THE OCEANOGRAPHIC OPERATIONS PROGRAM OF THE U.S. NAVY

Accomplishments
and
Prospects

DECEMBER 1967

OFFICE OF THE
OCEANOGRAPHER OF THE NAVY
ALEXANDRIA, VIRGINIA

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Foreword

In the search for new applications of ocean science and engineering the Navy continues to carry out its traditional oceanographic operations, improving and extending these as the state of the art permits. Notable among the extensions of oceanography to meet new defense requirements is the development of oceanographic prediction through the joint efforts of the Naval Oceanographic Office and the Naval Weather Service. This capability, developed over the past decade, has demonstrated substantial monetary savings and operational improvements. Research and development on the environment's effect on underwater acoustics has derived new knowledge concerning sound propagation, refraction, and reflection within the ocean and at its boundaries, and has led to a better understanding of sonar capabilities and limitations. Operational surveys based on this knowledge will result in major improvements in Fleet ASW capabilities.

Sophisticated use of electronics aboard oceanographic survey vessels enables the Navy to collect a greater variety and a greater quantity of information about the oceans than has been possible heretofore. Although operational use of space vehicles for oceanographic purposes is still in the future, Navy aircraft are routinely used in the rapid collection of data for oceanographic prediction and charting. In addition to meeting military requirements, information obtained is proving useful in such non-military areas as shipping and fishing. Aircraft used in oceanographic

operations are also blazing paths for oceanographic applications of space vehicles and sensors. More efficient operations are rapidly evolving from electronic computation of tables and chart projections, coupled with automated plotting of charts and graphs.

The close coupling of oceanographic operations to the engineering, and research carried out by the Navy provides quick access to new knowledge about the marine environment for the solution of Department of Defense problems and the improvement of its defense capability as well as its peacetime service to the Nation and to mankind.

Approximately two-fifths of the nearly quarter of a billion dollars allocated by the Navy for oceanography in 1968 is programmed for oceanographic operations. Most of this is in support of the U. S. Naval Oceanographic Office and the ships and aircraft assigned for oceanographic surveying. Thus, this report largely concerns the work of the Naval Oceanographic Office. It speaks also to the oceanographic activities of the Naval Weather Service, which include operation of an environmental prediction service of major importance to the Fleet and with great national potential.

Rear Admiral O. D. Waters, Jr., U. S. N.
Oceanographer of the Navy

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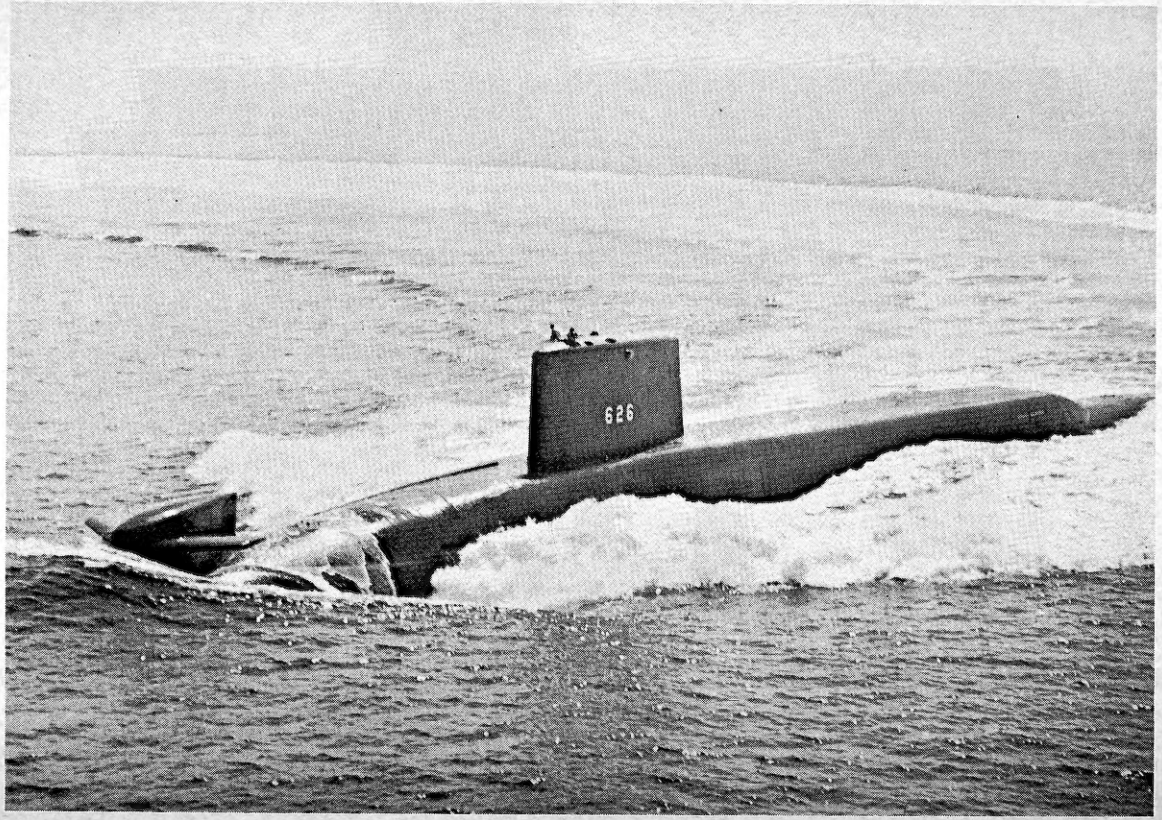


Oceanographic Operations—The science of oceanography in day-to-day direct support of fleet operations.

