year in number of postdoctoral appointments abroad.

TABLE 5 NATO Science Fellows, 1963-1982—Number and Percent of Fellows

Sending Country	Belgium		Canada		Denmark		France		Germany		Greece		Iceland	
Receiving Country	No.	%	No.	%	No	%	No.	%	No	%	No	%	No	%
Belgium	2	0.4	23	4.2	5	1.6	11	0.5	4	0.3	21	1.4	1	0.5
Canada	23	4.9	—	—	16	5.2	85	3.8	56	4.7	13	0.9	11	5.1
Denmark	5	1.1	13	2.4	7	2.3	6	0.3	6	0.5	5	0.3	16	7.5
France	24	5.2	49	9.0	10	3.3	1	—	87	7.3	152	10.2	2	0.9
Germany	11	2.4	40	7.3	5	1.6	19	0.9	—	—	107	7.2	7	3.3
Greece	—	—	—	—	1	0.3	—	—	—	—	—	—	—	—
Iceland	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Italy	8	1.7	6	1.1	1	0.3	21	0.9	10	0.8	34	2.3	—	—
Luxemburg	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Netherlands	5	1.1	23	4.2	4	1.3	10	0.4	6	0.5	8	0.5	4	1.9
Norway	1	0.2	12	2.2	—	—	1	—	6	0.5	—	—	14	6.5
Portugal	—	—	1	0.2	—	—	—	—	2	0.2	—	—	—	—
Turkey	1	0.2	—	—	—	—	—	—	6	0.5	—	—	—	—
UK	39	8.3	183	33.6	45	14.6	122	5.5	104	8.8	753	50.5	53	24.8
US	333	71.6	187	34.3	208	67.3	1,870	84.0	877	73.8	361	24.2	85	39.7
(Sweden)	4	0.9	—	—	1	0.3	19	0.9	5	0.4	5	0.3	12	5.6
(Swiss)	4	0.9	7	1.3	1	0.3	28	1.3	8	0.7	9	0.6	3	1.4
(Other)	5	1.1	1	0.2	5	1.6	34	1.5	12	1.0	24	1.6	6	2.8
TOTAL	465	100.0	545	100.0	309	100.0	2,227	100.0	1,189	100.0	1,492	100.0	214	100.0

[a] 1963-1981 data only (figures not yet available for 1982).
SOURCE: NATO Science Committee Year Book—1982.

national exchanges. Unfortunately, one must rely on anecdotal evidence available through extensive contacts and interviews with Western European science policy officials and educational authorities. The picture of a dramatic decrease in the U.S. presence at mid-career and senior levels in Western European research institutions was brought out at the June 1981 Lisbon Workshop on International Mobility of Scientists and Engineers discussed below. Similarly, Kidd[7] has underscored this significant decrease through interviews with Western European authorities; there was a unanimous opinion that a serious decline in U.S. senior-level researchers taking up foreign appointments had occurred.

NATO Fellowship Program. The picture of postdoctoral fellowship support available to U.S. Ph.D.s would be incomplete without reference to the invaluable, consistent contribution of the NATO Science Fellowship Program. This broad-based civil science program, established in 1958 also partly in response to Sputnik, offers a flexible mechanism to enhance collaboration among scientists in the 16 Alli-

