[COMMITTEE PRINT]

SCIENCE POLICY STUDY
BACKGROUND REPORT NO. 4

WORLD INVENTORY OF "BIG SCIENCE" RESEARCH INSTRUMENTS AND FACILITIES

R E P O R T

PREPARED BY THE

CONGRESSIONAL RESEARCH SERVICE
LIBRARY OF CONGRESS

TRANSMITTED TO THE

TASK FORCE ON SCIENCE POLICY

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

SECOND SESSION

Serial DD

DECEMBER 1986

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*Ranking Republican Member.
**Serving on Committee on the Budget for 99th Congress.

LETTER OF TRANSMITTAL

House of Representatives,
Committee on Science and Technology,
Washington, DC, September 24, 1986.

To the Members of the Task Force on Science Policy:

We submit herewith the fourth in a series of background studies prepared for the use of the Task Force on Science Policy. This Study is a "World Inventory of 'Big Science' Research Instruments and Facilities" which includes specific information about each facility and an analysis of the extent of international cooperation in their construction and use. The Study was prepared at the request of the Task Force by the Congressional Research Service.

A significant topic which the Science Policy Study will consider is the rapidly growing costs of the large research instruments and facilities which have become necessary in order to conduct leading edge scientific research in many fields of science. This growing cost of both their initial construction and their subsequent operation has led the Task Force to inquire whether, in the future, more reliance on the joint international shouldering of these costs should be sought.

We are indebted to Mr. William Boesman of the Congressional Research Service for undertaking the extensive data collection that made this inventory possible, and to the many experts throughout the government agencies who contributed. While every effort has been made to include in the study all the relevant big science facilities, additions and corrections would be welcome and should be addressed by the Chairman of the Task Force.

This report with its data base and its analysis will serve as a solid point of departure for the further work of the Science Policy Task Force in this area. We commend it to the attention of the Task Force Members, our witnesses, the members of the Committee on Science and Technology, and all members of the House of Representatives.

Manuel Lujan,
Ranking Republican Member.

Don Fuqua,
Chairman.

LETTER OF SUBMITTAL

CONGRESSIONAL RESEARCH SERVICE,
THE LIBRARY OF CONGRESS,
May 22, 1985.

Hon. DON FUQUA,
Chairman, Committee on Science and Technology,
House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: In response to your letter to me of November 2, 1984, I am pleased to provide you with a World Inventory of Big Science Research Instruments and Facilities prepared by the Science Policy Research Division under the coordination of William Boesman of that division. The report represents a large effort at collecting information on big science facilities and was facilitated by superb cooperation by several Federal agencies.

I believe that this report will be a useful contribution to the activities of the committee's Science Policy Task Force and for the hearings which you plan to hold this year on the subject of scientific facilities.

The Congressional Research Service looks forward to continuing to provide you with assistance in the very challenging activities of the Science Policy Task Force as well as the other ongoing activities of the committee.

Sincerely,

GILBERT GUDE,
Director.

CONTRIBUTORS

This project was coordinated and edited by William Boesman of the Science Policy Research Division. A number of division members contributed to the project. Glenn McLoughlin and Marcia Smith contributed significantly to the chapters on space and aeronautics; Fred Sissine to the chapter on high-energy and nuclear physics; and Nancy Miller to the chapter on supercomputers. Patricia Humphlett, Robert Civiak, Genevieve Knezo, and others also provided valuable insights, reviews, and inputs.

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CONTENTS

(See the following pages for a detailed table of contents of appendices 2 through 11 showing individual big science facilities.)

FUSION FACILITIES

Magnetic-Confinement Fusion

Inertial-Confinement Fusion

MATERIALS SCIENCE AND ENGINEERING FACILITIES

I. INTRODUCTION AND SUMMARY

A. INTRODUCTION

This report is an attempt to inventory "big science" instruments and facilities worldwide and to discuss briefly the extent of international cooperation in their construction, operation, and utilization.

The charge given to the Congressional Research Service by the House Committee on Science and Technology was to:

> . . . include facilities constructed since 1920 at a cost of approximately $25 million or more in 1984 Dollars or its equivalent. It should include, as well, the cost, the date of construction, and, if applicable, the date of decommissioning. The analysis should cover the extent to which these Big Science facilities have been funded, operated, and used for research on an international basis. We are also interested in the potential for obtaining international cooperation with respect to the support of present and future Big Science research instruments and facilities and the modes that have been successful and unsuccessful in funding, operating and conducting research on an international basis of such facilities.

In response to this assignment, the Congressional Research Service has identified and collected information on U.S. and foreign big science facilities or groups of facilities 1/ meeting the $25 million (1984 dollars) criterion established by the committee for this project.

The term "big science" is somewhat indefinite. Historically, it probably has been understood by most people to include what Harvey Brooks, for example, defined it to mean in 1968: 2/

> . . . the past fifteen years [since about 1953] have seen even pure science carried out on an

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1/ Satellites and oceanographic research vessels are arranged in groups in the inventory appendices. For example, all ASTROPHYSICS EXPLORER satellites and all Federal Oceanographic Fleet vessels are listed together on one page for convenience. Satellites and vessels are written in capital letters for ease of identification.

2/ Brooks, Harvey. The Government of Science. Cambridge, The M.I.T. Press, 1968. p. 35.

> entirely new scale. We have the new phenomenon loosely known as "big science," that is, pure science carried on with complex and expensive equipment, and with a large supporting technological effort. In order of cost, the most important examples of such big science are space sciences, high-energy physics, oceanography, radio astronomy, and optical astronomy.

This study has extended that definition in two ways. First, it has been extended to include other areas of science that involve large instruments and facilities that fall within the $25 million criterion noted above. Thus, to the above list are added here nuclear physics, fusion, materials science and engineering, atmospheric science, aeronautics, and superconducters used for scientific research. Second, this study also includes in its inventory "big engineering science" facilities, which fall outside of the "pure science" definition of big science noted above. Also, brief discussions are included of antarctic research, because of its relationship to big science in some respects, and biotechnology, because of its potential to develop large facilities in the future.

Thus, the following chapters will deal with, respectively, high-energy and nuclear physics, fusion, materials science and engineering, astronomy, atmospheric and oceanographic science, space, aeronautics, supercomputers, engineering science, antarctic research, and biotechnology. Following the body of the report are appendices that briefly described each U.S. and foreign big science facility which has been identified in this study. In some instances, it has not been possible to obtain all the data requested by the committee for some of the facilities in time to meet the publication date. This is particularly true of information about construction dates and costs of foreign high-energy and nuclear physics facilities. All data in this report are from unclassified sources. Omissions may exist because of U.S. and foreign national security considerations.

Modes of international cooperation are discussed individually for each big science facility where the information is available from the survey carried out by the Congressional Research Service. In addition, the following chapters briefly discuss international cooperation in each area of big science. The extent of international cooperation in big science depends on the balancing of "opportunities and benefits" versus "difficulties and costs." This varies, of course, from area to area of big science and from facility to facility within each specific area of big science. These major factors have been defined as follows: 3/

3/ Rycroft, Robert W. International Cooperation in Science Policy: The U.S. Role in Macroprojects. Technology in Society, v. 5, 1983. p. 51-68. (Also published as International Cooperation in

"Major opportunities and benefits"

- Making greater resources available, in terms of information, knowledge, and know-how necessary for any scientific activity;
- Making possible a wider range of topics and a broader range of approaches;
- Reducing the financial burden on all participants;
- Speeding up the entire innovation processes, from basic research to application;
- Reducing wasteful redundancy; and
- Enhancing good will and communication among the participants.

"Most significant difficulties and costs"

- Inherent difficulties in meshing disparate national bureaucracies;
- Delays in reaching decisions among differing political and legal systems;
- Complications of varying decision processes, priorities, and competencies;
- Costs of international bureaucracy;

Science: The U.S. Role in Megaprojects. In Emerging Issues in Science and Technology, 1982. Washington, National Science Foundation, 1983. p. 1-13.) Also see, Mitchell B. Wallerstein (ed.). Scientific and Technological Cooperation Among Industrialized Countries: The Role of the United States. (See especially, Appendix E: Annotated Bibliography, p. 252-259.) Washington, National Academy Press, 1984. 259 p. A study of large international facilities was undertaken by the National Academy of Sciences in May 1985.

A recent issue of Physics Today magazine has discussed several aspects of big science. See for example, Havens, William W., Jr. Major Facilities for Physics Research. Physics Today, v. 38, Mar. 1985. p. 23-24; and Hebel, L. Charles. Opportunities in Physics and Major Research Facilities. Physics Today, v. 38, Mar. 1985. p. 25-26. Other articles in this issue of Physics Today are referenced as appropriate in the following sections.

-- The danger that political inertia, which makes projects hard to start, but even harder to stop, will dominate;

-- The possibility of drains on national research budgets because of international commitments;

-- The tendency to undertake, internationally, only low-priority projects; and

-- The apparent conflict between cooperation and improving a nation's competitive position.

These types of opportunities and difficulties may well be the focus, for example, for discussions that have begun in the Congress, the Administration, and the international scientific community over the construction of the Superconducting Super Collider (SSC), a big science high-energy physics facility that may have construction costs that will fall in the range of $3 to $7 billion, an amount that dwarfs the costs of most big science facilities listed in this report. 4/

The 1982 Versailles Summit meeting of the heads of state or government of the United States, Canada, France, the Federal Republic of Germany, Italy, Japan, the United Kingdom, and the President of the Commission of the European Communities, as reaffirmed in their London Summit meeting, emphasized the importance of international science and technology to the nations involved. As a result of this initiative, a number of international working groups were established to deal with several areas of science. Those working groups which most closely relate to the areas of big science discussed in this report are solar system exploration (U.S. lead), remote sensing from space (U.S. lead), high-energy physics (U.S. lead), controlled thermonuclear fusion (U.S.-European Community co-lead), fast breeder reactor design (U.S.-France co-lead), and advanced materials and standards (U.S.-U.K. co-lead). These initiatives are summarized briefly in the most recent Title V Report of the President to the Congress. 5/ The summaries are included in this report as appendix 1. The Title V Report also discusses the current state of U.S. international cooperation in science in some detail.

4/ SSC: Progress on Magnets, Uncertainty on Foreign Collaboration. Physics Today, v. 38, Mar. 1985. p. 63-66.

5/ Science, Technology, and American Diplomacy, 1985: Sixth Annual Report Submitted to the Congress by the President Pursuant to Section 503(b) of Title V of Public Law 95-426. Mar. 20, 1985. p. 15-17.

There are a number of bilateral and multilateral agreements between the United States and foreign nations in the area of science and technology that provide the means for the international cooperation in big science discussed in the following chapters. Perhaps the most recent inventory of bilateral technical agreements, listed by lead agency, partner country, and as government-to-government agreements was included in the 1980 Title V Report, Science, Technology, and American Diplomacy 1980. 6/

The following chapters list the facilities identified and briefly discuss international cooperation in each area of big science discussed in the report.

B. SUMMARY OF INTERNATIONAL COOPERATION

Chapters II through XII and appendices 2 through 11 describe the big science facilities inventoried in this report and discuss the international cooperation involved in each area of big science and for each facility for which the information was obtained. Cooperation in big science varies both by broad area of science--there is more international cooperation, for example, in high-energy physics than in optical astronomy--and by individual facility within a specific area of big science. The following paragraphs of this section briefly summarize the major trends in international cooperation according to the specific areas of big science mentioned above. These general impressions, of course, may not apply to a specific facility at any given time. Reference, thus should be made to the individual summaries of each facility set forth in the appendices. 7/

For each of the facilities included in the inventory and briefly described in the appendices, an attempt was made to determine the nationality or nationalities of the ownership, the operational funding, and the management staff of, and the researchers using, the facility. A review of this information indicated that the facilities, with the few exceptions noted below, are not jointly-owned, jointly-funded, or jointly-managed, even where there is significant

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6/ U.S. Congress. House. Committee on Foreign Affairs and Committee on Science and Technology. Science, Technology and American Diplomacy, 1980. Joint Committee Print, 96th Cong., 2d sess. Washington, U.S. Govt. Print. Off., 1980. p. 159-190.

7/ In addition to the references in the preceding footnotes, also see the following for discussions of political and bureaucratic factors which affect international cooperation in big science: Nau, Henry R. National Politics and International Technology: Nuclear Reactor Development in Western Europe. Baltimore, The Johns Hopkins University Press, 1974. 287 p.; and Teich, Albert H. Politics and International Laboratories: A Study of Scientists' Attitudes In Albert H. Teich (ed.). Scientists and Public Affairs. Cambridge, The MIT Press, 1974. p. 173-235.

use of the facilities by non-national researchers. Thus, in general, international cooperation, unless otherwise noted in the following discussion, refers only to cooperative use of the facilities by foreign researchers. For further discussions of such scientific collaboration in each area of big science, see the individual discussions in chapters II through XII.

High-Energy and Nuclear Physics

These areas of big science in the United States have long histories of international cooperation and such cooperation is expected to continue. However, the dominant use of the high-energy and nuclear physics facilities in the United States is by U.S. scientists and not by foreign scientists. Moreover, all the U.S. big science facilities in high-energy and nuclear physics are owned, operationally funded, and managed by U.S. organizations and personnel. Recent discussions in the international scientific community and in the Federal legislative and executive branches about who should build and own the proposed Superconducting Super Collider (SSC) suggest that the Europeans may be looking to the United States to build and own it alone also because they, through the European Organization for Nuclear Research (CERN), are seriously considering their own alternative to the SSC. 8/

In Europe, there is greater international participation in the ownership of high-energy physics facilities than in the United States. The big science facilities of CERN, located in Switzerland, are owned, operationally funded, managed, and staffed multinationally. Moreover, the HERA storage rings of DESY in the Federal Republic of Germany, although currently not operating, are owned jointly by the Federal Republic of Germany, Canada, France, Israel, Italy, the Netherlands, and the United Kingdom.

The information collected in this report on foreign big science facilities in nuclear physics is not complete and does not indicate construction costs or the nationalities of ownership, operational funding, and management of those facilities.

Fusion

In the area of magnetic-confinement fusion, international collaboration has been an important part of the program since its inception. Most of this collaboration, however, has involved only the exchange of information. As in the case of high-energy and nuclear physics, most U.S. facilities are owned, operationally funded, and managed by U.S. organizations and personnel. The two exceptions are (1) the Doublet III-D facility, owned and operated by GA Technologies, Inc., in California, which is operationally funded jointly with the Japanese, who also have provided about $55 million in hardware; and (2) the International Fusion Superconducting Magnetic Test

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8/ Waldrop, M. Mitchell. The Supercollider, One Year Later. Science, v. 225, Aug. 3, 1984. p. 490-491.

Facility (IFSMTF) at the Oak Ridge National Laboratory. In the latter case, the United States owns and operates the basic facility, but three coils are foreign-owned and an International Executive Committee is involved in the management of the Large Coil Test at the facility.

In Europe, the Joint European Torus is owned, operated, managed, and staffed with researchers from the European Community.

The rather extensive international collaboration of researchers in the various magnetic-confinement fusion facilities is discussed in more detail in chapter III.

The inertial-confinement fusion facilities of the U.S. Government are restricted to U.S. researchers because of considerations of national defense. There may be significant opportunities for international cooperation, however, at the National Laser Users Facility ("OMEGA") of the University of Rochester, the GEKKO XII glass laser system at Osaka University in Japan, and the Central Laser Facility ("VULCAN") of the Rutherford Appleton Laboratory in the United Kingdom.

Materials Science and Engineering

The majority of research in this area of big science is small-scale research carried out by individual scientists located at a large number of universities and national and industrial laboratories, both in the United States and in foreign nations. International cooperation generally takes the form of informal information exchanges and research collaboration on an individual basis.

In Europe, materials science and engineering are conducted at a number of facilities, but only the High Flux Reactor at the Institut Laue-Langevin in France is jointly owned and operationally funded by several countries, in this case by France, the Federal Republic of Germany, and the United Kingdom. The planned European Synchrotron Radiation Facility in France will be a joint effort of France and the Federal Republic of Germany and probably other European nations.

Astronomy

Much radio astronomy involves very long baseline interferometry (VLBI) facilities used cooperatively by several nations. Moreover, two U.S. radio astronomical facilities, the Very Large Array (VLA) and the Arecibo 1,000-foot radio/radar telescope, are unique in the world and are used by foreign researchers who otherwise would not have access to such facilities. Of the radio astronomical big science facilities identified here, however, only the IRAM Interferometer in France is internationally owned and operated, in that case by France and the Federal Republic of Germany. It is managed by an international staff.

Optical telescopes tend to be owned and used exclusively by individual countries. The Anglo-Australian Telescope, located in

Australia, and the 140-inch telescope of the European Southern Observatory, located in Chile, are exceptions, being jointly owned, operationally funded, and managed by Australia and the United Kingdom in the first case and by the International European Consortium in the second case.

A number of astronomical big science facilities are located in space and are discussed in that chapter. These include such facilities as ORBITING GEOPHYSICAL OBSERVATORIES (OGO), ORBITING SOLAR OBSERVATORIES (OSO), ORBITING ASTRONOMICAL OBSERVATORIES (OAO), HIGH-ENERGY ASTRONOMY OBSERVATORIES (HEAO), the HUBBLE LARGE SPACE TELESCOPE (LST), the GAMMA RAY OBSERVATORY (GRO), and the INTERNATIONAL ULTRAVIOLET EXPLORER (IUE). The last one is about the only example of a satellite used for physics and astronomy that is owned, operationally funded, and managed jointly by the United States and another entity, in this case with the European Space Agency (ESA). The HUBBLE LARGE SPACE TELESCOPE will be managed by the United States, ESA, and the Federal Republic of Germany and some of the ASTROPHYSICS EXPLORER satellites involve international cooperation in various forms (see appendix 6 for details).

Atmospheric and Oceanographic Science

The major U.S. facilities identified in this area of big science are the National Center for Atmospheric Research (NCAR), the Deep Submergence Research Vehicle "ALVIN," and about 110 oceanographic research vessels, particularly those of the Federal Oceanographic Fleet. No foreign facility similar to NCAR was identified, although there are several hundred, particularly Soviet, research vessels. Apparently, most nations which conduct oceanographic research own and operate their own research vessels.

Space

The facilities specifically identified in this report as space big science facilities are satellites for conducting physics and astronomical research, lunar and planetary exploration, and Earth science. See the discussion in chapter VII concerning the land-based "infrastructure" which supports these big science facilities, but which are not themselves big science facilities.

Most U.S. satellites are owned, operationally funded, and managed by the United States. The few exceptions include a few of the ASTROPHYSICS and SOLAR TERRESTRIAL EXPLORERS (see appendix 8 for details); the HUBBLE LARGE SPACE TELESCOPE which will be jointly managed by the United States, ESA, and the Federal Republic of Germany; the GALILEO Jupiter orbiter/probe, which is jointly owned by the United States and the Federal Republic of Germany; and the INTERNATIONAL ULTRAVIOLET EXPLORER (IUE), which is jointly owned, operationally funded, managed, and staffed by the United States and the European Space Agency.

In Europe, there are several example of satellites which are jointly owned, operationally funded, managed, and staffed by the

European Space Agency: GEOS-1 and GEOS-2; EXOSAT; GIOTTO; INTERNATIONAL SOLAR-POLAR MISSION (ISPM); and HIPPARCOS. In addition, the COS-B astronomical observatory involves ESA, France, Italy, and the Federal Republic of Germany.

Some of the Soviet science satellites involve international cooperation in some forms. INTERKOSMOS, for example, involves some Eastern Bloc nations; VEGA involves a number of other nations, including the United States; and ASTRON involves France.

It is likely that U.S. international cooperation in space big science programs will continue to grow in the coming years.

Aeronautics

All of the aeronautical big science facilities identified for this report are U.S. owned, operationally funded, and managed, with the exception of a Japanese wind tunnel. No other foreign facilities meeting the $25 million criterion have been identified. These facilities include principally wind tunnels, other flight simulators, and facilities for structural research and development and flight testing. There apparently is relatively little international cooperation in the use of these facilities, probably mainly because they are used to varying degrees for proprietary and military purposes.

Supercomputers

The supercomputers identified in this report are used primarily for scientific research and all are owned, operated, and managed by U.S. laboratories. Four National Science Foundation supported Advanced Scientific Computing Centers are planned at four U.S. universitites and a Department of Energy supported Supercomputer Computational Research Institute has been created at another. The levels of international cooperation at the existing facilities currently seems to be minimal. No foreign supercomputer facilities primarily for scientific research meeting the $25 million criterion have been identified.

Engineering Science

Eighteen "big engineering science" facilities, both U.S. and foreign, have been identified for this report, although they do not fall within the classical definition of big science; see the discussion in chapter X. The facilities include those involved in ship hydrodynamics engineering, earthquake engineering, nuclear power reactor engineering, radio isotope production, and weapons engineering. There is no international ownership, operational funding (with the following three exceptions), or management of the identified facilities, and there appears to be no adequate generalization about international cooperation in the use of these facilities. See appendix 11 for details. The three noted exceptions are small amounts of Japanese operational funding involved in the Fast Flux Test Facility at the Hanford Engineering Development Laboratory and at the Experimental Breeder Reactor II at Argonne National Laboratory and international operational funding of the Loss-of-Fluid Test Facility (LOFT) at Idaho National Engineering Laboratory.

Antarctic Research and Biotechnology

Although not big science in the classical sense, these two areas are addressed in this report in chapters XI and XII, respectively, for the reasons discussed there. Although no big science facilities meeting the $25 million criterion have been identified in either area, research support in Antarctica is broadly multidisciplinary, reflects the involvement of a wide variety of institutions and Federal agencies, and includes substantial international cooperation. Biotechnology is included for discussion because of its potential for developing big science facilities in the near-term future. Because of the commercial nature of much biotechnology, however, perhaps much of the potential international cooperation in that area would be carried out by multinational corporations.

II. HIGH-ENERGY AND NUCLEAR PHYSICS 9/

High-energy and nuclear physics in the United States have long histories of international cooperation. Experimental and theoretical collaboration with Western Europe generally are carried out without formal international agreements. Europeans have participated in experimental efforts on the major U.S. accelerators and Americans have used unique European facilities. This productive collaboration is expected to continue. Selected interactions with the Soviet Union, the People's Republic of China, and Japan take place under the auspices of formal international agreements and also are expected to continue where they have proven to be mutually beneficial. The formal agreement with the Japanese is part of an overall accord for cooperation in energy matters. However, cooperation with the Japanese also has been carried out for many years on an informal basis as it has with the Western Europeans.

Because high-energy and nuclear physics research is an international activity, with knowledge freely shared among its practitioners, researchers at U.S. high-energy and nuclear physics facilities have extensive interactions with their foreign counterparts. The high level of interaction is reflected in the diversity of foreign scientists using the U.S. facilities as listed in tables 1 and 2 and briefly described in appendices 2 and 3. 10/

The heavy emphasis on international cooperation at certain facilities that is discussed in the appendices, however, does not present a balanced picture of the use of U.S. high-energy and nuclear physics facilities. Although international cooperation is an important element of both programs, the dominant use of U.S. high-energy and nuclear physics facilities is by U.S. scientists. Furthermore, all the U.S. facilities listed in tables 1 and 2 and discussed in appendices 2 and 3 are owned, operated, and managed by U.S. organizations and personnel, even though there is the extensive collaboration with foreign researchers as discussed above.

9/ The discussion in this chapter is based largely on information supplied by the Department of Energy, Apr. 22, 1985.

10/ Also see: Glashow, Sheldon L. and Leon M. Lederman. The SSC: A Machine for the Nineties. Physics Today, v. 38, Mar. 1985. p. 28-37; and Bayn, Gordon. Major Facilities for Nuclear Physics, Physics Today, v. 38, Mar. 1985. p. 40-48.

TABLE 1. High-Energy Physics Facilities

Name or Brief Description	Location or Country of Ownership
CORNELL ELECTRON STORAGE RING (CESR)	U.S.
FERMILAB PROTON SYNCHROTRON	U.S.
ENERGY SAVER-SUPERCONDUCTING PROTON SYNCHRONTRON	U.S.
TEVATRON I-ANTIPROTON/PROTON COLLIDING BEAM FACILITY	U.S.
TEVATRON II-1,000 GeV FIXED TARGET RESEARCH FACILITIES	U.S.
COLLIDER DETECTOR AT FERMILAB (CDF)	U.S.
D-ZERO DETECTOR AT FERMILAB	U.S.
SLAC LINEAR ACCELERATOR	U.S.
POSITRON ELECTRON PROJECT (PEP)	U.S.
STANFORD LINEAR ACCELERATOR (SLC)	U.S.
STANFORD LINEAR DETECTOR (SLD)	U.S.
ALTERNATING GRADIENT SYNCHROTRON (AGS)	U.S.
COSMOTRON	U.S.
ZERO GRADIENT SYNCHROTRON (ZGS)	U.S.
BEVATRON	U.S.
CAMBRIDGE ELECTRON ACCELERATOR (CEA)	U.S.
PRINCETON-PENNSYLVANIA ACCELERATOR (PPA)	U.S.
PROTON SYNCHROTRON (PS) (CERN)	Switz.-Int'l
INTERSECTING STORAGE RINGS (ISR) (CERN)	Switz.-Int'l
SUPER PROTON SYNCHROTRON (SPS) (CERN)	Switz.-Int'l
LARGE ELECTRON-POSITRON COLLIDER (LEP) (CERN)	Switz.-Int'l
LEP DETECTOR-ALEPH (CERN)	Switz.-Int'l
LEP DETECTOR-DELPHI (CERN)	Switz.-Int'l
LEP DETECTOR-L3 (CERN)	Switz.-Int'l
LEP DETECTOR-OPAL (CERN)	Switz.-Int'l
PROTON-ANTIPROTON COLLIDER (CERN)	Switz.-Int'l
DORIS-II	F.R. Germany
PETRA-II	F.R. Germany
HERA	F.R. Germany-Int'l
SYNCHROTRON	Japan
TRISTAN (Storage Ring)	Japan
BPS (Synchrotron)	P.R.C.
BEPC (Storage Ring)	P.R.C.
PROTON SYNCHROTRON	U.S.S.R.
UNK PROTON SYNCHROTRON	U.S.S.R.
VEPP-IV (Storage Ring)	U.S.S.R.
VAPP-IV (Storage Ring)	U.S.S.R.
U-10 (Synchrotron)	U.S.S.R.

TABLE 2. Nuclear Physics Facilities

Name or Brief Description	Location or Country of Ownership
COUPLED SUPERCONDUCTING CYCLOTRONS (Michigan State)	U.S.
INDIANA UNIVERSITY CYCLOTRON FACILITY (IUCF)	U.S.
TANDEM/AGS HEAVY ION FACILITY	U.S.
ARGONNE TANDEM/LINAC ACCELERATOR SYSTEM (ATLAS)	U.S.
BEVALAC	U.S.
88-INCH CYCLOTRON (LBL)	U.S.
184-INCH CYCLOTRON (LBL)	U.S.
LOS ALAMOS MESON PHYSICS FACILITY (LAMPF)	U.S.
HOLIFIELD HEAVY ION RESEARCH FACILITY	U.S.
BATES LINEAR ACCELERATOR CENTER	U.S.
A.W. WRIGHT NUCLEAR STRUCTURE LABORATORY	U.S.
CYCLOTRON INSTITUTE	U.S.
CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY (CEBAF)	U.S.
SYNCHRO-CYCLOTRON (CERN)	Switz.-Int'l
LOW ENERGY ANTIPROTON RING (LEAR) (CERN)	Switz.-Int'l
SIN (Cyclotron)	Switz.
LINEAR ACCELERATOR	Canada
SUPERCONDUCTING CYCLOTRON	Canada
TRIUMF	Canada
ELECTROSTATIC MACHINE	Argentina
ELECTROSTATIC MACHINE	U.K.
SARA (Cyclotron)	France
ALS (Linear Accelerator)	France
SATURNE-II (Synchrotron)	France
GANIL (Twin Cyclotrons)	France
CYCLOTRON	F.R. Ger.
LINEAR ACCELERATOR	F.R. Ger.
MP-TANDEM (Electrostatic Machine)	F.R. Ger.
UNILAC (Linear Accelerator)	F.R. Ger.
VICKSI (Cyclotron)	F.R. Ger.
SIS-18 (Synchrotron)	F.R. Ger.
NIKHEF (Linear Accelerator)	Netherlands
CYCLOTRON	Netherlands
CYCLOTRON	Sweden
SUPERCONDUCTING CYCLOTRON	Italy
XTU TANDEM	Italy
CYCLOTRON	South Africa
CYCLOTRON	Japan
ELECTROSTATIC MACHINE	Japan
RIKEN (Cyclotron)	Japan
NUMATRON (Synchrotron)	Japan
CYCLOTRON	P.R.C.
CYCLOTRON (Gatchina)	U.S.S.R.

TABLE 2. Nuclear Physics Facilities (continued)

Name or Brief Description	Location or Country of Ownership
SYNCHROPHASATRON	U.S.S.R.
CYCLOTRON (Dubna)	U.S.S.R.
LINEAR ACCELERATOR	U.S.S.R.

III. FUSION

A. MAGNETIC-CONFINEMENT FUSION 11/

International collaboration has been a valuable part of the U.S. magnetic-confinement fusion program since its inception. Most of the collaboration has involved only the exchange of information, that is, ideas, data, and results. There also have been many joint tasks at various facilities, which average about one man-year per year. Two notable exceptions, where substantial joint funding has taken place, are the Japanese collaboration on the Doublet-III facility with GA Technologies, Inc., and the collaboration between the United States, Switzerland, Japan, and the Europeans on the superconducting magnet technology at the International Fusion Superconducting Magnet Test Facility (IFSMTF) at Oak Ridge National Laboratory.

Each year typically, for these facilities, there are six personnel exchanges between the United States and the Soviet Union in each direction, involving a total of 25 to 30 persons. Over 100 exchanges are executed each year, involving more than 200 persons, as part of the U.S.-Japan agreement. The Doublet-III and other portions of the U.S.-Japan agreement involve the transfer of funds and joint work in U.S. facilities. Informal exchanges have taken place with European Community (EC) laboratories since 1958. Exchanges with the European Community now are arranged between the U.S. and EC laboratories and are somewhat greater than those with Japan. The United States and the European Community now are negotiating a formal agreement.

As a member of the International Atomic Energy Agency (IAEA) and the International Energy Agency (IEA), the United States participates in multilateral activities which support fusion energy development in specific areas. The Large Coil Test at the IFSMTF at the Oak Ridge National Laboratory involves four countries and is an example of a collaboration under IEA auspices. As a consequence of the Economic Summit process, mentioned in chapter I, a Fusion Working Group was formed to foster early joint planning. This group recently has chartered subpanels to identify major future facilities, enhance near-term collaboration in physics, technology and concept improvement, and administrative impediments. The development of an international consensus on the nature of the next generation fusion device is an important objective of the Summit process.

11/ The discussion in this section is based largely on information supplied by the Department of Energy, Apr. 16, 1985.

In regard to the future, there are a number of opportunities to enhance international collaboration consistent with a strong and effective U.S. magnetic-confinement fusion program. One area is the possibility for collaboration on a large-scale, next-step fusion device. In addition, the U.S. program is pursuing a variety of opportunities that will strengthen specific elements of its program. Joint work with the European Community in the impurity control area on ASDEX-Upgrade (the Federal Republic of Germany), through the Advanced Limiter project (ALT-III) on TEXTOR (the Federal Republic of Germany), and potentially on the new long pulse device, Tore Supra (France) provides examples of international activities that strengthen the U.S. program. This is also true in regard to the Doublet-III facility and in supporting concept approaches such as the tandem mirror and stellarator facilities.

See table 3 for a list of magnetic-confinement fusion facilities and appendix 4 for brief descriptions of each of these facilities. 12/

B. INERTIAL-CONFINEMENT FUSION

In the area of inertial-confinement fusion, eight (six U.S. and two foreign) facilities have been identified, also see table 3 and appendix 4. There may be significant opportunities for international cooperation at the National Laser Users Facility ("OMEGA") of the University of Rochester, the GEKKO XII glass laser system at Osaka University in Japan, and the Central Laser Facility ("VULCAN") of the Rutherford Appleton Laboratory in the United Kingdom. The other U.S. facilities are Government facilities involved in research associated with national defense.

12/ Also see Furth, Harold P. Reaching Ignition in the Tokamak. Physics Today, v. 38, Mar. 1985. p. 52-61.

TABLE 3. Fusion Facilities

Name or Brief Description	Location or Country of Ownership
Magnetic-confinement Fusion	
PRINCETON LARGE TORUS	U.S.
PRINCETON BETA EXPERIMENT (PBX)	U.S.
TOKAMAK FUSION TEST REACTOR (TFTR)	U.S.
DOUBLET III-D	U.S.-Japan
ALCATOR C	U.S.
IMPURITY STUDIES EXPERIMENT-B (ISX-B)	U.S.
TANDEM MIRROR EXPERIMENT UPGRADE (TMX-U)	U.S.
MIRROR FUSION TEST FACILITY (MFTF-B)	U.S.
ADVANCED TOROIDAL FACILITY (ATF)	U.S.
SCYLLAC	U.S.
C-STELLARATOR	U.S.
INTERNATIONAL FUSION SUPERCONDUCTING MAGNETIC TEST FACILITY (IFSMTF)	U.S.-Int'l
JOINT EUROPEAN TORUS	E.C.
TORE SUPRA	France
TEXTOR	F.R. Germany
ASDEX	F.R. Germany
ASDEX-UPGRADE	F.R. Germany
WENDELSTEIN VII AS	F.R. Germany
JT-60	Japan
JFT-2M	Japan
GAMMA 10	Japan
HELIOTRON-E	Japan
T-10	U.S.S.R.
T-15	U.S.S.R.
Inertial-confinement Fusion	
HIGH-ENERGY LASER FACILITY ("NOVA")	U.S.
PARTICLE BEAM FUSION ACCELERATOR II (PBFA II)	U.S.
ELECTRON BEAM FUSION ACCELERATOR	U.S.
NATIONAL LASER USERS FACILITY ("OMEGA")	U.S.
HIGH-ENERGY LASER FACILITY ("ANTARES")	U.S.
HIGH-ENERGY LASER FACILITY ("SHIVA")	U.S.
GEKKO XII GLASS LASER SYSTEM	Japan
CENTRAL LASER FACILITY ("VULCAN")	U.K.

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IV. MATERIALS SCIENCE AND ENGINEERING 13/

The majority of research supported in this area is small-scale research carried out by individual scientists located at a large number of universities, national laboratories, and industrial laboratories. Only a small part of this activity involves the use of large and expensive facilities.

These same characteristics apply to similar research carried out by foreign nations. Because of the nature of materials science and engineering, international cooperation generally takes the form of informal information exchanges and research collaboration on an individual basis. In addition, the broad nature of the research and the large number of individual researchers from many countries make it difficult to estimate accurately the future potential for cooperation on a facility-by-facility basis, other than the overall assessment that it is expected to remain about the same.

In general, international cooperation in materials science and engineering research has remained constant over many years. In part, this reflects the satisfaction of the diverse scientific community with the current level of cooperation among all of the major countries involved. This level of international cooperation is expected to continue. Significant changes probably will not occur with the present generation of facilities, but may increase in the future if larger and more expensive facilities are constructed.

See table 4 for a list of materials and engineering facilities and appendix 5 for brief descriptions of each of these facilities. 14/

13/ The discussion in this chapter is based largely on information supplied by the Deparement of Energy, Apr. 16, 1985.

14/ Also see Blume, Martin and David E. Moncton. Large Facilities for Condensed-Matter Science. Physics Today, v. 38, Mar. 1985. p. 68-76.

TABLE 4. Materials Science and Engineering Facilities

Name or Brief Description	Location or Country of Ownership
NBS RESEARCH REACTOR (NBSR)	U.S.
FRANCIS BITTER NATIONAL MAGNET LABORATORY (NML)	U.S.
TANTALUS, ALLADIN	U.S.
HIGH FLUX BEAM REACTOR (HFBR)	U.S.
NATIONAL SYNCHROTRON LIGHT SOURCE (NSLS)	U.S.
STANFORD SYNCHROTRON RADIATION LABORATORY	U.S.
SPALLATION NEUTRON SOURCE	U.S.
HIGH FLUX ISOTOPE REACTOR (HFIR)	U.S.
OAK RIDGE RESEARCH REACTOR (ORR)	U.S.
CORNELL HIGH ENERGY SYNCHROTRON SOURCE (CHESS)	U.S.
INTENSE PULSED NEUTRON SOURCE	U.S.
CP-5	U.S.
AMES RESEARCH REACTOR	U.S.
UNIVERSITY OF MISSOURI RESEARCH REACTOR (MURR)	U.S.
MIT RESEARCH REACTOR	U.S.
NRU REACTOR	Canada
SYNCHROTRON RADIATION SOURCE (SRS)	U.K.
DIDO AND PLUTO REACTORS	U.K.
SPALLATION NEUTRON RESEARCH SNS	U.K.
LURE	France
HIGH FLUX REACTOR (HFR)	Fr.-F.R. Ger.-U.K.
EUROPEAN SYNCHROTRON RADIATION FACILITY (ESRF)	Fr.-F.R. Ger.
SITOE REACTOR	France
MELUSINE REACTOR	France
ORPHEE REACTOR	France
HAMBURGER SYNCHROTRON STRAHLINGSLABOR (HASYLAB)	F.R. Germany
BESSY	F.R. Germany
FRM REACTOR	F.R. Germany
FRJ-2 REACTOR	F.R. Germany
BER-II RESEARCH REACTOR	F.R. Germany
HIGH FLUX REACTOR (HFR)	Netherlands
DR3 RESEARCH REACTOR	Denmark
HIGH FLUX REACTOR	Sweden
MAX	Sweden
ADONE	Italy
AUSTRALIAN RESEARCH REACTOR HIFAR	Australia
UVSOR	Japan
KYOTO UNIVERSITY REACTOR	Japan
JAPANESE RESEARCH REACTOR NO. 2	Japan
JAPANESE RESEARCH REACTOR NO. 3	Japan
INSOR	Japan
THE PHOTON FACTORY	Japan
KEN-1	Japan
N-100	U.S.S.R.
VEPP-2M, VEPP-3 BEPP-4	U.S.S.R.
KURCHATOV I	U.S.S.R.