The Oceanographic Operations Program of the U. S. Navy

Accomplishments and Prospects

INTRODUCTION

The ocean is the traditional operating environment of the Navy. Over 70 percent of the earth's surface is covered by water, and, therefore, the role of the Navy in upholding the United States' interest throughout the world and in providing impenetrable defenses against attack by alien forces is massive. Modern evolution of science and technology has added the airplane, the missile, and the submarine to the Navy's stock of weapons and has extended its operating medium to include the air above the ocean and the entire ocean, including the abyssal depths. The bottom of the ocean and the sediments and geological structure beneath the bottom are important to a variety of Navy installations, equipments, and applications. Effective use of the tools of modern warfare, wherein the ocean is a significant if not the dominant factor, has dictated that the Navy assume positive leadership in oceanography. The Oceanographic Program of the Navy, currently budgeted at about a quarter of a billion dollars, is directed toward these responsibilities.

The program has three separate but related divisions. First, the Ocean Science portion includes the study of physical, biological, and geological characteristics in order to advance our understanding of the nature of the world oceans and their boundaries. These studies range from fundamental research, through investigations of specific environmental conditions which affect equipment and systems, to tests which prove the scientific and technical feasibility of new system concepts.

SUBMARINE

Submariners Handbook
Submarine Guides
Sonar Atlases
Ice Forecasts

SEARCH, RESCUE and SALVAGE

Special Area Studies
Sound Velocity Studies
Bottom Contour Charts
Wave and Ice Forecasts
Oceanographic Atlases

ASW

ASWEPS
Sonar Atlases
Special Area Studies
Submariners'Handbook

MINE WARFARE

Mine Warfare Pilot
HODS
Coastal Studies
VAMP Publications

ENVIRONMENTAL FACTORS

Water Motion

Currents, Waves, Breakers and Surf, Internal Waves, Sea Level, Tides

Sea Ice Features and Properties

Distribution, Concentration, Thickness

Physical and Chemical Properties

Temperature, Salinity, Density, Dissolved Oxygen, pH, Nutrients

Oceanographic Acoustic Properties

Propagation, Reverberation, Ambient Noise, Sound Channels, Active and Passive Ranges

Marine Organisms

Fouling, Bioluminescence, Dangerous Animals, False Targets and Sound Scattering, Vegetation

Sea Floor and Bottom Strata

Submarine Topography, Micro-Bathymetry, Bottom Composition, Engineering and Chemical Properties

Geomagnetism

Spatial and Temporal Variation, Anomalies

Gravity

Anomalies, Deflection of the vertical

SURVEILLANCE

Special Area Studies
Sound Velocity Studies
Bottom Contour Charts
Wave and Ice Forecasts
Oceanographic Atlases

POLAR

Ice Forecasts
Ice Atlases
Long Range Ice Outlook
Ice Charts
Ice Manuals and Reports

GENERAL FLEET

Combat Charts
Nautical Charts
Sailing Directions
Optimum Ship Routing
Pilot Charts
Oceanographic Atlases

AMPHIBIOUS

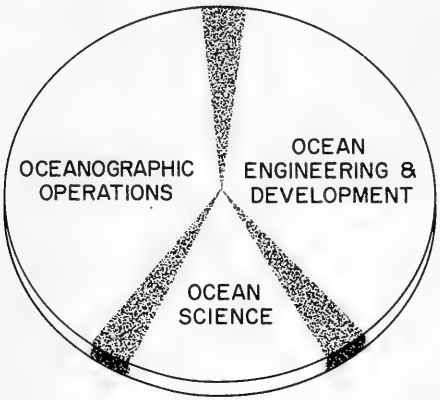
AOS Studies
Combat Charts
NIS Coastal Studies
Wave Forecasts

Environmental factors related to oceanography and associated with Navy operational needs.

Second, the Ocean Engineering and Development portion stresses such projects as the Deep Submergence Systems Project that will give us the capability for submarine search and rescue and improve man's ability to perform useful work at greater depths than ever before.

Finally, the Oceanographic Operations portion involves direct support of operating forces through the collection of environmental data by specially equipped ships, submarines, aircraft, and buoys as well as other devices. The transformation of these data into useful products for Fleet use, as well as for other national programs and, in some cases, for international distribution in accordance with mutual exchange agreements with other countries, is included in Oceanographic Operations. The program stresses military and statutory requirements because, by law, the Navy has responsibilities for the production of nautical charts and for

providing aids which promote safety at sea for all mariners. Military requirements are stated by the Department of Defense and by the Chief of Naval Operations. The Fleet Commanders provide regular inputs to the Oceanographer of the Navy. These requirements address specific areas which require support. For example, environmental studies directed toward the development of mine countermeasure techniques might be a stated requirement; antisubmarine warfare support is clearly another. A training program in oceanography is a small, though important, part of the Oceanographic Operations portion and includes foreign as well as United States personnel.



Nearly two-fifths of the Navy's Oceanographic Program is devoted to Oceanographic Operations.