From Each "Sending" Country Who Go to Each "Receiving" Country

Italy		Luxemburg		Netherlands		Norway		Portugal[a]		Turkey		UK		US		Total
No.	%	No	%	No.	%	No	%	No	%	No.	%	No	%	No	%	No
32	1 7	24	11.3	2	1 0	1	0 3	21	2 8	17	1 0	33	1 4	21	1 8	218
45	2.4	3	1 4	6	3.0	14	4 4	7	0 9	34	1 9	137	5 9	41	3 6	491
9	0 5	—	—	—	—	9	2 9	3	0 4	3	0 2	68	2 9	36	3.1	186
158	8 6	50	23 4	4	2 0	13	4 1	106	13 9	88	4 9	207	9 0	144	12 5	1.095
35	1 9	49	23.0	1	0 5	19	6 0	17	2 2	221	12 4	116	5 0	144	12 5	791
1	0 1	—	—	—	—	—	—	—	—	—	—	3	0 1	1	0 1	6
—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	0 3	4
2	0.1	—	—	3	1.5	1	0 3	9	1 2	8	0 4	33	1 4	34	2 9	170
—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0 1	1
25	1 4	1	0 5	—	—	4	1 3	17	2 2	10	0 6	112	4 8	50	4 3	279
8	0 4	2	0 9	—	—	—	—	2	0 3	1	0 1	53	2 3	39	3 4	139
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
—	—	1	0 5	—	—	—	—	—	—	—	—	2	0 1	1	0 1	11
442	24 0	10	4 7	8	4 1	76	24 1	484	63 6	421	23 6	—	—	515	44 6	3.255
1,000	54 4	34	16 0	160	80 8	169	53 5	77	10 1	942	52 9	1,137	49 1	—	—	7.440
22	1 2	—	—	8	4 1	5	1 6	1	0 1	9	0 5	95	4 1	24	2 1	210
35	1 9	38	17 8	2	1 0	3	0 9	9	1 2	9	0 5	140	6 1	56	4 8	352
25	1 4	1	0.5	4	2.0	2	0 6	8	1 1	18	1 0	180	7 8	44	3 8	369
1 839	100 0	213	100.0	198	100 0	316	100 0	761	100 0	1,781	100 0	2 316	100 0	1 155	100 0	15,020

ance nations of North America and Western Europe. The source of support comes from member nations; the U.S. contribution is channeled through State Department appropriations. An estimated 150,000 scientists and engineers of many nationalities have been supported through a range of exchange programs furthering collaboration with colleagues in other Alliance nations during the 25 years of the program. The NATO Fellowship Program provides support for nationally administered exchanges of some 800–900 fellows per year among Alliance nations. Well over one-half of these exchanges involve transatlantic travel.

The United States has concentrated its participation in this program on the support of postdoctoral fellows. (Some other countries give primary attention to NATO-supported predoctoral or senior postdoctoral exchanges.) On this basis about 65 U.S. postdoctoral scientists work each year in other Alliance scientific institutions (new awards plus extensions). About 70 percent of awardees attend institutions in the United Kingdom, France, and Germany. The total over the 25 years of the NATO Fellowship Program has been around 1,200 U.S.

TABLE 6 Trend in Transatlantic and Inter-European Exchanges

	1963–1980		1970		1975		1976		1977		1978		1979		1980	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Trans-Atlantic	8,177	60.1	451	62.3	429	61.7	439	59.1	451	61.6	432	56.4	570	65.6	563	62.9
Inter-European	5,133	38.7	270	37.3	254	36.6	299	40.2	271	37.0	323	42.2	272	31.3	293	32.7
Inter-North American	172	1.2	3	4	12	1.7	5	0.7	10	1.4	11	1.4	27	3.1	39	4.4
Total	13,310	100.0	724	100.0	695	100.0	743	100.0	732	100.0	766	100.0	869	100.0	895	100.0

SOURCE: The NATO Science Fellowships Programme, Analyses of Trends in Various Aspects of the Programme, 1963–1980 postdoctoral fellows, which is about the same order as the number of U.S. postdoctoral scientists going abroad under support from various NSF programs during "on-off" periods of activity.

The beneficial cost-benefit ratio to U.S. science of this NATO program is highlighted by the continuing flow of well over 50 percent of the fellows from other NATO nations to advanced studies in the United States, with support by NATO and their own countries. They contribute to the advancement of knowledge in U.S. institutions, as well as furthering long-lasting cooperative relations between their U.S. colleagues and their home institutions throughout the Alliance. The distribution and exchange of NATO Science Fellows over the past 20 years is given in Table 5. An overview of transatlantic and inter-European exchanges supported under the NATO Fellowship Program is given in Table 6.

SHORT-TERM TRAINING INSTITUTES

Next to doctoral fellowship experiences, participation in short-term international advanced-training projects has proven to be of greatest value to young scientists. An example is the NATO Advanced Study Institutes (ASI) Program, which has provided such opportunities over the past 25 years.

The ASI Program focuses directly on the dissemination of knowledge at the frontiers of science and the formation of lasting contacts among participating scientists from different countries. An ASI is primarily a high-level teaching activity at which a carefully defined subject is presented in a coherently structured program by members of the cognizant research community. Since its inception in 1959, the ASI Program has supported over 1,200 institutes in which some 100,000 scientists have participated. The proceedings of most ASIs have been published as advanced texts by world-recognized publishing firms.