V. ASTRONOMY

Much radio astronomy today is, by nature, an international undertaking in that it involves very long baseline interferometry (VLBI) facilities in cooperation with other nations. Moreover, two U.S. radio astronomical facilities--the Very Large Array (VLA) and the Arecibo 1,000-foot radio/radar telescope--are unique facilities which, consequently, are used by foreign scientists who otherwise would not have access to such facilities.

U.S. optical telescopes, on the other hand, tend to be used exclusively by U.S. scientists because other nations tend to have their own. In addition, an international European consortium owns, operates, manages, and staffs the 140-inch optical telescope of the European Southern Observatory which is located in Chile.

All the U.S. astronomical facilities listed in table 5 and briefly described in appendix 6, whether heavily involved in international cooperation or not, are owned, operated, and managed by U.S. organizations and personnel.

A number of astronomical big science facilities located in space are discussed in chapter VII (see table 9) and appendix 8. Such facilities include ORBITING GEOPHYSICAL OBSERVATORIES (OGO), ORBITING SOLAR OBSERVATORIES (OSO), ORBITING ASTRONOMICAL OBSERVATORIES (OAO), HIGH-ENERGY ASTRONOMY OBSERVATORIES (HEAO), the HUBBLE LARGE SPACE TELESCOPE (LST), the GAMMA RAY OBSERVATORY (GRO), and the INTERNATIONAL ULTRAVIOLET EXPLORER (IUE). The latter is about the only example of a satellite used for physics and astronomy that is owned, operationally funded, and managed jointly by the United States and another entity, in this case the European Space Agency (ESA). The HUBBLE LARGE SPACE TELESCOPE is managed by the United States, ESA and the Federal Republic of Germany and some of the ASTROPHYSICS EXPLORER satellites involve international cooperation in various forms (see appendix 6).

TABLE 5. Astronomical Facilities

Name or Brief Description	Location or Country of Ownership
200-INCH TELESCOPE (Mount Palomar)	U.S.
1,000-FOOT RADIO/RADAR TELESCOPE (Arecibo)	U.S.
FOUR-METER TELESCOPE (Kitt Peak)	U.S.
CTIO FOUR-METER TELESCOPE (Chile)	U.S.
140-FOOT RADIO TELESCOPE (Green Bank)	U.S.
NRAO VERY LARGE ARRAY (VLA)	U.S.
SACRAMENTO PEAK OBSERVATORY (Vacuum Tower Telescope)	U.S.
140-INCH TELESCOPE	Chile-Int'l
IRAM INTERFEROMETER	Fr.-F.R. Germany
RADIO STERNWARTE EFFELSBERG (EFFELSBERG TELESCOPE)	F.R. Germany
AUSTRALIA TELESCOPE	Australia
ANGLO-AUSTRALIAN TELESCOPE	Aust.-U.K.
MM-WAVE FIVE-ELEMENT SYNTHESIS TELESCOPE	Japan
45-METER RADIO TELESCOPE	Japan
SIX-METER OPTICAL TELESCOPE	U.S.S.R.

VI. ATMOSPHERIC AND OCEANOGRAPHIC SCIENCE

In the United States, the National Center for Atmospheric Research (NCAR) was identified as the major facility for atmospheric research. No similar foreign facilities were identified. Also, the Deep Submergence Research Vehicle "ALVIN" was identified as a principal oceanographic facility exceeding the $25 million construction cost criterion.

Most of the facilities identified for atmospheric and oceanographic research are research vessels, see table 6 and appendix 7. The Federal Oceanographic Fleet consists of 64 research vessels, over half of which would cost at least $25 million (replacement cost in 1984 dollars) for construction and scientific outfitting. Because of the large number of research vessels worldwide, only the vessels of the Federal Oceanographic Fleet are identified individually in appendix 7. However, in addition to the Federal Oceanographic Fleet, there may be as many as 20 additional U.S. privately-owned research vessels and perhaps 25 research vessels belonging to academic institutions, but not part of the University-National Oceanographic Laboratory System (UNOLS) which is considered to be part of the Federal Oceanographic Fleet. 15/

Worldwide, the Soviet Union, with at least 100 oceanographic research vessels, has the largest oceanographic fleet. In the rest of the world, there are about 225 vessels, the United Kingdom having the largest number at about 50. To these research vessels should be added a number of underwater habitats, immobile manned off-shore laboratories, and submersibles, some of which are used for research.

Although a number of vessels belonging to the Federal Oceanographic Fleet cost in excess of $25 million for construction and scientific outfitting, most of the costs are not for science per se, but are "infrastructural" costs that are necessary to provide the environment in which the science can be conducted. The discussions of the "bricks and mortar" costs of space science in chapter VII and of the antarctic program in chapter XI are relevant here also.

15/ Information on the Federal Oceanographic Fleet was obtained from conversations with Captain Robertson Dinsmore, Woods Hole Oceanographic Institution and the report: Committee on Atmosphere and Oceans. Report of Federal Oceanographic Fleet Study 1984. Washington, Federal Oceanographic Fleet Coordination Council, 1985. 92 p. plus appendices. Information on research vessels worldwide was obtained from Trillo, Robert L. (ed.). Jane's Ocean Technology, 1978. New York, Franklin Watts, Inc., 1978. 820 p.

TABLE 6. Atmospheric and Oceanographic Facilities

Name or Brief Description	Location or Country of Ownership
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (NCAR)	U.S.
DEEP SUBMERGENCE RESEARCH VEHICLE (DSRV) "ALVIN"	U.S.
FEDERAL OCEANOGRAPHIC FLEET (64 vessels)	U.S.

VII. SPACE

In considering big science facilities, both space and antarctic research (discussed in chapter XI) must be discussed carefully in order to distinguish between the infrastructure required to support the big science facilities and the big science facilities themselves. In this report, the space shuttles, for example, are not included as big science facilities because they are, in effect, trucks to take things into orbit, even if those things are scientific experiments. Nor are launch pads, tracking stations, and other infrastructure included in this inventory (see section A).

What are included here as big science facilities are satellites which conduct physics and astronomical research, lunar and planetary exploration, and Earth science. These are discussed in section B. Sections C and D deal with European and Japanese space big science programs, and Soviet space big science programs, respectively.

A. NASA INFRASTRUCTURE AND SCIENCE 16/

Since 1959 when NASA began operating, a number of major infrastructural programs have been funded. It is important to emphasize for the purpose of this report that these programs are not science programs per se, although they are necessary for the conduct of the big science projects discussed below. For example, in 1959-1961, major NASA efforts were directed toward the support of tracking and data facilities needed for the Mercury Program. During this period, both the Jet Propulsion Laboratory in Pasadena, California and the Wallops Flight Facility at Wallops Island, Virginia were expanded to support adequately NASA's space science programs, and the new Goddard Space Flight Center in Maryland begun operations.

From 1961-1968, the major NASA thrust was for the Apollo program. Projects included establishing a full range of support facilities, that is, manufacturing facilities, propulsion test facilities, development of the Saturn family of launch vehicles, land acquisitions, launch complexes at Kennedy Space Center, Florida, and construction of another new NASA field center (Johnson Space Center, Texas, which was completed in 1964).

16/ Some information in this section was provided by the NASA Facilities Engineering Division, Apr. 1985.

In 1969, major additions were made to the Deep Space Network tracking and data facilities in Australia and Spain. In the early 1970s, NASA's attention turned to development of the Skylab space station which was launched in 1973 and hosted three crews between 1973 and 1974. In 1972, President Nixon approved the space shuttle program, and the first shuttle flight was made in 1981. Currently, NASA is designing a permanent space station to begin operations in the early 1990s in accordance with President Reagan's 1984 State of the Union address in which he directed NASA to develop a permanent manned presence in space within a decade.

During 1977-1981, NASA constructed the National Transonic Facility in Langley, Virginia and modified the 40x80 Foot Subsonic Wind Tunnel at Ames, California. These latter facilities directly support NASA's aeronautical research program and are discussed in chapter VIII.

Most of NASA's budget is not for science per se; rather, it is for science infrastructure, as the term is used here, and for applications. Table 7 indicates that space science has accounted for about 10 to 20 percent of the total NASA budget since 1960. Because space big science is only part of total space science, these figures represent the upper limits of NASA's budgets which were devoted to big science during this period.

B. NASA BIG SCIENCE

The NASA big science program encompasses three major areas: physics and astronomy, planetary probes, and Earth science. These three categories include programs begun since 1959, both operational and defunct, ongoing operations as well as launches, and programs which are under development.

The programs not considered to be "big science" for the purpose of this report, which does not in any way detract from their importance to the overall NASA program, include space applications projects (including weather, communications, and land and ocean remote sensing) and the Mercury, Gemini, Apollo, Skylab, and space shuttle missions. Although very important scientific work was done on many of these missions, they are outside the scope of the big science perspective of this report. Also many programs which currently are in the planning stages, such as the International Solar Terrestrial Physics Program (ISTP), are not included because they may not have specific launch dates or because only "planning" funding, and not "development" funding, has been provided. Since these programs may be terminated for any reason without ever having demonstrated a big science purpose, they are not included here. Finally, some missions, such as the Solar Mesosphere Explorer, did not meet the minimum $25 million criterion.

The United States has actively engaged in international cooperation in space since the earliest days of NASA. Section 205 of the National Aeronautics and Space Act of 1958 provides for the conduct of international cooperative programs and, since then, NASA estimates

TABLE 7. Funding for Space Science as a Percentage of Total NASA Budget

Fiscal Year	Total NASA Appropriation a/	Amount for Space Science a/	Percentage for Space Science
1959	184.3	95.5	51.8
1960	523.6	105.6	20.2
1961	964.0	193.3	20.1
1962	1,825.3	345.8	18.9
1963	3,674.1	482.6	13.1
1964	5,099.7	561.2	11.0
1965	5,249.7	554.5	10.6
1966	5,174.9	595.0	11.5
1967	4,967.6	486.9	9.8
1968	4,588.9	428.1	9.3
1969	3,995.3	363.5	9.1
1970	3,749.2	403.1	10.8
1971	3,312.6	400.2	12.1
1972	3,310.1	562.1	17.0
1973	3,407.6	661.4	19.4
1974	3,039.7	681.5	22.4
1975	3,231.1	590.1	18.3
1976	3,551.8	601.5	16.9
Transition Quarter	932.2	157.4	16.9
1977	3,819.1	555.5	14.5
1978	4,063.7	528.6	13.0
1979 (estimate)	4,566.2	625.0	13.7
1980 (request)	4,725.0	726.8	15.4

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a/ NASA Budget Office.

Source: U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. United States Civilian Space Programs 1958-1978. Volume I. Committee Print. 97th Cong., 1st Sess. Washington, U.S. Govt. Print. Off., 1981. p. 716.

that it has signed more than 1000 agreements with more than 100 countries for cooperative activities. Many of these are related to scientific training, analysis of remote sensing data, analysis of soil samples returned by the Apollo missions to the Moon, and so forth, but there also are many instances of cooperative development of "big science" spacecraft. As noted in appendix 8, many of the EXPLORER missions involved international cooperation, the United States has launched satellites such as HELIOS which were developed entirely by other countries (in that case, by the Federal Republic of Germany), with data exchange as the quid pro quo, equipment has been developed jointly for some missions (for example, the INTERNATIONAL SUN-EARTH EXPLORERS), and so forth. International cooperation in space has grown as the economic situations in most countries have made it difficult for a single country to afford "big science" projects and as some countries, especially those in Europe and Japan, have developed their own expertise in building spacecraft.

No space big science projects supported by the Department of Defense, which now has a larger space R&D budget than NASA, have been identified. Table 8 shows the funding levels of the space activities of the U.S. Government. The U.S. and foreign space big science projects are listed in table 9 and discussed briefly in appendix 8.

C. EUROPEAN AND JAPANESE SPACE BIG SCIENCE PROGRAMS

Most, if not all, of the space big science in the rest of the world has been conducted recently by the European Space Agency (ESA). The big question is cost. It is difficult to be certain that any of the foreign space programs meet the $25 million criterion, although the individual ESA programs probably do. For Japan and specific European countries, space big science programs are included because cumulatively, at least, these programs probably meet the dollar cost criterion.

D. SOVIET SPACE BIG SCIENCE PROGRAMS

International cooperation in the Soviet space big science program began in 1967. In 1967, the U.S.S.R. and its allies formed the INTERKOSMOS organization, comprised of the U.S.S.R., Bulgaria, Cuba, Czechoslovakia, the Democratic Republic of Germany, Hungary, Mongolia, Poland, and Romania. Vietnam was added in 1979, although it has not yet participated in any big science programs. The INTERKOSMOS flights, IK-1 through IK-22 have been the most extensive space big science launches. Other programs include the recent VEGA flights with France.

Even including the INTERKOSMOS and VEGA programs, the U.S.S.R. has had fewer big science satellites with less international cooperation than have the United States or ESA. In lunar and planetary probes, the United States has gone farther and to more planets while the Soviets have concentrated on Venus and Mars. The Soviets have had more lunar orbiters and landers, but have not yet landed a man

TABLE 8.

Space Activities of the U.S. Government

HISTORICAL BUDGET SUMMARY—BUDGET AUTHORITY

(in millions of dollars)

Fiscal Year	NASA Total	NASA Space[a]	Defense	Energy	Commerce	Interior	Agriculture	NSF	Total Space
1959	330.9	260.9	489.5	34.3					784.7
1960	523.6	461.5	560.9	43.3				0.1	1,065.8
1961	964.0	926.0	813.9	67.7				.6	1,808.2
1962	1,824.9	1,796.8	1,298.2	147.8	50.7			1.3	3,294.8
1963	3,673.0	3626.0	1,549.9	213.9	43.2			1.5	5,434.5
1964	5,099.7	5,016.3	1,599.3	210.0	2.8			3.0	6,831.4
1965	5,249.7	5,137.6	1,573.9	228.6	12.2			3.2	6,955.5
1966	5,174.9	5,064.5	1,688.8	186.8	26.5			3.2	6,969.8
1967	4,965.6	4,830.2	1,663.6	183.6	29.3			2.8	6,709.5
1968	4,587.3	4,430.0	1,921.8	145.1	28.1	0.2	0.5	3.2	6,528.9
1969	3,990.9	3,822.0	2,013.0	118.0	20.0	.2	.7	1.9	5,975.8
1970	3,745.8	3,547.0	1,678.4	102.8	8.0	1.1	.8	2.4	5,340.5
1971	3,311.2	3,101.3	1,512.3	94.8	27.4	1.9	.8	2.4	4,740.9
1972	3,306.6	3,071.0	1,407.0	55.2	31.3	5.8	1.6	2.8	4,574.7
1973	3,406.2	3,093.2	1,623.0	54.2	39.7	10.3	1.9	2.6	4,824.9
1974	3,036.9	2,758.5	1,766.0	41.7	60.2	9.0	3.1	1.8	4,640.3
1975	3,229.1	2,915.3	1,892.4	29.6	64.4	8.3	2.3	2.0	4,914.3
1976	3,550.3	3,225.4	1,983.3	23.3	71.5	10.4	3.6	2.4	5,319.9
Transitional Quarter	931.8	849.2	460.4	4.6	22.2	2.6	.9	.6	1,340.5
1977	3,817.8	3,440.2	2,411.9	21.7	90.8	9.5	6.3	2.4	5,982.8
1978	4,060.1	3,622.9	2,738.3	34.4	102.8	9.7	7.7	2.4	6,518.2
1979	4,595.5	4,030.4	3,035.6	58.6	98.4	9.9	8.2	2.4	7,243.5
1980	5,240.2	4,680.4	3,848.4	39.6	92.6	11.7	13.7	2.4	8,688.8
1981	5,518.4	4,992.4	4,827.7	40.5	87.0	12.3	15.5	2.4	9,977.8
1982	6,043.9[b]	5,527.6	6,678.7	60.6	144.5	12.1	15.2	2.0	12,440.7
1983	6,875.3[c]	6,327.9	9,018.9	38.9	177.8	4.6	20.4	0.0[d]	15,588.5
1984 est	7,217.5	6,590.4	10,590.3	34.1	234.8	4.7	23.0	0.0[d]	17,477.3
1985 est	7,491.4	6,804.3	12,912.7	33.5	254.6	4.2	16.0	0.0[d]	20,025.3

[a] Excludes amounts for air transportation (subfunction 402).
[b] Includes $33.5 million unobligated funds that lapsed
[c] Includes $37.6 million for reappropriation of prior year funds
[d] NSF funding of balloon research transferred to NASA

SOURCE: Office of Management and Budget

Source: National Aeronautics and Space Administration. Space Report of the President: 1983 Activities. Washington, U.S. Govt. Print. Off., 1984. p. 100.

TABLE 9. Space Facilities

Name or Brief Description	Location or Country of Ownership
Physics and Astronomy	
ORBITING GEOPHYSICAL OBSERVATORIES (OGO)	U.S.
ORBITING SOLAR OBSERVATORIES (OSO)	U.S.
ORBITING ASTRONOMICAL OBSERVATORIES (OAO)	U.S.
ASTROPHYSICS EXPLORERS	U.S.-Int'l
HIGH-ENERGY ASTRONOMY OBSERVATORIES (HEAO)	U.S.
SOLAR MAXIMUM MISSION	U.S.
THE HUBBLE LARGE SPACE TELESCOPE (LST)	U.S.
COSMIC BACKGROUND EXPLORER (COBE)	U.S.
GAMMA RAY OBSERVATORY (GRO)	U.S.
EXTREME ULTRAVIOLET EXPLORER (EUVE)	U.S.
COS-B	E.S.A.-Int'l
INTERNATIONAL ULTRAVIOLET EXPLORER (IUE)	E.S.A.-U.S.
EXOSAT	E.S.A.
HIPPARCOS	E.S.A.
ARIEL 1-6	U.K.
JAPANESE SATELLITES	Japan
ASTRON	U.S.S.R.
Lunar and Planetary Probes	
RANGER	U.S.
SURVEYOR	U.S.
LUNAR ORBITER	U.S.
PIONEER 10 AND 11	U.S.
VIKING 1 AND 2 (ORBITERS 1 AND 2)	U.S.
VOYAGER I AND II	U.S.
PIONEER/VENUS (ORBITER AND PROBE)	U.S.
GALILEO (JUPITER ORBITER/PROBE)	U.S.-F.R. Ger.
VENUS RADAR MAPPER (VRM)	U.S.
MARS GEOSCIENCE CLIMATOLOGY OBSERVER (MGCO-MARS OBSERVER)	U.S.
MARINER I-X	U.S.
GEOS-1 AND GEOS -2	E.S.A.
GIOTTO	E.S.A.
INTERNATIONAL SOLAR-POLAR MISSION (ISPM)	E.S.A.
VEGA 1 AND 2	U.S.S.R.
MARS 1-7	U.S.S.R.
LUNA 1-24	U.S.S.R.
VENERA 1-16	U.S.S.R.
Earth Science	
SOLAR-TERRESTRIAL EXPLORERS	U.S.-Int'l
EARTH RADIATION BUDGET EXPERIMENT (ERBE)	U.S.
UPPER ATMOSPHERIC RESEARCH SATELLITE (UARS)	U.S.

TABLE 9. SPACE FACILITIES (continued)

Name or Brief Description	Location or Country of Ownership
Solar and Terrestrial Physics	
INTERKOSMOS 1-22	U.S.S.R.
PROGNOZ 1-9	U.S.S.R.

on the Moon. U.S. missions generally are more complex and U.S. international cooperation has been more tangible since the International Geophysical Year in 1958. When it comes to tracking and data analysis (items which usually are not included in big science, but which are crucial for its development), the United States has a far more extensive network with many more countries participating. Similarly, many countries eventually will have the opportunity to use the HUBBLE LARGE SPACE TELESCOPE after it is operational.

The Soviet space big science programs included here have their equivalents in the NASA and ESA programs and are serious efforts to broaden Soviet knowledge of space. What hampers an understanding of the Soviet big science program in space is the lack of hard information on many of their programs. This is particularly true of the cost data and of information on land-based facilities such as wind tunnels and observatories.

VIII. AERONAUTICS

This chapter deals with big science facilities in the area of aeronautics. This includes principally wind tunnels, other flight simulators, and facilities for structures research and development and flight testing. Many of these facilities may be engaged to a significant extent in big engineering science and could have been included in chapter X and appendix 11 just as appropriately as here.

All but one of the big science facilities discussed in this chapter are U.S. facilities, the exception being a Japanese wind tunnel. No other foreign aeronautical big science facilities meeting the $25 million criterion have been identified. The facilities are listed in table 10 and discussed briefly in appendix 9. The majority of the wind tunnels and flight simulators are operated by NASA, although the Navy operates two wind tunnels, the Air Force four, and the Air Force and Army each operate one flight simulator facility.

The NASA wind tunnel and flight simulator program is defined as advancing knowledge of aerodynamics, aviation, and aerospace. Many of these facilities were constructed in the 1940s and 1950s, with funding provided in later years for modifications and updates. The most recent wind tunnel facility is the National Transonic Facility at Langley Research Center, built in 1982. The National Transonic Facility is a state-of-the-art facility used for the most advanced aerospace testing programs. Of the remaining NASA facilities, several are complexes of smaller wind tunnel projects which NASA considers as together constituting single facilities.

All of the NASA facilities included here have the classic big science purpose of "science for science's sake," with two important qualifications. The first is that, although the stated need and purpose of the facilities are for science, there is some crossover into testing of instrumentation, maneuverability of aircraft, and testing of vertical rising aircraft. This is true of almost all of the facilities listed here. Their primary purpose, however, as defined by NASA, is for conducting science. Second, the percentage of use of these facilities for civil, proprietary and cooperative, and military purposes when known, are given in the appendix. Although for several of these facilities the non-NASA use is somewhat high, these facilities still are considered to be used primarily for science. Even the 8x6 Tran/Supersonic Tunnel at Lewis Research Center with 55 percent use by civil, proprietary, and cooperative ventures, is still considered by NASA as being a basic research center.

TABLE 10. Aeronautical Facilities

Name or Brief Description	Location or Country of Ownership
AERONAUTICAL FACILITIES	
Wind Tunnels	
NATIONAL TRANSONIC FACILITY	U.S.
UNITARY PLAN WIND TUNNEL (Langely)	U.S.
16-FOOT TRANSONIC WIND TUNNEL	U.S.
TRANSONIC DYNAMICS TUNNEL	U.S.
HYPERSONIC WIND TUNNEL COMPLEX	U.S.
EIGHT-FOOT HIGH-TEMPERATURE HYPERSONIC WIND TUNNEL	U.S.
EIGHT-FOOT TRANSONIC PRESSURE WIND TUNNEL	U.S.
20-INCH MACH 6 WIND TUNNEL	U.S.
HYPERSONIC WIND TUNNEL COMPLEX	U.S.
LOW-SPEED WIND TUNNEL COMPLEX	U.S.
UNITARY PLAN TUNNEL COMPLEX (Ames)	U.S.
14-FOOT TRANSONIC WIND TUNNEL	U.S.
6x6 SUPERSONIC WIND TUNNEL	U.S.
3.5-FOOT HYPERSONIC WIND TUNNEL	U.S.
8x6 TRAN/SUPERSONIC WIND TUNNEL	U.S.
10x10 UNITARY SUPERSONIC PROPULSION WIND TUNNEL	U.S.
6x9-FOOT ICING RESEARCH TUNNEL (IRT)	U.S.
AERODYNAMIC RESEARCH FACILITY	U.S.
16-FOOT SUPERSONIC PROPULSION WIND TUNNEL	U.S.
16-FOOT TRANSONIC PROPULSION WIND TUNNEL	U.S.
VON KARMAN SUPERSONIC WIND TUNNELS	U.S.
DTNSRDC TRANSONIC WIND TUNNEL	U.S.
HYPERVELOCITY WIND TUNNEL NO. 9	U.S.
V/STOL WIND TUNNEL	U.S.
TRAN/SUPERSONIC WIND TUNNEL	U.S.
TWO-METER TRANSONIC WIND TUNNEL	Japan
Structures R&D/Flight Testing	
STRUCTURES RESEARCH AND DEVELOPMENT FACILITY	U.S.
COMPRESSOR RESEARCH FACILITY	U.S.
AERONAUTICAL TEST RANGE	U.S.
Flight Simulators	
FLIGHT CONTROL DEVELOPMENT LABORATORY	U.S.
DIFFERENTIAL MANEUVERING SIMULATOR	U.S.
SIX-DEGREE-OF-FREEDOM MOTION SIMULATOR	U.S.
FLIGHT SIMULATOR FOR ADVANCED AIRCRAFT	U.S.
VERTICAL MOTION SIMULATOR	U.S.
PROPULSION SYSTEMS LABORATORY	U.S.
ADVANCED SIMULATION CENTER	U.S.

In assessing the potential of the wind tunnel and flight simulator program for future international cooperation, the civil, proprietary, cooperative, and military uses of these facilities should be a serious factor for consideration. Such uses may inhibit international cooperation, particularly if the proprietary and military nature of these facilities is tied in with national goals of increased U.S. national security and international economic competitiveness.

IX. SUPERCOMPUTERS

Large-scale scientific computers--or supercomputers--play a critical role in scientific and engineering research. These ultrafast "number crunchers" are used for modeling and simulating scientific and engineering problems in areas such as design and simulation of very large-scale integrated circuits; design of nuclear weapons; design and analysis of nuclear reactors; magnetic fusion energy research; aerodynamic design and evaluation; meteorological forecasting; and petroleum exploration.

The U.S. Government supports scientific research by providing access for researchers to state-of-the-art supercomputers in Federal laboratories and facilities such as the National Center for Atmospheric Research computing facility, the National Magnetic Fusion Energy Computing Center at Lawrence Livermore National Laboratory, and the Los Alamos National Laboratory computing center.

In 1985, the Department of Energy began support of the Superconducting Computational Research Institute at Florida State University. Also recently, the National Science Foundation announced its plans to establish four National Advanced Scientific Computing Centers at Princeton University, Cornell University, the University of Illinois, Urbana-Champaign, and the University of California, San Diego.

These supercomputer facilities are listed in table 11 and discussed briefly in appendix 10. 17/

The levels of international cooperation at the existing facilities currently seems to be minimal.

17/ Also see U.S. Library of Congress. Congressional Research Service. Supercomputers and Artificial Intelligence: Recent Federal Initiatives, Issue Brief 85105 (continually updated).

TABLE 11. Supercomputers

Name or Brief Description	Location or Country of Ownership
NCAR SCIENTIFIC COMPUTING FACILITY	U.S.
NATIONAL MAGNETIC FUSION ENERGY COMPUTING CENTER (LLNL)	U.S.
LANL COMPUTING AND COMMUNICATIONS DIVISION	U.S.
NOAA GEOPHYSICAL FLUID DYNAMICS LABORATORY	U.S.
NASA NUMERICAL AERODYNAMIC SIMULATOR (NAS)	U.S.
NATIONAL ADVANCED SCIENTIFIC COMPUTER CENTER:	
-- Princeton University	U.S.
-- Cornell University	U.S.
-- University of Illinois, Urbana-Champaign	U.S.
-- University of California, San Diego	U.S.
FSU SUPERCONDUCTING COMPUTATIONAL RESEARCH INSTITUTE	U.S.
LLNL COMPUTER CENTER	U.S.

X. ENGINEERING SCIENCE

As mentioned previously, this study attempts to include big engineering science facilities as well as "classical" big science facilities devoted primarily to pure research. This is done for three reasons. First, much engineering science is conducted in the "classical" big science facilities like those involved in high-energy physics research. Second, the Committee is interested both in the "big" of big science and in its international aspects. Engineering science can be both big and international in scope. Third, engineering science explicitly has become a major thrust of current science policy, as evidenced by the reorganization of the National Science Foundation to include a Directorate of Engineering and the establishment of federally-supported Engineering Research Centers (ERCs) at major universities under that Directorate. The recent congressional interest in legislation proposing the creation of a national technology foundation or similar organizations is further evidence of the importance of engineering science in current science policy.

With that in mind, 18 big engineering science facilities were identified in several areas, including ship hydrodynamics engineering, earthquake engineering, nuclear power reactor engineering, radio isotope production, and weapons engineering. Three of these facilities are foreign. Because of the difficulty in identifying such facilities, others, both U.S. and foreign, may be identified subsequently.

It should be noted here that, in the same way that much engineering science is inherent in the facilities discussed in preceding chapters and labeled "big science" facilities, much pure science probably is inherent in many of the facilities listed in table 12 and discussed briefly in appendix 11 as "big engineering" facilities. Also, as noted previously, many of the aeronautical facilities discussed in chapter VIII may be engaged to a significant extent in big engineering science and could be included in this chapter just as well as in chapter VIII.

There is no international ownership, operational funding (with the following three exceptions), or management of the identified big engineering science facilities, and there appears to be no adequate generalization about international cooperation in their use. There is Japanese operational funding involved in the Fast Flux Test Facility at the Hanford Engineering Development Laboratory and the Experimental Breeder Reactor II at Argonne National Laboratory and international operational funding of the Loss-of-Fluid Test Facility (LOFT) at Idaho National Engineering Laboratory. Reference can be made to the discussions of the individual facilities in appendix 11.

TABLE 12. Engineering Facilities

Name or Brief Description	Location or Country of Ownership
Ship Hydrodynamics Engineering	
DTNSRDC TOWING BASIN, HIGH SPEED	U.S.
DTNSRDC TOWING BASIN, DEEP WATER	U.S.
DTNSRDC TOWING BASIN, SHALLOW WATER	U.S.
Earthquake Engineering	
TODOTSU ENGINEERING LABORATORY (Earthquake Shake Table)	Japan
Nuclear Power Reactor Engineering	
FAST FLUX TEST FACILITY (FFTF)	U.S.
EXPERIMENTAL BREEDER REACTOR II (EBR-II)	U.S.
LOSS-OF-FLUID TEST FACILITY (LOFT)	U.S.
TRANSIENT REACTOR TEST FACILITY (TREAT)	U.S.
ZERO POWER PLUTONIUM REACTOR (ZPPR)	U.S.
JOYO (Fast Flux Test Facility)	Japan
BOR-60 (Fast Flux Test Reactor)	U.S.S.R.
Isotope Production	
CALUTRONS ELECTROMAGNETIC ISOTOPE SEPARATIONS FACILITY	U.S.
Weapons Engineering	
SHIVA (High-energy Physics Simulation)	U.S.
DIRECTED ENERGY EFFECT RANGE (DEER)	U.S.
TRESTLE (Electromagnetic Pulse Research)	U.S.
ADVANCED RADIATION TECHNOLOGY FACILITY (ARTF)	U.S.
AURORA RADIATION TEST FACILITY	U.S.
ADVANCED TEST ACCELATOR (ATA)	U.S.

XI. ANTARCTIC RESEARCH 18/

As discussed in the chapter on space, both space and antarctic research involve large amounts of funds, for work classified as research and development, that are expended for what may be characterized best as R&D infrastructure. Although such infrastructural facilities may fall within the "big" of big science, they are not themselves scientific facilities. The space shuttles are an example. A similar situation obtains in antarctic research.

The U.S. program in the Antarctic includes a physical plant in the form of station facilities, ships, and aircraft. Since there are no indigenous sources of life support or other logistics in Antarctica, the U.S. effort must provide everything needed to reach the area and to exist and function there. The U.S. Antarctic Program (USAP) supports national goals to maintain the Antarctic Treaty, to ensure that the continent continues to be used for peaceful purposes only, to foster internationally cooperative research, to protect the environment, and to ensure equitable and wise use of living and nonliving resources. The U.S. scientific research program continues to be the principal expression of national interest and policy in the Antarctic. Several of the specific elements of the USAP logistics and science support system probably would satisfy the $25 million criterion of the inventory, although others of equal significance would not.

The research supported in Antarctica is broadly multidisciplinary, reflects the involvement of a wide variety of institutions and Federal agencies, and includes substantial international cooperation. 19/

18/ Much of the discussion in this chapter is based on information supplied by the National Science Foundation, Apr. 1985.

19/ Further information on the USAP is included in U.S. Congress. House. Committee on Appropriations. Dept. of Housing and Urban Development--Independent Agencies Appropriations for 1984. Hearings, 98th Cong. 1st sess. Washington, U.S. Govt. Print. Off., 1983. p. 444-463.

XII. BIOTECHNOLOGY

No big science facilities in the area of biotechnology have been identified for this inventory. The subject has been included here, however, because the potential exists for such facilities to be developed over the next five to ten years according to some experts in the field. Should this occur, it would represent a further extension of the classical definition of big science from "pure" areas like high-energy physics into more applied and engineering-oriented areas. In terms of construction costs, biotechnology "big science" facilities in the near-term future likely would be in the neighborhood of the $25 million level. Because of the commercial nature of much biotechnology, perhaps much of the potential international cooperation in this area would be carried out through multinational corporations rather than through international agreements or practices between governments and agencies.

APPENDIX 1

INTERNATIONAL BIG SCIENCE COOPERATION SUPPORTED UNDER THE SUMMIT SCIENCE AND TECHNOLOGY INITIATIVE 20/

(1) Solar System Exploration (U.S. lead). Under this project coordinated by NASA, two primary areas of solar system exploration have been identified: solar terrestrial research and the study of planets and small bodies. NASA, the European Space Agency (ESA) and Japanese representatives of the planning group in the new International Solar Terrestrial Physics Program (ISTP) met twice this year to coordinate design studies of spacecraft and ground systems. Under this Summit project, three joint studies are underway concerning planetary and small bodies missions, a joint U.S.-Germany CRAF mission, a joint NASA-ESA mission to Saturn and its moon Titan, and a NASA-ESA study on primitive body missions.

(2) Remote Sensing from Space (U.S. lead). In 1984, under NOAA's guidance, this project made substantial progress towards its objective to enhance international collaboration in remote sensing activities. The project's panel members established a streamlined remote sensing coordination group, which met in September and a group on meteorological satellite cooperation, which met in November. In October, the countries involved in the satellite search and rescue program, COSPAS-SARSAT, signed an agreement which assures services through 1990. Discussions were also held regarding provision of new remote sensing instruments for flight on the shuttle or satellites. Also, plans are well underway for holding remote sensing training activities for developing countries.

(3) High-Energy Physics (U.S. lead). Under DOE's leadership, this project aims to further international cooperation in high-energy physics. During 1984, subgroups met to survey high energy physics plans and programs among Summit nations and to develop long-term, cooperative plans for construction and sharing of new, major facilities. Other groups assessed research underway in accelerator and detector technology areas and explored mechanisms for facilitating international collaboration.

20/ Science, Technology, and American Diplomacy, 1985: Sixth Annual Report Submitted to the Congress by the President Pursuant to Sec. 503(b) of Title V of Public Law 95-426, Mar. 20, 1985. p. 15-17.

APPENDIX 1 (continued)

INTERNATIONAL BIG SCIENCE COOPERATION SUPPORTED UNDER THE SUMMIT SCIENCE AND TECHNOLOGY INITIATIVE

(4) Controlled Thermonuclear Fusion (U.S.-European Communities co-lead). The objectives of this project under DOE guidance are to accelerate world development of a new energy source, using inexhaustible fuels and possessing potential environmental advantages, and avoid duplication of costly facilities through joint collaboration. In 1984, subpanels met to identify and plan future facilities required to establish the feasibility of fusion, to identify near-term fusion physics and technology subjects for collaboration, and explore reactor concept improvements.

(5) Fast Breeder Reactor Design (U.S.-France co-lead). Under DOE's purview, this project aims to provide a stable and supportive atmosphere for facilitating orderly breeder development. In 1984, expanded governmental understandings were reached within Europe for breeder cooperation, and the project's participants are examining other cooperative arrangements among this group.

(6) Advanced Materials and Standards (U.S.-U.K. co-lead). This project, under NBS leadership. promoted multilateral collaboration in advanced engineering materials to develop measurement standards and codes of practice for these materials. By harmonizing the regulatory systems for advanced technologies, the interest of free, competitive trade will be advanced. Four technical working groups have been launched in the areas of Wear Test Methods, Surface Chemical Analyses, Ceramics, and Polymer Alloys or Blends.