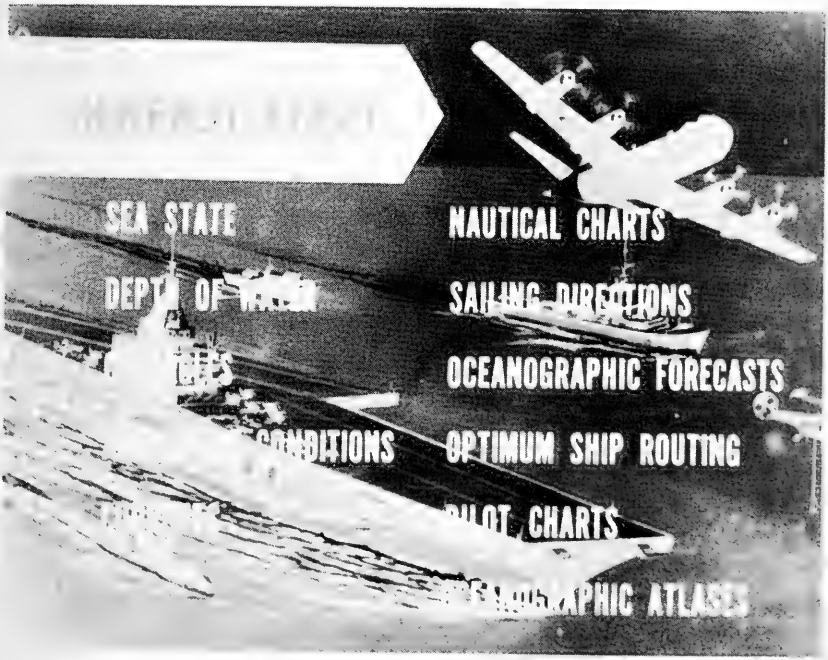
The Navy is uniquely responsive to the various facets of the national oceanographic program because it lives and works at sea and is therefore constantly aware that a thorough understanding of the oceans contributes significantly in the contest for national prestige and influence. This report describes the Navy Oceanographic Operations Program.

The Navy Oceanographic Operations Program responds to military requirements in many ways. The gathering of data by oceanographic surveys leads to the production of charts, publications, advisories, and other services to meet specific Fleet needs. In the following illustrations, principal oceanographic factors which affect a specific type of operation are listed at the left. The products or services which support that operation are indicated at the right.

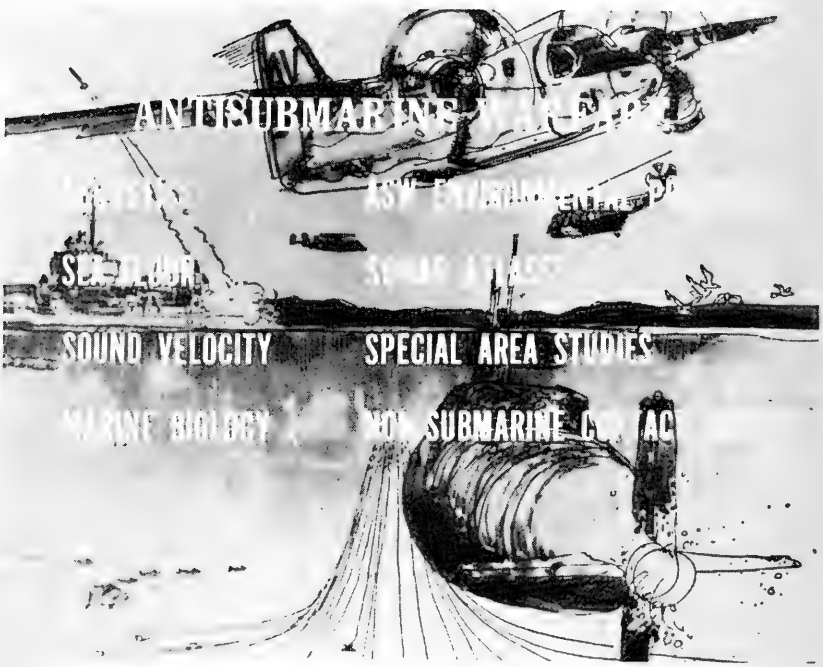

MINE WARFARE
SEA FLOOR
LITTORAL
MAGNETICS
SURFACE AND INTERNAL WAVES
MARINE FOULING
CURRENTS
MINE WARFARE PILOT
COASTAL STUDIES
VISIBILITY, ACOUSTIC, MAGNETIC, PRESSURE STUDIES


AMPHIBIOUS
SEA STATE - SURF
LITTORAL
TIDES
CURRENTS
AMPHIBIOUS OBJECTIVE STUDIES
COMBAT CHARTS
COASTAL STUDIES
OCEANOGRAPHIC FORECASTS


SEARCH, RESCUE & SALVAGE
MARINE BIOLOGY
CURRENTS
SOUND VELOCITY
VISIBILITY
SEA FLOOR
SOUND VELOCITY
BOTTOM CONTOUR CHARTS
OCEANOGRAPHIC FORECASTS