Each ASI has a relatively small number of participants (70–100 persons), facilitating informal discussion of presentations directed largely toward a postdoctoral audience. But the participants range from graduate students to highly qualified senior scientists with achievements in the area of the ASI or related fields. A lecturer-to-student ratio of around 1:5 is usual. Furthermore, it is evident that only if the meeting is of sufficient length can an adequate program be presented—experience has shown that a duration of about 2 weeks is preferable, with a minimum of 10 working days. Finally, an ASI is frequently structured as an interdisciplinary meeting, with specialists in one field teaching scientists highly qualified in a different area. The roles of lecturer and student will be interchanged during the meeting as the theme of common interest is developed from the viewpoint of different sciences.

The distribution of ASIs according to fields of research over the 1959–1981 period, presented in Table 7, shows that the physical and mathematical sciences have dominated this program to date. However, increased attention is now being given to research topics of industrial interest. U.S. scientists have actively contributed to and participated in the ASI Program. Some 28 percent of the ASI Directors have come from the United States, and it is estimated that about 15 percent of the student participants (some 15,000) have been American scientists, primarily at the postdoctoral level.

At the time of the Twentieth Anniversary Commemoration Conference of the NATO Science Program (1978), a review was carried out on the various aspects of the program.[8] The answers to a question-

TABLE 7 Distribution of ASIs according to Fields of Research, 1959–1981

Field of Study	1981	Total	Percent
Life sciences			
Agricultural sciences	2	15	1.4
Biochemistry	5	18	1.7
Biology	6	87	8.1
Botany	0	13	1.2
Ecological sciences	1	10	0.9
Medical sciences	6	52	4.8
Zoology	1	16	1.5
Physical and mathematical sciences			
Atmospheric sciences	1	29	2.7
Computer sciences	4	42	3.9
Chemistry	5	81	7.6
Earth sciences	4	35	3.3
Mathematics	3	99	9.2
Oceanography	0	7	0.6
Physics	22	403	37.6
Behavioral and social sciences			
Behavioral sciences	2	42	3.9
Social sciences	0	12	1.1
Diverse applied sciences			
Engineering	7	63	5.9
Materials science	3	11	1.0
Systems science	2	32	3.0
Information science	1	7	0.6
Total	75	1,071	100.0

SOURCE: NATO Science Committee Year Book (1981).

naire completed by ASI participants noted that "the most beneficial and outstanding value of the Institutes was in the new ideas for research they generated and the new professional associations they made possible." This review concluded by noting, "If the ASIs can be assumed to be unique, then their uniqueness derives from their ability to lessen the gaps between scientists that could exist because of their status, physical location, and other deterrents to the activity of science. The suggestion is certainly clear in this assessment that the ASIs are indeed unique—through their format of encouraging extending scientific associations that endure long after the termination of the Institutes." This international collaboration within tutorial schemes at the frontiers of research is of fundamental importance to young American researchers.

INTERNATIONAL COLLABORATION IN RESEARCH

Another mechanism for promoting international exchanges of young scientists is through collaborative research projects. Although the major interactions within such projects are probably between principal investigators, normally senior scientists, these projects provide invaluable opportunities for postdoctoral scientists to engage in and experience important developments abroad. As major examples, the NATO Collaborative Research Grants Program and certain aspects of NSF Research Grants and Travel Grants Programs are briefly discussed below.

NATO Collaborative Research Grants Program

NATO grants specifically assist projects in which the basic costs are met mainly by country funding, but where the international collaboration entails costs that are not met by other sources. Supported projects are carried out as a joint effort of teams in university, government, and other research institutions in at least two member countries, with exchanges of personnel through short visits. NATO support mainly covers travel and living expenses of the investigators while working abroad in each other's institutions. Since its inception in 1960, this NATO program has supported about 2,000 projects (awards were made in 1982 for 270 new grants). American scientists are by far the most active participants in this program with some 65 percent of collaborative-research projects involving exchanges between U.S. research labs and their counterparts in other Alliance nations. It is interesting to note that when Canadian participation is taken into account, three-fourths of the projects involve transatlantic collaboration.