APPENDIX 2

HIGH-ENERGY PHYSICS FACILITIES

For U.S. facilities, the values in fiscal year 1984 dollars are estimated by escalating construction costs, except where the replacement value is estimated in several cases. Due to advances in technology, the cost of accelerator replacement would, in most cases, be much lower than escalated construction costs. In addition, if the costs of U.S. facilities are compared to those of foreign facilities, it should be recognized that it is common practice abroad not to include as construction costs the cost of laboratory manpower and laboratory services, such as machine shops. Such costs can account for one-half of the cost of a construction project in high-energy physics.

The information in this appendix was supplied by the Department of Energy, April 22, 1985.

Ithaca, NY., U.S.A.

CORNELL ELECTRON STORAGE RING (CESR)
Floyd R. Newman Laboratory for Nuclear Studies
Cornell University

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: CESR is an 8 GeV x 8 GeV electron-positron colliding beam storage ring facility. It has two interaction regions. In one, the focus of research has been the study of leptons and photons using a segmented sodium iodide detector (CUSB). The other region contains a large magnetic general purpose detector (CLEO) with which almost everything known about the bottom quark has been learned.

Date of Construction: 1977-79 (operational since 1979).

Construction Cost: Original: $20.7 million
1984 $$: $28 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: Mainly U.S. (105 scientists from 11 institutions).

Potential for Future International Cooperation: The Cornell superconducting radio-frequency cavity technology has been shared through collaborations with European and Japanese laboratories. High energy physics has led the way with a long tradition of active and intimate international cooperation.

Other Information: A major comprehensive improvement plan has been initiated to be completed in FY87 which incorporates storage ring and detector upgrades. The upgrades will provide the capability to perform the most precise experiments possible in the CESR energy range. The estimated cost of these improvements is about $36 million. The facility will continue to be open to national and international researchers on the basis of scientific merit of the experiments proposed.

Batavia, IL., U.S.A.

FERMILAB PROTON SYCHROTRON
Fermi National Accelerator Laboratory (Fermilab)
U.S. Dept. of Energy

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This conventional magnet synchrotron of 6000-foot diameter provided protons at 400 billion electron volts (GeV), which was twice the design energy, and various secondary beams from fixed targets. It is now used at 150 GeV as an injector into the new superconducting synchrotron which upgraded the facility under the Energy Saver project, described separately. Other upgrades include Tevatron I and Tevatron II, also described separately, which integrate extensive new capabilities into the Fermilab accelerator complex.

Date of Construction: 1968-1974

Construction Cost: Original: $248 million
1984 $$: $727 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: Largely U.S., but includes Argentina, Belgium, Brazil, Canada, China, England, France, Greece, India, Israel, Italy, Japan, Mexico, Poland, South Korea, Spain, Sweden, Switzerland, the U.S.S.R., the Federal Republic of Germany, and Yugoslavia

Because high-energy physics is an international activity, with knowledge freely shared among its practitioners, this laboratory has extensive interactions with people and institutions in foreign countries.

Of 348 experiments approved to run at Fermilab, 148 have had scientists taking part from institutions outside the United States. Typically, about 600 physicists are involved in the Fermilab research program each year, of which over one-fourth are from foreign institutions. Generally, scientists from about 20 countries are involved in the program at any one time.

There are three government-to-government agreements involving high-energy physics which affect Fermilab. These are with the U.S.S.R., the Peoples Republic of China, and Japan.

Potential for Future International Cooperation: As at all forefront world highenergy physics facilities, beam time is available without charge for the best research proposals worldwide. Foreign researchers have provided substantial pieces of capital equipment for experiments. Such collaboration would be expected to continue.

Batavia, IL., U.S.A.

ENERGY SAVER - SUPERCONDUCTING PROTON SYNCHROTRON
Fermi National Accelerator Laboratory (Fermilab)
U.S. Dept. of Energy

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: The Energy Saver project provided a ring of over 1000 superconducting magnets which operate at reduced electric power consumption and have the potential for 1000 GeV operation. The conventional magnet accelerator serves as a 150 GeV injector for the Energy Saver accelerator ring. The Energy Saver was designed to deliver 500 GeV protons to three external experimental areas and protons at about 800 GeV to an internal target. The Energy Saver is now operating routinely as part of the overall Fermilab Tevatron capability.

Date of Construction: 1979-1982

Construction Cost: Original: $50.8 million
1984 $$: $67 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: (See the Fermilab Proton Synchrotron on the preceding page for a list of international researchers and a discussion of international cooperation.)

Potential for Future International Cooperation: See the discussions under the Fermilab Proton Synchrotron on the preceding page.

Batavia, IL., U.S.A.

TEVATRON I - ANTIPROTON/PROTON COLLIDING BEAM FACILITY
Fermi National Accelerator Laboratory (Fermilab)
U.S. Dept. of Energy

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: The Tevatron I is an upgrade of the Energy Saver to reach a 1000 GeV acceleration capability and to allow the storage of protons and antiprotons simultaneously. This will provide up to 2000 GeV in reaction energy when two beams collide head-on, to open up a new era of important research opportunities at the highest energies ever made available for laboratory physics experimentation.

Date of Construction: 1981-1986

Construction Cost: Original: $84.0 million
1984 $$: $85.5 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: (See the Fermilab Proton Synchrotron for a list of international researchers and a discussion of international cooperation.)

In addition, R&D on the lithium lens system for the antiproton source represented a significant cooperative effort with the U.S.S.R., and the Collider Detector Facility at Fermilab represents an outstanding example of a joint effort with Japan and Italy.

Potential for Future International Cooperation: See the discussion under the Fermilab Proton Synchrotron.

Batavia, IL., U.S.A.

TEVATRON II - 1000 GeV FIXED TARGET RESEARCH FACILITIES
Fermi National Accelerator Laboratory (Fermilab)
U.S. Dept. of Energy

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: The Tevatron II provides the necessary facilities for a 1000 GeV fixed target experimental program in existing areas to fully exploit the higher energy of the superconducting accelerator complex, now referred to as the Tevatron. Tevatron II provides a unique opportunity for producing secondary particle beams at higher energies and intensities than anywhere else in the world. There are four new secondary beams and eight other upgraded beams. These 12 can be run simultaneously. The eight upgraded beams are completed and operating.

Date of Construction: 1982-1986

Construction Cost: Original: $49.0 million
1984 $$: $50.3 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: (See the Fermilab Proton Synchrotron for a list of international researchers and a discussion of international cooperation.)

Potential for Future International Cooperation: See the discussion under the Fermilab Synchrotron.

Batavia, IL., U.S.A.

COLLIDER DETECTOR AT FERMILAB (CDF)
Fermi National Accelerator Laboratory (Fermilab)
U.S. Dept. of Energy

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This versatile research detector is capable of recording the results of antiproton-proton collisions at reaction energies up to 2000 GeV; detecting hundreds of simultaneously created particles; and identifying photons, electrons, muons, and hadrons separately. It measures energies of charged particles with a strong magnetic field and of all particles (except neutrions) with massive calorimeters.

Date of Construction: 1981-1986 (See note below.)

Construction Cost: 1984 $$: $54 million (See note below.)

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: (See the Fermilab Proton Synchrotron for a list of international researchers.)

Funding over six years includes about $39 million (in 1984 dollars) from the Dept. of Energy, plus $15 million from Japanese, Italian, and National Science Foundation-supported collaborators.

Potential for Future International Cooperation: See the discussion under the Fermilab Proton Synchrotron.

Other Information: This facility is expected to be ready for test running in 1985 and for its first physics research use in October 1986.

Note: This detector was not built as a construction project. It was fabricated using capital equipment funds. Therefore, "Date of Construction" and "Construction Cost" in this case refer to this type of fabrication.

Batavia, IL., U.S.A.

D-ZERO DETECTOR AT FERMILAB
Fermi National Accelerator Laboratory (Fermilab)
U.S. Dept. of Energy

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This facility provides detection capabilities complementary to those of the collider detector (CDF), effectively doubling Tevatron I physics utilization by operating simultaneously. It is optimized for accurate measurements of energies of electrons, muons, and jets of hadrons. It has no magnetic field; energies are measured with calorimeters only. High resolution calorimetry will allow excellent identification of missing energy in an interaction. The D-Zero Detector has very complete large solid angle coverage.

Date of Construction: 1985-1989 (See note below.)

Construction Cost: 1984 $$: $43 million (est.) (See note below.)

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: (See the Fermilab Proton Synchrotron for a list of international researchers and a discussion of international cooperation.)

Potential for Future International Cooperation: See the discussion under the Fermilab Proton Synchrotron.

Other information:

Note: This detector was not built as a construction project. It was fabricated using capital equipment funds. Therefore, "Date of Construction" and "Construction Cost" in this case refer to this type of fabrication.

Palo Alto, CA., U.S.A.

SLAC LINEAR ACCELERATOR
Stanford Linear Accelerator Center (SLAC)
U.S. Dept. of Energy

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This facility is a two-mile long linear electron accelerator (linac) that can produce intense beams of electrons at energies up to 32 billion electron volts (GeV), or of positrons with energies up to 20 GeV. The electrons and positrons are used for fixed target experiments to probe the ultimate structure of matter in ways that reveal more details than any other probe. The linac also can be used as the injector for the SPEAR and PEP storage rings and will be used to inject beams into the Stanford Linear Collider (SLC). Starting in FY85, the linear accelerator at SLAC also can be operated for nuclear physics research using a new off-axis source and injector. The linac's energy will be increased from 32 GeV to 50 GeV for both electrons and positrons by the end of FY86.

Date of Construction: 1961-1968

Construction Cost: Original: $114 million
1984 $$: $486 million

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: Primarily U.S. but also from Switzerland, Israel, Japan, the Federal Republic of Germany, the Netherlands, Italy, Canada, the Peoples Republic of China, England, and Poland. Users include 138 foreign researchers from 37 foreign institutions.

Because high-energy physics is an international activity, with knowledge freely shared among its practitioners, this laboratory has extensive interactions with people and institutions in foreign countries.

Typically, about 400 physicists are involved in the SLAC research program each year, of which about 15 percent are from foreign institutions. SLAC has a significant collaboration with the Institute of High Energy Physics of the Peoples Republic of China (PRC) as consultant to the PRC on building a 2.5 GeV electron-positron collider and a detector. There is collaboration on the SLAC Linear Detector (SLD) between the United States and Italy, Canada, and Great Britain. In accordance with a U.S.-Japan bilateral agreement, there is collaboration between these countries on advanced accelerator R&D and on the Time Projection Chamber (TPC) at the PEP storage ring.

Potential for Future International Cooperation: Beam time at this facility, as at all forefront world high energy physics accelerators, is available without charge for the best research proposals worldwide.

Palo Alto, CA., U.S.A.

POSITRON ELECTRON PROJECT (PEP)
Stanford Linear Accelerator Center (SLAC)
U.S. Dept. of Energy

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This facility is a storage ring with beams injected by the SLAC linear accelerator for 30 GeV interactions using intersecting beams of 15 GeV electrons and 15 GeV positrons. The average radius of the ring is 350 meters. There are six regions for simultaneous experiments. PEP was a joint construction project by SLAC and by the Lawrence Berkeley Laboratory.

Date of Construction: 1976-1979

Construction Cost: Original: $80 million
1984 $$: $132 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: (See the SLAC Linear Accelerator for a list of international researchers and a discussion of international cooperation.)

Potential for Future International Cooperation: Beam time at this facility is available without charge for the best research proposals worldwide.

Palo Alto, CA., U.S.A.

STANFORD LINEAR COLLIDER (SLC)
Stanford Linear Accelerator Center (SLAC)
U.S. Dept. of Energy

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This is an experimental accelerator used to develop the design and to test key technical issues of the linear collider concept as a potentially cost-effective approach to high luminosity and very high-energy electron-positron collisions. It also provides a source of electron-positron collisions at 100 GeV center-of-mass energy which is expected to provide the earliest capability for producing copious quantities of Z particles in electron-positron collisions.

Date of Construction: 1984-1986

Construction Cost: 1984 $$: $110 million

Present International Cooperation

Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: (See the SLAC Linear Accelerator for a list of international researchers and a discussion of international cooperation.)

Potential for Future International Cooperation: Beam time at this facility will be available without charge for the best research proposals worldwide, as at all forefront world high-energy physics facilities.

Palo Alto, CA., U.S.A.

STANFORD LINEAR DETECTOR (SLD)
Stanford Linear Accelerator Center (SLAC)
U.S. Dept. of Energy

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This state-of-the-art second generation detector for the SLAC Linear Collider has good electromagnetic and hadronic calorimetry over the complete solid angle, high resolution measurement of secondary vertices, full instrumental capability over the complete solid angle, and good particle identification over a wide range of momentum. It measures the energy of charged particles with strong magnetic fields and of all particles (except neutrinos) with massive calorimeters.

Date of Construction: 1985-1989 (See note below.)

Construction Cost: 1984 $$: $45 million (See note below.)

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: (See the SLAC Linear Accelerator for a list of international researchers and a discussion of international cooperation.)

Potential for Future International Cooperation: See the discussion under the SLAC Linear Accelerator.

Other information:

Note: This detector was not built as a construction project. It was fabricated using capital equipment funds. Therefore, "Date of Construction" and "Construction Cost" in this case refer to this type of fabrication.

Palo Alto, CA., U.S.A.

ALTERNATING GRADIENT SYNCHROTRON (AGS)
Brookhaven National Laboratory (BNL)
U.S. Dept. of Energy

"Big Science" Descriptor: High-energy physics (soon also nuclear physics)

Description of Facility/Instrument: This synchrotron provides protons on fixed targets at energies up to 33 GeV, and various secondary beams. The AGS main ring is 800 meters in circumference and contains 240 magnets. Current research focuses on neutrino interactions and the study of certain rare decay modes of the K meson. Other experiments involve the study of interactions of protons, pions, kaons, etc. with target nuclei. Capability to accelerate polarized protons has been added recently. A link to the Tandem Van de Graaff is being established to provide the capability to accelerate medium weight heavy tons.

Date of Construction: 1956-1960, upgraded 1966-1971

Construction Cost: Original: \$79 million
1984 \$\$: \$325 million

Present International Cooperation
Nationslity(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S. primarily, but also from Mexico, Japan, Canada, Denmark, France, Great Britain, Israel, Italy, the Netherlands, the U.S.S.R., Sweden, Switzerland, the Federal Republic of Germany, China, and Yugoslavia

Because high-energy physics is an international activity, with knowledge freely shared among its practitioners, this laboratory has extensive interactions with people and institutions in foreign countries.

Of about 300 scientists actively involved in current utilization of the AGS, some 50 are from 17 foreign institutions.

There are collaboration on current experiments with the Japanese and with the Canadians. The U.S.-Japanese experiment, with Japanese scientists from KEK and from Osaka University, has been in progress for several years. Japan has furnished abcut one-fourth of the manpower and equipment for a detector that cost \$4-\$5 million total. Canadians from TRIUMF are participating with the United States in an experiment to study rare K decay. The Canadian manpower fraction is about one-third. They also share detector costs.

Potential for Future International Cooperation: Beam time at this facility is available without charge for the best research proposals worldwide, as with all forefront world high-energy physics facilities.

Upton, NY., U.S.A.

COSMOTRON
Brookhaven National Laboratory (BNL)
U.S. Atomic Energy Commission (now the Dept. of Energy)

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This facility was a three GeV Proton Synchrotron with a variety of secondary beams.

Date of Construction: Constructed in 1948-1952 and decommissioned in 1967

Construction Cost: Original: $10 million
1984 $$: $65 million

Present International Cooperation
Nationality(s) of Ownership: (Currently
Nationality(s) of Operational Funding: not
Nationality(s) of Management Staff: operating)
Nationality(s) of Researchers:

Argonne, IL., U.S.A.

ZERO GRADIENT SYNCHROTRON (ZGS)
Argonne National Laboratory (ANL)
U.S. Dept. of Energy

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This was a 12 GeV proton synchrotron with various secondary beams.

Date of Construction: Constructed in 1957-1963 and decommissioned in 1979

Construction Cost: Original: $51 million
1984 $$: $240 million

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:
(Currently not operating)

Berkeley, CA., U.S.A.

BEVATRON
Lawrence Berkeley Laboratory (LBL)
U.S. Atomic Energy Commission (now the Dept. of Energy)

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This was a 6.2 GeV protron synchrotron with various secondary beams. After completion of its operation as a high-energy physics facility, the Bevatron was placed into service for research in nuclear physics and remains in use as part of the Bevalac.

Date of Construction: 1950-54 and 61; operation for high-energy physics ended in 1975

Construction Cost: Original: $20 million
1984 $$: $105 million

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:
(Currently not operating for high-energy physics)

Cambridge, MA., U.S.A.

CAMBRIDGE ELECTRON ACCELERATOR (CEA)
Harvard University
U.S. Atomic Energy Commission (now the Dept. of Energy)

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This facility was a six billion electron volt (GeV) Electron Synchrotron. A later upgrade provided capability for 3 GeV x 3 GeV electron-positron collisions.

Date of Construction: Constructed in 1956-1962 and decommissioned in 1973

Construction Cost: Original: $10 million
1984 $$: $50 million

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:
(Currently not operating)

Princeton, NJ., U.S.A.

PRINCETON-PENNSYLVANIA ACCELERATOR (PPA)
U.S. Atomic Energy Commission (now the Dept. of Energy)

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This was a three GeV proton synchrotron with various secondary beams.

Date of Construction: Constructed in 1957-1963 and decommissioned in 1970

Construction Cost: Original: $22 million
1984 $$: $105 million

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(a) of Management Staff:
Nationality(s) of Researchers:
(Currently not operating)

Geneva, SWITZERLAND

PROTON SYNCHROTRON (PS)
CERN

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This synchrotron has a maximum energy of 28 GeV.

Date of Construction: 1953-1960

Construction Cost: 1984 $$: $15 million

Present International Cooperation
Nationality(s) of Ownership: (Multinational)
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Geneva, SWITZERLAND

INTERSECTING STORAGE RINGS (ISR)
CERN

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument:

Date of Construction: 1971, decommissioned in the 1980s

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: (Multinational)
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Geneva, SWITZERLAND

SUPER PROTON SYNCHROTRON (SPS)
CERN

"Big Science" Descriptor: High-energy and nuclear physics

Description of Facility/Instrument: In this synchrontron, oxygen ion beams can be accelerated from 9 to 200 GeV/AMU energy levels.

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: (Multinational)
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Geneva, SWITZERLAND

LARGE ELECTRON-POSITRON COLLIDER (LEP)
CERN

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: In this storage ring, positron and electron particle beams could be collided, each up to a 60 GeV energy level. A Phase II storage ring is planned in which a positron beam could be collided with an electron beam, each up to a 130 GeV energy level.

Date of Construction: under construction, due in 1988

Construction Cost: 1984 $$: $980 million

Present International Cooperation
Nationality(s) of Ownership: (Multinational)
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Potential for Future International Cooperation: Beam time at the CERN facility is available without charge for the best research proposals worldwide.

Geneva, SWITZERLAND

LEP DETECTOR-ALEPH
CERN

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: The Apparatus for LEP pHysics (ALEPH) has a large superconducting coil enclosing a central track detector which permits precise momentum determinations of charged particles over a wide energy range.

Date of Construction: Due in 1988

Construction Cost: 1984 $$: $32 million

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding: (Multinational)
Nationality(s) of Management Staff:
Nationality(s) of Researchers: ALEPH involves about 300 researchers from 25 research centers in nine countries, including the United States.

Geneva, SWITZERLAND

LEP DETECTOR-DELPHI
CERN

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: The Detector with Lepton, Photon, and Hadron Identification (DELPHI) is designed to provide three-dimensional measurements, fine grain energy deposition, and particle identification over the complete solid angle surrounding the beam intersection.

Date of Construction: Due in 1988

Construction Cost: 1984 $$: $30 million

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding: (Multinational)
Nationality(s) of Management Staff:
Nationality(s) of Researchers: DELPHI involves about 300 researchers from 30 research institutes in 17 countries, including the United States.

Geneva, SWITZERLAND

LEP DETECTOR-L3
CERN

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: L3 is optimized for high resolution measurement of energy and momentum for electrons, gamma rays, and muons at 50 GeV. It uses an 8,000-ton magnet, approximately 12mx12mx12m bismuth germanate crystals for electromagnetic calorimetry and uranium for hadron calorimetry.

Date of Construction: Due in 1988

Construction Cost: 1984 $$: $60 million (est.) (See note below.)

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding: (Multinational)
Nationality(s) of Management Staff:
Nationality(s) of Researchers: L3 involves about 400 scientists, including about 125 from 12 U.S. institutions. It is the first major physics collaboration involving Western Europe, the Soviet Union, the United States, and the People's Republic of China.

Other Information: Note: This detector was not built as a construction project. It was fabricated using capital equipment funds. Therefore, "Date of Construction" and "Construction Cost" in this case refer to this type of fabrication. U.S. funding of the LEP-3 Detector is expected to total $22 million.

Geneva, SWITZERLAND

LEP DETECTOR-OPAL
CERN

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: The Omni Purpose Apparatus for LEP (OPAL) is designed to cover a wide range of high-energy physics, much of it unexplored, using well-tested and powerful techniques and technologies.

Date of Construction: Due in 1988

Construction Cost: 1984 $$: $32 million

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding: (Multinational)
Nationality(s) of Management Staff:
Nationality(s) of Researchers: OPAL involves about 130 researchers from 21 research institutes in 9 countries, including the United States.

Geneva, SWITZERLAND

PROTON-ANTIPROTON COLLIDER
CERN

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: The total center-of-mass energy of this facility can reach as high as 540 GeV.

Date of Construction: 1981

Construction Cost: 1984 $$: $166 million

Present International Cooperation
Nationality(s) of Ownership: (Multinational)
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Hamburg, FEDERAL REPUBLIC OF GERMANY

DORIS-II
DESY

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This is a storage ring. Its positron beam can collide with an electron beam, each up to a 5.6 GeV energy level.

Date of Construction: July 1982

Construction Costs: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Hamburg, FEDERAL REPUBLIC OF GERMANY

PETRA-II
DESY

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This is a storage ring. Its positron beam is collided with an electron beam, each up to the 23 GeV energy level.

Date of Construction: October 1983

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Hamburg, FEDERAL REPUBLIC OF GERMANY

HERA
DESY

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: These are storage rings in which an electron beam (30 GeV) will be collided with a proton beam (820 GeV).

Date of Construction: under construction, due in 1990

Construction Cost: 1984 $$: $394 million

Present International Cooperation
Nationality(s) of Ownership: The Federal Republic of Germany, Canada, France, Israel, Italy, the Netherlands, and the U.K.
Nationality(s) of Operational Funding: (Currently
Nationality(s) of Management Staff: not
Nationality(s) of Researchers: operating)

Tsukuba, JAPAN

SYNCHROTRON
KEK

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This synchrotron can accelerate a proton beam up to 12 GeV.

Date of Construction: March 1976

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership:
- Nationality(s) of Operational Funding:
- Nationality(s) of Management Staff:
- Nationality(s) of Researchers:

Tsukuba, JAPAN

TRISTAN
KEK

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This is a storage ring with a positron beam that will collide with an electron beam, each up to the 30 GeV energy level. A storage ring in which an electron beam of 25 GeV can collide with a protron beam of 300 GeV is planned.

Date of Construction: under construction, due in 1986

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: (Currently
- Nationality(s) of Operational Funding: not
- Nationality(s) of Management Staff: operating)
- Nationality(s) of Researchers:

Beijing, PEOPLE'S REPUBLIC OF CHINA

BPS
Institute of High Energy Physics

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This is a synchrotron with a proton beam that can be accelerated to the 50 GeV energy level.

Date of Construction: postponed indefinitely

Construct'on Cost: 1984 $$:

Present International Cooperation

Nationality(s) of Ownership:	(Currently
Nationality(s) of Operational Funding:	not
Nationality(s) of Management Staff:	operating)
Nationality(s) of Researchers:	

Bejing, PEOPLE'S REPUBLIC OF CHINA

BEPC
Institute of High Energy Physics

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This is a storage ring in which a positron beam will be collided with an electron beam, each up to the 2.5 GeV energy level.

Date of Construction: under construction, due in 1987

Construction Cost: 1984 $$:

Present International Cooperation

Nationality(s) of Ownership:	(Currently
Nationality(s) of Operational Funding:	not
Nationality(s) of Management Staff:	operating)
Nationality(s) of Researchers:	

Serpukhov, U.S.S.R.

PROTON SYNCHROTRON
Institute of High Energy Physics

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This synchrotron has a proton beam which can be accelerated to the 76 GeV energy level. It will be upgraded to 400 GeV protons to be used in conjunction with the UNK Proton Synchrotron, described on the following page.

Date of Construction: 1967; upgrade under construction, due in 1990

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Serpukhov, U.S.S.R.

UNK PROTON SYNCHROTRON
Institute of High Energy Physics

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: In Phase I, this storage ring facility will produce 3,000 GeV protons to be collided with the 400 GeV protons produced by the Booster Synchrotron described on the preceding page. In Phase II, a second storage ring will be built to supply 3,000 GeV antiprotons and protons to replace the 400 GeV protons.

Date of Construction: under construction, due in 1990

Construction Cost: 1984 $$: $297 million

Present International Cooperation
Nationality(s) of Ownership: (Currently
Nationality(s) of Operational Funding: not
Nationality(s) of Management Staff: operating)
Nationality(s) of Researchers:

Novosibirsk, U.S.S.R.

VEPP-IV
Institute of Nuclear Physics

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This is a storage ring. Its positron beam can collide with the electron beam, each up to a seven GeV energy level.

Date of Construction: 1979

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Novosibirsk, U.S.S.R.

VAPP-IV
Institute of Nuclear Physics

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This is a storage ring. Its positron beam is reported to be able to collide with the electron beam, each up to 25 GeV energy level.

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Moscow, U.S.S.R.

U-10
Institute of Theoretical and Experimental Physics

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: This synchrotron has a proton beam which can be accelerated to the ten GeV energy level.

Date of Construction: October 1961

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

APPENDIX 3

NUCLEAR PHYSICS FACILITIES

For U.S. facilities, the values in fiscal year 1984 dollars are estimated by escalating construction costs, except where the replacement value is estimated in several cases. Due to advances in technology, the cost of accelerator replacement would, in most cases, be much lower than escalated construction costs. In addition, if the costs of U.S. facilities are compared to those of foreign facilities, it should be recognized that it is common practice abroad not to include as construction costs the cost of laboratory manpower and laboratory services such as machine shops. Such costs can account for one-half of the cost of a construction project in nuclear physics.

The information in this appendix was supplied by the Department of Energy, April 22, 1985.

East Lansing, MI., U.S.A.

COUPLED SUPERCONDUCTING CYCLOTRONS
National Superconducting Cyclotron Laboratory (NSCL)
Michigan State University

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: This construction project is the completion of "Phase II" of a two-stage superconducting cyclotron facility for heavy ions. Phase I, a K500 MeV cyclotron, was completed in FY82 and has been operational since 1982. The intense beam of the K500 MeV machine will be injected into a K800 MeV superconducting cyclotron after its construction is completed. Phase II includes the building to house the cyclotrons and their associated experimental areas and support facilities, the K800 MeV cyclotron, the beam lines, computing facilities, and experimental equipment.

Date of Construction: 1980-present (Phase II is still under construction.)

Construction Cost: Original: $33 million
1984 $$: $40 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: Mainly U.S. to date.

Potential for Future International Cooperation: Upon completion, this will be a unique national heavy ion facility attractive also to scientists from Europe and Japan.

Other Information: Dr. Blosser of Michigan State University (MSU) has collaborated with Europeans in the design of superconducting cyclotrons. Dr. Resmini, before his untimely death, worked at MSU in preparation for construction of a similar facility at the University of Milan.

Bloomington, IN., U.S.A.

INDIANA UNIVERSITY CYCLOTRON FACILITY (IUCF)
Indiana University

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: The Indiana University Cyclotron Facility provides high quality beams of protons, deuterons, helium ions, and lithium ions in energies up to 200 million electron volts for nuclear physics research. IUCF has been operating as a national users facility since the first beams available for research in the spring of 1976. The current demand is running at a rate about three times that available (5000 hours per year). Comprehensive studies are made of nuclear processes, including fundamental nucleon-nucleon interactions, tests of charge-symmetry of the nuclear force, near-threshold production of pions, and detailed nuclear structure efforts throughout the periodic table.

Date of Construction: 1969-75 (operational 1976).

Construction Cost: Original: $10 million
1984 $$: $30 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: 350 scientists from 60 institutions from 13 countries.

Potential for Future International Cooperation: The addition of a "Cooler" ring (see below) will enhance the attraction of this facility to foreign scientists.

Other Information: Construction of a "Cooler" Storage Ring began in FY83 (total estimated cost, $6 million) with $5.4 million provided to date and with $0.6 million to be provided in FY86. The "Cooler" will introduce new technology into nuclear physics by providing charged particle beams of light ions with very low emittance, small energy spread. It will make practical the use of ultra-thin targets without loss in beam luminosity.

The application of Cooler ring technology to nuclear physics was initiated at IUCF. Dr. Pollock, who heads the construction projects, has cooperated and consulted with several European laboratories which are undertaking this technology for complementary nuclear physics research facilities.

Upton, NY., U.S.A.

TANDEM/AGS HEAVY ION FACILITY
Brookhaven National Laboratory (BNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: The Tandem Complex consists of two model MP tandem accelerators which, in the coupled mode, are equivalent to a single 20 million volt terminal tandem. Accelerated ions of over 50 isotopes of 40 different elements are available for experiments. Using a beam transfer line under construction from the Tandem Complex to the Alternating Gradient Synchrotron (AGS), heavy ions up to mass 32 (sulphur) will be injected into the AGS and accelerated up to 14 billion electron volts per atomic mass unit, seven times higher than the heavy ion energies available at the Bevalac. Accelerated heavy ions from the Tandem Complex are used for research programs in heavy ion reactions, nuclear structure, and atomic physics. The Tandem/AGS facility will be used to search for evidence of the quark-gluon plasma or quark matter by the collision of relativistic heavy ions with heavy targets like uranium.

Date of Construction: Tandems 1965-1969, Transfer Line 1984-86

Construction Cost: 1984 $$: $47 million plus AGS cost

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: U.S., England, the Federal Republic of Germany, Argentina, Brazil, Denmark, and Israel

Because nuclear physics is an international activity, with knowledge freely shared among its practitioners, this laboratory has extensive interactions with people and institutions in foreign countries.

More than 95 percent of researchers working at DOE nuclear physics accelerators are from U.S. institutions. On approximately equal and reciprocal bases, American nuclear scientists use foreign facilities.

A heavy ion experiment has been approved for the AGS when the Transfer Line from the Tandem to the AGS is complete. About one-fourth of the participants in the first large experiment planned for the completed Tandem/AGS heavy ion facility are Japanese and, under a U.S.-Japan Accord, about $300,000 in equipment will be furnished by the Japanese.

Potential for Future International Cooperation: Beam time at this facility is available without charge for the best research proposals worldwide.

Argonne, IL., U.S.A.

ARGONNE TANDEM/LINAC ACCELERATOR SYSTEM (ATLAS)
Argonne National Laboratory (ANL)
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: ATLAS includes two component parts, a tandem Van de Graaff with a nine million volt terminal potential, and the ATLAS superconducting linear accelerator (linac) which raised the accelerating power to the equivalent of a 50 million volt (terminal) tandem. Heavy ion beams are used for studies of high-spin nuclear states, fission and fusion reactions, quasi-elastic and deep inelastic reactions, and mass spectrometry. Technical performance of the accelerator emphasizes precise timing and energy stability.

Date of Construction: Tandem in 1959-61, ATLAS linac in 1982-85

Construction Cost: 1984 $$: $27.5 million

Present International Cooperation

Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S., Canada, England, Denmark, the Federal Republic of Germany, Japan, Israel, the People's Republic of China, France, Finland, Australia, Brazil, Sweden, Belgium, Poland, and Hungary

Because nuclear physics is an international activity, with knowledge freely shared among its practitioners, this laboratory has extensive interactions with people and institutions in foreign countries.

More than 95 percent of researchers working at DOE nuclear physics accelerators are from U.S. institutions. On approximately equal and reciprocal bases, U.S. nuclear scientists use foreign facilities.

Potential for Future International Cooperation: Beam time at this facility is available without charge for the best research proposals worldwide.

Berkeley, CA., U.S.A.

BEVALAC
Lawrence Berkeley Laboratory (LBL)
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: The Bevalac is a combined accelerator system, consisting of the SuperHILAC and the Bevatron. The SuperHILAC is a linear accelerator capable of accelerating all elements to energies of 8.5 million electron volts per nucleon (MeV/AMU). It is connected by a transfer line to the Bevatron, which can further accelerate ions to energies up to 4.9 GeV for protons, 2.1 GeV/AMU for carbon, or other ions with energies up to 960 MeV/AMU for uranium. Bevalac research includes: peripheral fragmentation reactions and studies of internal momentum; nuclear reactions induced by beams of radioactive nuclei; central collisions that create extremely hot, dense nuclear matter complexes; production mechanisms of pions, kaons, hyperons, and antiparticles in nuclear matter; searches for new forms of matter such as pion condensates and nuclear isomers; searches for evidence of quark-gluon plasma; and searches for free quarks.

Date of Construction: 1950-54, 1954-57, and 1973-74

Construction Cost: 1984 $$: $135 million (estimated replacement cost)

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S., Canada, France, Japan, the Federal Republic of Germany, the People's Republic of China, Egypt, India, Ireland, Israel, Italy, Mexico, South Africa, Sweden, and Switzerland

Because nuclear physics is an international activity, with knowledge freely shared among its practitioners, this laboratory has extensive interactions with people and institutions in foreign countries.

More than 95 percent of researchers working at DOE nuclear physics accelerators are from U.S. institutions. On approximately equal and reciprocal bases, U.S. nuclear scientists use foreign facilities. A ten-year-old cooperation with GSI, Darmstadt, the Federal Republic of Germany, has included development of the Plastic Ball detector, which is used for a most significant experiment on the properties and flow of highly compressed nuclear matter. The Plastic Ball has been in operation for about three years. There has been an ongoing collaboration with INS, Tokyo, Japan, on a magnetic spectrometer at the Bevalac for about eight years.

Potential for Future International Cooperation: Beam time at this facility is available without charge for the best research proposals worldwide.

Berkeley, CA., U.S.A.

88-INCH CYCLOTRON
Lawrence Berkeley Laboratory (LBL)
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: The cyclotron can accelerate all ions from hydrogen through krypton to energies above the Coulomb barrier for targets as heavy as uranium. The maximum energy is 35 million electron volts per nucleon. The basic research program is focused in four major areas: investigation of heavy ion reaction mechanisms; production and study of exotic nuclei far from stability; structure of nuclei at high angular momentum; and studies of spin-polarization effects and basic symmetry principles in nuclear interactions.

Date of Construction:

Construction Cost: 1984 $$: $40.5 million (estimated replacement cost)

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: U.S., Argentina, Belgium, Canada, Denmark, England, Finland, France, Israel, Japan, the Federal Republic of Germany, Lebanon, Mexico, the Netherlands, Norway, Poland, Sweden, Switzerland, Taiwan--53 users from 18 other countries over three years

Because nuclear physics is an international activity, with knowledge freely shared among its practitioners, this laboratory has extensive interactions with people and institutions in foreign countries.

More than 95 percent of researchers working at DOE nuclear physics accelerators are from U.S. institutions. On approximately equal and reciprocal bases, U.S. nuclear scientists use foreign facilities.

In connection with a scientific exchange program with the Jagellonian University, Cracow, Poland, a 60-inch diameter scattering chamber was constructed [on a National Science Foundation (NSF) grant] and moved to the 88-Inch Cyclotron where it is now in use.

There is a formal exchange agreement between LBL and CNRS (France); a cooperative research grant with scientists from Buenos Aires, Argentina (NSF funded); and informal exchange arrangements with Grenoble, France; Lanchow, China; and the Weizmann Institute, Israel.

Potential for Future International Cooperation: Beam time at this facility is available without charge for the best research proposals worldwide.

Berkeley, CA., U.S.A.

184-INCH CYCLOTRON
Lawrence Berkeley Laboratory (LBL)
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: This is a cyclotron with maximum energy of 730 million electron volts (MeV) for protons and 460 MeV for deuterons. The 184-Inch Cyclotron was transferred to medical use on June 30, 1975, principally for the clinical treatment of cancer. It has been particularly successful in the treatment of occular melanoma.

Date of Construction: Constructed in 1940-46 and 1955-57; it ceased nuclear physics in 1975

Construction Cost: Original: $3.4 million
1984 $$: $18.4 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers:

Los Alamos, NM., U.S.A.

CLINTON P. ANDERSON (LOS ALAMOS) MESON PHYSICS FACILITY (LAMPF)
Los Alamos National Laboratory (LANL)
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: This facility is a high-current, 800 million electron volt (MeV) proton linear accelerator about one-half mile in length. It provides up to 12 simultaneously operating secondary beams including neutrons, pions, muons, and neutrons. The research emphasis is on nulcear structure, mechanisms by which pions and protons react with nuclei, basic particle interactions, and the fundamental weak interaction. LAMPF concurrently provides proton beams for weapons nulcear research.