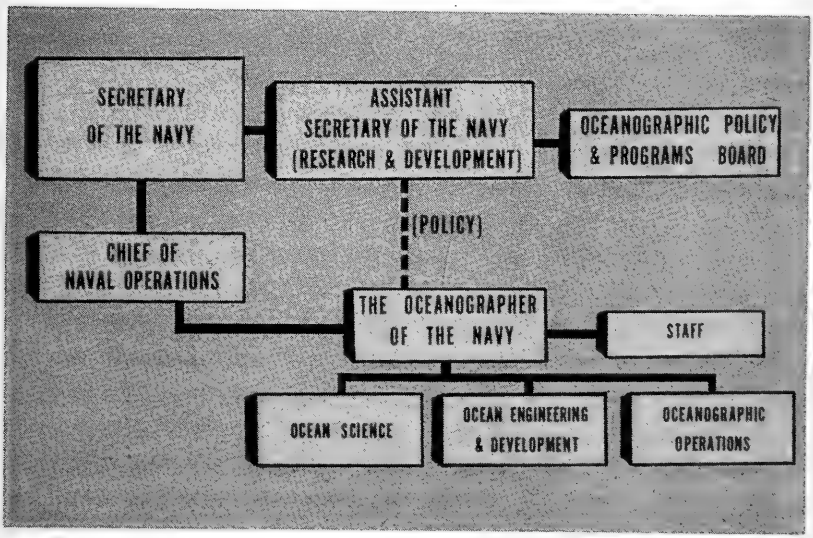

SEA STATE
NAUTICAL CHARTS
SAILING DIRECTIONS
OCEANOGRAPHIC FORECASTS
OPTIMUM SHIP ROUTING
PILOT CHARTS


ICE FORECASTS
ACOUSTICS


ANTISUBMARINE
SOUND VELOCITY
SPECIAL AREA STUDIES

ORGANIZATION AND MANAGEMENT

Management of the Navy Oceanographic Operations Program is under the direction of the Assistant Oceanographer of the Navy for Oceanographic Operations. A new management structure for the Navy's overall oceanography program was recently established by instructions from the Secretary of the Navy and the Chief of Naval Operations. Under this structure, the Oceanographer of the Navy has been given the responsibility for the entire oceanography program of the Navy. He reports directly to the Chief of Naval Operations for command purposes and receives policy guidance from the Assistant Secretary of the Navy (Research and Development). The Oceanographer of the Navy is assisted in the management of the Navy's program by the Chief of Naval Research in his collateral assignment as Assistant Oceanographer for Ocean Science and by the Deputy Chief of Naval Material (Development) as the assistant Oceanographer for Engineering and Development, as well as by the Assistant for Oceanographic Operations.



Navy Oceanographic Program management structure.

The directive by which tasks and functions have been assigned to the Oceanographer of the Navy by the Chief of Naval Operations describes oceanographic operations as follows: "That effort to provide oceanographic data, services, and operational support including hydrographic mapping, charting, and geodetic activities; and the ..... technical support of operations involving underwater search and rescue, recovery, salvage, emplacements, and facilities."*

Although many Navy laboratories and scientific institutions participate in operational oceanography, their role is primarily in the research and development area. The oceanographic operations program is predominantly a function of the U. S. Naval Oceanographic Office for most areas and of the U. S. Naval Weather Service Command for short-term environmental forecasting.

THE U. S. NAVAL OCEANOGRAPHIC OFFICE

The U. S. Naval Oceanographic Office (until July 1962 known as the U. S. Navy Hydrographic Office) traces its origin to 1830 when the Navy first undertook to centralize responsibility for the care and issue of charts and navigational instruments needed by its ships. Today, the mission of the Oceanographic Office includes conducting hydrographic and oceanographic surveys, preparation of hydrographic and other navigational charts and publications, and conduct of applied oceanographic programs for the Navy throughout the oceans of the world.

The U. S. Naval Oceanographic Office is a scientific and engineering organization having a complement of about 25 officers, 25 enlisted men and over 3000 civilian employees. With a total financial budget of about $60 million, it operates a research facility, a printing plant, an extensive distribution system, an instrument center, and other specialized facilities. It also employs a fleet of surface ships, a submarine, and several airplanes in support of its mission.

First and foremost in the Oceanographic Operations Program is the physical measurement and description (the surveying and

*OPNAVINST 5450.165 of 26 August 1966 (CH-1 of 15 February 1967)

charting) of that portion of the earth's surface comprising the ocean. The year 1966 marked the 100th anniversary of the establishment by Congressional statute of a hydrographic office in the United States for the purpose of charting the waters of the earth for the benefit of navigators generally. This job of charting—based on hydrographic surveys—is basic to all exploration and exploitation of the oceans. Precise charts are needed for navigation; for use as a framework for other oceanographic surveys and studies; for gun-fire support of land troops by Navy ships offshore, as in Vietnam; for ship location on the high seas; for purposes of missile launch, tracking, and recovery; for equipment installation on the ocean bottom; for salvage and mineral recovery on the continental shelves; for submarine and anti-submarine warfare; and for oceanographic research and marine exploitation.

Although the Oceanographic Office has on issue today nearly 6000 different marine charts, these are far from adequate for the job that lies ahead. Despite the availability of detailed charts for many world areas, the job of charting the physical size, shape, and form of the oceans adequately and completely remains a major Navy requirement. It is after all, the base from which all further effort in oceanography must proceed.

Surveys from surface vessels are organized to obtain accurately controlled coastal and oceanic depth information, physical, chemical, and biological characteristics, surface and subsurface currents, ocean bottom samples and cores, sub-bottom profiles, geodetic positions, and geomagnetic and gravity field data. This program is supplemented by airborne geomagnetic and ice surveys of the oceanic areas throughout the world.

Research to improve our understanding of ocean phenomena and our charting and measurement capability is conducted in many aspects of oceanography and hydrography under the related research and engineering sectors of the Navy Oceanographic Program. This research is concerned with such topics as ocean thermal structure; oceanographic instrument development; navigation; and geophysical, oceanographic, and hydrographic charting and prediction. Particular emphasis is placed on improvement of data collection and handling procedures and the rapid conversion of data into finished products.

An integral part of the mission of the Naval Oceanographic

Office is the provision of worldwide navigational, hydrographic, and oceanographic data not only to the military services but also to the maritime industry and the general public. Scientific and technical information procured, processed, and disseminated by the Oceanographic Office is made available through its charts and publications, its library and public information services, its field offices, and the National Oceanographic Data Center. At present approximately 8500 separate nautical, aeronautical, and oceanographic charts and publications produced by the Oceanographic Office are available for issue and sale through more than 150 sales agents throughout the world.

The United States is a member of the International Hydrographic Bureau, and through the Bureau, the Naval Oceanographic Office maintains an exchange of hydrographic charts, publications, and related data with 40 other hydrographic institutions.

An extensive information exchange relationship is maintained with U. S. Government mapping agencies, including the U. S. Air Force Aeronautical Chart and Information Center, the U. S. Army Map Service, the Coast and Geodetic Survey, and other government organizations. Exchange agreements assure that Navy requirements are reflected in Air Force, Army, and Coast and Geodetic Survey maps and charts and, similarly, that other agency requirements are incorporated in Navy charts. Additionally, standardization of products and elimination of duplication of effort result from this liaison.