NSF Research and Foreign Travel Grants

Over the years, the NSF staff in the Division of International Programs has not only managed a wide-ranging number of cooperative research and training activities under bilateral programs, but has also periodically attempted to provide analyses of the overall international activities of the foundation. A recent analysis has provided a basis for policy discussions by the National Science Board. A major examination of science in the international setting was prepared for the June 1982 board meeting.[9]

A board statement[10] issued some weeks after the meeting, in September 1982, noted in particular:

> Scientific interaction at the international level is an essential element in the continued vitality of science. Historically, the Nation has profited from its positive stance of encouraging outstanding scientists from throughout the world to be aware of and participate in our scientific activities and encouraging U.S. scientists to travel and interact closely with scientific projects in other nations.
>
> Cooperation with the industrialized democracies, such as OECD members and our NATO allies, is clearly of great value to the economic well-being and industrial capability of our own Nation as well as theirs. These nations enjoy comparable levels of technical sophistication and the potential for sharing advanced, costly facilities. Since opportunities for interaction with these countries are readily available, the greatest latitude should be given to individual cooperation and exchanges independent of formal bilateral programs. However, the NSF should continue to participate in selected intergovernmental agreements that serve identifiable useful functions.
>
> The nature of science requires that its international dimension be considered an organic aspect of the scientific enterprise. This dimension must be actively provided for in all Foundation programs, from education and fellowships to the various disciplinary efforts in the natural sciences, social sciences, and engineering. Planning for new facilities and the setting of priorities for major scientific investigations and programs should be carried out with the full recognition of the priorities of other countries and in an environment which encourages complementarity or planned supplementation, cost sharing, and coherence of the various efforts of cooperating countries. National Science Foundation organization and management procedures should reflect these principles.

The staff's analysis, from which the board worked, was based in part on the recorded and coded information from all foundation awards on specific modes on international "implication," that is, international involvement. Some important findings are:

- Of 28,125 NSF awards of all directorates studied for the period, 26.7 percent had international implications.
- Although large international group efforts use most of the NSF funding that has international implications, the largest number of NSF grants are for research by individuals and nearly 1,000 U.S. scientists annually receive some NSF support for such activities, under bilateral programs alone.
- The figures related to industrial, or scientifically advanced, countries show high values for mathematical and physical sciences, engineering, and biological, behavioral, and social sciences, mainly reflecting cooperation with Western Europe and Japan.
- The "nature of implication" (i.e., international involvement) varied greatly according to program needs of the directorates, as shown in Table 8 below.

In summary, foundation awards do include significant support for international interactions, although the nature of such interactions varies considerably among the discipline.programs. One can assume that there is an involvement of young researchers through these support mechanisms, although the amount cannot be determined from current data collection. It is noteworthy that under foreign travel the foundation does give special consideration to supporting participation of postdoctoral and young scientists who wish to attend NATO Advanced Study Institutes.

TABLE 8 Nature of Implication According to Directorate

Percent of Awards With:	AAEO[a]	BBS[b]	ENG[c]	MPS[d]	STIA[e]	Other
Foreign travel	68.2	87.4	91.2	84.2	91.3	66.7
Foreign citizens	9.2	22.2	11.6	19.3	16.5	20.6
Long visit	37.9	55.3	16.2	4.0	62.2	24.8
Coop. proj.	22.1	6.8	19.3	3.4	64.5	17.6
Agreement	49.8	3.3	14.9	2.4	75.4	23.6
Other	5.6	7.9	1.5	0.4	1.3	25.5

[a] AAEO Astronomical, Atmospheric, Earth, and Ocean Sciences.
[b] BBS Biological, Behavioral, and Social Sciences.
[c] ENG Engineering.
[d] MPS Mathematical and Physical Sciences.
[e] STIA Scientific, Technological and International Affairs.

INTERNATIONAL MOBILITY OF YOUNG SCIENTISTS AND ENGINEERS

This discussion has touched on trends and concerns pertaining to some of the most important programs that provide young American scientists with opportunities to profit from advanced research and training experiences abroad. The value and need of such experience is largely supported by anecdotal evidence—we are all familiar with a number of "Rabi" examples of perhaps more modest yet significant contributions to science and world affairs. There are convincing arguments to support increased international interactions as essential elements in the career development of the coming generations of American science and engineering leaders.