Date of Construction: 1967-1972

Construction Cost: 1984 $$: $250 million (estimated replacement cost)

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: U.S., Great Britain, Canada, France, the Federal Republic of Germany, Japan, Australia, Bangladesh, the People's Republic of China, Columbia, Cyprus, Egypt, El Salvador, India, Iran, Iraq, Ireland, Israel, Italy, Lebanon, Malaysia, Mexico, the Netherlands, Norway, South Korea, Sweden, Switzerland, and Taiwan.

Because nulcear physics is an international activity, with knowledge freely shared among its practitioners, this laboratory has extensive interactions with people and institutions in foreign countries.

More than 95 percent of researchers working at DOE nuclear physics accelerators are from U.S. institutions. On approximately equal and reciprocal bases, U.S. nuclear scientists use foreign facilities.

In 1983-84, a dilution refrigerator and frozen spin polarized target system for both protons and deuterons has been provided by the Los Alamos National Laboratory for High Energy Physics (KEK), Japan for a joint research program on proton-proton and dueteron-deuteron spin dependent scattering.

In 1985-86, a closed-loop, temperature-controlled, helium-cooled system for proton radiation effects studies was provided by KFA, Julich, West Germany, for a joint research program.

Potential for Future International Cooperation: Beam time at this facility is available without charge for the best research proposals worldwide.

Oak Ridge, TN., U.S.A.

HOLIFIELD HEAVY ION RESEARCH FACILITY
Oak Ridge National Laboratory (ORNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: The facility includes a 25 million volt electrostatic tandem accelerator and the Oak Ridge Isochronous Cyclotron. Heavy ion projectiles are used to study nuclear structure and nuclear behavior under a variety of extreme conditions such as high excitation energy, large angular momentum, and mass far from the valley of stability.

Date of Construction: Cyclotron 1959-63, Tandem 1974-81

Construction Cost: 1984 $$: $54 million (estimated replacement cost)

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: U.S., France, the United Kingdom, Israel, Denmark, Sweden, the Federal Republic of Germany, Taiwan, Iran, Poland, Mexico, Brazil, Argentina, Malaysia, the Netherlands, Sri Lanka, Finland, the People's Republic of China, Algeria, India, Greece, and Australia

Because nuclear physics is an international activity, with knowledge freely shared among its practitioners, this laboratory has extensive interactions with people and institutions in foreign countries.

More than 95 percent of researchers working at DOE nuclear physics accelerators are from U.S. institutions. On approximately equal and reciprocal bases, U.S. nuclear scientists use foreign facilities.

Potential for Future International Cooperation: Beam time at this facility is available without charge for the best research proposals worldwide.

Middleton, MA., U.S.A.

BATES LINEAR ACCELERATOR CENTER
Massachusetts Institute of Technology
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: This facility supplies very high quality electron beams with energies up to 750 million electron volts. The beams are generated by a linear accelerator and a beam recirculation system. The experimental program has centered on high-precision experiments which resolve complicated nuclear structures. A growing program of coincidence measurements is addressing a variety of important questions including nuclear collective motion at high excitation energy, nuclear reaction mechanisms, and fundamental properties of few-nucleon systems.

Date of Construction: 1966-74

Construction Cost: 1984 $$: $62 million (estimated replacement cost)

Present International Cooperation

Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S., Canada, the United Kingdom, Sweden, the Federal Republic of Germany, France, Japan, and Israel

Because nuclear physics is an international activity, with knowledge freely shared among its practitioners, this laboratory has extensive interactions with people and institutions in foreign countries.

More than 95 percent of researchers working at DOE nuclear physics accelerators are from U.S. institutions. On approximately equal and reciprocal bases, U.S. nuclear scientists use foreign facilities.

A current collaboration involves investigators from the University of Alberta, Canada, and from SATURNE in France. Foreign contribution to detector equipment includes a polarization polarimeter and scintillation detectors.

Potential for Future International Cooperation: Beam time at this facility is available without charge for the best research proposals worldwide.

New Haven, CT., U.S.A.

A. W. WRIGHT NUCLEAR STRUCTURE LABORATORY
Yale University
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: This is a MP class Tandem Van de Graaff accelerator improved to 13.5 million volts. The accelerator will be removed from operation in June 1985 to permit conversion to an ESTU class tandem, operating with terminal potential up to 22.5 million volts. The Wright Nuclear Structure Laboratory has a broad program of study of nuclear phenomena ranging from the most fundamental to highly applied research.

Date of Construction: MP 1962-66, ESTU 1985-86

Construction Cost: 1984 $$: $38 million (estimated replacement cost)

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: A representative list includes U.S., Israel, Turkey, Italy, France, the United Kingdom, the Federal Republic of Germany, the Netherlands, the People's Republic of China, Taiwan, Australia, Japan, Canada, Lebanon, and Ireland

More than 95 percent of researchers working at DOE nuclear physics accelerators are from U.S. institutions. On approximately equal and reciprocal bases, U.S. nuclear scientists use foreign facilities.

Potential for Future International Cooperation: This facility is dedicated to the educational use of Yale University.

College Station, TX., U.S.A.

CYCLOTRON INSTITUTE
Texas A&M University
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: This is a sector-focusing, variable energy cyclotron capable of accelerating protons to energies as high as 55 million electron volts (MeV), deuterons to 65 MeV, and ^{3}He and alpha particles to 130 MeV. Intense beams of polarized protons and deuterons can be generated. A broad-based program in basic and applied science is carried out at the Cyclotron Institute. With $7.25 million added by the State of Texas and the Welch Foundation in 1982, a K=500 superconducting cyclotron is being added as an injector to the existing cyclotron. The completed facility is expected to provide beams of 160 MeV deuterons and 320 MeV alpha particles and heavy ion beams up to 60 MeV/AMU for nuclei less than 20 AMU; up to 40 MeV/AMU for nuclei in the 20 to 40 AMU range; and up to 8 MeV/AMU for nuclei as massive as 136 AMU. The construction period is 1981 to 1986.

Date of Construction: 1964-67

Construction Cost: 1984 $$: $28 million (estimated replacement cost plus superconducting cyclotron cost)

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: U.S., Canada, France, the Federal Republic of Germany, Japan, Poland, Chile, Mexico, Italy, Hungary, Australia, Iran, the Philippines, India, the People's Republic of China, Hong Kong, Sweden, and Syria

More than 95 percent of researchers working at DOE nuclear physics accelerators are from U.S. institutions. On approximately equal and reciprocal bases, U.S. nuclear scientists use foreign facilities.

There is a formal exchange agreement with Japan and an extensive collaboration with CNRS, France.

Potential for Future International Cooperation: This facility is dedicated to the educational use of Texas A&M University.

Newport News, VA., U.S.A.

CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY (CEBAF)
Southeastern Universities Research Association (SURA)

"Big Science" Descriptor: Nuclear physics

Description of Facility/Instrument: This facility is planned as a four GeV electron accelerator.

Date of Construction: Planned

Construction Cost: 1984 $$: $225 million

Present International Cooperation
Nationality(s) of Ownership: (Currently
Nationality(s) of Operational Funding: not
Nationality(s) of Management Staff: operating)
Nationality(s) of Researchers:

Geneva, SWITZERLAND

SYNCHRO-CYCLOTRON
CERN

"Big Science" Descriptor: Nuclear physics: light ion facility

Description of Facility/Instrument: This facility is a cyclotron which accelerates proton beams up to the 600 MeV energy level. It can accelerate carbon ions up to 86 MeV/AMU energy level.

Date of Construction: 1957-1974

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: (Multinational)
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Geneva, SWITZERLAND

LOW ENERGY ANTIPROTON RING (LEAR)
CERN

"Big Science" Descriptor: Nuclear physics: light ion facility

Description of Facility/Instrument: This storage ring accelerates antiproton beams from 5 MeV to 1,370 MeV energy levels. It also has a stretcher ring with an acceleration and deceleration capacity.

Date of Construction: 1982

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: (Multinational)
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Villigen, SWITZERLAND

SIN
Swiss Institute for Nuclear Research

"Big Science" Descriptor: Nuclear physics: meson facility

Description of Facility/Instrument: In this cyclotron, a proton beam can be accelerated to the 590 MeV energy level.

Date of Construction: 1974

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: Switzerland
Nationality(s) of Operational Funding: Switzerland
Nationality(s) of Management Staff: Switzerland
Nationality(s) of Researchers: Switzerland

Saskatoon, CANADA

LINEAR ACCELERATOR
University of Saskatchewan

"Big Science" Descriptor: Nuclear physics: electron facility

Description of Facility/Instrument: This linear accelerator can boost electron beams up to the 300 MeV energy. It also has a pulse stretcher ring with an additional 300 MeV capability.

Date of Construction: 1964

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Chalk River, CANADA

SUPERCONDUCTING CYCLOTRON
Chalk River Nuclear Laboratory

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This superconducting cyclotron has a tandem injector. It can accelerate ion beams up to the energy level where K=520.

Date of Construction: 1985

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Mangement Staff:
Nationality(s) of Researchers:

Vancouver, CANADA

TRIUMF
Tri Universities Meson Facility

"Big Science" Descriptor: Nuclear physics: meson facility

Description of Facility/Instrument: This cyclotron can accelerate a proton beam to the 520 MeV energy level.

Date of Construction: 1974

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Buenos Aires, ARGENTINA

ELECTROSTATIC MACHINE
National Atomic Energy Commission

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This electrostatic machine has a potential difference of 20 megawatts.

Date of Construction: 1984

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Daresbury, ENGLAND, U.K.

ELECTROSTATIC MACHINE
Daresbury Laboratory
Science and Engineering Research Council

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This electrostatic machine has a potential difference of 20 megawatts.

Date of Construction: 1983

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Grenoble, FRANCE

SARA
Institute for Nuclear Science
University of Grenoble

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This is a cyclotron with an injector. The injector can accelerate ions up to an energy level where K=90. The cyclotron can accelerate an additional amount equivalent to K=160.

Date of Construction: 1982

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Gif-sur-Yvette, FRANCE

ALS
Nuclear Physics Dept. of Saclay

"Big Science" Descriptor: Nuclear physics: electron facility

Description of Facility/Instrument: This linear accelerator can boost electron beams up to the 720 MeV energy level.

Date of Construction: 1968

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Gif-sur-Yvette, FRANCE

SATURNE-II
Saturne National Laboratory
Nuclear Physics Dept. of Saclay

"Big Science" Descriptor: Nuclear physics: light ion facility

Description of Facility/Instrument: This synchrotron can accelerate protons in a polarized beam up to the 2.3 GeV energy level. It also can accelerate carbon and argon ion beams up to the 1.1 GeV/AMU energy level.

Date of Construction: 1977, 1984

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Caen, FRANCE

GANIL
Grand Accelerator National d'Ions Lourds

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This facility has twin cyclotrons. Each has the capability of accelerating ion beams up to the energy level where K=100.

Date of Construction: 1983

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Julich, FEDERAL REPUBLIC OF GERMANY

CYCLOTRON
Institute for Nuclear Physics

"Big Science" Descriptor: Nuclear physics: light ion facility

Description of Facility/Instrument: This cyclotron accelerates alpha particle beams up to the 180 MeV energy level.

Date of Construction: 1969

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Bonn, FEDERAL REPUBLIC OF GERMANY

LINEAR ACCELERATOR
University of Bonn

"Big Science" Descriptor: Nuclear physics: electron facility

Description of Facility/Instrument: This linear accelerator can boost electron beams up to the 3.5 GeV energy level. It also has a pulse stretcher ring.

Date of Construction: 1985

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Heidelberg, FEDERAL REPUBLIC OF GERMANY

MP-TANDEM
Max Planck Institute for Nuclear Physics

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This is a tandem electrostatic machine with a potential difference of 13 megawatts. It also has a 22.5 megawatt pulsed, room temperature linear accelerator.

Date of Construction: 1982

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Darmstadt, FEDERAL REPUBLIC OF GERMANY

UNILAC
Institute for Heavy Ion Research

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This linear accelerator can accelerate uranium ion beams up to the ten MeV/AMU energy level. It was upgraded to the 23 MeV/AMU.

Date of Construction: 1975

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

West Berlin, FEDERAL REPUBLIC OF GERMANY

VICKSI
Hahn-Meitner Institute for Nuclear Research

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This cyclotron can accelerate ions up to energy levels where K=127. Its total energy depends on the charge and mass of the ion.

Date of Construction: 1977

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Darmstadt, FEDERAL REPUBLIC OF GERMANY

SIS-18
Institute for Heavy Ion Research

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This synchrotron can accelerate neon ion beams up to 1.9 GeV/AMU; uranium ion beams can be accelerated to the 0.9 GeV/ AMU energy level. It also has a pulse stretcher ring which accelerates neon beams to the 0.5 GeV/AMU energy level and uranium beams to the 0.3 energy level.

Date of Construction: under construction, due in 1990

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Amsterdam, THE NETHERLANDS

NIKHEF
National Institute for Nuclear and High Energy Physics

"Big Science" Descriptor: Nuclear physics: electron facility

Description of Facility/Instrument: This linear accelerator can boost electron beams up to the 500 MeV energy level.

Date of Construction: 1982

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Groningen, THE NETHERLANDS

CYCLOTRON
Nuclear Physics Accelerator Institute

"Big Science" Descriptor: Nuclear physics: heavy ion facilities

Description of Facility/Instrument: This cyclotron produces proton beams which can be accelerated to 55 MeV energy level.

Date of Construction: 1970

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Uppsala, SWEDEN

CYCLOTRON
University of Sweden

"Big Science" Descriptor: Nuclear physics: light ion facility

Description of Facility/Instrument: This cyclotron can accelerate proton beams up to the 200 MeV energy level.

Date of Construction: 1984

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Milan, ITALY

SUPERCONDUCTING CYCLOTRON
Institute of Physics/INFN
University of Milan

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This superconducting cyclotron can accelerate ion beams up to the energy level where K=800.

Date of Construction: 1985

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Padova, ITALY

XTU TANDEM
National Laboratory of Legnaro

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This tandem electrostatic machine has a 16 megawatt potential difference.

Date of Construction: 1981

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Faure, SOUTH AFRICA

CYCLOTRON
National Accelerator Center

"Big Science" Descriptor: Nuclear physics: light ion facility

Description of Facility/Instrument: This cyclotron can accelerate proton beams up to the 200 MeV energy level. It can accelerate argon ions up to the 660 MeV energy level.

Date of Construction: 1985

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Osaka, JAPAN

CYCLOTRON
Research Center for Nuclear Physics

"Big Science" Descriptor: Nuclear physics: light ion facility

Description of Facility/Instrument: This cyclotron can accelerate alpha particle beams up to the 120 MeV energy level. It can accelerate nitrogen ion beams up to the 215 MeV level.

Date of Construction: 1974

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Tokai, JAPAN

ELECTROSTATIC MACHINE
Japan Atomic Energy Research Institute

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This electrostatic machine has a potential difference of 20 megawatts.

Date of Construction: 1980

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership:
- Nationality(s) of Operation Funding:
- Nationality(s) of Management Staff:
- Nationality(s) of Researchers:

Tokyo, JAPAN

RIKEN
Institute for Physical and Chemical Research

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This cyclotron has a linear accelerator injector. It can accelerate ions up to the energy level where K=520.

Date of Construction: 1984

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) Ownership:
- Nationality(s) Operational Funding:
- Nationality(s) Management Staff:
- Nationality(s) of Researchers:

Tokyo, JAPAN

NUMATRON
Institute for Nuclear Studies

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This synchrotron can accelerate neon ion beams up to the 1.4 GeV/AMU energy level. Uranium ion beams can be accelerated to the 1.0 GeV/AMU energy level.

Date of Construction: under construction, due in 1990

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Lanzhov, PEOPLE'S REPUBLIC OF CHINA

CYCLOTRON
Lanzhov Institute of Modern Physics

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This is a cyclotron with an injector. The injector can accelerate ions up to the energy level where K=69. The cyclotron can accelerate an additional amount equivalent to K=450.

Date of Construction: under construction, due in 1987

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Gatchina, U.S.S.R.

CYCLOTRON
Leningrad Nuclear Physics Institute

"Big Science" Descriptor: Nuclear physics: light ion facility

Description of Facility/Instrument: This cyclotron can accelerate proton beams up to the one GeV energy level.

Date of Construction: 1967

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Dubna, U.S.S.R.

SYNCHROPHASATRON
Joint Institute for Nuclear Research

"Big Science" Descriptor: Nuclear physics: light ion facility

Description of Facility/Instrument: This synchrotron can accelerate proton beams up to the four GeV energy level. It can accelerate carbon ions up to the four GeV/AMU energy level.

Date of Construction: 1957

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:

Dubna, U.S.S.R.

CYCLOTRON
Joint Institute for Nuclear Research

"Big Science" Descriptor: Nuclear physics: heavy ion facility

Description of Facility/Instrument: This cyclotron can accelerate ion beams up to the 23 MeV/AMU energy levels.

Date of Construction: 1980

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership:
- Nationality(s) of Operational Funding:
- Nationality(s) of Management Staff:
- Nationality(s) of Researchers:

Moscow, U.S.S.R.

LINEAR ACCELERATOR
Institute for Nuclear Research

"Big Science" Descriptor: Nuclear physics: meson facility

Description of Facility/Instrument: This linear accelerator includes a pulse storage ring facility. The proton beam can be accelerated up to the 600 MeV energy level. It includes a pulse storage ring facility.

Date of Construction: under construction, due in 1986

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership:
- Nationality(s) of Operational Funding:
- Nationality(s) of Management Staff:
- Nationality(s) of Researchers:

APPENDIX 4

FUSION FACILITIES

In the magnetic-confinement fusion program, there is a strong evolution of projects. If an initial project works well and it advances to its next step, it may well incorporate much of the initial hardware. Each new step may not be considered to be a new device, even though the name has been modified, since it may involve the same people, the same basic facility, the same location, the same general purpose, and much of the same hardware. As a consequence, in this appendix, the evolution of a specific facility is treated as one facility rather than several and is described briefly.

These programs in magnetic-confinement fusion involve a wide variety of international activities including informal information exchange, informal collaboration by researchers, and formal umbrella agreements which allow the countries involved to carry out specific technical projects, such as joint funding of research and hardware. While each of the programs is involved in some or all of these actities, the role and level of involvement varies from program to program and evolves according to scientific need and economic and political conditions both in the United States and abroad. Since there are so many factors involved, it is difficult to project the potential for international cooperation on a facility-by-facility basis.

In general, the dollar values given for the magnetic-confinement fusion facilities are estimates of the equivalent U.S. replacement values, that is, estimates of what it would cost in 1984 dollars to build the same facility in the United States. The estimates have been obtained from staff members of the Department of Energy who have firsthand knowledge of the facility and from people in the field who have been involved in building the facility, or a similar facility, as would be the case with foreign facilities. Estimates have been used rather than published construction costs because, for several reasons, the published figures do not reflect the true cost of the facility. One reason is that the published figures do not include the value of the elements carried over from the previous device, which is usually substantial, nor are the published figures updated to include additions such as new diagnostics or more neutral beam power. Also, for the smaller foreign devices, the actual construction costs could not be found.

There are four cases, however, where published figures rather than estimates are given in this appendix. These are three of the four major tokamak facilities in the world: the Tokamak Fusion Test Reactor at Princeton (U.S.), the Joint European Torus (European Community), and JT-60 (Japan); and the major mirror facility, the Mirror Fusion Test Facility-B at Livermore (U.S.). In these cases, the Department of Energy reported the actual or planned costs. For the foreign facilities, however, there may be some expenses which have not been reported, but these are not more than ten percent of the total.

The ability to provide cost estimates for foreign magnetic-confinement fusion facilities also varies from program to program and by facility. The more significant factor, however, is that funding information for foreign facilities is not generally comparable to U.S. cost estimates because foreign estimates generally include only the cost of construction materials but not the cost of construction manpower. Estimates of U.S. construction costs include both.

The information in this appendix on magnetic-confinement and initial-confinement fusion facilities was supplied by the Department of Energy in April and May 1985.

Princeton, NJ., U.S.A.

PRINCETON LARGE TORUS (PLT)
Princeton Plasma Physics Laboratory (PPPL)
U.S. Dept. of Energy

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: PLT is a medium-sized tokamak device. Its primary objective has been to determine how plasma parameters scale with device size and heating power. Auxiliary heating and radio frequency systems were added subsequently. The present objective of PLT is to investigate ion cycloton radio frequency (ICRF) heating and lower hybrid current drive.

Date of Construction: 1975

Constructed Cost: 1984 $$: $50-$70 million

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: U.S., although individual scientists, as well as teams from foreign programs, have participated in PLT throughout the year.

Princeton, NJ., U.S.A.

PRINCETON BETA EXPERIMENT (PBX)
Princeton Plasma Physics Laboratory (PPPL)
U.S. Dept. of Energy

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: This was known previously as the Poloidal Divertor Experiment (PDX). The PDX was constructed as a mainline tokamak device in which impurity ions were to be removed by magnetically diverting such ions into a collection chamber (separated from the plasma). Other objectives were to investigate impurity control by experimenting with different startup modes and to evaluate the stability of a D-shaped plasma.

After successfully completing its mission, the device was modified to investigate high beta operation in highly shaped plasmas. Current experiments involve using a "bean"-shaped plasma.

Date of Construction: PDX-1979, PBX-1984

Construction Cost: 1984 $$: $50-$70 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Princeton, NJ., U.S.A.

TOKAMAK FUSION TEST REACTOR (TFTR)
Princeton Plasma Physics Laboratory (PPPL)
U.S. Dept. of Energy

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: The TFTR is the major U.S. tokamak scaling experiment. It has been designed to produce fusion energy at the breakeven level, using a deuterium-tritium plasma. One outstanding feature of the experiment is that it has 30 megawatts of neutral beam power for plasma heating. The experiment will be used to study the physics of breakeven plasmas and the engineering aspects of deuterium-tritium operation with power densities approaching those required for a working reactor.

Date of Construction: 1982

Construction Cost: 1984 $$: $681 million in current year dollars

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: U.S., although individuals from Japan, the European Community, and the U.S.S.R. have participated in experiments on TFTR.

Other Information: Construction on the main TFTR facility began in 1976 and was completed in 1982 with the start of operations. During the operational phase, additional capacity has been added to reach full capability. These additions will be completed in 1986. The peak construction years were 1979-1983. The cost of $681 million is given in actual (that is, year of expenditure) dollars and includes all (either incurred or planned and approved) costs associated with the facility, including R&D, up through 1986.

San Diego, CA., U.S.A.

DOUBLET III-D
GA Technologies, Inc.
U.S. Dept. of Energy

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: This facility was known formerly as Doublet III. Doublet III is a major tokamak facility initiated to investigate the confinement characteristics and beta limits of doublet-shaped plasmas. Doublet III-D is an upgrade which will explore the properties of highly shaped, high beta plasmas with low aspect ratios.

Date of Construction:: 1978 for Doublet III, 1986 for Doublet III-D

Construction Cost: 1984 $$: $175-$225 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.-Japan

A major part of the Doublet program has been accomplished in collaboration with the Japan Atomic Energy Research Institute (JAERI). A five-year agreement which was initiated in August 1979 provided for a major upgrading of the base Doublet III capability, and for an equal sharing of the experimental time between the U.S. and JAERI physics teams. The collaboration has proceeded well, with both experimental teams having obtained important new results. An extension of the five-year agreement which started in September 1984 has provided for continued participation of several JAERI scientists per year in Doublet III experiments as equal members of a single scientific team. At present, the Japanese have contributed about $70 million to the collaborative effort, of which $55 million is hardware, and the rest is operating expenses. In addition, the Japanese have provided about 25 percent of the scientific manpower on the experiment.

Boston, MA., U.S.A.

ALCATOR C
Massachusetts Institute of Technology (MIT)
U.S. Dept. of Energy

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: Alcator C is a small, high field tokamak. The high field allows it to achieve high densities and good confinement. It currently holds the record for the product of density and confinement time for all magnetic confinement devices. In recent years it has explored the plasma-RF radiation interaction and pellet injector tokamak fueling.

Date of Construction: 1978

Construction Cost: 1984 $$: $20-$30 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Other Information: Alcator is now being used as a test bed for the plasma physics and radio frequency (RF) techniques for the proposed compact copper ignition device.

Oak Ridge, TN., U.S.A.

IMPURITY STUDIES EXPERIMENT - B (ISX-B)
Oak Ridge National Laboratory (ORNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: ISX-B was a small tokamak. It was designed to study techniques to control impurities. It was later modified to investigate the stability and transport of noncircular, high beta plasmas. Significant contributions were made by the ISX group toward the understanding of the tokamak beta limit and the energy confinement during neutral beam auxiliary heating

Date of Construction: 1978, decommissioned in 1984

Construction Cost: 1984 $$: $20-$30 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Other Information: ISX-B in its last year was the site of the Joint European Torus (JET) beryllium test. In this test, ISX-B successfully showed that beryllium could be used as a limiter material in a neutral beam heated tokamak. This test was performed under contract to the JET undertaking.

See also JOINT EUROPEAN TORUS (JET).

Livermore, CA., U.S.A.

TANDEM MIRROR EXPERIMENT UPGRADE (TMX-U)
Lawrence Livermore National Laboratory (LLNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: The objective of TMX-U is to test the basic principles of a thermal barrier tandem mirror. The TMX-U mirror device uses, as basic elements, two mirror cells placed at either end of a central cell. The mirrors act as "plugs" to increase the plasma confinement time in the central cell. A region known as the thermal barrier is also created in the plug to isolate electrons in the plug from the center cell. This thermal barrier helps to increase plugging. Scaling of the thermal barrier tandem mirror will be tested in the Mirror Fusion Test Facility (MFTF-B), see next page.

Date of Construction: 1978 for TMX, 1980 for TMX-U

Construction Cost: Original: $20 million
1984 $$: $40 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S., although there has been modest international collaboration on this device, approximately one man-year per year. It has been primarily with the Japanese and to a lesser extent with the Soviets.

Other Information: The project originated in 1978 as TMX (Tandem Mirror Experiment) at a cost of about $20 million (1978 dollars). Because of successful results, it was modified in 1980 to TMX-U (Tandem Mirror Experiment Upgrade) at a cost of about $20 million (1980 dollars). Since then, there have been a few minor additions in the areas of pumping power and diagnostics. The current estimated cost (1984 dollars) for the facility is approximately $40 million, which includes the cost of TMX-U, the parts retained from TMX (about $10 million), and various additions.

Livermore, CA., U.S.A.

MIRROR FUSION TEST FACILITY (MFTF-B)
Lawrence Livermore National Laboratory (LLNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: The MFTF-B will be the world's largest tandem mirror experimental fusion device, and it will be utilized to investigate the physics and engineering performance of thermal barrier tandem mirror confinement systems. It will extend the plasma performance parameters of density, temperature, and confinement into the near reactor regime.

Date of Construction: 1988

Construction Cost: 1984 $$: $420 million at completion in current year dollars

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S. (planned)
Nationality(s) of Management Staff: U.S. (planned)
Nationality(s) of Researchers: U.S. (planned)

Other Information: MFTF began in 1978 as a single cell mirror and was changed to a tandem mirror (MFTF-B) in 1980.

Oak Ridge, TN., U.S.A.

ADVANCED TOROIDAL FACILITY (ATF)
Oak Ridge National Laboratory (ORNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: ATF is a torsatron stellarator. Its purpose is to investigate plasma behavior at high toroidal beta under "steady-state" conditions and to explore a high beta mode known as the "second stability" regime.

Date of Construction: 1987

Construction Cost: 1984 $$: $50-$70 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S. (planned)
Nationality(s) of Management Staff: U.S. (planned)
Nationality(s) of Researchers: U.S. (planned)

Potential for Future International Cooperation: ATF is the U.S. facility from which active collaboration is based in the stellarator area. The United States is now completing negotiations on two agreements formalizing productive work in this field. One is an International Energy Agency agreement with the European Community (specifically with the Federal Republic of Germany) and the other is an agreement with Spain.

Los Alamos, NM., U.S.A.

SCYLLAC
Los Alamos National Laboratory (LANL)
U.S. Dept. of Energy

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: Scyllac was a high beta theta pinch stellarator. It was designed to achieve betas of one, and confinement times of 50 microseconds.

Date of Construction: 1972, decommissioned 1977

Constitution Cost: 1984 $$: $10 million

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: U.S. There was collaboration between the United States and the Federal Republic of Germany on Scyllac. There was one long-term visit to the United States and several exchanges that lasted for a few weeks.

Other Information: Scyllac was shut down in 1977 after the configuration was deemed to be unworkable at the reactor level, and the physics results were not promising.

Princeton, NJ., U.S.A.

C-STELLARATOR
Princeton Plasma Physics Laboratory (PPPL)
U.S. Dept. of Energy

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: C-Stellarator was a medium-sized, racetrack-shaped stellarator.

Date of Construction: 1965, decommissioned 1970

Construction Cost: 1984 $$: $30-$40 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Other Information: This machine was converted to the ST tokamak in 1970, after the very promising experimental results of the U.S.S.R. tokamak program became known. ST has been replaced with a number of medium-sized tokamaks.

Oak Ridge, TN., U.S.A.

INTERNATIONAL FUSION SUPERCONDUCTING MAGNETIC TEST FACILITY (IFSMTF)
Oak Ridge National Laboratory (ORNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: This is a facility to evaluate the performance features of six large-scale superconducting magnets designed and manufactured by both U.S. and foreign industrial concerns. The magnets are arranged in a toroidal array in the IFSMTF and tested individually and collectively to investigate scalable magnetic coupling effects and forces on the coil structures and the superconductors.

Date of Construction: 1983

Construction Cost: 1984 $$: $36 million in current year dollars

Present International Cooperation
Nationality(s) of Ownership: U.S. owns and operates the facility; three coils are foreign-owned.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S. (International Executive Committee for the Large Coil Task)
Nationality(s) of Researchers: U.S., Japan, Switzerland, EURATOM

The IFSMTF at ORNL is one of two major interrelated tasks under the Large Coil Test (LCT) organized in 1977 as an international cooperative program to develop, test, and demonstrate steady-state 8 Tesla field superconducting magnet coils. The other task under the LCT is the design and manufacture of six large superconducting coils which will be tested in the facility. Three of the large coils are fabricated by U.S. industry and three by foreign participants (Japan, Switzerland, EURATOM) under the formal International Energy Agency agreement.

The total cost of the six coils is estimated to be $6-$7 million, which includes the costs of development.

Culham, ENGLAND, UK.

JOINT EUROPEAN TORUS (JET)
Culham
EURATOM and the European Community

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: JET is the world's largest tokamak. It is designed to achieve reactor grade plasmas in order to provide the information necessary to build the Next European Tokamak (NET). It is equipped with 20 megawatts of ion cyclotron radio frequency (ICRF) heating and 15 megawatts of neutral beam heating. It also is designed with a tritium handling capability. If the plasma conditions are sufficient, this capability will be used to create deuterium-tritium plasmas, which will make it possible to study alpha particle effects.

Date of Construction: 1983

Construction Cost: 1984 $$: $660 million in current dollars

Present International Cooperation

Nationality(s) of Ownership: European Community

Nationality(s) of Operational Funding: European Community

Nationality(s) of Management Staff: European Community

Nationality(s) of Researchers: European Community. At present, the U.S. collaboration with JET has been limited to exchanges of information and personnel. The personnel exchanges have been at the two to three man-years per year rate.

JET represents a major triumph of international collaboration in fusion. The ten member states of the European Community were able to develop a coordinated approach to their next major step, and conceived a Joint Undertaking for the JET project.

Other Information: Construction of JET began in 1977 and will end in 1987 when full capability is achieved. The total budgeted construction cost is 533 million ECUs. Most of the funds were spent between 1978 and 1983. The DOE estimate of the cost in current (that is, year of expenditure) U.S. dollars is $660 million. The cost figures for JET may not include all of the commissioning and R&D costs.

Cadarache, FRANCE

TORE SUPRA
Cen De Cadarache
French Atomic Energy Commission and EURATOM

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: Tore Supra is a medium-sized tokamak which uses superconducting coils to achieve long-pulse operation. This long-pulse length will allow the project to study steady-state problems that will be appropriate to the Next European Tokamak (NET): current drive, current ramp, inductive heating recharge, particle removal, and steady-state heating and profile control.

Date of Construction: 1988

Construction Cost: 1984 $$: $200-$250 million

Present International Cooperation
- Nationality(s) of Ownership: France
- Nationality(s) of Operational Funding: France and EURATOM (planned)
- Nationality(s) of Management Staff: France (planned)
- Nationality(s) of Researchers: France (planned)

Potential for Future International Cooperation: Since the machine is under construction, there is no experimental collaboration. However, the United States is now negotiating participation in the development of a number of pieces of equipment for the device. These include developing a steady-state pellet injector, developing ergodic pumped limiters, and developing the radio frequency (RF) systems. At present, $600,000 to $1 million is budgeted in FY86 to achieve work in these areas that could be best done in collaboration with Tore Supra.

TEXTOR
KFA-Juelich
Federal Republic of Germany and EURATOM

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: TEXTOR is a medium-sized tokamak. Its main objectives are to study the plasma wall interaction and create the data base in this area that will be required for designing the Next European Tokamak (NET). TEXTOR has been built so that the liner can be quickly removed and replaced.

Date of Construction: 1981

Construction Cost: 1984 $$: $50 to $70 million

Present International Cooperation

Nationality(s) of Ownership: Federal Republic of Germany

Nationality(s) of Operational Funding: Federal Republic of Germany and EURATOM

Nationality(s) of Management Staff: Federal Republic of Germany

Nationality(s) of Researchers: Federal Republic of Germany. At present, the United States is spending about $1.2 million for collaboration on TEXTOR. There are also exchanges of personnel that total about four to five man-years of effort per year. Most of this effort is directed toward the advanced limiter test (ALT) pumped limiter experiments ALT-I and ALT-II.

Garching, FEDERAL REPUBLIC OF GERMANY

ASDEX
Institute of Plasma Physics
Federal Republic of Germany and EURATOM

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: ASDEX is a medium-sized tokamak. Its primary objective is to study the effect that a poloidal divertor has on the plasma. ASDEX has three megawatts of ion cyclotron radio frequency (ICRF) and three megawatts of neutral beam heating. The ASDEX group had made significant contributions to the understanding and enhancement of tokamak performance. It was the first device to achieve performance with auxiliary heating that was comparable to performance with ohmic heating.

Date of Construction: 1979

Construction Cost: 1984 $$: $50-$70 million

Present International Cooperation

Nationality(s) of Ownership: Federal Republic of Germany

Nationality(s) of Operational Funding: Federal Republic of Germany

Nationality(s) of Management Staff: Federal Republic of Germany

Nationality(s) of Researchers: Federal Republic of Germany. The United States supports exchanges of people with ASDEX at the three to four man-years per year rate.

Potential for Future International Cooperation: The United States and the European Community/Federal Republic of Germany are now completing negotiations for a formal collaborative agreement on the use of this facility. The United States currently has $1 million budgeted for collaboration.

Garching, FEDERAL REPUBLIC OF GERMANY

ASDEX-UPGRADE
Institute of Plasma Physics
Federal Republic of Germany and EURATOM

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: ASDEX-Upgrade is a medium-sized tokamak. It is currently under construction and will replace ASDEX when it becomes operational. Its objective is to develop the poloidal divertor physics data base needed to design the Next European Tokamak (NET).

Date of Construction: 1988

Construction Cost: 1984 $$: $80-$100 million

Present International Cooperation
Nationality(s) of Ownership: Federal Republic of Germany
Nationality(s) of Operational Funding: Federal Republic of Germany and EURATOM (planned)
Nationality(s) of Management Staff: Federal Republic of Germany (planned)
Nationality(s) of Researchers: Federal Republic of Germany (planned)

Potential for Future International Cooperation: There is an agreement pending for U.S. collaboration. The United States and the European Community/Federal Republic of Germany are now completing negotiations for a formal collaborative agreement on the use of this facility. The funding for this collaboration will be about $1 million per year.

Garching, FEDERAL REPUBLIC OF GERMANY

WENDELSTEIN VII AS
Institute of Plasma Physics
Federal Republic of Germany and EURATOM

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: Wendelstein VII AS is a medium-sized stellarator. One of the main difficulties with stellarators is their complicated system of continuous helical coils. The objective of Wendelstein VII AS is to determine if a stellarator built with modular coils can achieve results comparable to stellarators built with continuous helical coils. Modular coils would greatly increase the attractiveness of the stellarator concept as a fusion energy source.

Date of Construction: 1988

Construction Cost: 1984 $$: $50-$70 million

Present International Cooperation
Nationality(s) of Ownership: Federal Republic of Germany
Nationality(s) of Operational Funding: Federal Republic of Germany and EURATOM (planned)
Nationality(s) of Management Staff: Federal Republic of Germany (planned)
Nationality(s) of Researchers: Federal Republic of Germany (planned)

Potential for Future International Cooperation: At present, the exchanges of personnel with Wendelstein VII total between one to two man-years per year. It is planned to continue this level of collaboration when Wendelstein VII AS replaces Wendelstein VII in 1988.