The Naval Oceanographic Office collects and generates information in the following operational fields:

Navigation: Aids and dangers to surface, subsurface, and aerial navigation; radar plotting techniques; satellite-based navigation systems; radio positioning systems; and celestial navigation.

Cartography and Photogrammetry: Computer methods for cartography and photogrammetry, evaluation of commercial equipment, aerial and underwater stereophotography, satellite photography, chart materials, chart production techniques, video mapping, and visual cockpit displays for aircraft.

Oceanography and Hydrography: Ocean soundings and

depth profiles; bottom sediments and topography; ocean wave characteristics; special oceanographic forecasts; internal waves; ocean currents; surface and subsurface thermal structure; heat exchange between sea and atmosphere; ice physics; ice reconnaissance and prediction; submarine oceanographic observations (temperature, salinity, bottom pressure, sound velocity, ambient light, relative waterflow, etc.); microbathymetry survey techniques; biological fouling; flushing and dispersion of contaminants in marine areas; correlating environmental phenomena associated with harbors; visibility; acoustic reflectivity; bioluminescence; ambient noise; and unusual phenomena.

Geophysics: Airborne and shipboard geomagnetic surveys and gravity measurements.

U. S. NAVAL WEATHER SERVICE COMMAND

Operational oceanographic support has been added as a task for many of the shore activities of the Naval Weather Service Command in order to meet the requirements for short-term environmental forecasting services. Some 33 activities, ranging from the highly automated Fleet Numerical Weather Facility with its data processing center at Monterey, California, to the smaller Naval Weather Service Environmental Detachments, are involved in producing operational oceanographic services. The Fleet Numerical Weather Facility (FNWF), Monterey, with 10 Naval officers and professional grade civilians committed to the oceanographic program, is the hub of the Naval Environmental Data Network (NEDN) which extends from the Philippines and Japan across the Pacific Ocean and the United States to England and Spain. The network links the computer installations that are used for both meteorological and oceanographic data processing and forecast production.

The three general classes of weather/oceanographic support activities are: Fleet Weather Centrals, Weather Facilities, and Environmental Detachments. Each collects various types of data which are relayed via high speed data link for processing and use in various programs developed to meet many of the Fleet require-

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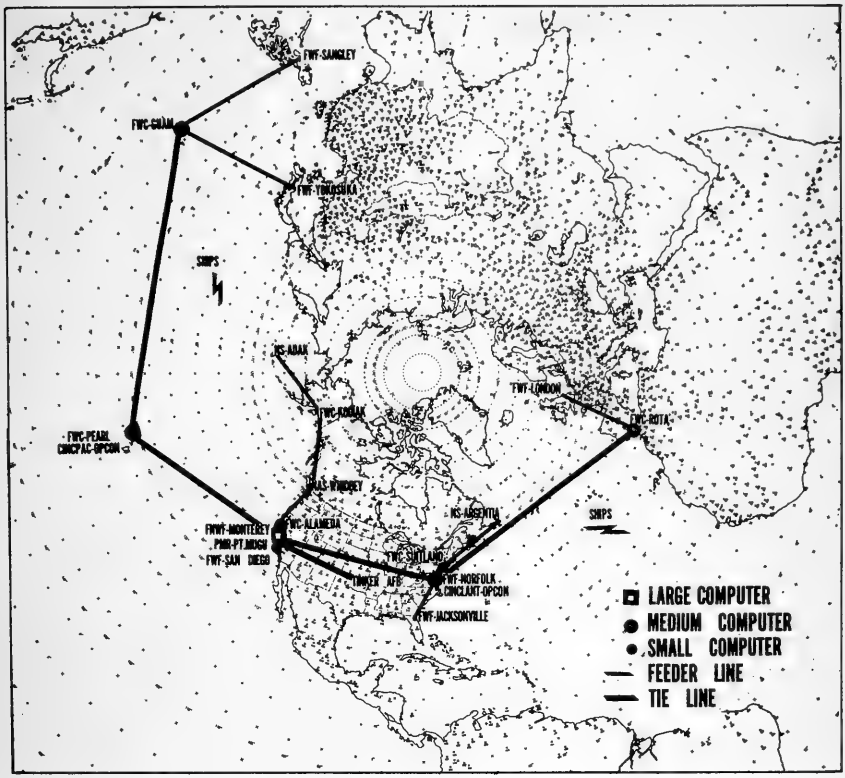
Physical plants of the U. S. Naval Oceanographic Office.



Naval environmental data network.

ments. The Fleet Weather Centrals and certain selected weather facilities have a lesser computer capability to take data fields from Monterey and, by application of local programs, produce tailored products for specific Fleet requirements as assigned. The remaining Weather Facilities and Environmental Detachments have plotter and special tape units to receive charts and teletype information formed directly from a computer for local use and for briefing operating forces prior to commencement of their operations.

Of the total effort involved at Fleet Weather Centrals and Facilities, from 10 to 20% is directed toward oceanographic programs. Approximately 10% of the effort at each of 17 Environmental Detachments is devoted to operational oceano-

graphic support, and oceanography amounts to about 10% of the annual Naval Weather Service Command budget. As of July 1967, there were 22 officer billets, 186 enlisted, and 4 professional grade civilian billets of the Naval Weather Service Command allocated to the operational oceanographic support programs. The foregoing does not include those Anti-Submarine Warfare Environmental Prediction Service (ASWEPS) teams which are an integral part of the afloat staffs involved primarily in antisubmarine warfare operations. The ASWEPS teams are generally comprised of one officer and 4 to 5 enlisted men, all specially trained in the air-ocean environment area.