Professor Kurt Fleischhauer of the Anatomisches Inst. der Rheinischen Friedrich-Wilhelms-Universitat noted most aptly at the June 1981 Lisbon Workshops on International Mobility of Scientists and Engineers that

> the most important form of establishing effective international collaboration is to provide opportunities for young scientists, preferably still in their twenties or early thirties, to work in a foreign institute of high scientific standard for a period of not less than one year and preferably two years. Any experience gained at this stage of the career is of utmost importance and long-lasting influence because at this stage the scientist still has an open mind and is not only able to gain enormously with respect to his actual scientific achievements but also to form international links that are based on personal understanding and friendship. And since, after all, science is an undertaking of persons with all their likings and dislikings and with all the prejudices every one of us has, links based on personal trust are of particular importance for international exchange.[11]

The Lisbon Workshop dealt with a number of issues relevant to the interests of young researchers. A Working Group on Mobility and the Career Paths of Individuals identified three problems of overwhelming importance:

- the reentry and job security problem
- the dual-career family problem
- lack of obvious reward for taking the adventurous step[12]

The Working Group on Research Systems and International Mobility devoted major attention to the problems of transatlantic mobility, noting the greatly changed environment and two-way movement of young scientists through the 1950s to now when one workshop participant spoke of the "missing partner"—the United States. The group suggested that:

> There should be a U.S. effort to assist foreign institutions on a reciprocal basis—not to place researchers in the U.S. (this is still possible since the links established for this in the forties and fifties continue to work successfully)—but to get postdoctoral fellowships and travel grants for the outgoing Americans and postdoctoral foreigners. U.S. Foundation assistance would be warmly welcomed.[13]

Among the conclusions of the workshop, three, in particular, are relevant to providing convincing arguments for encouraging increased international mobility of the young researcher:

> International mobility of scientists and engineers is important to the excellence of the scientific enterprise, the health of technologically-based industries, and the intellectual and professional growth of the individual.
>
> For individuals, international mobility constitutes a major vehicle for the development of inventive and innovative ability. Such experience is particularly valuable early in a professional career—for it is at this stage of intellectual and professional growth when one is especially responsive to new ideas and opportunities. At later career stages international mobility may allow a mature investigator to renew his innovative capabilities.
>
> International mobility is a valuable component in the development and renewal of research systems. The mutual confidence that is built between host and guest leads to long-term cooperation, understanding of different concepts and techniques, and adaption of new technologies more quickly and accurately than is possible when working in isolation.[14]

The key point here is national "isolation"—a condition inimical to scientists and the dynamism of the research system. We are proud of our mobility within and among national institutions. For reasons noted above, we found international interactions of critical importance during the first half of this century. Why not now? And to whom should we pose this question?

Recent policy statements portray a curious perspective on the position of the United States in the world research system on the part of important decision makers. The National Science Board document referred to earlier, entitled "Statement on Science in the International Setting," introduces a first idea that "American scientists no longer lead in every field of science. . . ."[13] Similarly, the President's Science Adviser in the President's "Annual Science and Technology Report to the Congress" for 1981 states that "one of the realities of the 1980s is that whereas the United States retains international preeminence in many areas across the spectrum of science and technology, we no longer hold undisputed dominance in virtually all fields."[15]

In addressing these policymakers one could point out that now, with many fields of science and technology advancing rapidly at the world level (not just at the U.S. level), we have the most convincing argument of all for promoting the international mobility of young researchers—to lead, to participate, to keep up, to provide a mature (a world view) perspective as future managers of our research system, be they in industry, university, or government.

This analysis has shown that isolation is an imminent problem that must be faced. The NSF graduate fellowship program currently encourages a trivial level of participation of fellows to attend foreign institutions. This should be much enlarged.

There is no longer a regular NSF postdoctoral fellowship program. Serious and urgent attention should be devoted to devising mechanisms to promote an increase in the overall postdoctoral appointments abroad from something less than 2 percent to the order of 5 percent. In this, it would be particularly important to give special attention to the mathematical, physical, and engineering sciences. Whether the trends in postdoctural study abroad have declined or remained relatively constant is not the point. Specific measures should be established to encourage increases in foreign research appointments in order to ensure our future participation in the advancement of science as well as provide a vital supply of internationally minded research managers.

Coupled with meeting these needs is the enlargement of opportunities for young American scientists to participate in short-term training schemes such as the NATO ASIs as well as collaborative research projects of all kinds, particularly those supported by the National Science Foundation.

The dynamic interaction of young American researchers with their colleagues in the advanced countries of the Western world is fundamental to the health of our research system. The benefits to the United States—its economy, its political system, its position in the world of science and technology—lie in their hands and intellectual leadership.

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