Naka, JAPAN

JT-60
Japan Atomic Energy Research Institute (JAERI)-Naka
Japanese Atomic Energy Research Institute (JAERI)

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: JT-60 is one of the four largest tokamaks in the world. A feature that is unique to JT-60 is its outboard poloidal diverter. It is equipped with neutral beams, ion cyclotron radio frequency (ICRF), and lower hybrid current drive and heating. This makes its auxiliary heating systems the most extensive of all the large tokamaks. JT-60 is also the only large tokamak that is capable of doing noninductive current drive. On the other hand, it is not equipped to handle tritium, which means that the Japanese will have to rely on JET and TFTR (discussed previously) for their alpha particle physics.

Date of Construction: 1985

Construction Cost: $947 million in current year dollars

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: Japan. At present, there is less than one man-year in personnel exchanges with JT-60.

Other Information: Construction on JT-60 began in 1978 and will be completed in 1985. Most of the funds for construction were spent between 1980 and 1983. The budgeted cost of the facility in current (year of expenditure) funds is 270 billion yen. There may be some expenditures not included in this sum, but they are minor. DOE's estimate of the cost in current U.S. dollars is $947 million.

Tokai, JAPAN

JFT-2M
Japan Atomic Energy Research Institute (JAERI)-Tokai
Japanese Atomic Energy Research Institute (JAERI)

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: JFT-2M is a medium-sized tokamak. It serves as a test bed for the radio frequency (RF) heating and current drive that is to be used in JT-60. It is similar in size and research program to PLT in the United States.

Date of Construction: 1982

Construction Cost: 1984 $$: $30-$50 million

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: Japan

Tsukuba, JAPAN

GAMMA 10
Plasma Research Center
Monbusho

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: GAMMA 10 is the Japanese thermal barrier tandem mirror experiment. Its parameters are comparable to TMX-U in the U.S. program. GAMMA 10 is different from TMX-U in that its end plugs have more axisymmetry, which is expected to increase radical confinement. On the other hand, the end plugs are larger than the TMX-U end plugs, and this is a disadvantage.

Date of Construction: 1982

Construction Coat: 1984 $$: $30 million

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: Japan

In designing GAMMA 10, the Japanese collaborated with scientists from the U.S. mirror program because of their experience in designing TARA and TMX-U.

Kyoto, JAPAN

HELIOTRON-E
Kyoto University Plasma Physics Laboratory
Monbusho

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: Heliotron-E is a medium-sized stellarator. It uses neutral beams and gyrotrons to heat the plasma and initiate the discharge. It is the first stellarator to initiate discharge without using any inductive current drive.

Date of Construction: 1980

Construction Cost: 1984 $$: $40-$60 million

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: Japan. DOE supports personnel exchanges at the rate of one to two man-years per year.

Other Information: This machine complements the new U.S. stellarator (ATF) being built at Oak Ridge, TN.

Moscow, U.S.S.R.

T-10
Kurchatov Institute

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: T-10 is a medium-sized tokamak. It was one of the first medium-sized tokamaks in the world. It uses gyrotrons to heat the plasma. Its objectives are to explore high temperature, well confined plasmas and to create the data base needed for the U.S.S.R.'s next step.

Date of Construction: 1976

Construction Cost: 1984 $$: $50-$70 million

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R.
Nationality(s) of Operational Funding: U.S.S.R.
Nationality(s) of Management Staff: U.S.S.R.
Nationality(s) of Researchers: U.S.S.R.

Potential for Future International Cooperation: The United States has an exchange agreement with the U.S.S.R. The U.S. Dept. of Energy has sent delegations of five to ten people to review T-10 results. These exchanges last up to two weeks at a time, but do not occur every year. This year an exchange of five to seven people is planned to study the latest T-10 results.

Moscow, U.S.S.R.

T-15
Kurchatov Institute

"Big Science" Descriptor: Magnetic fusion

Description of Facility/Instrument: T-15 is one of the four largest tokamaks in the world. Its principal unique feature is its superconducting toroidal field coils. In spite of the coils being superconducting, T-15 will not be a long-pulse or steady-state machine. It will have neutral beams and 90 GHz gyrotrons for heating. It will continue the investigations of T-10 and try to achieve reactor grade plasmas.

Date of Construction: 1987

Construction Cost: 1984 $$: $400-$600 million

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R.
Nationality(s) of Operational Funding: U.S.S.R. (planned)
Nationality(s) of Management Staff: U.S.S.R. (planned)
Nationality(s) of Researchers: U.S.S.R. (planned)

Potential for Future International Cooperation: The United States and the U.S.S.R. have an exchange agreement that allows the United States to send delegations to review the technical work and results.

Livermore, CA., U.S.A.

HIGH-ENERGY LASER FACILITY ("NOVA")
Lawrence Livermore National Laboratory
U.S. Dept. of Energy

"Big Science" Descriptor: Inertial-confinement fusion

Description of Facility/Instrument: NOVA is a ten-beam, high-energy (70-100 kilojoule), short-pulse neodymium glass system and target chamber. NOVA operates at the second harmonic, but can, in principle, be converted to third and fourth harmonic operation with some degradation in beam energy. NOVA is, at present and for the foreseeable future, the world's most powerful laser system.

Date of Construction: December 1984

Construction Cost: 1984 $$: $221 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: Unknown. The laboratory director recently stated before a congressional committee that the laboratory has not as yet explored the potential for wider use of the facility beyond its designated role as an inertial-confinement fusion and weapons physics research facility.

Albuquerque, NM., U.S.A.

PARTICLE BEAM FUSION ACCELERATOR II (PBFA II)
Sandia National Laboratories
U.S. Dept. of Energy

"Big Science" Descriptor: Inertial-confinement fusion

Description of Facility/Instrument: PBFA II is a pulse power generator rated at about 3.5 megajoules delivered to the diode. Present plans are to operate the machine as a lithium ion accelerator for focusing experiments and possible target experiments.

Date of Construction: under construction, due in 1986

Construction Cost: 1984 $$: $45.3 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: None at this time.

Albuquerque, NM., U.S.A.

ELECTRON BEAM FUSION ACCELERATOR
Sandia National Laboratories
U.S. Dept. of Energy

"Big Science" Descriptor: Inertial-confinement fusion

Description of Facility/Instrument: This facility is a pulse power generator rated at about one megajoule at the diode, where the energy was originally designed to emerge as a beam of electrons focused in a small spot size. After 1980, the diode design was changed to emit positive ions (protons) and the voltage has been raised to permit experiments with lithium ions. The facility is scheduled to be converted in 1986 to a weapons effects simulator.

Date of Construction: 1980

Construction Cost: Original: $13.5 million
1984 $$: $19 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: None.

Rochester, NY., U.S.A.

NATIONAL LASER USERS FACILITY ("OMEGA")
Laboratory for Laser Energetics
University of Rochester

"Big Science" Descriptor: Inertial-confinement fusion

Description of Facility/Instrument: A 24-beam high-energy (one to two kilojoule), short-pulse neodymium glass laser system is housed in the laboratory. The laser is U.S. Government property, the laboratory that of the University provided by the State of New York. The laser recently has been converted to operate at the third harmonic. Work is funded by the U.S. Department of Energy as well as by a consortium of industrial and utility sponsors. In addition, the DOE funds experiments by selected users.

Date of Construction: 1982

Construction Cost: Original: \$20.1 million
1984 \$\$: \$31.3 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: mainly U.S.

Potential for Future International Cooperation: Substantial, although the facility is rather specialized. A number of non-fusion experiments have been done and many more could be done given funding and interest among researchers.

Los Alamos, NM., U.S.A.

HIGH-ENERGY LASER FACILITY ("ANTARES")
Los Alamos National Laboratory
U.S. Dept. of Energy

"Big Science" Descriptor: Inertial-confinement fusion

Description of Facility/Instrument: ANTARES is a high-energy (35 kilojoule), short-pulse carbon dioxide laser, consisting of two power amplifier modules of 12 beams each. The facility consists of the laser, a target chamber and beam turning and focusing system, an office, and a warehouse space. The facility cost is that of all the buildings and equipment.

Date of Construction: September 1983

Construction Cost: Original: \$62.5 million
1984 \$\$: \$82.5 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: Essentially none. The laser system is located in and used by the nuclear weapon research and development program at Los Alamos.

Livermore, CA., U.S.A.

HIGH-ENERGY LASER FACILITY ("SHIVA")
Lawrence Livermore National Laboratory
U.S. Dept. of Energy

"Big Science" Descriptor: Inertial-confinement fusion

Description of Facility/Instrument: SHIVA was a 20-beam neodymium glass laser used for inertial fusion target experiments and related research within the AEC-ERDA-DOE nuclear weapons programs.

Date of Construction: Commissioned in October 1977 and decommissioned in December 1980

Construction Cost: Original: $25 million
1984 $$: $37 million

Present International Cooperation
Nationality(s) of Ownership: (Currently
Nationality(s) of Operational Funding: not
Nationality(s) of Management Staff: operating)
Nationality(s) of Researchers:

Osaka, JAPAN

GEKKO XII GLASS LASER SYSTEM
Osaka University

"Big Science" Descriptor: Inertial-confinement fusion

Description of Facility/Instrument: GEKKO XII is a 12-beam 20 kilojoule/40 tetrawatts neodymium glass laser system with two separate target experimental rooms. Beams are switched to the two experimental areas, permitting overlapping experiments. Target chamber 1 is equipped for uniform irradiation by 12 beams at 1.053 microns or 0.526 microns of spherical targets. Target chamber 2 is equipped to irradiate flat plate targets in a 100-degree cone. The system with target chamber 1 is roughly comparable to the OMEGA laser system at the Unviersity of Rochester.

Date of Construction: 1984

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: mostly Japan

Potential for Future International Cooperation: Probably large, although U.S. classification rules and policy on cooperation in inertial fusion would severely inhibit cooperation from U.S. Inertial Fusion Program laboratory groups.

Harwell, ENGLAND, U.K.

CENTRAL LASER FACILITY ("VULCAN")
Rutherford Appleton Laboratory
Science and Engineering Research Council

"Big Science" Descriptor: Laser research

Description of Facility/Instrument: The main instrument is a large neodymium-doped glass laser which was upgraded in 1980-81 to provide a range of wavelengths by harmonic generation in non-linear crystals. As such, it was the first multi-beam compression facility capable of operating at more than one wavelength.

Date of Construction: 1976; upgraded in 1981

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.K.
Nationality(s) of Operational Funding: U.K.
Nationality(s) of Management Staff: U.K.
Nationality(s) of Researchers: U.K.

APPENDIX 5

MATERIALS SCIENCE AND ENGINEERING FACILITIES

These programs carry out a wide variety of international activities including informal information exchange, informal collaboration by researchers, and formal umbrella agreements which allow the countries involved to carry our specific technical projects such as joint funding of research and hardware. While each of the programs is involved in some or all of these activities, the role and level of involvement varies from program to program and evolves according to scientific need and economic and political conditions both in the United States and abroad. Since there are so many factors involved, it is difficult to project the potential for international cooperation on a facility-facility-basis.

The ability to provide cost estimates for foreign facilities also varies from program to program and by facility. The more significant factor, however, is that funding information for foreign facilities is not generally comparable to U.S. cost estimates because foreign estimates generally include only the cost of construction materials but not the cost of construction manpower. Estimates of U.S. construction costs include both.

In addition to the facilities included in this appendix, which are believed to be the main ones, there are several other synchrotron sources being planned and at various stages of approval. These include ones at Grenoble, France, which is a combined European effort (5 GeV); the People's Republic of China (2.8 GeV); the U.S.S.R. (2.5 GeV); Lawrence Berkeley Laboratory (1.3 GeV); Taiwan (1.0 GeV); and India (0.8 GeV).

The information in this appendix was supplied by the Department of Energy, April 16, 1985, and by the National Bureau of Standards, April 1985.

Gaithersburg, MD., U.S.A.

NBS RESEARCH REACTOR (NBSR)
Center for Materials Science
National Bureau of Standards (NBS), U.S. Dept. of Commerce

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: The NBSR is a national center for the development and application of neutron methods in materials science, chemistry, physics, biology, and radiation standards. The NBSR is a high-performance 20 megawatt research reactor. It runs 24 hours per day and has 25 major experimental facilities which are widely used each year by 250 scientists and engineers from NBS, industries, and universities. The NBSR is installing the largest cold neutron source in the country and is planning a new center for cold neutron research with 15 instruments to serve U.S. needs in these research areas.

Date of Construction: Operational December 1967

Construction Cost: Original: $12 million
1984 $$: $110 million (including instruments)

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: Many foreign visitors engaged in cooperative research; cooperative R&D agreement between NBS and the Institut Laue-Langevin (French, German, British Reactor Center at Grenoble).

Potential for Future International Cooperation: Initiated in 1984. Significant potential for mutual, cost-effective R&D on neutron research instrumentation with the Institut Laue-Langevin and other French and German centers, which will enhance capabilities at all neutron centers.

Cambridge, MA., U.S.A.

FRANCIS BITTER NATIONAL MAGNET LABORATORY (NML)
Massachusetts Institute of Technology

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: The National Magnet Laboratory provides high field facilities for experiments in solid state and low temperature physics, atomic and molecular physics, chemistry, materials research, magnet engineering, and materials research.

Date of Construction: 1960

Construction Cost: 1984 $$: more than $50 million

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: About 95 percent U.S.; 5 percent foreign.

Potential for Future International Cooperation: It is expected that international cooperation will continue at this level. Several foreign scientists spend their sabbatical years at NML. Users from non-U.S. institutions in 1983-84 were from Poland (1), Japan (4), France (2), Switzerland (1), Brazil (2), and Finland (1).

Stoughton, WI., U.S.A.

TANTALUS, ALADDIN
Wisconsin Synchrotron Radiation Center (SRC)
University of Wisconsin

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: Tantalus is a synchrotron radiation (SR) source providing radiation in the ultraviolet range up to 150 eV. It would cost approximately $5 million to duplicate this 240 MeV storage ring today. Aladdin is an enhanced SR source with a 1.0 GeV ring with 36 ports designed for very high brightness. It is currently in the commissioning stage. The facility includes a very soft x-ray source and associated photoemission spectrometers. The construction and instrumentation costs so far are $6 million and $7.5 million respectively. Another $18 million for an upgrade can be anticipated. The total capital cost of the SRC is estimated to be about $44 million.

Date of Construction: 1968 for Tantalus and 1978 for Aladdin.

Construction Cost: 1984 $$: $44 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: Primarily U.S. Currently there is a Canadian Beam Line on Aladdin funded by the Canadian Synchrotron Radiation Center ($1-$2 million).

Potential for Future International Cooperation: There are probably 10 to 12 foreign users of SRC facilities each year. If foreign users were interested in putting up their own beam lines on Aladdin, this could be accommodated.

Other Information: The beam line instrumentation on Aladdin is estimated to be about $1 million per beam line. It is expected that 20 beam lines will be implemented immediately with expansion to 30 in several years.

Upton, NY., U.S.A.

HIGH FLUX BEAM REACTOR (HFBR)
Brookhaven National Laboratory (BNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Materials science and engineering

Description of Facility/Instrument: This facility is a high flux (about 10^{15} neutron/cm^2/second) beam reactor used for neutron scattering, positron source, nuclear physics, irradiation, and isotope production.

Date of Construction: 1965

Construction Cost: Original: $12.5 million
1984 $$: $52.1 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: 80 percent U.S.

Upton, NY., U.S.A.

NATIONAL SYNCHROTRON LIGHT SOURCE (NSLS)
Brookhaven National Laboratory (BNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a vacuum ultraviolet source and an x-ray ring with insertion devices. About 100 separate experiments for biological, medical, chemical, atomic physics, and materials sciences are conducted. The ring energies are 0.75 GeV and 2.5 GeV and were commissioned in April 1984 and July 1985, respectively.

Date of Construction: 1981

Construction Cost: Original: $24 million
1984 $$: $29.5 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: Primarily U.S. with occasional foreign collaborators.

There are numerous international collaborative research programs conducted at this facility.

68-022 O - 87 - 6

Palo Alto, CA., U.S.A.

STANFORD SYNCHROTRON RADIATION LABORATORY
Stanford Linear Accelerator Center
Stanford University and U.S. Dept. of Energy

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This laboratory uses SPEAR (4.0 GeV) and PEP (16 GeV) rings for synchrotron gamma radiation for atomic physics, biological sciences, chemical sciences, materials sciences, industrial processing, and medical sciences. These are run in a parasitic mode with the high-energy physics research facility of the Stanford Linear Accelerator Center.

Date of Construction: (See below.)

Construction Cost: (See below.)

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: Primarily U.S. with occasional foreign collaborators.

This facility is used for many international research collaborations.

Other Information: Construction costs are not readily available. The facility initially began operation in a parasitic mode on the SPEAR ring of the Stanford Linear Accelerator Center. It was built over a number of years on a piecemeal basis by the National Science Foundation.

See also STANFORD LINEAR ACCELERATOR CENTER (SLAC).

Los Alamos, NM., U.S.A.

SPALLATION NEUTRON SOURCE
Los Alamos National Laboratory (LANL)
U.S. Dept. of Energy

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This facility provides neutron scattering from cold to thermal to epithermal regions. It is parasitic on the Los Alamos Meson Physics Facility (LAMPF).

Date of Construction: 1977, proton storage ring in 1984-85

Construction Cost: Original: $27.5 million
1984 $$: $48.9 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: 95 percent U.S.

Other Information: The cost figures do not include the fact that this facility utilizes the Los Alamos Meson Physics Facility (LAMPF) as a source of protons. The proton storage ring was constructed in 1984-85.

Oak Ridge, TN., U.S.A.

HIGH FLUX ISOTOPE REACTOR (HFIR)
Oak Ridge National Laboratory (ORNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This facility produces a high flux (10^{15} neutrons/cm^2/sec) for neutron scattering, neutron irradiation, and isotope production.

Date of Construction: 1965

Construction Cost: Original: $15 million
1984 $$: $62.5 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: 90 percent U.S.

There is a U.S.-Japan agreement and informal arrangements.

Oak Ridge, TN., U.S.A.

OAK RIDGE RESEARCH REACTOR (ORR)
Oak Ridge National Laboratory (ORNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Materials science and engineering

Description of Facility/Instrument: This facility provides a flux of about 10^{14} neutrons/cm^2/second for neutron scattering, neutron irradiation, isotope production, and engineering.

Date of Construction: 1958

Construction Cost: Original: $5 million
1984 $$: $24.9 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: 90 percent U.S.

Ithaca, NY., U.S.A.

CORNELL HIGH ENERGY SYNCHROTRON SOURCE (CHESS)
Cornell Electron Storage Ring (CESR)
Cornell University

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This facility is primarily for extended x-ray absorption fine structure (EXAFS) investigations. CESR works between 4 and 8 GeV. The spectrometers cost $1.3 million in 1981.

Date of Construction: 1967

Construction Cost: Original: $11.5 million
1984 $$: $44.7 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: Primarily U.S. with occasional foreign collaborators.

Other Information: See also CORNELL ELECTRON STORAGE RING (CESR).

Argonne, IL., U.S.A.

INTENSE PULSED NEUTRON SOURCE
Argonne National Laboratory (ANL)
U.S. Dept. of Energy

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This facility provides neutron scattering from cold to thermal to epithermal regions.

Date of Construction: 1981

Construction Cost: Original: $6.4 million
1984 $$: $7.9 million, but this does not account for millions of dollars of surplus equipment used by this facility.

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: 85 percent U.S.

Argonne, IL., U.S.A.

CP-5
Argonne National Laboratory (ANL)
U.S. Dept. of Energy

"Big Science" Descriptor: Materials science and engineering

Description of Facility/Instrument: This facility was used for neutron scattering, irradiation, isotope production, and engineering.

Date of Construction: 1954, decommissioned in 1979

Construction Cost: Original: $2.1 million
1984 $$: $11.8 million

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding: (Currently
Nationality(s) of Management Staff: not
Nationality(s) of Researchers: operating)

Ames, IA., U.S.A.

AMES RESEARCH REACTOR
Ames Laboratory
U.S. Dept. of Energy

"Big Science" Descriptor: Materials science and engineering

Description of Facility/Instrument: This facility was used for neutron scattering, nuclear physics, and engineering.

Date of Construction: 1965, decommissioned in 1977

Construction Cost: Original: $4.6 million
1984 $$: $19.2 million

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:
(Currently not operating)

Columbia, MO., U.S.A.

UNIVERSITY OF MISSOURI RESEARCH REACTOR (MURR)
University of Missouri

"Big Science" Descriptor: Materials science and engineering

Description of Facility/Instrument: This facility is a research reactor with a flux of 10^{14} neutrons/cm^2/second for neutron scattering, activation analysis, radioisotope application, radiography, nuclear engineering, and nuclear sciences.

Date of Construction: 1966

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: 95 percent U.S.

Cambridge, MA., U.S.A.

MIT RESEARCH REACTOR
Massachusetts Institute of Technology

"Big Science" Descriptor: Materials science and nuclear engineering

Description of Facility/Instrument: This facility is used for neutron scattering, nuclear physics, and nuclear medicine.

Date of Construction: mid-1950s

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: 90 percent U.S.

Chalk River, CANADA

NRU REACTOR
Chalk River Nuclear Laboratory
Atomic Energy of Canada Limited

"Big Science" Descriptor: Materials science and engineering

Description of Facility/Instrument: This is a facility with a flux of about 5×10^{14} neutrons/cm^2/second for neutron scattering, nuclear engineering, nuclear physics, materials testing, irradiation, and isotope production.

Date of Construction: 1950s

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: Canada
- Nationality(s) of Operational Funding: Canada
- Nationality(s) of Management Staff: Canada
- Nationality(s) of Researchers: A number of British scientists are there.

Daresbury, ENGLAND, U.K.

SYNCHROTRON RADIATION SOURCE (SRS)
Science and Engineering Research Council

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a 2.0 GeV synchrotron source dedicated to research in materials science. It has about 18 experimental stations. It began generation in March 1981.

Date of Construction: 1981

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.K.
Nationality(s) of Operational Funding: U.K.
Nationality(s) of Management Staff: U.K.
Nationality(s) of Researchers: U.K.

Harwell, ENGLAND, U.K.

DIDO AND PLUTO REACTORS
Atomic Energy Research Establishment

"Big Science" Descriptor: Materials science and engineering

Description of Facility/Instrument: This facility is a reactor with a flux of about 2 x 10^{14} neutrons/cm^2/second for neutron scattering, materials testing, engineering, radiography, and isotope production.

Date of Construction: 1954

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.K.
Nationality(s) of Operational Funding: U.K.
Nationality(s) of Management Staff: U.K.
Nationality(s) of Researchers: U.K.

Harwell, ENGLAND, U.K.

SPALLATION NEUTRON RESEARCH SNS
Rutherford Appleton Laboratory
Science and Engineering Research Council

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a facility for scattering, irradiation, and nuclear physics.

Date of Construction: 1984

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.K.
Nationality(s) of Operational Funding: U.K.
Nationality(s) of Management Staff: U.K.
Nationality(s) of Researchers: U.K.

Orsay, FRANCE

LURE

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This establishment runs three dedicated synchrotron sources for materials research. Their energies are 0.540 (ACO), 0.800 (Super ACO), and 1.800 GeV (DCI).

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: France
Nationality(s) of Operational Funding: France
Nationality(s) of Management Staff: France
Nationality(s) of Researchers: France

In 1983, the Orsay-Stanford group operated the first storage-ring free electron laser.

Grenoble, FRANCE

HIGH FLUX REACTOR (HFR)
Institut Laue - Langevin

"Big Science" Descriptor: Materials science and nuclear physics

Description of Facility/Instrument: This is a reactor with a flux of about 10^{15} neutrons/cm^2/second for neutron scattering, cold and hot sources, guide halls, nuclear physics, chemistry, and biology.

Date of Construction: 1971

Construction Cost: Original: $70 million
1984 $$: $162.9 million

Present International Cooperation
Nationality(s) of Ownership: France, Federal Republic of Germany, U.K.
Nationality(s) of Operational Funding: France, Federal Republic of Germany, U.K.
Nationality(s) of Management Staff: Majority are French
Nationality(s) of Researchers: Mostly European, others are from the U.S., Canada, Australia, Japan, and the U.S.S.R.

Grenoble, FRANCE

EUROPEAN SYNCHROTRON RADIATION FACILITY (ESRF)
European Science Foundation

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This facility will be a five GeV synchrotron radiation machine, 770 meters in circumference, using intense x-rays to study organic and inorganic materials.

Date of Construction: 1985 or 1986

Construction Cost: 1984 $$: $200 million

Present International Cooperation

Nationality(s) of Ownership: France-Federal Republic of Germany

Nationality(s) of Operational Funding: France-Federal Republic of Germany

Nationality(s) of Management Staff: Mainly France and the Federal Republic of Germany

Nationality(s) of Researchers: Mainly European

Potential for Future International Cooperation: It is planned that there will be additional funding by other members of the European Economic Community.

Other Information: In June 1985, it still was not definite that this facility will be located in Grenoble or what will be the extent of participation by other European nations.

Grenoble, FRANCE

SITOE REACTOR
Center for Nuclear Studies, Grenoble (CENG)

"Big Science" Descriptor: Materials science and nuclear science

Description of Facility/Instrument: This is a reactor with a flux of abou 10^{14} neutrons/cm^2/second for neutron scattering, nuclear engineering, nuclear physics, and materials testing.

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: France
Nationality(s) of Operational Funding: France
Nationality(s) of Management Staff: France
Nationality(s) of Researchers: France

Grenoble, FRANCE

MELUSINE REACTOR
Center for Nuclear Studies, Grenoble (CENG)

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a reactor with a flux of about 10^{13} neutrons/cm^2/second for neutron scattering and nuclear science research.

Date of Construction: late 1950s

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: France
Nationality(s) of Operational Funding: France
Nationality(s) of Management Staff: France
Nationality(s) of Researchers: France 95 percent, Federal Republic of Germany and others five percent

Saclay (Paris), FRANCE

ORPHEE REACTOR
Leon Brilloun Institute

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a reactor with a flux of 10^{14} neutrons/cm^2/second for neutron scattering, nuclear physics, guide hall, cold sources, and a hot source.

Date of Construction: 1980

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: France
- Nationality(s) of Operational Funding: France
- Nationality(s) of Management Staff: France
- Nationality(s) of Researchers: France 80 percent, Federal Republic of Germany 10 percent, others 10 percent

Hamburg, FEDERAL REPUBLIC OF GERMANY

HAMBURGER SYNCHROTRON STRAHLINGSLABOR (HASYLAB)

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a 5.0 GeV synchrotron source run in a parasitic mode, from DORIS. It has 24 experimental stations. The laboratory started about 15 years ago.

Date of Construction: 1970

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: Federal Republic of Germany
- Nationality(s) of Operational Funding: Federal Republic of Germany
- Nationality(s) of Management Staff: Federal Republic of Germany
- Nationality(s) of Researchers: Federal Republic of Germany

West Berlin, FEDERAL REPUBLIC OF GERMANY

BESSY

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a 0.8 GeV dedicated source of synchrotron radiation with 21 ports. It has strong usage by German industry.

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation

Nationality(s) of Ownership: Federal Republic of Germany
Nationality(s) of Operational Funding: Federal Republic of Germany
Nationality(s) of Management Staff: Federal Republic of Germany
Nationality(s) of Researchers: Almost all German

Garching (Munich), FEDERAL REPUBLIC OF GERMANY

FRM REACTOR
Technische Universitat

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a reactor with a flux of $3x10^{13}$ neutrons/cm^2/second for neutron scattering and nuclear physics research.

Date of Construction: About 1958

Construction Cost: 1984 $$:

Present International Cooperation

Nationality(s) of Ownership: Federal Republic of Germany
Nationality(s) of Operational Funding: Federal Republic of Germany
Nationality(s) of Management Staff: Federal Republic of Germany
Nationality(s) of Researchers: Federal Republic of Germany

Julich, FEDERAL REPUBLIC OF GERMANY

FRJ-2 REACTOR
Institute for Festkorperforschung
Kernforschunganlage

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a reactor with a flux of about 10^{14} neutrons/cm^2/second for neutron scattering, nuclear physics, guide hall, and cold source use.

Date of Construction: 1962

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: Federal Republic of Germany
Nationality(s) of Operational Funding: Federal Republic of Germany
Nationality(s) of Management Staff: Federal Republic of Germany
Nationality(s) of Researchers: Federal Republic of Germany

West Berlin, FEDERAL REPUBLIC OF GERMANY

BER-II RESEARCH REACTOR
Hahn-Meitner Institute

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a research reactor with a flux of about $3x10^{13}$ neutrons/cm^2/second scheduled to be upgraded to $2x10^{14}$ for neutron scattering, nuclear physics, nuclear science, and neutron radiography.

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: Federal Republic of Germany
Nationality(s) of Operational Funding: Federal Republic of Germany
Nationality(s) of Management Staff: Federal Republic of Germany
Nationality(s) of Researchers: 80 percent German and 20 percent others

Petten, THE NETHERLANDS

HIGH FLUX REACTOR (HFR)

ECN Petten
Netherlands Energy Research Foundation ECN

"Big Science" Descriptor: Materials science and nuclear science

Description of Facility/Instrument: This is a reactor with a flux of about $5x10^{14}$ neutrons/cm^2/second in trap for neutron scattering, nuclear physics, and multipurpose testing reactor uses.

Date of Construction: 1961

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: The Netherlands
Nationality(s) of Operational Funding: The Netherlands
Nationality(s) of Management Staff: The Netherlands
Nationality(s) of Researchers: The Netherlands

Roskilde, DENMARK

DR3 RESEARCH REACTOR
Riso National Laboratory

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a research reactor with a flux of about 10^{14} neutrons/cm^2/second for neutron scattering, nuclear physics, guide halls, cold sources, and neutron production.

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: Denmark
Nationality(s) of Operational Funding: Denmark
Nationality(s) of Management Staff: Denmark
Nationality(s) of Researchers: Denmark

Studsvick, SWEDEN

HIGH FLUX REACTOR
Studsvick Energiteknik

"Big Science" Descriptor: Materials science and engineering

Description of Facility/Instrument: This is a reactor with a flux of about 2×10^{14} neutrons/cm^2/second for neutron scattering, nuclear physics, and nuclear engineering.

Date of Construction: early 1960s

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: Sweden
- Nationality(s) of Operational Funding: Sweden
- Nationality(s) of Management Staff: Sweden
- Nationality(s) of Researchers: Sweden

Lund, SWEDEN

MAX

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a 550 MeV synchrotron source.

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: Sweden
- Nationality(s) of Operational Funding: Sweden
- Nationality(s) of Management Staff: Sweden
- Nationality(s) of Researchers: Sweden

Frascoti, ITALY

ADONE

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a 1.55 GeV source of synchrotron radiation run in a parasitic mode. There are six experimental stations on five beamlines.

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: Italy
- Nationality(s) of Operational Funding: Italy
- Nationality(s) of Management Staff: Italy
- Nationality(s) of Researchers: Italy

Sutherland, AUSTRALIA

AUSTRALIAN RESEARCH REACTOR HIFAR
Lucas Heights Research Laboratories
Australian Atomic Energy Commission Research Establishment

"Big Science" Descriptor: Materials science and engineering

Description of Facility/Instrument: This is a research reactor with a flux of about 5×10^{13} neutrons/cm^2/second for neutron scattering, irradiation, isotope production and nuclear physics research.

Date of Construction: 1980

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: Australia
- Nationality(s) of Operational Funding: Australia
- Nationality(s) of Management Staff: Australia
- Nationality(s) of Researchers: Australia with some U.K. researchers

Osaka, JAPAN

UVSOR
Institute of Molecular Science

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a 0.6 GeV synchrotron radiation source dedicated to materials science. It has 200 scientists.

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: Japan
- Nationality(s) of Operational Funding: Japan
- Nationality(s) of Management Staff: Japan
- Nationality(s) of Researchers: Japan

Osaka, JAPAN

KYOTO UNIVERSITY REACTOR
Research Reactor Institute
Science Council of Japan

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a five megawatt research reactor. A new 30 megawatt Kyoto University High Flux Reactor is planned.

Date of Construction: 1964, upgraded 1967

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: Japan
- Nationality(s) of Operational Funding: Japan
- Nationality(s) of Management Staff: Japan
- Nationality(s) of Researchers: Japan

This facility has some foreign scientists on long- and short-term assignments.

Tokai, JAPAN

JAPANESE RESEARCH REACTOR NO. 2
Tokai Research Establishment
Japan Atomic Energy Research Institute

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a ten megawatt CP-5 reactor producing a flux of 2×10^{14} neutrons/cm^2/second. It is equipped with 13 horizontal beams and irradiation facilities.

Date of Construction: January 1957 through October 1960

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Tokai, JAPAN

JAPANESE RESEARCH REACTOR NO. 3
Tokai Research Establishment
Japan Atomic Energy Research Institute

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a reactor with a maximum thermal flux of 2.7×10^{13} neutrons/cm^2/second. It operates at ten megawatts with eight neutron scattering horizontal beams and many irradiation facilities. An upgrade will be finished by 1988. It will operate at 20 megawatts and produce 2.7×10^{14} neutrons/cm^2/second. It will have a cold neutron source.

Date of Construction: January 1959 through September 1962

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: Japan
- Nationality(s) of Operational Funding: Japan
- Nationality(s) of Management Staff: Japan
- Nationality(s) of Researchers: Japan

Tokyo, JAPAN

INSOR
Institute for Solid State Physics
Institute of Nuclear Science, University of Tokyo

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a 0.4 synchrotron radiation source for dedicated materials science use.

Date of Construction: 1974

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: Japan

Tsukuba, JAPAN

THE PHOTON FACTORY

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This facility has 2.5 and 0.6 GeV synchrotron radiation sources dedicated to materials science.

Date of Construction: 1982

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: Japan

Tsukuba, JAPAN

KENS-1
KEK

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a facility for neutron scattering and nuclear physics research.

Date of Construction: 1980

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: Japan

Karkhov, U.S.S.R.

N-100
Karkhov Physics Institute

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a 0.100 GeV synchrotron source dedicated to materials science.

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R.
Nationality(s) of Operational Funding: U.S.S.R.
Nationality(s) of Management Staff: U.S.S.R.
Nationality(s) of Researchers: U.S.S.R.

Novosibirsk, U.S.S.R.

VEPP-2M, VEPP-3, BEPP-4
Institute of Nuclear Physics

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This facility has 0.7, 2.2, and 5-7 GeV storage rings for vacuum ultraviolet/soft x-rays, x-rays, and intense x-ray sources.

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R.
Nationality(s) of Operational Funding: U.S.S.R.
Nationality(s) of Management Staff: U.S.S.R.
Nationality(s) of Researchers: U.S.S.R.

Moscow, U.S.S.R.

KURCHATOV I
Kurchatov Institute

"Big Science" Descriptor: Materials science

Description of Facility/Instrument: This is a 0.45 GeV synchrotron source dedicated to materials science.

Date of Construction:

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R.
Nationality(s) of Operational Funding: U.S.S.R.
Nationality(s) of Management Staff: U.S.S.R.
Nationality(s) of Researchers: U.S.S.R.

APPENDIX 6

ASTRONOMICAL FACILITIES

The information in this appendix was supplied by the National Science Foundation and the U.S. Air Force, April 1985.

Mount Palomar, CA., U.S.A.

200-INCH TELESCOPE
Palomar Observatory
California Institute of Technology

"Big Science" Descriptor: Optical astronomy

Description of Facility/Instrument: This is a 200-inch aperture optical telescope and associated instrumentation.

Date of Construction: 1948

Construction Cost: 1984 $$: $58 million estimated replacement cost

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: International collaborations are arranged on a case-by-case basis.

Arecibo, PR., U.S.A.

1000-FOOT RADIO/RADAR TELESCOPE
Arecibo Observatory
National Astronomy and Ionosphere Center (NAIC)

"Big Science" Descriptor: Radio astronomy, radar astronomy, and atmospheric physics

Description of Facility/Instrument: NAIC, with headquarters at Cornell University in Ithaca, N.Y., provides unique instrumentation and facilities for basic research in radio astronomy, radar astronomy, and atmospheric physics. The major NAIC observing instrument is a 1000-foot diameter fixed reflector which together with sensitive receivers and very high-power transmitters is the world's largest radio/radar telescope.

Date of Construction: Completed in 1963, upgraded in 1974

Construction Cost: Original: 18.1 million
1984 $$: 46.1 million

Present International Cooperation

Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: Mostly U.S.A. with some foreign nationals.

The NAIC Arecibo Observatory always has had a strong component of international cooperation in its research operations. Aside from foreign scientists regularly making use of the 1000-foot telescope for competitively-reviewed observing programs, in recent years NAIC has participated in numerous Very Long Baseline Interferometry (VLBI) experiments with intercontinental baselines, which are continuing; coordinated incoherent scatter radar observations of the ionosphere in support of International World Day programs, also continuing; hosted support for temporary on-site instrumentation of foreign institutions (for example, German 50 MHz middle-atmosphere radar and French meteor radar; and engaged in international research campaigns (for example, search for radio pulsations from gamma ray sources and simultaneous measurements for Faraday rotation measures of pulsars).