NAVIGATION AND SAFETY AT SEA

The liner she's a lady, an 'er route is cut and dried;
The man-o' -war's 'er 'usband
an' 'e always keeps beside— *Rudyard Kipling*

It would be hard to add to Kipling's description of the close relationship which exists between the Navy and the merchant marine. For the Navy is the guardian and the protector of private shipping on the high seas and on the foreign waters of the world, in both peace and time of war. The principal ocean and foreign trade routes followed by American ships are in fact "cut and dried" only because of the navigational tools developed and made available by the Navy to all mariners and others needing them.

NAVIGATIONAL TOOLS

Navigational tools take many forms. They may be charts, which will be discussed later, or instruments, or position fixing systems, or navigational manuals or tables. All have one primary purpose—that of enabling a navigator to reach his destination safely. This involves alerting him to any hazards on his journey, no matter where he may be on, above, or below the surface of that part of our planet which man calls the ocean. Only with such knowledge can ship navigators entrusted with human lives and other cargoes follow the best routes and avoid hidden dangers. Only with such knowledge can further accurate and useful surveys be made of the world's oceans, or of what has been so aptly described as "inner space".

In the early 1800's, American ships were dependent largely upon other nations for the navigational instruments, charts, and sailing directions needed for navigation on the high seas. Lack of a hydrographic service in the United States forced the U. S. Navy—

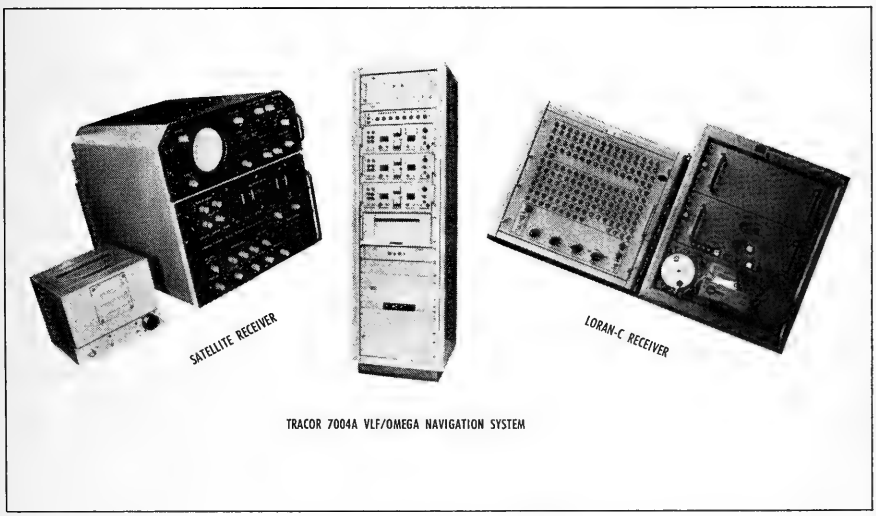
as early as 1811—to make surveys of our domestic harbors. The seriousness of the matter was finally recognized by the Board of Naval Commissioners and the Secretary of the Navy in 1830, when, at the suggestion of Lieutenant Louis Goldsborough, a Navy Depot of Charts and Instruments was established in Washington, D. C.

The Depot and its successors—the Naval Observatory and Hydrographical Office, the Navy Hydrographic Office, and the Naval Oceanographic Office, in that order—have been responsible for improving the means of navigating vessels of the Navy and merchant marine. As an integral part of the Naval Oceanographic Operations Program, the Oceanographic Office provides a global navigation service to the Fleet, the Merchant Marine, and other ship users, and thus gives primary support not only to naval, but to other national and international oceanographic needs and objectives.

This service includes the preparation, production, and issue of nautical charts and related navigational publications such as navigational manuals and tables, and Sailing Directions and Light Lists for all world areas except United States coastal and territorial waters. In addition, it includes production and issue of a wide range of other navigational tools needed by the mariner, such as radio and weather navigational aids publications; manuals on air, marine, submarine, and ice navigation; and marine atlases of all types. Equally important, it includes a continuing product correction service and a navigational warning system for the benefit of navigational chart and publication users. This system utilizes radio broadcasts, periodicals, and other publications advising navigators of newly reported hazards and important changes affecting U. S. navigational charts and publications held by them.

A system of continuous product correction is essential to assure the safety of life and property at sea. The method used to advise mariners is determined by the urgency of the corrective material. The failure of a major navigational light, the blocking of a channel by a wreck, or the discovery of a dangerous shoal is broadcast as an emergency message by radio, whereas less urgent information of importance to navigation is prepared and distributed in printed form. Scheduled radio transmission of navigational warnings was

Navigation requires an assortment of publications, charts, and devices, plus— — —



— — —the latest in electronic navigation equipment.