Potential for Future International Cooperation: This is very high due to the international nature of radio astronomy which involves very long baseline interferometry. Also, atmospheric physics research using incoherent scatter radars is strongly international in nature.

Kitt Peak, AZ., U.S.A.

FOUR-METER TELESCOPE
Kitt Peak National Observatory (KPNO)
National Optical Astronomy Observatory (NOAO)

"Big Science" Descriptor: Astronomy

Description of Facility/Instrument: This facility is a four-meter aperture telescope.

Date of Construction: 1965-1973

Construction Cost: Original: \$10.7 million
1984 \$\$: \$30 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S. and foreign

Potential for Future International Cooperation: Time on the telescope is available to all qualified scientists on a competitive basis.

Cerro Tololo, CHILE (U.S.A.)

CTIO FOUR-METER TELESCOPE
Cerro Tololo Inter-American Observatory (CTIO)
National Optical Astronomy Observatory (NOAO)

"Big Science" Descriptor: Astronomy

Description of Facility/Instrument: This U.S. four-meter aperture telescope, located in Cerro Tololo, Chile, is the largest optical telescope in the Southern Hemisphere.

Date of Construction: 1967, became operational in 1976

Construction Cost: Original: $10.4 million
1984 $$: $27.5 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S. and foreign

The University of Chile has an agreement with the observatory for scientific cooperation in astronomical research. Each year, the observatory employs students from Chilean universities.

Potential for Future International Cooperation: Time on the telescope is available to all qualified scientists on a competitive basis with preference to scientists from North and South America.

Green Bank, WV., U.S.A.

140-FOOT RADIO TELESCOPE
National Radio Astronomy Observatory (NRAO)

"Big Science" Descriptor: Radio astronomy

Description of Facility/Instrument: This 140-foot radio telescope has a fully steerable parabolic mirror with receiving equipment.

Date of Construction: 1964

Construction Cost: Original: $13.5 million
1984 $$: $41.6 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S. and foreign

Potential for Future International Cooperation: This facility is part of the international Very Long Baseline Interferometry (VLBI) network.

Socorro, NM., U.S.A.

NRAO VERY LARGE ARRAY (VLA)
National Radio Astronomy Observatory (NRAO)

"Big Science" Descriptor: Radio astronomy

Description of Facility/Instrument: This facility is an aperture synthesis radio telescope comprised of 27 antennas with receiving equipment.

Date of Construction: 1972-1979

Construction Cost: Original: $78.5 million
1984 $$: $139 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: This facility conducts worldwide Very Long Baseline Interferometry (VLBI) experiments.

Sunspot, NM., U.S.A.

SACRAMENTO PEAK OBSERVATORY (VACUUM TOWER TELESCOPE)
Air Force Systems Command

"Big Science" Descriptor: Solar astronomy

Description of Facility/Instrument: The vacuum telescope built at Sacramento Peak was designed to provide information on the cause of solar flares, methods for predicting their occurrence, and for determining the effects of solar activity on the Earth's upper atmosphere.

Date of Construction: Began in 1966, placed in operation in 1969

Construction Cost: 1984 $$: $21 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: Mainly U.S.

CHILE

140-INCH TELESCOPE
European Southern Observatory (ESO)

"Big Science" Descriptor: Optical astronomy

Description of Facility/Instrument: This facility includes a 140-inch optical telescope and associated instrumentation.

Date of Construction: mid 1970s

Construction Cost: 1984 $$: probably more than $25 million

Present International Cooperation
- Nationality(s) of Ownership: International European Consortium
- Nationality(s) of Operational Funding: International European Consortium
- Nationality(s) of Management Staff: International European Consortium
- Nationality(s) of Researchers: International European Consortium

Potential for Future International Cooperation: The project is designed as an international collaboration among France, the Federal Republic of Germany, the Netherlands, and Sweden.

Plateau de Bure, FRANCE

IRAM INTERFEROMETER
Institut de Radio Astronomie Millimetrique

"Big Science" Descriptor: Radio astronomy

Description of Facility/Instrument: This facility has three 15-meter diameter antennas to be used simultaneously as an aperture synthesis telescope. It will be usable to a minimum wavelength of 0.75 millimeters. It has baseline tracks of 320 meters east-west and 192 meters north-south.

Date of Construction: 1984-1988

Construction Cost: 1984 $$: About $20 million

Present International Cooperation
- Nationality(s) of Ownership: France-Federal Republic of Germany
- Nationality(s) of Operational Funding: France-Federal Republic of Germany
- Nationality(s) of Management Staff: International
- Nationality(s) of Researchers: International, primarily French-German

Potential for Future International Cooperation: This is a joint French-German research institute with headquarters in Grenoble, France. International collaboration on individual scientific projects will occur. Each project will be evaluated on the merits of scientific value and appropriateness for this instrument on a case-by-case basis.

Effelsberg, FEDERAL REPUBLIC OF GERMANY

RADIOSTERNWARTE EFFELSBERG (EFFELSBERG TELESCOPE)
Max Planck Institute fur Radioastronomie
Max Planck Gesellschaft

"Big Science" Descriptor: Radio astronomy

Description of Facility/Instrument: This is a 100-meter, fully steerable, parabolic reflector. It is usable to a minimum wavelength of seven millimeters. It is used primarily in the wavelength range of 21 centimeters to 7 millimeters. It is the largest single antenna, fully steerable radio telescope in the world.

Date of Construction: 1973

Construction Cost: 1984 $$: About $23 million

Present International Cooperation

Nationality(s) of Ownership: Federal Republic of Germany
Nationality(s) of Operational Funding: Federal Republic of Germany
Nationality(s) of Management Staff: Federal Republic of Germany
Nationality(s) of Researchers: Federal Republic of Germany

Potential for Future International Cooperation: Observing time is awarded on the basis of scientific merit and appropriateness for this instrument. Proposals for time from scientists outside the Institute are evaluated and time allocated on a case-by-case basis.

Other Information: In principle, this facility is for the sole use of Institute staff scientists. In practice, between 25 and 50 percent of the telescope time has gone to scientists outside of the Institute.

New South Wales, AUSTRALIA

AUSTRALIA TELESCOPE
Commonwealth Scientific and Industrial Research Organization (CSIRO)

"Big Science" Descriptor: Radio astronomy

Description of Facility/Instrument: The six 20-meter antennas are used simultaneously as a synthesis radio telescope.

Date of Construction: 1984-1987

Construction Cost: 1984 $$: $22 million

Present International Cooperation
Nationality(s) of Ownership: Australia
Nationality(s) of Operational Funding: Australia
Nationality(s) of Management Staff: Australia
Nationality(s) of Researchers: Australia

Potential for Future International Cooperation: Australia may desire to enlist international cooperation to add additional elements to this array telescope which would extend the baseline coverage for dedicated very long baseline interferometry observations.

Coonabarabran, New South Wales, AUSTRALIA

ANGLO-AUSTRALIAN TELESCOPE
Anglo-Australian Observatory

"Big Science" Descriptor: Optical astronomy

Description of Facility/Instrument: This facility is a 150-inch optical telescope.

Date of Construction: 1974-75

Construction Cost: 1984 $$: probably more than $25 million

Present International Cooperation
Nationality(s) of Ownership: Australia-U.K.
Nationality(s) of Operational Funding: Australia-U.K.
Nationality(s) of Management Staff: Australia-U.K.
Nationality(s) of Researchers: some non-Australia-U.K. observers

Nobeyama, JAPAN

MM-WAVE FIVE-ELEMENT SYNTHESIS TELESCOPE
Nobeyama Radio Observatory
Tokyo Astronomical Observatory

"Big Science" Descriptor: Radio astronomy

Description of Facility/Instrument: The ten-meter diameter antennas are to be used simultaneously as an aperture synthesis telescope.

Date of Construction: 1985

Construction Cost: 1984 $$: $25 million estimate, see below.

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: Japan

Potential for Future International Cooperation: Collaboration on individual scientific projects is welcomed. The merits of projects will be evaluated on a case-by-case basis.

Other Information: This telescope and the Nobeyama 45-meter telescope, see the next page, were funded together and built during the same period. The total construction funds for both telescopes was $50 million.

Nobeyama, JAPAN

45-METER RADIO TELESCOPE
Nobeyama Radio Observatory
Tokyo Astronomical Observatory

"Big Science" Descriptor: Radio astronomy

Description of Facility/Instrument: This is a 45-meter diameter, fully steerable, parabolic reflector. It can be used to a minimum wavelength of about three millimeters.

Date of Construction: 1984

Construction Cost: 1984 $$: $25 million estimate, see below.

Present International Cooperation
- Nationality(s) of Ownership: Japan
- Nationality(s) of Operational Funding: Japan
- Nationality(s) of Management Staff: Japan
- Nationality(s) of Researchers: Japan

Potential for Future International Cooperation: Collaboration on individual scientific projects is welcomed. The merits of projects will be evaluated on a case-by-case basis.

Other Information: This telescope and the five-element synthesis telescope (see preceding page) were funded together and built during the same period. The total construction funds for both telescopes was $50 million.

Zelenchukskaya, U.S.S.R.

SIX-METER OPTICAL TELESCOPE
Special Astrophysical Observatory
U.S.S.R. Academy of Sciences

"Big Science" Descriptor: Optical astronomy

Description of Facility/Instrument: This is a six-meter diameter primary mirror optical telescope.

Date of Construction: 1978

Construction Cost: 1984 $$: Probably more than $25 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.S.R.
- Nationality(s) of Operational Funding: U.S.S.R.
- Nationality(s) of Management Staff: U.S.S.R.
- Nationality(s) of Researchers: U.S.S.R.

Potential for Future International Cooperation: Occasional collaboration may be possible for scientific projects on an individual, case-by-case basis.

APPENDIX 7

ATMOSPHERIC AND OCEANOGRAPHIC FACILITIES

The information in this appendix was supplied by the National Science Foundation, April 1985 and the Woods Hole Oceanographic Institution, May 1985, and from the following two publications: Committee on Atmosphere and Oceans. Report of Federal Oceanographic Fleet Study 1984. Washington, Federal Oceanographic Fleet Coordination Council, 1985. 92 p. plus appendices; and Trillo, Robert L. (ed.). Jane's Ocean Technology 1978. New York, Franklin Watts Inc., 1978. 820 p.

Boulder, CO., U.S.A.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (NCAR)

"Big Science" Descriptor: Atmospheric science

Description of Facility/Instrument: Atmospheric science research laboratories, scientific computers, and research facilities such as aircraft and radars.

Date of Construction: 1966

Construction Cost: Original: $ 5.5 million
1984 $$: $65 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: 89 percent U.S. and 11 percent foreign

Potential for Future International Cooperation: Scientific visitors; joint research field experiments, such as the Hydrologic Atmospheric Pilot Experiment in France in FY85-86, Solar Eclipse Expeditions, and joint international cooperative programs.

Other Information: NCAR has participated in many cooperative international programs. Examples include the Indo - U.S. Cooperative Program in Moonson Prediction; U.S. - Peoples Republic of China Cooperative Program; Indo - U.S. Science and Technology Initiative; and the Eighth Session of the Joint U.S. - U.S.S.R. Working Group on Protection of the Environment.

Additionally, NCAR has participated in major international research field experiments such as the Global Atmospheric Research Program, the ALPINE and MONSOON experiments, and numerous solar eclipse expeditions.

See also NCAR SCIENTIFIC COMPUTING FACILITY.

Woods Hole, MA., U.S.A.

DEEP SUBMERGENCE RESEARCH VEHICLE (DSRV) "ALVIN"
Woods Hole Oceanographic Institution

"Big Science" Descriptor: Oceanography

Description of Facility/Instrument: DSRV ALVIN is an untethered, manned submersible capable of operation at depths of 4000 meters. It is a national oceanographic facility jointly funded by the National Science Foundation (NSF), the Office of Naval Research, and the National Oceanic and Atmospheric Administration.

Date of Construction: 1964, converted 1973-74

Construction Cost: Original: $950,000
1984 $$: more than $25 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: Usually U.S.

Potential for Future International Cooperation: Japanese scientists (JAMSTEC) have expressed interest in exchanging submersible time in ALVIN for the SHINKAI 2000. At present, no firm plans have been made for any international programs.

Other Information: In 1974, ALVIN participated in the first major sea floor spreading study as a part of the French-American Mid-Ocean Undersea Study (FAMOUS). This expedition also included the French submersibles CYANA and ARCHIMEDE and was the first to be carried out by ALVIN using the new titanium sphere which replaced the original steel sphere.

DSRV ALVIN was constructed by Litton Industries in 1964 at a cost of $950,000. In 1974, the original steel pressure hull was replaced with one fabricated from titanium, increasing the depth capability from 1800 to 4000 meters. The best estimates for new construction of a submersible similar to ALVIN and capable of operating at 6000 meters are that it would cost in excess of $25 million in 1984 dollars. A 6000 meter capability would permit exploration of 97 percent of the world's ocean floor.

U.S.A.

FEDERAL OCEANOGRAPHIC FLEET

"Big Science" Descriptor: Oceanography

Description of Facility/Instrument: The Federal oceanographic fleet consists of 13 Navy oceanographic research ships operated by civilian crews; 20 NOAA ships operated by the NOAA Corps and civilian personnel; 5 Coast Guard icebreakers, also used for general oceanographic research and for support of NSF's Antartic research program; 2 ships operated by the U.S. Geological Survey; 2 ships operated by the Environmental Protection Agency for water quality monitoring; 2 ships operated by the National Science Foundation; and 20 ships operated by 14 academic institutions under the University--National Oceanographic Laboratory Systems (UNOLS).

Other than the UNOLS fleet, the vessels are owned and operated by the Federal Government, with the exception of the two NSF vessels which are leased from a private firm. About half of the UNOLS fleet (the larger ships) are owned by the Federal Government. The other half (the smaller ships) are owned by some of 14 academic institutions which operate the ships.

Date of Construction: 1929-1981

Construction Cost: 1984 $$: (See the note below.)

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: mainly U.S.

Potential for Future International Cooperation: There are a number of existing cooperative programs with foreign nations, involving several bilateral agreements. The potential is good for continued international cooperation.

Other Information:

Note: Those vessels below which have an asterisk each cost over $25 million in construction plus scientific outfitting costs.

U.S. Navy Oceanographic Fleet

*BOWDITCH	: 1945, precision echo sounding, mapping and charting
*DUTTON	: 1945, mapping and charting
*HESS	: 1965, mapping and charting
*WYMAN	: 1971, general oceanography, mapping and charting
*CHAUVENET	: 1970, mapping and charting

*HARKNESS	: 1971, mapping and charting
*SILAS BENT	: 1965, general oceanography, precision echo sounding
*KANE	: 1967, general oceanography, precision echo sounding
*WILKES	: 1971, general oceanography, precision echo sounding
*BARTLETT	: 1969, general oceanography
*DE STEIGUER	: 1969, general oceanography
*LYNCH	: 1965, general oceanography
ACANIA	: 1929, general oceanography
*HAYES	: 1971, reassigned in 1983 from oceanographic duties

NOAA Oceanographic Fleet

*DISCOVERER	: 1964, general oceanography
*RESEARCHER	: 1968, general oceanography
*SURVEYOR	: 1959, general oceanography, precision echo sounding
*FAIRWEATHER	: 1967, mapping and charting
*RANIER	: 1967, mapping and charting
*MT. MITCHELL	: 1966, mapping and charting
*MILLER FREEMAN	: 1967, general oceanography, fisheries research
PIERCE	: 1962, mapping and charting
WHITING	: 1962, mapping and charting
MCARTHUR	: 1965, mapping and charting
DAVIDSON	: 1966, mapping and charting
OREGON II	: 1967, fisheries research
ALBATROSS IV	: 1962, fisheries research
TOWNSEND CROMWELL	: 1963, fisheries research
DAVID STARR JORDAN	: 1964, fisheries research
DELAWARE II	: 1967, fisheries research
CHAPMAN	: 1979, fisheries research
FERRELL	: 1968, mapping and charting
RUDE	: 1966, mapping and charting
HECK	: 1966, mapping and charting
*OCEANOGRAPHER	: 1964, inactive

U.S. Coast Guard Polar Icebreakers

*POLAR STAR	: 1976, ice worthy, general oceanography
*POLAR SEA	: 1978, ice worthy, general oceanography
*GLACIER	: 1953, ice worthy, general oceanography
*NORTHWIND	: 1945, ice worthy, general oceanography
*WESTWIND	: 1943, ice worthy, general oceanography

U.S. Geological Survey Ships

*S.P. LEE	: 1967, multi-channel seismics
POLARIS	: 1965, mapping and charting

Environmental Protection Agency Oceanographic Ships

ANTELOPE	: 1967, general oceanography
SIMONS	: 1939, general oceanography
CARSON	: 1967, converted in 1978, deactivated in 1981

National Science Foundation Oceanographic Ships

HERO	: 1966, out of service, ice worthy, general oceanography
*GLOMAR CHALLENGER	: 1968, out of service, deep-sea drilling
*JOIDES RESOLUTION	: 1978, deep-sea drilling, geology
*POLAR DUKE	: 1978, oceanography, supply of NSF Antartic program.

University-National Oceanographic Laboratory System (UNOLS)

*MELVILLE	: 1969, general oceanography
*KNORR	: 1969, general oceanography
*ATLANTIS II	: 1963, general oceanography, precision echo sounding, submersible handling
*T. WASHINGTON	: 1965, general oceanography, precision ocean sounding, multi-channel seismics
*T.G. THOMPSON	: 1965, general oceanography
*CONRAD	: 1962, general oceanography, multi-channel seismics, precision echo sounding
OCEANUS	: 1975, general oceanography
WECOMA	: 1975, general oceanography
ENDEAVOR	: 1976, general oceanography
GYRE	: 1973, general oceanography
MOANA WAVE	: 1973, general oceanography, multi-channel seismics
ISELIN	: 1971, general oceanography
NEW HORIZON	: 1978, general oceanography
CAPE FLORIDA	: 1981, general oceanography
CAPE HATTERAS	: 1981, general oceanography
ALPHA HELIX	: 1965, general oceanography
CAPE HENLOPEN	: 1975, general oceanography
VELERO IV	: 1948, general oceanography
R. WARFIELD	: 1967, general oceanography
E. B. SCRIPPS	: 1965, out of service
SPROAL	: 1981, general oceanography

APPENDIX 8

SPACE FACILITIES

The information in this appendix was supplied by the National Aeronautics and Space Administration, April 1985.

U.S.A.

ORBITING GEOPHYSICAL OBSERVATORIES (OGO)
NASA

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: These observatories conducted experiments within the Earth's atmosphere and magnetosphere, and in cislunar space (between the Earth and the Moon). The first two observatories, although launched, failed mechanically in orbit (OGO-1 and OGO-2). Subsequent missions (OGO-3, 4, 5, and 6) had varied success in obtaining data. All operations have been terminated since OGO-6, (7/14/72).

Date of Construction: 1964-1969 (launches)

Construction Cost: 1984 $$: $228.4 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Other Information:

	Launched
OGO - I(A) :	September 5, 1964
OGO - II(C) :	October 14, 1965
OGO - III(B):	June 7, 1966
OGO - IV(D) :	July 28, 1967
OGO - V(E) :	March 4, 1968
OGO - VI(F) :	June 5, 1969

U.S.A.

ORBITING SOLAR OBSERVATORIES (OSO)
NASA

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: Eight spacecraft out of nine were successfully launched for continuous observation of the Sun. These observations added to knowledge of the Sun in x-ray, ultraviolet, and infrared wavelengths, and studied celestial objects as well.

Date of Construction: 1962-1975 (launches)

Construction Cost: 1984 $$: $171.1 million

Present International Cooperation

Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

OSO-8 had French instrumentation for ultraviolet spectroscopy.

Other Information:

	Launched
OSO - 1(S-16):	March 7, 1962
OSO - 2(B-2) :	February 3, 1965
OSO - C :	Failed to orbit
OSO - 3(E) :	March 8, 1967
OSO - 4(D) :	October 18, 1967
OSO - 5(F) :	January 22, 1969
OSO - 6(G) :	August 9, 1969
OSO - 7(H) :	September 29, 1971
OSO - 8(I) :	June 21, 1975

U.S.A.

ORBITING ASTRONOMICAL OBSERVATORIES (OAO)
NASA

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: Three satellites were launched successfully, but one failed in orbit. The two completely successful missions gathered information on several stars, nebulae in the ultraviolet range, and information on the coronas of stars.

Date of Construction: 1966-1972 (launches)

Construction Cost: 1984 $$: $336.4 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

The Mullard Space Science Laboratory in the U.K. supplied gamma ray instrumentation for the OAO-C mission.

Other Information: OAO - I(A): Successfully launched on April 8, 1966, but lost power in orbit and did not complete mission.

OAO - II(A2): Successfully launched on December 7, 1968, successfully completed mission, no longer operational.

OAO - B: Failed launch on November 30, 1970.

OAO - C (Copernicus): Successfully launched on August 21, 1972, completed mission objectives, no longer operational.

ASTROPHYSICS EXPLORERS
NASA

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: EXPLORER projects for x-ray, gamma-ray, and ultraviolet ray explorations.

Date of Construction: 1961-1983 (launches)

Construction Cost: 1984 $$: Total cost undetermined

Present International Cooperation

Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

(Except where international cooperation is noted below.)

Other Information: X-RAY ASTRONOMY EXPLORERS: EXPLORER 42 was launched from Kenya in 1970. EXPLORER 53, launched in 1975, successfully broadened the knowledge of x-ray sources, discovering 200 when 40 had been known previously. EXPLORERS 42 and 53 also are known as SAS-1 and SAS-3, respectively.

Two international cooperative ventures in this field were the Astronomical Netherlands Satellite (ANS), launched in 1974, and the Ariel 5 (U.S.-U.K.), launched in 1974, which broadened the knowledge of "bursters," new x-ray sources and ultra-violet emissions.

GAMMA-RAY ASTRONOMY EXPLORERS: EXPLORER 11 (1961) and EXPLORER 48 (1972) both relayed data on gamma-ray emissions from the cosmic background and gamma-ray point sources. EXPLORER 48 also investigated cosmic ray gas and the Vela supernova remnant.

RADIO ASTRONOMY EXPLORERS: EXPLORER 38 (also known as RAE-1, 1968) and EXPLORER 49 (also known as RAE-2, 1973) were to map out the galaxy in the 10 to 400 megahertz region, which cannot be studied from Earth. The satellites also have provided information on cosmic background noise, solar radio bursts, and radio emissions from Earth.

ULTRAVIOLET ASTRONOMY EXPLORERS: The International Ultraviolet Explorer (IUE), launched in 1978, is still operational, at a total cost of $37 million. Primarily a U.S. venture, this is also a cooperative venture with the British Science Research Council and the European Space Agency (ESA). The satellite is used to determine the various spectra of hot stars, cool stars, the interstellar medium, x-ray sources, extragalactic objects, and objects within the solar system. Accomplishments include the first ultraviolet observation of a supernova, high resolution ultraviolet spectrum of a star in another galaxy, and observation of globular clusters.

INFRARED ASTRONOMICAL SATELLITE (IRAS): This satellite was launched in January 1983 to survey the infrared light in the Earth's sky. It ceased operation in December 1983. The project included cooperation with the United Kingdom and the Netherlands. The total cost was $95 million.

U.S.A.

HIGH ENERGY ASTRONOMY OBSERVATORIES (HEAO)
Marshall Space Flight Center
NASA

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: These three missions have been successful in determining the source of x-ray sources, particularly from the stars. In addition, HEAO-3 has studied the origin and nature of gamma and cosmic rays.

Date of Construction: 1977-1979 (launches)

Construction Cost: 1984 $$: $250 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

The HEAO-2 mission used an x-ray spectrometer supplied by the Netherlands. The HEAO-3 mission included French experimentation for analysis of the isotropic composition of galactic radiation.

Other Information: These satellites are no longer operational, although their data still are being analyzed:

	Launched
HEAO-1 :	August 12, 1977
HEAO-2 :	November 13, 1978
HEAO-3 :	September 20, 1979

U.S.A.

SOLAR MAXIMUM MISSION
Goddard Space Flight Center
NASA

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: This mission studies the Sun. To date, it has studied 1500 solar flare-ups and flare-related phenomena. This satellite was retrieved by astronauts and repaired for continued use.

Date of Construction: February 14, 1980 (launch)

Construction Cost: 1984 $$: $90 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

This mission included U.K. x-ray instrumentation.

U.S.A.

THE HUBBLE LARGE SPACE TELESCOPE (LST)
Marshall Space Flight Center
NASA

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: This space telescope is designed to significantly expand optical capability for observing the universe. The telescope will have five scientific instruments: the High Resolution Spectrograph; the Faint Object Spectrograph; the Wide Field Planetary Camera; the Faint Object Camera; and the High Speed Photometer.

Date of Construction: Currently being constructed. The launch date is scheduled for the second half of 1986.

Construction Cost: 1984 $$: Projected total cost: $1,175 million to $2,000 million.

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S. - ESA - Federal Republic of Germany
- Nationality(s) of Researchers: U.S. - ESA - Federal Republic of Germany

Potential for Future International Cooperation: Although specifics have yet to be determined, both German and European Space Agency participation in instrumentation and use of the Hubble Telescope is planned. Also, British image-processing software packages will be included.

U.S.A.

COSMIC BACKGROUND EXPLORER (COBE)
Goddard Space Flight Center
NASA

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: The purpose of this satellite will be to observe cosmology through the measure of light.

Date of Construction: Currently being constructed. The launch date in early 1988.

Construction Cost: 1984 $$: Projected total cost: $125 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: This is as yet undetermined.

U.S.A.

GAMMA RAY OBSERVATORY (GRO)
Goddard Space Flight Center
NASA

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: To explore emissions from gamma-ray spectrum (1 MeV-30 GeV).

Date of Construction: Currently being constructed. The launch date is early 1988.

Construction Cost: 1984 $$: Projected total cost: $475 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: It is planned that this mission will include a German telescope for the measurement and analysis of gamma-rays.

U.S.A.

EXTREME ULTRAVIOLET EXPLORER (EUVE)
Jet Propulsion Laboratory
NASA

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: This low-Earth orbiting satellite is planned for surveying the sky for ultraviolet sources.

Date of Construction: Late 1988, projected launch

Construction Cost: 1984 $$: $140 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

EUROPE

COS-B
E.S.A., Center for Nuclear Studies (France), and the Max Planck Institute for Extraterrestrial Physics (Federal Republic of Germany)
European Space Agency (E.S.A.)

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: This satellite is a remotely controlled astronomical observatory for the study of radiation emitted from known and assumed sources of gamma-rays. It is still operational.

Date of Construction: August 1975 (launch)

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: E.S.A., France, Italy, and the Federal Republic of Germany
- Nationality(s) of Operational Funding: E.S.A., France, Italy, and the Federal Republic of Germany
- Nationality(s) of Management Staff: E.S.A., France, Italy, and the Federal Republic of Germany
- Nationality(s) of Researchers: E.S.A., France, Italy, and the Federal Republic of Germany

EUROPE

INTERNATIONAL ULTRAVIOLET EXPLORER (IUE)
European Space Agency (E.S.A.), NASA, and the Science and Engineering Research Council (U.K.)

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: This satellite has obtained ultraviolet spectra from objects ranging from planets, planetary nebulae, supernova remnants, galaxies, and quasars.

Date of Construction: January 26, 1978 (launch)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: E.S.A.-U.S.
Nationality(s) of Operational Funding: E.S.A.-U.S.
Nationality(s) of Management Staff: E.S.A.-U.S.
Nationality(s) of Researchers: E.S.A.-U.S.

This program involves extensive international cooperation, including two other satellites and six ground telescopes worldwide.

EUROPE

EXOSAT
European Space Agency (E.S.A.)

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: This E.S.A. satellite was launched by Ariane (France). Its purpose is to determine the positions and examine the structures of celestial x-ray sources. Its most common mode of operation will be the use of lunar occultation, that is, taking account of the time and speed of disappearance of celestial objects behind the lunar disc.

Date of Construction: May 26, 1983 (launch)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: E.S.A.
Nationality(s) of Operational Funding: E.S.A.
Nationality(s) of Management Staff: E.S.A.
Nationality(s) of Researchers: E.S.A.

The satellite involved European participation (U.K., the Federal Republic of Germany, the Netherlands, and European industrial firms in addition to E.S.A.). It was launched by the United States on May 26, 1983.

EUROPE

HIPPARCOS
European Space Agency (E.S.A.)

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: This satellite will study and measure the five main astrometric positions of the stars, and their distance, position, and proper motions. The survey of HIPPARCOS will include 10,000 selected stars.

Date of Construction: 1987-1988 (projected launch)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: E.S.A.
Nationality(s) of Operational Funding: E.S.A.
Nationality(s) of Management Staff: E.S.A.
Nationality(s) of Researchers: E.S.A.

UNITED KINGDOM

ARIEL 1-6
Rutherford Appleton Laboratory Satellite Control Center

"Big Science" Descriptor: Space: physics and astronomy

Description of Facility/Instrument: These six satellite launches studied ionosphere, atmospheric ozone, radio astronomy, atmospheric physics, meteorology, micrometeorites, ionospheric plasmas, magnetic fields, galatic x-rays, and high-energy astrophysics.

Date of Construction: 1962-1979 (launches)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.K.
Nationality(s) of Operational Funding: U.K.
Nationality(s) of Management Staff: U.K.
Nationality(s) of Researchers: U.K.

Other Information:

	Launched
ARIEL 1 (UK 1):	April 26, 1962, ionospheric and solar studies
ARIEL 2 (UK 2):	May 27, 1962, atmospheric ozone
ARIEL 3 (UK 3):	May 5, 1967, atmospheric physics
ARIEL 4 (UK 4):	December 9, 1971, ionospheric plasmas, magnetic fields
ARIEL 5 (UK 5):	October 15, 1974, galactic x-rays
ARIEL 6 (UK 6):	June 2, 1979, science satellite

JAPANESE SATELLITES
Institute of Space and Aeronautical Science (ISAS) and
National Space Development Agency (NASDA)

"Big Science" Descriptor: Space

Description of Facility/Instrument: These satellites cover a variety of science flights, including ionospheric and astrophysics experiments. A crucial part of Japanese space history was the 1969 agreement with the United States, making available to Japan technological information for future flights.

Date of Construction: 1971-1984 (launches)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: Japan

Other Information:

	Launched
SHINESEI SS-1 (Mu 4S-3):	September 28, 1971, ionospheric plasma, solar radio waves, cosmic rays
DENPA REX SS-2 (Mu 4S-4):	August 19, 1972, radio exploration, ionospheric plasmas
TAIYO SRATS (Mu SS-3, 3C-2):	February 24, 1975, solar radiation, thermosphere
CORSA SS-4:	February 4, 1976, cosmic radiation, x-ray (failed to orbit)
UME ISS:	February 29, 1976, ionospheric soundings (malfunction in flight)
KYO KKO (EXOS A):	February 4, 1978, scientific experimentation
UME 2:	February 16, 1978, ionospheric sounding
JIKIKEN (EXOS B):	September 16, 1978, scientific experimentation
HA KUCHO (CORSA B):	February 21, 1979, scientific experimentation
HINOTORI (ASTRO A):	February 21, 1981, scientific experimentation
HINOTORI (ASTRO B):	February 20, 1983, scientific experimentation
EXOS C:	February 14, 1984, scientific experimentation

ASTRON
U.S.S.R.

"Big Science" Descriptor: Space physics and astronomy

Description of Facility/Instrument: Launched in 1983, the ASTRON satellite is a large observatory-class satellite performing celestial observations in the x-ray and ultraviolet wavelengths.

Date of Construction: March 23, 1983 (launch)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R.-France
Nationality(s) of Operational Funding: U.S.S.R.-France
Nationality(s) of Management Staff: U.S.S.R.-France
Nationality(s) of Researchers: U.S.S.R.-France

Other Information: The participation of French scientists is to develop an ultraviolet telescope.

U.S.A.

RANGER
NASA

"Big Science" Descriptor: Space: lunar and planetary probes

Description of Facility/Instrument: These probes were intended to photograph the surface of the Moon up to the moment of landing impact. Difficulties in initial orbits and transmission meant that a successful probe did not occur until RANGER 7. Early failures were blamed on poor management, inadequate ground testing, and degrading and deterioration of equipment during flight.

Date of Construction: 1961-1965 (launches)

Construction Cost: 1984 $$: $468.9 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Other Information:

	Launched	
RANGER 1 :	August 23, 1961	BLOCK I: Successfully launched,
RANGER 2 :	November 18, 1961	but did not escape Earth's orbit.
RANGER 3 :	January 26, 1961	BLOCK II: Came close to the Moon
RANGER 4 :	April 23, 1962	(3, 5) and landed on the farside (4).
RANGER 5 :	October 18, 1962	All had limited technical success.
RANGER 6 :	January 30, 1964	BLOCK III: First full success with
RANGER 7 :	July 28, 1964	7, 8, 9. All transmitted photos and
RANGER 8 :	February 17, 1965	landed on the Moon. However, further
RANGER 9 :	March 21, 1965	RANGER programs were cancelled.

U.S.A.

SURVEYOR
NASA

"Big Science" Descriptor: Space: lunar and planetary probes

Description of Facility/Instrument: These probes soft-landed on the surface of the Moon, relayed pictures, and analyzed lunar soil. This program aided the United States in its basic understanding of the Moon's surface, as well as providing practical data for later Apollo flights.

Date of Construction: 1966-1968 (launches)

Construction Cost: 1984 $$: $468.9 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Other Information:

		Launched
SURVEYOR I	:	May 30, 1966, successful soft landing.
SURVEYOR II	:	September 20, 1966, communications lost just before lunar impact.
SURVEYOR III	:	April 17, 1967, successful soft landing.
SURVEYOR IV	:	July 14, 1967, communications lost just before lunar impact.
SURVEYOR V	:	September 8, 1967, successful soft landing.
SURVEYOR VI	:	November 7, 1967, successful soft landing.
SURVEYOR VII	:	January 7, 1968, successful soft landing.

U.S.A.

LUNAR ORBITER
NASA

"Big Science" Descriptor: Space: lunar and planetary probes

Description of Facility/Instrument: Complementing the SURVEYOR programs, the LUNAR ORBITERS took photographs of the lunar surface from lunar orbit, converted these directly into electronic signals, and transmitted them back to Earth. This provided increased knowledge of both the lunar surface and space telecommunications.

Date of Construction: 1966-1967 (launches)

Construction Cost: 1984 $$: $162.3 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Other Information:

	Launched
LUNAR ORBITER I :	August 10, 1966, successful relay of pictures.
LUNAR ORBITER II :	November 6, 1966, successful relay of pictures.
LUNAR ORBITER III:	February 5, 1967, successful relay of pictures.
LUNAR ORBITER IV :	May 4, 1967, successful relay of pictures.
LUNAR ORBITER V :	August 1, 1967, successful relay of pictures.

U.S.A.

PIONEER 10 AND 11
Ames Research Center
NASA

"Big Science" Descriptor: Space: lunar and planetary probes

Description of Facility/Instrument: These two missions were part of the PIONEER Program for Jupiter (10) and Saturn (11). PIONEER 10 made the first reconnaissance of Jupiter and was the first to leave the solar system and search for its heliospheric boundary. PIONEER 11 investigated Saturn and the outer solar system.

Date of Construction: 1972-1973 (launches)

Construction Cost: 1984 $$: $180 million (Total program cost. PIONEER 10 and 11 cost undetermined at this time.)

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Other Information: PIONEERS 1 through 9 were applications-oriented satellites. Only with PIONEER 10 did this program become more science oriented.

	Launched
PIONEER 10:	1972
PIONEER 11:	1973

U.S.A.

VIKING 1 AND 2 (ORBITER 1 AND 2)
Jet Propulsion (VIKINGS) and Langley (ORBITERS)
NASA

"Big Science" Descriptor: Space: lunar and planetary probes

Description of Facility/Instrument: Both VIKING landers soft landed on Mars, searched for life, and analyzed soil and measured meteorology near the surface. The ORBITERS imaged the surface, mapped Mars, and determined atmospheric structure and composition.

Date of Construction: 1975 (launches)

Construction Cost: 1984 $$: $950 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

This mission included French and Swedish instrumentation.

Other Information:

	Launched
VIKING 1 and ORBITER 1:	August 20, 1975
VIKING 2 and ORBITER 2:	September 9, 1975

U.S.A.

VOYAGER I AND II
Jet Propulsion Laboratory
NASA

"Big Science" Descriptor: Space: lunar and planetary probes

Description of Facility/Instrument: VOYAGER I encountered Jupiter and Saturn during 1979 to 1981 to study their atmospheres, satellites, and rings; to search for the heliospheric boundary; and to investigate interstellar space. VOYAGER II encountered Jupiter and Saturn during 1979 to 1981. It is scheduled to encounter Uranus in 1986 and Neptune in 1989.

Date of Construction: 1977 (launches)

Construction Cost: 1984 $$: $350 million.

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Other Information:

	Launched
VOYAGER I :	September 5, 1977
VOYAGER II:	August 20, 1977

U.S.A.

PIONEER/VENUS (ORBITER AND PROBE)
Ames Research Center
NASA

"Big Science" Descriptor: Space: lunar and planetary probe

Description of Facility/Instrument: A satellite designed to penetrate and investigate the atmosphere of Venus, produce a (radar) map of its surface, measure the temperature of the surface (probe), collect data on the Venusian ionosphere, and make ultraviolet spectrometer observations of Halley's comet.

Date of Construction: 1978 (launch)

Construction Cost: 1984 $$: $190 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

The PIONEER/VENUS ORBITER had French and British instrumentation.

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U.S.A.

GALILEO (JUPITER ORBITER/PROBE)
Jet Propulsion Laboratory
NASA

"Big Science" Descriptor: Space: lunar and planetary probe

Description of Facility/Instrument: This project will continue examination of the Jovian atmosphere, physical environment, and moons. This project includes an ORBITER, which will image Jovian atmospheric conditions for data examination.

Date of Construction: 1986, projected launch

Construction Cost: 1984 $$: $910 million

Present International Cooperation
Nationality(s) of Ownership: U.S. and Federal Republic of Germany
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S. and Federal Republic of Germany

Potential for Future International Cooperation: This project has included the following German participation: for the ORBITER, dust instrumentation; for the PROBE, helium measurement instrumentation; and for the launch, propulsion system and 13 German scientists.

U.S.A.

VENUS RADAR MAPPER (VRM)
Jet Propulsion Laboratory
NASA

"Big Science" Descriptor: Space: lunar and planetary probe

Description of Facility/Instrument: This probe will map Venus with a synthetic aperture radar and investigate the origin and evolution of planet study morphology and composition.

Date of Construction: First half of 1988, projected launch

Construction Cost: 1984 $$: $400 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: As yet undetermined.

U.S.A.

MARS GEOSCIENCE CLIMATOLOGY OBSERVER (MGCO--MARS OBSERVER)
Jet Propulsion Laboratory

"Big Science" Descriptor: Space: lunar and planetary probe

Description of Facility/Instrument: A satellite to determine the global, elemental, and minerological character of Mars.

Date of Construction: 1990, projected launch

Construction Cost: 1984 $$: $375 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: As yet undetermined.

U.S.A.

MARINER I-X
NASA

"Big Science" Descriptor: Space: lunar and planetary probes

Description of Facility/Instrument: Planetary probes of Venus (I, II, V, X), Mars (III, IV, VI, VII, VIII, IX), and Mercury (X). Mariners I and III, although successfully launched, failed to complete their missions. Data received from successful missions include atmospheric temperature and terrestrial photographs. Mariner VIII was unsuccessfully launched.

Date of Construction: 1962-1973 (launches)

Construction Cost: 1984 $$: Estimated at $1,487 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Other Information:

		Launched
MARINER I	:	July 22, 1962, failed mission.
MARINER II	:	August 27, 1962, successful flyby of Venus.
MARINER III	:	November 5, 1964, failed mission.
MARINER IV	:	November 28, 1964, successful flyby of Mars.
MARINER V	:	June 14, 1967, successful flyby of Venus.
MARINER VI	:	February 25, 1969, successful flyby of Mars.
MARINER VII	:	March 27, 1969, successful flyby of Mars.
MARINER VIII	:	May 8, 1971, unsuccessful launch.
MARINER IX	:	May 30, 1971, successful flyby of Mars.
MARINER X	:	November 3, 1973, successful flyby of Venus and Mercury.

GEOS-1 AND GEOS-2
European Space Agency (E.S.A.)

"Big Science" Descriptor: Space: lunar and planetary probes

Description of Facility/Instrument: GEOS-1, launched in 1977, failed to achieve its original orbit, but did achieve an unplanned orbit which lasted 14 months. GEOS-2, launched in 1978, has achieved its mission of providing data on how the near-Earth environment reacts to phenomena occurring in outer space.

Date of Construction: 1977-1978 (launches)

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: E.S.A.
- Nationality(s) of Operational Funding: E.S.A.
- Nationality(s) of Management Staff: E.S.A.
- Nationality(s) of Researchers: E.S.A.

Other Information:

	Launched
GEOS-1	1977
GEOS-2	1978

GIOTTO
European Space Agency (E.S.A.)

"Big Science" Descriptor: Space: lunar and planetary probe

Description of Facility/Instrument: This satellite is due to be launched in 1985 to encounter Halley's Comet in 1986. The satellite will investigate the matter left in Halley's wake which many researchers believe is the earliest matter left over from the creation of the universe.

Date of Construction: July 1985 (projected launch)

Construction Cost: 1984 $$:

Present International Cooperation
- Nationality(s) of Ownership: E.S.A.
- Nationality(s) of Operational Funding: E.S.A.
- Nationality(s) of Management Staff: E.S.A.
- Nationality(s) of Researchers: E.S.A.

INTERNATIONAL SOLAR-POLAR MISSION (ISPM)
European Space Agency (E.S.A.)

"Big Science" Descriptor: Space: lunar and planetary probe

Description of Facility/Instrument: This satellite will provide detailed exploration of the solar environment and multi-angled observations of the Sun.

Date of Construction: 1985 (projected launch)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: E.S.A.
Nationality(s) of Operational Funding: E.S.A.
Nationality(s) of Management Staff: E.S.A.
Nationality(s) of Researchers: E.S.A.

VEGA 1 AND 2
U.S.S.R.

"Big Science" Descriptor: Space: lunar and planetary probes

Description of Facility/Instrument: The purpose of these two satellites was to study Venus and Halley's Comet. As the satellites pass Venus, the spacecraft will drop off landers. Balloons developed by the French will slowly drift through the atmosphere of Venus and make "in situ" measurements.

Date of Construction: 1984 (launches)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R. and others
Nationality(s) of Operational Funding: U.S.S.R. and others (see below)
Nationality(s) of Management Staff: U.S.S.R. and others
Nationality(s) of Researchers: U.S.S.R. and others

Besides the U.S.S.R., eight other countries are directly participating in the VEGA program: Austria, Bulgaria, Czechoslovakia, the Democratic Republic of Germany, France, Hungary, Poland, and the Federal Republic of Germany. The United States has agreed to track the balloons dropped in the atmosphere of Venus for the French. The United States also will track the Soviet spacecraft as they reach Halley's Comet and provide E.S.A. with data so it can target its GIOTTO spacecraft towards the Comet.

Other Information:		Launched
VEGA 1	:	December 15, 1984
VEGA 2	:	December 21, 1984

MARS 1-7
U.S.S.R.

"Big Science" Descriptor: Space: lunar and planetary probes

Description of Facility/Instrument: The purpose of these satellites was to gather data and relay pictures and information on Mars. Four attempts at achieving survivable landings were unsuccessful. Only one probe (MARS 5) is considered a full success.

Date of Construction: 1971-1973 (launches)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R.
Nationality(s) of Operational Funding: U.S.S.R.
Nationality(s) of Management Staff: U.S.S.R.
Nationality(s) of Researchers: U.S.S.R.

Other Information: Launched

MARS 1 : November 1, 1962, partial success, communication failed, passed Mars.

MARS 2 : May 19, 1971, intended to soft-land on Mars; partially successful, returned data from orbiter, but the lander destroyed. This satellite carried a French stereo experiment for photographing the surface.

MARS 3 : May 28, 1971, successful, returned orbital data and survived landing on Mars, but only for 20 seconds. This satellite carried a French stereo experiment for photographing the surface.

MARS 4 : July 21, 1973, partially successful, returned data in flyby of Mars, but did not enter orbit.

MARS 5 : July 22, 1973, successful, returned data and pictures.

MARS 6 : August 5, 1973, partial success returned data from flyby of Mars, but lander signals ceased. This satellite carried French experiments for photographing the surface and for studying the proton and electron fluxes enroute to Mars.

MARS 7 : August 9, 1973, partial success, returned data from flyby of Mars, but the lander missed its mark upon landing. This satellite carried French experiments for photographing the surface and for studying the proton and electron fluxes enroute to Mars.

LUNA 1-24
U.S.S.R.

"Big Science" Descriptor: Space: lunar and planetary probes

Description of Facility/Instrument: This was an extensive lunar program by the Soviets which included "hard" landers, soft landers, orbiters, and sample return vehicles. Three spacecraft sent back approximately 330 grams of lunar soil by automated means: two were roving vehicles (LUNOKHODS) which would travel over the lunar surface for extended observation and experiments.

Date of Construction: 1959-1974 (launches)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R
Nationality(s) of Operational Funding: U.S.S.R.
Nationality(s) of Management Staff: U.S.S.R.
Nationality(s) of Researchers: U.S.S.R.

Other Information: Launched

LUNA 1 : January 2, 1959, to strike the Moon, it missed the Moon and entered solar orbit.

LUNA 2 : September 12, 1959, to strike the Moon, it was a success.

LUNA 3 : October 4, 1959, to photograph the Moon. It succeeded and returned pictures of 70 percent of the far side of the Moon.

LUNA 4 : April 2, 1963, partial success. It attempted to soft land on the Moon, but missed the Moon and entered solar orbit.

LUNA 5 : May 9, 1965, partial success. It attempted a soft landing on the Moon, but missed the Moon and went into solar orbit.

LUNA 6 : June 8, 1965, partial success. It attempted a soft landing on the Moon, but missed the Moon and went into solar orbit.

LUNA 7 : October 4, 1965, partial success. This intended soft landing, retrofitted early, fell on the Moon.

LUNA 8 : December 3, 1965, partial success. This intended soft landing, retrofitted early, fell on the Moon.

U.S.S.R.

LUNA 9	:	January 31, 1966, soft landing on Moon, returned 27 pictures.
LUNA 10	:	March 31, 1966, successful Moon orbit, returned physical measurements from lunar orbit.
LUNA 11	:	August 24, 1966, partial success. It failed to return pictures from the lunar orbit.
LUNA 12	:	October 22, 1966, success. It returned pictures from the Moon.
LUNA 13	:	December 21, 1966, success. It returned pictures and soil density measures.
LUNA 14	:	April 7, 1968, success. It returned data on lunar mass distribution.
LUNA 15	:	July 13, 1969, partial success. The lunar orbit was a success, but the landing failed.
LUNA 16	:	September 12, 1969, success. It made an automated sample return.
LUNA 17	:	November 10, 1969, success. It landed an automated roving vehicle for long-term exploration.
LUNA 18	:	September 2, 1971, partial success. The lunar orbit was a success, but it crashed on landing.
LUNA 19	:	September 28, 1971, success. It returned photos and other data.
LUNA 20	:	February 14, 1972, successful. It made an automated sample return.
LUNA 21	:	January 8, 1973, successful soft Moon landing. It placed an automated roving vehicle for long-term exploration.
LUNA 22	:	May 29, 1974, success. It returned pictures and data.
LUNA 23	:	October 28, 1974, partial success. It landed safely, but the drill was damaged so no sample was returned.
LUNA 24	:	August 9, 1976, successful soft landing on the Moon. It made an automated sample return of soil.

VENERA 1-16
U.S.S.R.

"Big Science" Descriptor: Space: lunar and planetary probes

Description of Facility/Instrument: These spacecraft had the mission of gathering data on Venus. Some sent back pictures from the surface of Venus and performed analysis of the atmosphere and soil. Two are currently operating (VENERA 15 and 16) and are planning radar mapping of the surface from orbit.

Date of Construction: 1961-1983 (launches)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R.
Nationality(s) of Operational Funding: U.S.S.R.
Nationality(s) of Management Staff: U.S.S.R.
Nationality(s) of Researchers: U.S.S.R.

Other Information: Launched

VENERA 1	:	February 14, 1961, partial success. The communications failed, but it did pass Venus.
VENERA 2	:	November 12, 1965, partial success. The communications failed, but it did pass Venus.
VENERA 3	:	November 16, 1965, partial success. The communications failed, and it struck Venus.
VENERA 4	:	June 12, 1967, success. It returned direct readings of the atmosphere.
VENERA 5	:	January 5, 1969, success. It returned direct readings of the atmosphere near the surface.
VENERA 6	:	January 10, 1964, success. It returned direct readings of the atmosphere near the surface.
VENERA 7	:	August 17, 1970, successful soft landing. It sent back data on the atmosphere and surface of Venus.
VENERA 8	:	March 27, 1972, success. Atmospheric data and soil analyses were returned.
VENERA 9	:	June 8, 1975, success. It returned pictures and other data.

VENERA 10	:	June 14, 1975, success. It returned pictures and other data.
VENERA 11	:	September 9, 1978, success. It returned data from the surface.
VENERA 12	:	September 14, 1978, success. It returned data from the surface.
VENERA 13	:	October 20, 1978, success. It soft-landed on March 1, 1982.
VENERA 14	:	November 4, 1981, success. It soft-landed on March 5, 1982.
VENERA 15	:	June 2, 1983, success. It achieved orbit on October 19, 1983. It carries radar.
VENERA 16	:	June 7, 1983, success. It achieved orbit on October 14, 1983. It carries radar.

SOLAR-TERRESTRIAL EXPLORERS
NASA

"Big Science" Descriptor: Space: earth science

Description of Facility/Instrument: These were the EXPLORER missions which had Earth-oriented and solar-oriented purposes

Date of Construction: Launches began in 1959; many still are operational

Construction Cost: 1984 $$: Total cost undetermined

Present International Cooperation
Nationality(s) of Ownership:
Nationality(s) of Operational Funding:
Nationality(s) of Management Staff:
Nationality(s) of Researchers:
(U.S. with some international cooperation as discussed in detail below.)

Potential for Future International Cooperation: See below.

Other Information:

AIR DENSITY EXPLORERS

EXPLORERS 9 (launched 1961), 19 (1963), 24 (1964), and 39 (1968) were 12-foot inflatable spheres designed to measure the upper atmosphere and lower exosphere and to determine air density as a function of latitude, season, and local solar time.

ATMOSPHERE EXPLORERS

Five U.S. ATMOSPHERE EXPLORERS [EXPLORERS 17 (launched 1963), 32 (1966), 51 (1973), 54 (1975), and 55 (1975)] and eight international satellites [U.K.-U.S.: ARIEL 2 (1964), 3 (1967), 4 (1971); Italy-U.S.: SAN MARCO 1 (1964), 2 (1967), 3 (1971), 4 (1974); and U.S.-Federal Republic of Germany: AEROS (1972)] were designed to collect temperature composition density and pressure data to permit the study of the physics of the atmosphere.

ENERGETIC PARTICLE EXPLORERS

Four EXPLORER missions [EXPLORER 12 (launched 1961), 14 (1962), 15 (1962), and 26 (1964)] were designed to study injection trapping and loss mechanisms of the Earth's radiation belts. International cooperation projects for similar purposes were conducted with the United States by the European Space Agency (ESA) [ESRO IIA (launched 1967), and ESRO IIB (1968)] and the Federal Republic of Germany [AZUR (1969)].

GEODETIC EXPLORERS

EXPLORERS 29 (launched 1965) and 36 (1968).

IONOSPHERIC EXPLORERS

Four U.S. [EXPLORERS 8 (1960), 20 (1964), 22 (1964), and 27 (1965)] and nine international satellites [U.K.-U.S.: ARIEL 1 (1962) and ARIEL 4 (1971); U.S.-Canada: ALOUETTE 1 (1962), ISIS-X (1965), ISIS A (1969), and ISIS B (1971); U.S.-France: FR-1 (1968); and the European Space Agency (ESA): ESRO I (1969) and ESRO IB (1969)] were designed to determine the nature, dynamic behavior, and distribution of changed particles, electrons, and ions as observed from above the ionosphere.

MAGNETOSPHERE EXPLORERS

General: EXPLORERS 6 (1959) and 10 (1961) were designed to measure radiation levels in space. EXPLORER 45 (1971) was designed to measure ring currents and magnetic storms.

Injun-Hawkeye: EXPLORERS 25 (1964) and 40 (1968) were designed to measure the radiation of atomic ions into the Earth's atmosphere. EXPLORER 52 (1974) was designed to measure the solar wind and magnetic field interactions in the polar regions of the Earth.

Interplanetary Monitoring Platforms (IMPs): Ten missions [EXPLORERS 18 (1963), 21 (1964), 28 (1965), 34 (1966), 34 (1967), 35 (1967), 41 (1969), 43 (1971), 47 (1972), and 50 (1973)] were designed to study interplanetary magnetic fields between the Earth and the Moon. [1984 $$: $80 million]

International Sun-Earth EXPLORERS (ISEE): U.S.: ISEE 1 (1977); U.S.-E.S.A.: ISEE 2 (1977) and ISEE 3 (1978). ISEE 2 had Swedish instruments and ISEE 3 had Swedish, Dutch, and British instruments. These satellites were designed to study the solar-terrestrial relationships at the outermost boundary of the magnetosphere. [1984 $$: $60 million]

Dynamics EXPLORER A/B: Launched in August 1981 to image the polar caps. It continues to investigate the plasma of the magnetosphere. [1984 $$: $52.9 million]

Active Magnetospheric Particle Trace EXPLORERS (AMPTE): Launched on August 16, 1984, to study entry windows, entry mechanisms, energization, and transport of energetic particles in magnetospheric radiation. International participation in the program includes the Federal Republic of Germany (spacecraft and experiments), United States (spacecraft, experiments, launch site, and operations), and the U.K. (extreme ultraviolet camera).

SOLAR-PHYSICS EXPLORERS

EXPLORERS 7 (1959), 20 (1964), 37 (1968), and 44 (1971) were designed to monitor solar x-rays and solar radiation.

U.S.A.

EARTH RADIATION BUDGET EXPERIMENT (ERBE)
Goddard Space Flight Center
NASA

"Big Science" Descriptor: Space: earth science

Description of Facility/Instrument: This is a three-satellite system, Earth Radiation Budget Satellite (ERBS), NOAA-F, and NOAA-G. The three-satellite ERBE system will measure thermal and solar radiation of the entire Earth at some time each day. Each satellite will contain two instruments: a scanner and non-scanner to measure radiant intensities and solar intensities.

Date of Construction: 1984-1986 (launches)

Construction Cost: 1984 $$: $130 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Other Information:

	To Be Launched
ERBE :	1984
NOAA F:	1985
NOAA G:	1986

U.S.A.

UPPER ATMOSPHERIC RESEARCH SATELLITE (UARS)
Goddard Space Flight Center
NASA

"Big Science" Descriptor: Space: earth science

Description of Facility/Instrument: The UARS mission will provide the first integrated global measure of ozone concentration; chemical species that affect the ozone; energy inputs; temperature readings; and measurement of the stratosphere and mesosphere.

Date of Construction: 1989, projected launch

Construction Cost: 1984 $$: $707 million

Present International Cooperation

Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: Unknown at this time.

IK 5 : December 2, 1971, studied charged particles and low frequency electromagnetic waves. Czechoslovakia and the U.S.S.R. provided the equipment. There were participating tracking stations in Czechoslovakia, the U.S.S.R., and the Democratic Republic of Germany.

IK 6 : April 7, 1972, studied the chemical composition and energy spectrum of cosmic rays. The equipment was made in the U.S.S.R. according to specifications made in Hungary, Mongolia, Poland, Romania, Czechoslovakia, and the U.S.S.R. A meteorite experiment was developed and manufactured in Hungary, Czechoslovakia, and the U.S.S.R.

IK 7 : June 30, 1972, continued short-wave radiation and hard x-ray studies. It observed solar flares not seen from Earth stations. It carried equipment from the Democratic Republic of Germany, Czechoslovakia, and the U.S.S.R.

IK 8 : December 1, 1972, the satellite carried equipment from Bulgaria, the Democratic Republic of Germany, Czechoslovakia, and the U.S.S.R. The first IK satellite was launched from Plesetsk, where specialists from participating Eastern Bloc countries observed the launch.

IK-9/KOPERNIK 500 : April 19, 1973, measured solar radiation and the ionosphere. It also commemorated the 500th birthday of Copernicus. The equipment was Polish, Czechoslovakian and Soviet. The data were received at ground stations in the U.S.S.R. and Czechoslovakia.

IK-10 : October 30, 1973, the payload carried East German and Soviet equipment to determine the concentration and temperature of ionospheric electrons, Soviet apparatus to measure magnetic field variation, and Czechoslovakian equipment to study low-frequency electric oscillation of plasma.

IK-11 : May 17, 1974, measured solar ultraviolet and x-ray radiation in the upper atmosphere of Earth. The experiments were provided by the Democratic Republic of Germany, the U.S.S.R., and Czechoslovakia.

INTERKOSMOS 1-22 (IK 1-22)
U.S.S.R.

"Big Science" Descriptor: Space: solar and terrestial physics

Description of Facility/Instrument: This is a series of satellites specifically designed to foster cooperation between the U.S.S.R. and its allies as well as selected Western countries. The spacecraft primarily make studies of the upper atmosphere, although two have been devoted to oceanographic research.

Date of Construction: 1969-1981 (launches)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R. plus extensive Eastern Bloc participation
Nationality(s) of Operational Funding: U.S.S.R. plus extensive Eastern Bloc participation
Nationality(s) of Management Staff: U.S.S.R. plus extensive Eastern Bloc participation
Nationality(s) of Researchers: U.S.S.R. plus extensive Eastern Bloc participation

Other Information: Launched

INTERKOSMOS 1 (IK 1): October 14, 1969, to study the effects of solar ultraviolet and x-ray radiation on the structure of the upper atmosphere. It carried equipment from the U.S.S.R., the Democratic Republic of Germany, and Czechoslovakia.

IK 2 : December 25, 1969, studied the ionosphere, electronic temperatures near the payload, and electronic concentration between the payload and ground receiving stations. It carried instruments from Bulgaria and Czechoslovakia. The principal tracking stations included two in Poland and seven in the U.S.S.R.

IK 3 : August 7, 1970, studied the interactions between solar activity and the radiation belts of Earth, and electromagnetic oscillations in the upper ionosphere. It carried Czechoslovakian and Soviet experiments.

IK 4 : October 14, 1970, studied the effects of solar ultraviolet and x-ray radiation. It had equipment from the Democratic Republic of Germany, Czechoslovakia, and the U.S.S.R.

IK-12 : October 31, 1974, continued studies of the atmosphere and ionosphere and flow of micrometeorites. It carried equipment from Hungary, Czechoslovakia, the Democratic Republic of Romania, and the U.S.S.R.

IK-13 : March 27, 1975, studied dynamic processes in the magnetosphere and polar ionosphere. It carried equipment from Czechoslovakia and the U.S.S.R.

IK-14 : December 11, 1975, studied low-frequency eletromagnetic fluctuations in the magnetosphere to measure micrometeoritic intensity. It carried equipment from Bulgaria, Hungary, Czechoslovakia, and the U.S.S.R.

IK-15 : June 19, 1976, introduced a new payload called automatic universal orbital station (AUOS) which carried a greater volume and weight of scientific equipment than previous payloads, and could be controlled at any point in its orbit, not just over ground command stations. A new unified telemetric system (YeTMS) for digital transmission also was included. Participants in the telemetric system included Hungary, Poland, the Democratic Republic of Germany, Czechoslovakia, and the U.S.S.R.

IK-16 : July 27, 1976, continued studies of ultraviolet and x-ray radiation from the Sun and the effect of radiation on the Earth's upper atmosphere equipment came from Czechoslovakia, the Democratic Republic of Germany, the U.S.S.R.and Sweden. Simultaneous observations of the Sun were made by Bulgaria, Hungary, the Democratic of Republic of Germany, Czechoslovakia, and the U.S.S.R.

IK-17 : September 24, 1977, continued previous experiments on the relationship between solar activity and the Earth's upper atmosphere. It carried equipment from Hungary, Romania, Czechoslovakia, Bulgaria and the U.S.S.R.

IK-18/MAGION : October 24, 1978, conducted studies of electromagnetic relationships between the Earth's magnetosphere and ionosphere and of low-frequency radio waves in the circumterrestial plasma. The MAGION satellite separated from IK-18 and went in a trajectory very close to the parent satellite and conducted similar studies of low-frequency electromagnetic fields. MAGION was the first artificial satellite to be developed and built by Czechoslovakia.

IK-19 : February 27, 1979, experiments continued on the Earth's ionosphere, wave processes, and radio propagation in the ionospheric. The equipment and experiments included those from Bulgaria, Poland, Czechoslovakia and the U.S.S.R. Data from IK-19, IK-18, MAGION, and two U.S. satellites were jointly analyzed by scientists in the Soviet Union, the United States, and Japan. The Soviets combined the results from IK-17, IK-18, and MAGION into a program they called "International Investigations of the Magnetosphere."

IK-20 : November 1, 1979, oceanographic research on zones of biological productivity in the ocean and sea surface temperatures. The equipment was developed in Hungary, the Democratic Republic of Germany, Czechoslovakia, and the U.S.S.R.

IK-21 : February 6, 1981, the satellite was designed to study the ocean and land masses; locate areas of high bioproductivity and pollution and ice, water, land, and water boundaries; and define optical thickness of the atmosphere and thermodynamic temperatures of the ocean's surface. The equipment was from Hungary, the Democratic Republic of Germany, Romania, Czechoslovakia and the U.S.S.R.

IK-22/BULGARIA 1,300: August 7, 1981, for ionospheric and magnetospheric studies. The IK-BULGARIA satellite was named to commemorate the 1,300th anniversary of the founding of Bulgaria. Of the 15 instruments carried by IK-BULGARIA, 12 were from Bulgaria. This included instrumentation for studying ions and electrons in near-Earth space, studying permanent and varying electronic fields, determining weak emissions of light and ultraviolet radiation, and laser reflectors for goedetic studies.

PROGNOZ 1-9
U.S.S.R.

"Big Science" Descriptor: Space: solar and terrestial physics

Description of Facility/Instrument: These were Earth-orbiting satellites used primarily to study the magnetosphere with the exception of PROGNOZ 9, which performed radio astronomy.

Date of Construction: 1972-1983 (launches)

Construction Cost: 1984 $$:

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R.
Nationality(s) of Operational Funding: U.S.S.R.
Nationality(s) of Management Staff: U.S.S.R.
Nationality(s) of Researchers: U.S.S.R.

These satellites involved a number of instances of cooperation with the United States and other Western nations as well as with nations of the Eastern Bloc.

Other information:		Launched
PROGNOZ 1	:	April 14, 1972, magnetospheric studies.
PROGNOZ 2	:	June 29, 1972, magnetospheric studies and French solar wind experiment.
PROGNOZ 3	:	February 15, 1973, magnetospheric studies and French solar wind experiment.
PROGNOZ 4	:	December 22, 1975, magnetospheric studies and French solar wind experiment.
PROGNOZ 5	:	November 25, 1976, magnetospheric studies and French solar wind experiment.
PROGNOZ 6	:	September 22, 1977, magnetospheric studies, French ultraviolet experiments, and Czechoslovakian experiments for solar flares.
PROGNOZ 7	:	October 30, 1978, magnetospheric experiments. The satellite carried Swedish, French, Czechoslovakian, and Bulgarian experiments. There also was coordinated data analysis with PIONEER/VENUS, (U.S.), ISEE (U.S.-international), PROGNOZ 7, and VENERA 11 and 12.
PROGNOZ 8	:	December 25, 1980, magnetospheric experiments. The satellite carried Polish, Czechoslovakian, and Swedish experiments.
PROGNOZ 9	:	July 1, 1983, radio astronomy. It carried French and Czechoslovakian experiments.

APPENDIX 9

AERONAUTICAL FACILITIES

The information in this appendix was supplied by the National Aeronautics and Space Administration, the U.S. Air Force, the U.S. Navy, and the U.S. Army, April 1985. Information on wind tunnels was obtained from National Aeronautics and Space Administration Aeronautical Facilities Catalogue, Volume 1, Wind Tunnels. Washington, U.S. Govt. Print. Off., 1985. 288 p.; and Office of Science and Technology Policy. Aeronautical Research and Technology Policy, Volume II: Final Report. Washington, Executive Office of the President, Nov. 1982. (various pagination).

Langley, UT., U.S.A.

NATIONAL TRANSONIC FACILITY
Langley Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This national transonic wind tunnel facility is used for transports; maneuvering aircraft; and correlation with flight performance. Its purpose is high Rn testing. (Use: 40 percent civil, proprietary, and cooperative; 40 percent military; and 20 percent NASA unique.)

Date of Construction: 1982

Construction Cost: 1984 $$: $146 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Langley, UT., U.S.A.

UNITARY PLAN WIND TUNNEL
Langley Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This wind tunnel is used for Supersonic testing of aerodynamic configuration and propulsion airframe interactions, military aircraft, supersonic transport, configuration development, and advanced concepts. (Use: 6 percent civil, proprietary, and cooperative; 8 percent military; and 86 percent NASA unique).

Date of Construction: 1954, updated in 1979

Construction Cost: 1984 $$: $101.8 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Langley, UT., U.S.A.

16-FOOT TRANSONIC WIND TUNNEL
Langley Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This wind tunnel is used for propulsion and airframe integration and multi-force measuring system diagnostic instrumentation. This is the largest transonic tunnel available to NASA. (Use: 27 percent military and 73 percent NASA unique).

Date of Construction: 1941, modified and updated in 1975

Construction Cost: 1984 $$: $89.7 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Langley, UT., U.S.A.

TRANSONIC DYNAMICS TUNNEL
Langley Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This facility is used for aeroelastics and flutter model tests; for flutter clearance; and stores/wing flutter active control. (Use: 7 percent civil, proprietary, and cooperative; 45 percent military; and 48 percent NASA unique).

Date of Construction: 1959, modified in 1980

Construction Cost: 1984 $$: $61.3 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

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Langley, UT., U.S.A.

HYPERSONIC WIND TUNNEL COMPLEX
Langley Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This Hypersonic Wind Tunnel Complex is used for three-dimensional turbulent boundary layer studies. The complex includes a Mach 20 tunnel, hypersonic helium tunnels, a hypersonic nitrogen tunnel, and a Scramjet Test Facility.

Date of Construction: 1952, upgraded through 1983

Construction Cost: 1984 $$: $49 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Langley, UT., U.S.A.

EIGHT-FOOT HIGH-TEMPERATURE HYPERSONIC WIND TUNNEL
Langley Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This tunnel is capable of large-scale temperature, pressure, and Mach number simulation for structures and propulsion. This facility is also used for evaluating hypersonic and space structures, Ram/Scramjets and missiles, and aero/thermodynamics. (Use: 10 percent military and 90 percent NASA unique.)

Date of Construction: 1964

Construction Cost: 1984 $$: $43.6 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Langley, UT., U.S.A.

EIGHT-FOOT TRANSONIC PRESSURE WIND TUNNEL
Langley Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This facility conducts variable Reynolds number testing over a Mach number range in support of aerodynamic research.

Date of Construction: 1953, upgraded in 1980

Construction Cost: 1984 $$: $40 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Langley, UT., U.S.A.

20-INCH MACH 6 WIND TUNNEL
Langley Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This tunnel measures heat transfer pressures, forces and moments, skin friction equilibrium temperatures, boundary layers, and flow profiles.

Date of Construction: 1958, upgraded in 1982

Construction Cost: 1984 $$: $38.1 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Langley, UT., U.S.A.

HYPERSONIC WIND TUNNEL COMPLEX
Langley Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This wind tunnel complex includes a Mach 8 variable density tunnel that can measure heat transfer, pressure, force, and flow visualization data, and a Mach 6 high Reynolds number tunnel that is capable of fundamental aerodynamics and fluid dynamics studies over a large Reynolds number Range.

Date of Construction: 1952, upgraded in 1958

Construction Cost: 1984 $$: $38 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Ames, CA., U.S.A.

LOW-SPEED WIND TUNNEL COMPLEX
Ames Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This complex has wind tunnels to test airplane and aerospace craft, including a 40x80 wind tunnel; 80x120 wind tunnel; static stand; anechoic chamber; a 7x10 wind tunnel, and a 12-foot pressure tunnel. They are used for testing V/STOL; helicopters; propulsion airframe integration; engines and nozzles; propulsion/ Nacelle wings in large-scale subsonic testing; static performance and noise; and airframes in tunnel scale.

Date of Construction: 1941 (modified in 1944, 1972, 1974, 1982, 1983)

Construction Cost: 1984 $$: $260 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Ames, CA., U.S.A.

UNITARY PLAN TUNNEL COMPLEX
Ames Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This facility includes a system of tunnels: 11-foot transonic; 9X7 foot supersonic; 8X7 foot supersonic. The tunnels are used for military aircraft, missile tests, and propulsion/airframe integration. (Use: 11-foot transonic tunnel; 19.9 percent civil, proprietary, and cooperative; 43.7 percent military; and 36.4 NASA unique. 9X7 foot supersonic tunnel; 42.5 percent civil, proprietary, and cooperative; 26.8 percent military; and 30.7 NASA unique.)

Date of Construction: 1955

Construction Cost: 1984 $$: $146 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Ames, CA., U.S.A.

14-FOOT TRANSONIC WIND TUNNEL
Ames Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This facility is used primarily for performance and stability and control testing of aircraft configurations.

Date of Construction: 1956

Construction Cost: 1984 $$: $58 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Ames, CA., U.S.A.

6X6 SUPERSONIC WIND TUNNEL
Ames Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This wind tunnel provides sub/trans/ supersonic tests of larger models. It is used for missile aerodynamics, high studies, boundary layer control, and comformal inlet aerodynamics. (Use: 53.2 percent civil, proprietary, and cooperative; 23.5 percent military direct; and 23.3 percent NASA unique.)

Date of Construction: 1948

Construction Cost: 1984 $$: $42.3 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Ames, CA., U.S.A.

3.5-FOOT HYPERSONIC WIND TUNNEL
Ames Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This tunnel is used for high stress test development of aerodynamic materials.

Date of Construction: 1960, upgraded in 1972

Construction Cost: 1984 $$: $35 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Lewis, OH., U.S.A.

8X6 TRAN/SUPERSONIC WIND TUNNEL
Lewis Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This facility, for aerodynamic and propulsion cycle testing, is needed for military aircraft and missiles transport aircraft; propulsion system and component performance testing; and turboprop performance and aeroelastic research. (Use: 55 percent civil, proprietary, and cooperative and 45 percent NASA unique.)

Date of Construction: 1949

Construction Cost: 1984 $$: $80.2 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Lewis, OH., U.S.A.

10X10 UNITARY SUPERSONIC PROPULSION WIND TUNNEL
Lewis Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This facility is used for military aircraft; supersonic transports; engine/inlet integration; engine nozzle interaction; and high distortion turboprop performance and aeroelastic research. Tests are continuous flow and aerodynamic. (Use: 4 percent civil, proprietary, and cooperative; 62 percent military; and 34 percent NASA unique.)

Date of Construction: 1955

Construction Cost: 1984 $$: $70 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Lewis, OH., U.S.A.

6x9-FOOT ICING RESEARCH TUNNEL (IRT)
Lewis Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This subsonic IRT is used to study the effects of icing on aircraft components. Instrumentation is available for measuring cloud parameters and for determining drag characteristics of airfoils.

Date of Construction: 1944, upgraded in 1984

Construction Cost: 1984 $$: $40 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Dayton, OH., U.S.A.

AERODYNAMIC RESEARCH FACILITY
Air Force Wright Aeronautical Laboratories
U.S. Air Force

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: Wind tunnel complex dedicated to research in the subsonic through hypersonic region.

Date of Construction: 1959 and continuing

Construction Cost: 1984 $$: $95 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: For Western Bloc nations only.

Tullahoma, TN., U.S.A.

16-FOOT SUPERSONIC PROPULSION WIND TUNNEL
Arnold Engineering Development Center
U.S. Air Force

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This tunnel is used for both aerodynamic and propulsion system testing.

Date of Construction: 1954

Construction Cost: 1984 $$: $550 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Tullahoma, TN., U.S.A.

16-FOOT TRANSONIC PROPULSION WIND TUNNEL
Arnold Engineering Development Center
U.S. Air Force

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This facility conducts force and moment pressure, dynamic stability, jet effects, decelerator deployment, internal duct flow, and flutter buffet tests.

Date of Construction: 1952

Construction Cost: 1984 $$: $300 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Tullahoma, TN., U.S.A.

VON KARMAN SUPERSONIC WIND TUNNELS
Arnold Engineering Development Center
U.S. Air Force

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: These tunnels are used for force and moment pressure, heat transfer, dynamic stability, cold flow jet effects, and free flight tests.

Date of Construction: 1954

Construction Cost: 1984 $$: $151 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Carderock, MD., U.S.A.

DTNSRDC TRANSONIC WIND TUNNEL
Aviation and Surface Effects Department
David Taylor Naval Ship R&D Center (DTNSRDC)

"Big Science" Descriptor: Aircraft and missile aerodynamics

Description of Facility/Instrument: Continuous-flow wind tunnel with 7x10 foot transonic test section (Mach 0.2 to 1.15) and 12x15 foot low speed test section (Mach 0.05 to 0.2). Stagnation pressure 0.3 to 1.5 atmospheres. Captive trajectory system for study of the behavior of aircraft-launched weapons.

Date of Construction: Tunnel with high speed test section commissioned in 1957 and upgraded in 1983-84. Low speed test section scheduled for 1987 commissioning.