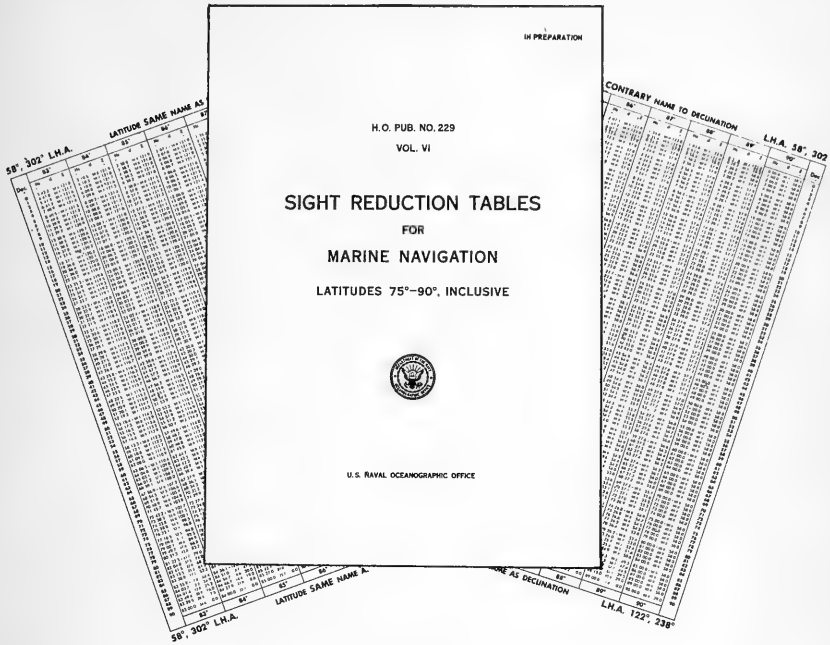
originated by the Navy in November 1904, whereas the first Notice to Mariners was published in 1848. Courts have held masters of U. S. ships responsible for any casualty due to failure to receive or heed a navigational warning thus issued.

In fulfilling its mission to provide information and data for the safe navigation of air and surface craft, the Oceanographic Office prepares and publishes a wide variety of navigational publications, including instructional manuals and operational tables. Among the early navigational tables were the azimuth tables for finding the deviation of the compass and for use in determining the best time for sun observations. Other tables were designed for rapid sight reduction, and contained precomputed data with which the navigator compared his observations and established the resulting line of position.

Although the earliest tables represented considerable progress from the manual Cosine-Haversine solution, they required many rules and instructions. More comprehensive tables soon followed in their wake, catering to the more rapid reduction of sights as required by more rapidly moving ships and aircraft.

During the decade 1936 to 1945, the Navy published what are historically the most comprehensive tables ever issued for the intercept method of plotting position lines in the practice of astronomical navigation at sea. These Tables of Computed Altitude and Azimuth, identified as H. O. Pub. No. 214 (in nine volumes), so far surpassed all others in range and completeness that they became identified with the "tabular method" of sight reduction at sea. Sight Reduction Tables for Air Navigation, H. O. Pub. No. 249 (in three volumes), was first published in 1951-1952 to meet the requirements of military and commercial aviation throughout the world

In recent years, many navigators and scientists have expected automatic astronomical, electronic, or satellite navigational methods to supersede the older methods of navigation. This expectation has not yet come to pass, and despite tremendous developments in navigational systems of all kinds, including electronic and satellite systems, the need continues for better and faster methods of sight reduction for conventional astronomical navigation purposes.



The latest in navigation tables.

Accordingly, the Navy, in collaboration with H. M. Nautical Almanac Office of Great Britain, is participating in the production of a newly-designed, newly-computed set of tables intended as a replacement for H. O. Pub. No. 214. The new Sight Reduction Tables for Marine Navigation, to be indentified as H. O. Pub. No. 229, will facilitate the practice of astronomical navigation at sea, to the highest precision possible by conventional methods of observation and altitude correction. Since many years will pass before even the majority of ships are fully equipped with automatic position-fixing systems, these new tables will meet a vital national and international need of navigators for many years to come.

Of the tables issued by the Navy for use with electronic position-fixing systems, the Loran Tables of the H. O. Pub. No. 221 Series are best known and most widely used. Familiar to nearly all ships of the Navy and merchant marine, the tables provide the mariner with charting coordinates for hyperbolic lines of position

corresponding to the time difference readings obtained with a Loran receiver.

Loran (LOng RAnge Navigation) is an electronic navigation system that provides for rapid and accurate position fixing by air and marine navigators, especially in areas of poor visibility or other areas where normal methods fail. The system was developed during World War II by the Radiation Laboratory of the Massachusetts Institute of Technology, in collaboration with the Navy. The necessary computational techniques, tables, and charts needed for effective use of the new system were developed and perfected and the voluminous computations carried out by the Navy. Tables for other electronic navigational systems that may be developed for marine navigational use will be developed and published by the Oceanographic Office as part of its statutory mission.

Volumes of the Sailing Directions contain navigational information that facilitates the navigation and operation of ocean-going ships in unfamiliar waters. In addition to presenting information that cannot be shown on charts, they supplement, interpret, and clarify, where necessary, charted information. Their publication fulfills that part of the statutory mission of the Oceanographic Office which specifically requires publication of sailing directions in the interest of safe navigation.

Sailing Directions were first published in the 1840's and 1850's to accompany the famous "Wind and Current Charts" of Lieutenant Matthew Fontaine Maury, U. S. N., who is often referred to as the "Founder of the Science of Oceanography". Each of the 69 volumes on issue today contains, for specific foreign areas, detailed descriptions of the coasts and harbors of the foreign waters of the world. Included are details on channels, dangers, aids, winds, currents, tides, port facilities, signal systems, pilotage, directions for approaching and entering harbors, and a host of other material.

Sailing Directions are complemented by a variety of other navigational guides and manuals. These include such items as Fleet Guides which provide U. S. naval ships with pertinent navigational information for the various naval bases. The List of Lights and Fog Signals (in seven volumes) has been published

Detailed information filling many volumes provides the needed margin of safety in coastal waters.

by the Navy since 1871 for foreign waters of the world. Other manuals are concerned with distances between ports, world port facilities, radar plotting, air navigation, marine navigation, ship maneuvering, compass adjustment, navigational observations, and hydrographic and geodetic surveying.