Construction Cost: Original: $5 million
1984 $$: $50 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: There are no plans under active discussion, but a possibility of future international cooperation lies in the fact that this facility is exceptionally accurate and efficient in its captive trajectory mode of operation. This is an area of growing importance in connection with efforts to reduce the observability of tactical aircraft.

Silver Spring, MD., U.S.A.

HYPERVELOCITY WIND TUNNEL NO. 9
Naval Surface Weapons Center, White Oak Laboratory
U.S. Navy

"Big Science" Descriptor: Hypersonic aerodynamics

Description of Facility/Instrument: The Hypervelocity Wind Tunnel is a unique facility which provides ground simulation of aerodynamics and aerothermal conditions required for the design and performance evaluation of reentry vehicles, decoys, and interceptors at Mach numbers of 10 and 14. It currently simulates reentry flow conditions from 40,000 feet to about 200,000 feet which is the critical moderate altitude regime of interest to strategic missile systems and defensive interceptor systems.

Date of Construction: 1972-1976

Construction Cost: Original: $17.6 million
1984 $$: $30.6 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Other Information: There have not been any cooperative Tunnel-9 testing efforts with foreign governments to date. Tunnel 9 is utilized primarily to support Department of Defense programs and, to a lesser degree, NASA programs.

Philadelphia, PA., U.S.A.

V/STOL WIND TUNNEL
Boeing Vertol Company

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This tunnel tests fixed-wing in-ground effect, powered models, high angle of attack, helicopter, and jet aircraft performance.

Date of Construction: 1968, upgraded in 1980 and 1982

Construction Cost: 1984 $$: $40 million

Present International Cooperation
Nationality(s) of Owner: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Dallas, TX., U.S.A.

TRANS/SUPERSONIC WIND TUNNEL
Vought Corporation

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This facility is used for testing aircraft, spacecraft and missile configurations for force and moment pressure, inlet performance, flutter, buffet and jet effects.

Date of Construction: 1958, upgraded in 1972 and 1975

Construction Cost: 1984 $$: $25 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Tokyo, JAPAN

TWO-METER TRANSONIC WIND TUNNEL
National Aerospace Laboratory

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This test facility is used for data acquisition of aerodynamic design of airplanes and other configurations under development and for calibration of aerodynamic computational methods.

Date of Construction: 1960

Construction Cost: 1984 $$: $200 million

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: Japan

Dayton, OH., U.S.A.

STRUCTURES RESEARCH AND DEVELOPMENT FACILITY
Air Force Wright Aeronautical Laboratories
U.S. Air Force

"Big Science" Descriptor: Aerodynamic structures research and development

Description of Facility/Instrument: Aircraft structural research and development testing, including high temperatures testing.

Date of Construction: 1959 with improvements over the next five years

Construction Cost: 1984 $$: $80 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: For Western Bloc countries only.

Dayton, OH., U.S.A.

COMPRESSOR RESEARCH FACILITY
Air Force Wright Aeronautical Laboratories
U.S. Air Force

"Big Science" Descriptor: Turbine engine engineering research

Description of Facility/Instrument: Electrical drive system for turbine engine compressor engineering research with fully automated state-of-the-art computer controls for detailed study of steady-state and transient compressor phenomena with immediate data analysis.

Date of Construction: 1979

Construction Cost: 1984 $$: $94 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: For Western Bloc countries only.

Edwards, CA., U.S.A.

AERONAUTICAL TEST RANGE
Dryden Flight Research Facility
NASA

"Big Science" Descriptor: Flight testing

Description of Facility/Instrument: This is a facility to control, monitor, and conduct tests and experimental research in real time and to conduct flight research on all classes of manned aircraft and RPRVs. (Use: 75 percent military and 25 percent NASA unique.)

Date of Construction: 1945, modified in 1980

Construction Cost: 1984 $$: $33.9 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Dayton, OH., U.S.A.

FLIGHT CONTROL DEVELOPMENT LABORATORY
Air Force Wright Aeronautical Laboratories
U.S. Air Force

"Big Science" Descriptor: Flight control engineering research

Description of Facility/Instrument: The Large Amplitude Multimode Aerospace Research Simulator (LAMARS), the predominant flight simulator in the laboratory, consists of an electrohydraulic five degree-of-freedom motion system.

Date of Construction: 1980 and continuing over the next five years

Construction Cost: 1984 $$: $45 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: For Western Bloc nations only.

Langley, UT., U.S.A.

DIFFERENTIAL MANEUVERING SIMULATOR
Langley Research Center
NASA

"Big Science" Descriptor: Flight simulation

Description of Facility/Instrument: This facility is capable of dual high fidelity large amplitude visual scene simulation for extensive up-and-away maneuvering, high angle of attack departures, spin entry and recovery, and air-to-air combat. The facility is unique within government for research on air-to-air combat and spin prevention and alleviation. (Use: 25 percent civil, 55 percent military, and 20 percent NASA unique).

Date of Construction: 1971

Construction Cost: 1984 $$: $23.3 million (without computer)

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Ames, CA., U.S.A.

SIX-DEGREE-OF-FREEDOM MOTION SIMULATOR
Ames Research Center
NASA

"Big Science" Descriptor: Flight simulation

Description of Facility/Instrument: This simulator is used for handling qualities research and assessments for takeoff and landing of vertical rising aircraft. (Use: 100 percent military).

Date of Construction: 1964, currently undergoing modification.

Construction Cost: 1984 $$: $15.4 million (without display system and computer)

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Ames, CA., U.S.A.

FLIGHT SIMULATOR FOR ADVANCED AIRCRAFT
Ames Research Center
NASA

"Big Science" Descriptor: Flight simulation

Description of Facility/Instrument: This facility is used for handling qualities research and assessments in critical take-off and approach landing phases of flight. It is unique for demonstrating "high lateral motion fidelity." The 100-foot lateral travel enhances study of critical maneuvers such as lateral slideslip during landing approach and engine failure. (Use: 10 percent civil, proprietary, and cooperative; 55 percent military; and 35 percent NASA unique.)

Date of Construction: 1969

Construction Cost: 1984 $$: $25.7 million (not including the visual system and computer)

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Ames, CA., U.S.A.

VERTICAL MOTION SIMULATOR
Ames Research Center
NASA

"Big Science" Descriptor: Flight simulation

Description of Facility/Instrument: This facility handles qualities research and assessments in critical take-off and approach/landing phases of aircraft. Its capability of vertical travel enhances the studies of critical maneuvers, particularly for VTOL and STOL operations. (Use: 25 percent civil, 15 percent military, and 60 percent NASA unique.)

Date of Construction: 1981

Construction Cost: 1984 $$: $11.4 million (without visual system and computer).

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Lewis, OH., U.S.A.

PROPULSION SYSTEMS LABORATORY
Lewis Research Center
NASA

"Big Science" Descriptor: Aerodynamics

Description of Facility/Instrument: This facility provides full-scale testing with simulated speed and altitude. It is needed for engine systems research; performance; control; engine/nozzle tests; and systems dynamics studies (stagnation stall and flutter). (Use: 54 percent military and 46 percent NASA unique.)

Date of Construction: 1952, modified in 1972

Construction Cost: 1984 $$: $170.5 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

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Huntsville, AL., U.S.A.

ADVANCED SIMULATION CENTER
Army Missile Laboratory
Army Missile Command, Redstone Arsenal
U.S. Army

"Big Science" Descriptor: Hardware-in-the-loop simulation facility

Description of Facility/Instrument: This facility has the capability to accommodate missile guidance and control, signal processing, autopilot, and sensor hardware in a real-time, time critical simulation, thereby reducing the need for actual flight tests. It can be used throughout the missile system life cycle from early development through deployment. It has a capability for radio frequency, infra-red, electro-optical, and millimeter wave guidance systems.

Date of Construction: 1971-1975

Construction Cost: Original: $50 million
1984 $$: about $115 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: This facility has co-operated with Israel and the U.K. It is preparing to cooperate with the international consortium of companies from the United States, Federal Republic of Germany, France, and Great Britain on the Terminally Guided Warhead for the Multiple Launch Rocket System. It also welcomes any opportunity for international co-operation with nations friendly to the United States and is willing to accommodate their staff members as part of the team conducting the hardware-in-the-loop simulations or to provide the total team itself.

APPENDIX 10

SUPERCOMPUTERS

The information in this appendix was supplied by the National Science Foundation and by each of the organizations at which the supercomputers currently are located, March and April 1985.

Boulder, CO., U.S.A.

NCAR SCIENTIFIC COMPUTING FACILITY
National Center for Atmospheric Research (NCAR)
U.S. National Science Foundation

"Big Science" Descriptor: Supercomputers for atmospheric science

Description of Facility/Instrument: The facility has two Cray 1 machines. It serves the computational needs of members of the U.S. atmospheric science community who address problems in the theory of weather prediction, climate studies, severe storm research, ocean circulation, and the influences of the Sun, land, and oceans on the atmosphere. The facility serves approximately 1500 to 2000 outside users and 500 on-site users, but no overseas users.

Date of Construction: The center began operating in 1963. It acquired its first Cray machine in 1977.

Construction Cost: 1984 $$: $25-30 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Other Information: The NCAR Scientific Computing Facility is managed by the University Corporation for Atmospheric Research, a consortium of 49 universities.

Livermore, CA., U.S.A.

NATIONAL MAGNETIC FUSION ENERGY COMPUTER CENTER
Lawrence Livermore National Laboratory (LLNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Supercomputers for magnetic fusion energy research

Description of Facility/Instrument: This is a large-scale computing facility which enables scientists to study the physics of magnetically-confined plasmas by means of computer simulations and engineers to design models needed in fusion reactor studies. The Center serves 3500 individual users in 58 universities, 19 industrial concerns, and 23 laboratories. The users access the Center through five gateways dispersed throughout the United States which communicate by means of 56 K baud satellite channels. Its large-scale computers include two Cray 1 machines; one Cray XMP, and one Cray 2 scheduled for delivery in May 1985. The users are supported by a staff of 85 professionals.

Date of Construction: The center began operating in July 1974. It acquired its first Cray around 1977.

Construction Cost: 1984 $$: $33-$40 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: Some users are not U.S. citizens, but such use is sporadic.

Potential for Future International Cooperation: There are current discussions regarding possible use by Japanese researchers for a potential U.S.-Japan joint effort in magnetic fusion energy research.

Other Information: This center is managed by the University of California under contract with the U.S. Dept. of Energy.

See also LAWRENCE LIVERMORE NATIONAL LABORATORY COMPUTER CENTER, which is used for national security classified work.

Los Alamos, NM., U.S.A.

LANL COMPUTING AND COMMUNICATIONS DIVISION
Los Alamos National Laboratory (LANL)
U.S. Dept. of Energy

"Big Science" Descriptor: Supercomputers mainly (about 70 percent) for nuclear weapons research; about 30 percent for a number of other research areas.

Description of Facility/Instrument: Four Cray 1 machines and two Cray XMPs. The entire Computing and Communications Division serves about 5000 users in LANL and about 2000 remote users. The largest outside user is the Defense Nuclear Agency. In addition, the facility is accessed by Dept. of Energy contractors and other Federal agencies.

Date of Construction: The Division acquired its first Cray 1 in November 1976.

Construction Cost: 1984 $$: $60 million for the six Cray machines

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: The facility is not used directly by foreign researchers. However, it is possible to get dial-up access from anywhere in the world to two unclassified Cray 1 machines.

Princeton, NJ., U.S.A.

NOAA GEOPHYSICAL FLUID DYNAMICS LABORATORY
Environmental Research Laboratories
National Oceanic and Atmospheric Administration, U.S. Dept. of Commerce

"Big Science" Descriptor: Supercomputers for meteorology, atmospheric sciences, and oceanography

Description of Facility/Instrument: The laboratory has two Cyber 205 machines (manufactured by Control Data Corporation) for modeling and simulating those physical processes that govern the behavior of the atmosphere and the oceans as complex fluid systems.

Date of Construction: The laboratory began operating in 1955. It leased its first Cyber in June 1982 and its second in November 1983.

Construction Cost: 1984 $$: The charge for the annual lease of the supercomputers is $5 million. The value of the lifetime lease of eight years is $40-45 million. The purchase price is $25-30 million.

Present International Cooperation

Nationality(s) of Ownership: U.S.

Nationality(s) of Operational Funding: U.S.

Nationality(s) of Management Staff: U.S.

Nationality(s) of Researchers: Mainly U.S., plus foreigners participating in international programs (generally 10 to 20 visiting scientists who stay one to two years).

Moffett Field, CA., U.S.A.

NASA NUMERICAL AERODYNAMIC SIMULATOR (NAS)
Ames Research Center
National Aeronautics and Space Administration

"Big Science" Descriptor: Supercomputers for computational aerodynamics

Description of Facility/Instrument: Plans call for the facility to be centered around two high-speed processors which will be the most advanced commercially available supercomputers. The first, a Cray 2 supercomputer, is scheduled for delivery in 1985. The system also will have long-haul telecommunications links to allow access to the NAS by remote users. The system is being designed so that more advanced hardware can be added as it becomes available in future years. The NAS will assist in simulating the three-dimensional flow of air over aircraft, thus complementing NASA's wind tunnels used in aerodynamic design and testing. The NAS will be available to other users including government laboratories, university scientists, and aeronautical industries.

Date of Construction: NAS is scheduled to be fully operational by 1986.

Construction Cost: 1984 $$: NASA estimates the cost of the NAS to be approximately $120 million for FY84 to FY88. NASA received $43.5 million for the NAS in FY84 and FY85 and has requested $28.2 million for FY86.

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: Not yet operational, probably all U.S.
Nationality(s) of Researchers: Not yet operational, probably all U.S.

Princeton, NJ., U.S.A.

NATIONAL ADVANCED SCIENTIFIC COMPUTING CENTER at the
John Von Neumann Center
Princeton University

"Big Science" Descriptor: Supercomputers for scientific and engineering research

Description of Facility/Instrument: The supercomputer will be a Cyber 205 manufactured by Control Data Corporation, connected to form megawords of memory and ten gigabytes of storage. The machine will be upgraded to the ETA-10, a multiprocessor supercomputer which currently is being developed by ETA Systems, Inc., a spin-off of Control Data, and will be available in 1987. Also included are an extensive files system and graphics subsystem. The center will be managed by the Consortium for Scientific Computing, a collection of 12 universities. The facility will be supported partially by the State of New Jersey.

Date of Construction: Late 1985 or early 1986.

Construction Cost: 1984 $$: $123.5 million

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: Not yet operational.
- Nationality(s) of Researchers: Not yet operational.

Other Information: In response to the expressed need of U.S. researchers for access to supercomputers, the National Science Foundation (NSF) announced in February 1985 the selection of four institutions that will receive approximately $200 million over the next five years to establish and operate National Advanced Scientific Computing Centers. Awards will range from $7 million to $13 million per year over the grant period. Each award will have a cost-sharing provision in which the States, industries, and institutions will contribute an amount that will approximately double the NSF award. The centers should be available for use by the scientific and engineering research communities in late 1985 or early 1986. Plans call for the supercomputer centers to be connected via a nationwide highspeed data network that will allow researchers to communicate with the centers from any location. In addition to providing high quality advanced computing systems for researchers, the centers will educate students and researchers in the use of supercomputers.

The cost includes five years of funding for facility operations and maintenance. The NSF component of the funding for this facility will be $69.2 million. The remainder will be supplied from local sources.

See also the NATIONAL ADVANCED SCIENTIFIC COMPUTING CENTERS to be established at the Center for Theory and Simulation in Science and Engineering at Cornell University; the University of Illinois; and the University of California at San Diego.

Ithaca, NY., U.S.A.

NATIONAL ADVANCED SCIENTIFIC COMPUTING CENTER at the
Center for Theory and Simulation in Science and Engineering
Cornell University

"Big Science" Descriptor: Supercomputers for scientific and engineering research.

Description of Facility/Instrument: The supercomputer at this center will be a pioneering combination of an IBM 3084 QX mainframe computer with 128 megabytes of main storage attached to a number of FPS 164 and 264 scientific processors which are manufactured by Floating Point Systems. The center will be supported partially by the State of New York.

Date of Construction: Late 1985 or early 1986.

Construction Cost: 1984 $$: $65.4 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: Not yet operational
Nationality(s) of Researchers: Not yet operational

Other Information: In response to the expressed need of U.S. researchers for access to supercomputers, the National Science Foundation (NSF) announced in February 1985 the selection of four institutions that will receive approximately $200 million over the next five years to establish and operate National Advanced Scientific Computing Centers. Awards will range from $7 million to $13 million per year over the grant period. Each award will have a cost-sharing provision in which the States, industries, and institutions will contribute an amount that will approximately double the NSF award. The centers should be available for use by the scientific and engineering research communities in late 1985 or early 1986. Plans call for the supercomputer centers to be connected via a nationwide high-speed data network that will allow researchers to communicate with the centers from any location. In addition to providing high quality advanced computing systems for researchers, the centers will educate students and researchers in the use of supercomputers.

The cost includes three years of funding for facility operations and maintenance. The NSF component of the funding for this facility will be $21.9 million. The remainder will be supplied from local sources.

See also the NATIONAL ADVANCED SCIENTIFIC COMPUTING CENTERS to be established at the John Von Neumann Center at Princeton University; the University of Illinois; and the University of California at San Diego.

Urbana-Champaign, IL., U.S.A.

NATIONAL ADVANCED SCIENTIFIC COMPUTING CENTER
University of Illinois in Urbana-Champaign

"Big Science" Descriptor: Supercomputers for scientific and engineering research

Description of Facility/Instrument: The facility will be centered around a Cray XMP/24 supercomputer with four million words of memory and an additional 128 million words of high-speed memory on a solid state device. There will be a close connection between this center and the newly-established Center for Supercomputer Research and Development in Urbana, which is involved in the design of supercomputer hardware and software. The facility will be supported partially by the State of Illinois.

Date of Construction: Late 1985 or early 1986.

Construction Cost: 1984 $$: $76.1 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: Not yet operational.
Nationality(s) of Researchers: Not yet operational.

Other Information: In response to the expressed need of U.S. researchers for access to supercomputers, the National Science Foundation (NSF) announced in February 1985 the selection of four institutions that will receive approximately $200 million over the next five years to establish and operate National Advanced Scientific Computing Centers. Awards will range from $7 million to $13 million per year over the grant period. Each award will have a cost-sharing provision in which the States, industries, and institutions will contribute an amount that will approximately double the NSF award. The centers should be available for use by the scientific and engineering research communities in late 1985 or early 1986. Plans call for the supercomputer centers to be connected via a nationwide highspeed data network that will allow researchers to communicate with the centers from any location. In addition to providing high quality advanced computing systems for researchers, the centers will educate students and researchers in the use of supercomputers.

The cost includes five years of funding for facility operations and maintenance. The NSF component of the funding for this facility will be $43.9 million. The remainder will be supplied from local sources.

See also the NATIONAL ADVANCED SCIENTIFIC COMPUTING CENTERS to be established at the John Von Neumann Center at Princeton University; the Center for Theory and Simulation in Science and Engineering at Cornell University; and the University of California at San Diego.

San Diego, CA., U.S.A.

NATIONAL ADVANCED SCIENTIFIC COMPUTING CENTER
University of California at San Diego

"Big Science" Descriptor: Supercomputers for scientific and engineering research

Description of Facility/Instrument: The facility is to be managed by GA Technologies. It will be centered around a Cray XMP/48 machine, including four parallel processors and eight megawords of memory, a state-of-theart supercomputer manufactured by Cray Research Corporation. A consortium of 19 universities around the Nation will be connected via high-speed networks to the San Diego center. The facility will be supported by the State of California.

Date of Construction: Late 1985 or early 1986.

Construction Cost: 1984 $$: $96.1 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: Not yet operational
Nationality(s) of Researchers: Not yet operational

Other Information: In response to the expressed need of U.S. researchers for access to supercomputers, the National Science Foundation (NSF) announced in February 1985 the selection of four institutions that will receive approximately $200 million over the next five years to establish and operate National Advanced Scientific Computing Centers. Awards will range from $7 million to $13 million per year over the grant period. Each award will have a cost-sharing provision in which the States, industries, and institutions will contribute an amount that will approximately double the NSF award. The centers should be available for use by the scientific and engineering research communities in late 1985 or early 1986. Plans call for the supercomputer centers to be connected via a nationwide highspeed data network that will allow researchers to communicate with the centers from any location. In addition to providing high quality advanced computing systems for researchers, the centers will educate students and researchers in the use of supercomputers.

The cost includes five years of funding for facility operations and maintenance. The NSF component of the funding for this facility will be $58.4 million. The remainder will be supplied from local sources.

See also the NATIONAL ADVANCED SCIENTIFIC COMPUTING CENTERS to be established at the John Von Neumann Center at Princeton University; the Center for Theory and Simulation in Science and Engineering at Cornell University; and the University of Illinois in Urbana-Champaign.

Tallahassee, FL., U.S.A.

FSU SUPERCOMPUTER COMPUTATIONAL RESEARCH INSTITUTE
Florida State University (FSU)

"Big Science" Descriptor: Supercomputer for research in computational science.

Description of Facility/Instrument: The current Cyber 205 is scheduled to be replaced by an ETA-10 supercomputer in January 1988, although it may be provided on a test-site basis in the fall of 1986 if it is available by then.

Date of Construction: May 1985, to be updated in 1988

Construction Cost: 1984 $$: $19 million plus associated equipment costs (see note below)

Present International Cooperation
- Nationality(s) of Ownership: U.S.
- Nationality(s) of Operational Funding: U.S.
- Nationality(s) of Management Staff: U.S.
- Nationality(s) of Researchers: U.S.

Other Information: The Department of Energy received $7 million in fiscal year 1985 appropriations to begin funding the FSU supercomputer facility. It is planned that Department of Energy researchers and contractors will use the facility about 65 percent of the time. The other 35 percent of the time will be allocated to Florida State University, other universities in Florida, universities in the Southern University Research Association, and industry. Until the present, the departments of meteorology and physics at Florida State University have been the largest users.

Note: The current value of the installed equipment is about $15 million ($12 million for the Cyber 205 and $3 million for other hardware). The total cost of the supercomputer equipment over the five-year period of the cooperative agreement between Florida State University and the Department of Energy is estimated to be at least $19 million plus associated equipment costs.

Livermore, CA., U.S.A.

LLNL COMPUTER CENTER
Lawrence Livermore National Laboratory (LLNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Supercomputers primarily for nuclear weapons research

Description of Facility/Instrument: The facility has four Cray 1 and one Cray XMF machines.

Date of Construction: acquired first Cray 1 in 1979

Construction Cost: 1984 $$: $50-$60 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: The classified nature of this work prohibits outside access. Researchers must have security clearance.

Other Information: See also NATIONAL MAGNETIC FUSION ENERGY COMPUTER CENTER at Lawrence Livermore National Laboratory.

APPENDIX 11

ENGINEERING FACILITIES

The information in this appendix was supplied by the U.S. Navy, the Department of Energy, the U.S. Air Force, the U.S. Army, the National Science Foundation, and the MTS Systems Corporation.

Carderock, MD., U.S.A.

DTNSRDC TOWING BASIN, HIGH SPEED
Ship Performance Department
David Taylor Naval Ship R&D Center (DTNSRDC)

"Big Science" Descriptor: High performance craft/torpedo/towed body, high-speed hydrodynamics

Description of Facility/Instrument: Concrete fresh water basin 2968 feet long, 21 feet wide, and 10 feet deep for 1168 feet and 16 feet deep for 1800 feet with a pneumatic wavemaker which can generate waves up to 2 feet high and 40 feet long. Three towing carriages operate with top speeds of 35, 50, and 70 knots over the basin on tracks. Typical tests performed on this facility include: resistance, self-propulsion, and static stability in calm water; seakeeping and propulsion evaluations in head or following waves; planar motion experiments; open water propeller characterizations of large propellers; unsteady propeller blade force measurements; hydrodynamic forces on hydrofoils, planning boats, and other high speed craft operating in calm water and in waves; towed body experiments; knot-meter calibrations.

Date of Construction: 1941, 1947 (doubled length and added 50 knot towing carriage), 1980 (added 70 knot towing carriage).

Construction Cost: Original: (1941) $4 million
1984 $$: $45 million (including three towing carriages)

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: Excellent

Other Information: The Center's Ship Performance Department participates on a continuing basis in activities with the International Towing Tank Conference, American Towing Tank Conference, International Exchange Program (ABC-17 Ship Hydrodynamics), NATO Exchange Program, NSMB Co-op Research Program, and miscellaneous experimental work for various foreign companies and governments.

Carderock, MD., U.S.A.

DTNSRDC TOWING BASIN, DEEP WATER
Ship Performance Department
David Taylor Naval Ship R&D Center (DTNSRDC)

"Big Science" Descriptor: Surface ship/submarine resistance, propulsion, seakeeping, stability, and control characterizations

Description of Facility/Instrument: Concrete fresh water basin 1886 feet long, 51 feet wide, and 22 feet deep with a pneumatic wavemaker capable of generating waves up to 2 feet high and 40 feet long. A towing carriage operates over the basin on tracks at speeds up to 20 knots. Typical tests performed on this facility include: resistance and self-propulsion in calm water; open water propeller characterizations; seakeeping and propulsion evaluations in head or following waves; unsteady propeller blade force measurements; wake surveys; knot-meter calibrations under simulated dynamic conditions; vertical and horizontal planar motion experiment; hydrodynamic forces on submerged bodies, foils, etc.; towed body experiments.

Date of Construction: 1947

Construction Cost: Original: $6 million
1984 $$: $30 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: Excellent

Other Information: The Center's Ship Performance Department participates on a continuing basis in activities with the International Towing Tank Conference, American Towing Tank Conference, International Exchange Program (ABC-17 Ship Hydrodynamics), NATO Exchange Program, NSMB Co-op Research Program, and miscellaneous experimental work for various foreign companies and governments.

Carderock, MD., U.S.A.

DTNSRDC TOWING BASIN, SHALLOW WATER
David Taylor Naval Ship R&D Center (DTNSRDC)

"Big Science" Descriptor: Surface ship resistance and propulsion characterization

Description of Facility/Instrument: Concrete fresh water basin 1192 feet long, 51 feet wide, and 22 feet deep, including a shallow water section 303 feet long and 10 feet deep which can be used to simulate rivers, canals, and restricted channels. A towing carriage operates over the basin on tracks at speeds up to 18 knots. Typical tests performed on this facility include: resistance and self-propulsion in calm water; open water propeller characterizations; self-propelled model steering maneuvers; unsteady propeller blade force measurements; wake surveys; knotmeter calibrations under simulated dynamic conditions; vertical planar motion experiments; hydrodynamic forces on submerged bodies, foils, etc.; towed body experiments; longitudinal wave cut experiments.

Date of Construction: 1941

Construction Cost: Original: $4 million
1984 $$: $25 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: Excellent

Other Information: The Center's Ship Performance Department participates on a continuing basis in activities with the International Towing Tank Conference, American Towing Tank Conference, International Exchange Programs (ABC-17 Ship Hydrodynamics), NATO Exchange Program, NSMB Co-op Research Program, and miscellaneous experimental work for various foreign companies and governments.

Tadotsu, JAPAN

TADOTSU ENGINEERING LABORATORY
Nuclear Power Engineering Test Center

"Big Science" Descriptor: Earthquake research

Description of Facility/Instrument: Large shake table (15 x 15 meters) for evaluating damage to structures due to earthquakes.

Date of Construction: 1980

Construction Cost: 1984 $$: About $112 million

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: Japan

Richland, WA., U.S.A.

FAST FLUX TEST FACILITY (FFTF)
Hanford Engineering Development Laboratory (HEDL)
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear reactor research

Description of Facility/Instrument: This is a 400 megawatt-thermal (no electricity production) Fast Flux Test Facility with peak neutron flux of 70×10^{16} neutrons/cm^2/second, cooled by liquid metal sodium at 800° F, inlet to reactor and 1,050° F outlet. It has three operating sodium loops, fueled by uranium-plutonium dioxide. It is capable of operating with closed loops to 1,400° F. The facility has interim examinations of fuel capabilities and operates with sophisticated, instrumental test assembles.

Date of Construction: Began in 1970, criticality was achieved in 1980.

Construction Cost: Original: $640 million
1984 $$: more than $1 billion

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: 98 percent U.S., 2 percent Japan
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers:

Potential for Future International Cooperation: There is substantial interest from foreign countries, with Japanese dollars now included in the base program activities in FFTF.

Idaho Falls, ID., U.S.A.

EXPERIMENTAL BREEDER REACTOR II (EBR-II)
Argonne National Laboratory (ANL)
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear reactor research

Description of Facility/Instrument: This reactor provides 62.5 megawatts-thermal; 19.5 megawatts-gross electrical; 95 percent uranium metal 67 without enriched U-235 cooled with sodium. It is used to test fuels and reactor operational characteristics.

Date of Construction: Began in 1958, criticality was achieved in 1963

Construction Cost: Original: $30 million
1984 $$: more than $100 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.-Japan
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.-Japan

Potential for Future International Cooperation: There is good potential for international cooperation, joint programs, and the exchange of personnel.

Idaho Falls, ID., U.S.A.

LOSS-OF-FLUID TEST FACILITY (LOFT)
Idaho National Engineering Laboratory (INEL)
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear reactor research

Description of Facility/Instrument: LOFT is an approximately 1/30-scale light water pressurized reactor for simulated response to a loss-of-coolant accident and for source term fission product experiments. It has a design power of 55 megawatts (thermal) and design pressure and temperature of 2,500 psig and 650°F. It has a 5-1/2 foot core length and a 24-inch equivalent core diameter. The facility is mounted on double-width railroad flat car to enable its removal from the containment facility.

Date of Construction: Began in 1976, criticality was achieved in 1978

Construction Cost: Original: $ 65 million
1984 $$: $110 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S., U.K., Federal Republic of Germany, Japan, Sweden, Finland, Spain, Switzerland, Austria
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S., U.K., Federal Republic of Germany, Japan, Sweden, Finland, Spain, Switzerland, Austria

Potential for Future International Cooperation: None. It is scheduled to be decommissioned and decontaminated in 1986.

Idaho Falls, ID., U.S.A.

TRANSIENT REACTOR TEST FACILITY (TREAT)
Argonne National Laboratory (ANL)
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear reactor research

Description of Facility/Instrument: TREAT is an air-cooled thermal reactor designed to test reactor fuels and materials under conditions simulating various types of nuclear excursions. It has the capability to obtain full temperatures up to 600°C, reactor periods as short as 20 milliseconds, an energy release of 2,500 megawatts, and shaped power transients under computer control. Fuel motion measurements can be made with a neutron hodoscope.

Date of Construction: Began in 1957, criticality was achieved in 1959

Construction Cost: Original: \$ 2 million
1984 \$\$: \$75 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S., U.K.

Potential for Future International Cooperation: No near-term interest is evident.

Mito, JAPAN

JOYO
O-arai
Power Reactor and Nuclear Fuel Development Corporation (PNC)

"Big Science" Descriptor: Nuclear test reactor

Description of Facility/Instrument: This 100 megawatt-thermal (no electricity production) fast flux test reactor is fueled with uranium-plutonium dioxide enriched to 23 without U-235 and cooled with sodium. It is used to test fuels and reactor operational characteristics.

Date of Construction: Began in 1970, criticality was achieved in 1977

Construction Cost: Original: more than \$25 million
1984 \$\$: more than \$50 million

Present International Cooperation
Nationality(s) of Ownership: Japan
Nationality(s) of Operational Funding: Japan
Nationality(s) of Management Staff: Japan
Nationality(s) of Researchers: Japan-U.S.

Idaho Falls, ID., U.S.A.

ZERO POWER PLUTONIUM REACTOR (ZPPR)
Argonne National Laboratory (ANL)
U.S. Dept. of Energy

"Big Science" Descriptor: Nuclear reactor research

Description of Facility/Instrument: ZPPR is a split table critical facility designed for study of the physics of nuclear power breeder systems. Its matrix is made up of two 14x14x5-foot assemblies of matrix tubes mounted on separate steel tables. Its output power is less than 100 watts. It simulates commercial reactor cores of 1,000 megawatts (electric).

Date of Construction: 1968, criticality was achieved in 1969

Construction Cost: Original: $ 20 million (including fuel)
1984 $$: $170 million (including fuel)

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S. and Japan

Potential for Future International Cooperation: There is a possible cooperative program between the Dept. of Energy and the Japanese Jupiter 3 program.

Dimitrovgrad, U.S.S.R.

BOR-60
Scientific and Research Institute for Atomic Reactors
U.S.S.R. State Committee for Utilization of Atomic Energy

"Big Science" Descriptor: Nuclear reactor research

Description of Facility/Instrument: This is a 60 megawatt-thermal fast flux test reactor fueled with 90 percent enriched U-235 uranium oxide cooled with sodium. It is used to test fuels and sodium components.

Date of Construction:

Construction Cost: 1984 $$: more than $25 million

Present International Cooperation
Nationality(s) of Ownership: U.S.S.R.
Nationality(s) of Operational Funding: U.S.S.R.
Nationality(s) of Management Staff: U.S.S.R.
Nationality(s) of Researchers:

Oak Ridge, TN., U.S.A.

CALUTRONS ELECTROMAGNETIC ISOTOPE SEPARATIONS FACILITY
Oak Ridge National Laboratory (ORNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Physics

Description of Facility/Instrument: This facility provides very high current mass separations. Feed material is vaporized, ionized, electromagnetically accelerated, and magnetically focused to impinge on a target. Isotopes of a given mass collect separately from those of another mass. Runs are from 50 to hundreds of hours.

Date of Construction: 1944

Construction Cost: Original: $110 million (see note 1 below).
1984 $$: $200 million (see note 2 below).

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Other Information: The calutrons provide the only U.S. means of producing separated stable isotopes critically needed for research in the physical sciences and as precursors to produce short-lived radioisotopes used for nuclear medicine. These isotopes are sold internationally for research, medical, and industrial applications.

Note 1. The 1944 construction project produced 1156 separators at a cost of about $2 billion. The 1984 facility has 63 separators or about one percent of the original.
Note 2. This estimated figure was not obtained by applying 40 years of escalating costs to the 1944 number. It is the result of a 1984 analysis by calutron staff.

Albuquerque, NM., U.S.A.

"SHIVA"
Air Force Weapons Laboratory
U.S. Air Force

"Big Science" Descriptor: High-energy physics

Description of Facility/Instrument: X-ray simulation device and pulse power system for research on the effects of very high-energy x-rays on matter.

Date of Construction: 1984

Construction Cost: 1984 $$: $27 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: None because of national security considerations.

Albuquerque, NM., U.S.A.

DIRECTED ENERGY EFFECTS RANGE (DEER)
Air Force Weapons Laboratory
U.S. Air Force

"Big Science" Descriptor: Laser and particle beam research

Description of Facility/Instrument: The facility contains laser and particle beam devices with assorted range equipment for research on high-energy lasers and their effects.

Date of Construction: 1984-85

Construction Cost: 1984 $$: $50 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: None because of national security considerations.

Albuquerque, NM., U.S.A.

TRESTLE
Air Force Weapons Laboratory
U.S. Air Force

"Big Science" Descriptor: Electromagnetic pulse research

Description of Facility/Instrument: Large, all-wood structure for aircraft electromagnetic pulse (EMP) experimentation.

Date of Construction: 1979

Construction Cost: 1984 $$: $60 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: None because of national security considerations.

Albuquerque, NM., U.S.A.

ADVANCED RADIATION TECHNOLOGY FACILITY (ARTF)
Air Force Weapons Laboratory
U.S. Air Force

"Big Science" Descriptor: High-energy laser research

Description of Facility/Instrument: High-energy CO_2 laser and associated support equipment.

Date of Construction: Constructed in 1977 and decommissioned in 1984.

Construction Cost: 1984 $$: $27 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Researchers: U.S.

Potential for Future International Cooperation: None because of national security considerations.

Adelphi, MD., U.S.A.

AURORA RADIATION TEST FACILITY
Harry Diamond Laboratories
U.S. Army

"Big Science" Descriptor: Non-destructive testing and engineering

Description of Facility/Instrument: AURORA is the largest flash x-ray machine and is used to test electronics systems for nuclear hardening purposes.

Date of Construction: 1970-1971, modified in 1984-1985

Construction Cost: Original: $20/$1.6 million
1984 $$: $48 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(s) of Reaearchers: U.S.

Potential for Future International Cooperation: Limited due to military use.

Livermore, CA., U.S.A.

ADVANCED TEST ACCELERATOR (ATA)
Lawrence Livermore National Laboratory (LLNL)
U.S. Dept. of Energy

"Big Science" Descriptor: Electron beam research

Description of Facility/Instrument: This induction linear accelerator produces a 50 megawatt, 10,000 amp pulsed electron beam of 50 nanosecond duration for air propagation experiments for military applications and free electron laser research at infrared wavelengths. It can be used in magnetic-confinement fusion research.

Date of Construction: 1979-83

Construction Cost: 1984 $$: $55 million

Present International Cooperation
Nationality(s) of Ownership: U.S.
Nationality(s) of Operational Funding: U.S.
Nationality(s) of Management Staff: U.S.
Nationality(a) of Researchers: U.S.