Perhaps the most notable single navigational publication is The American Practical Navigator, which is identified as H. O. Pub. No. 9, and more commonly referred to as "Bowditch" in honor of Nathaniel Bowditch, the author of the original edition published in 1802. It supplies, in the language of the navigator, basic information covering the procedures, methods, and techniques of navigation, exploring both practical and theoretical aspects of the science. This publication is often referred to as the navigator's modern reference "bible" and is generally recognized by

navigators as the final authority on marine navigation. In perpetuating the volume, the Naval Oceanographic Office accepts the challenge to pass to successive generations of navigators the codified accumulation of what they have discovered, tested, and accepted.

With oceanographic and hydrographic surveys extending farther from shore there is a loss of accurate positioning for survey control. The control available from the precise electronic positioning systems is limited in range and area coverage. Celestial positioning, prevented at times by weather, is available to ships at sea only during periods of darkness and is generally not of sufficient accuracy for survey control. This has generated the requirement to support evolving position fixing systems which are available continuously, or nearly so, on a world-wide basis. Accuracies are investigated and calibration charts and tables are prepared.

PROMOTION OF SAFETY AT SEA

The Navy provides for the safety of ships of the United States on the high seas and other navigable waters through the collection and dissemination of timely nautical information. The Oceanographic Office is in constant communication with ships of the international maritime community, foreign hydrographic offices, and other government agencies concerned with shipping. This collection effort is supplemented by five Branch Oceanographic Offices, four collection representatives located at naval activities in the United States, and by rotational assignments of specialists to problem areas, such as Vietnam. A Maritime Proficiency Program, wherein Marine Information Specialists make personal contact with naval and maritime activities as well as foreign hydrographic offices, was inaugurated in Fiscal Year 1967 to provide for additional interchange of navigational safety information and to develop closer customer relations.

The steady flow of marine navigational information received is evaluated and published as urgency demands. In Fiscal Year 1967 about 180,000 navigational information items from various sources were evaluated. Receipt of such information results in

Marine Information Specialist visits the Chilean Hydrographic Institute to maintain world-wide maritime proficiency.

the broadcast of several thousand radio navigational warning messages annually affecting immediate safety of navigation; weekly dissemination of navigational information in the Notice to Mariners and Navy Notice to Mariners; plus issuance of change information to many of the publications previously mentioned, including Light Lists, Radio Navigational Aids, Sailing Directions and Fleet Guides. In Fiscal Year 1967, this involved over 300 separate issues of periodicals and other publications to some 10,000 maritime organizations and ships.

The Navy continually supplies technical information and material for the improved navigation of U. S. ships and the use of the merchant marine and navigators everywhere. In this Electronic and Space Age, many new requirements for such support have developed. These are being met by automation of data analysis, development of new navigation techniques and procedures, and preparation of material and information in support of electronic and satellite navigation systems.

Increased demands for navigational information have been met by the following actions:

Publications and charts have been improved in design and content.

New techniques and procedures have been developed to cope with increased speed of communication and transportation.

More precise formulas have been developed, and more accurate and more detailed constants have been utilized in navigational computations.

New measurement techniques have been formulated and utilized.

New navigational systems have been evaluated, and estimates of their capability have been ascertained.

Manual computation, data reduction, plotting, and typesetting have been replaced in varying degree by automated procedures.

SURVEYING THE OCEANS (HYDROGRAPHIC)

Hydrography is the science of measurement and description of the physical features of the oceans, seas, lakes, rivers, and other waters and their adjoining coastal areas, with particular reference to their use for navigational purposes. Hydrographic surveying is the process of making these measurements. In addition to serving as source material for nautical charts, Sailing Directions, and other publications for the Navy's operating Fleet and the country's merchant marine, results of the surveys are used in planning harbor improvements and in meeting various defense requirements, as well as for studies of silting and erosion.

Only a small part of the ocean has been adequately surveyed. The changes caused by nature and man, and the continual increase in requirements for more precise and more nearly automatic systems and methods of navigation, render obsolete the charts or surveys once considered adequate. Consequently, the need for more accurate and complete surveys continues.

Small sounding boats carried by survey ships are used to survey shallow water areas.

The Harbor Survey Assistance Program utilizes indigenous personnel and Navy equipment to conduct surveys under the guidance of a Navy expert.

SURVEYING FOR NAVIGATIONAL HAZARDS (PORT, HARBOR, AND COASTAL)

Highly skilled personnel—both military and civilian—using specially equipped ships and auxiliary sound boats conduct hydrographic surveys primarily in waters outside the United States and its possessions to acquire information needed for producing charts of ports, harbors, and coastal areas. Although the depth of water is of primary concern, the surveys also delineate the coastlines; position dangers and aids to navigation; collect tide and current information; establish heights of conspicuous landmarks; and gather bottom samples, weather information, and a variety of other data necessary for a complete description. During the past two years, the Navy's somewhat limited coastal survey capability has been committed to direct support of the military effort in Southeast Asia. Approximately 50,000 miles of controlled survey track have been run, providing vitally needed information for new charts of the area. Recently completed coastal surveys have also resulted in new charts of portions of the coasts of Greece, Colombia, Johnston Island, and Subic-Manila Bay of the Philippines.

In late 1964, the Navy initiated its Harbor Survey Assistance Program (HARSAP). This program has the dual purpose of helping friendly countries develop their own hydrographic surveying capability while at the same time ensuring issue of new or improved charts. The program has been successful from the beginning, and HARSAP surveys in Ecuador, Guatemala, El Salvador, Nicaragua, and Colombia are resulting in charts that meet established standards. Not only are much needed charts acquired at a relatively low cost, but the participating nations now have the capability to chart their own waters—thus favorably influencing shipping insurance rates and stimulating their foreign commerce.

PHOTOGRAMMETRY AND AERIAL PHOTOGRAPHY

Photogrammetry, the science of making precise measurements from photographs, has been used in charting operations from at least the mid-1880's, when panoramic terrestrial photographs

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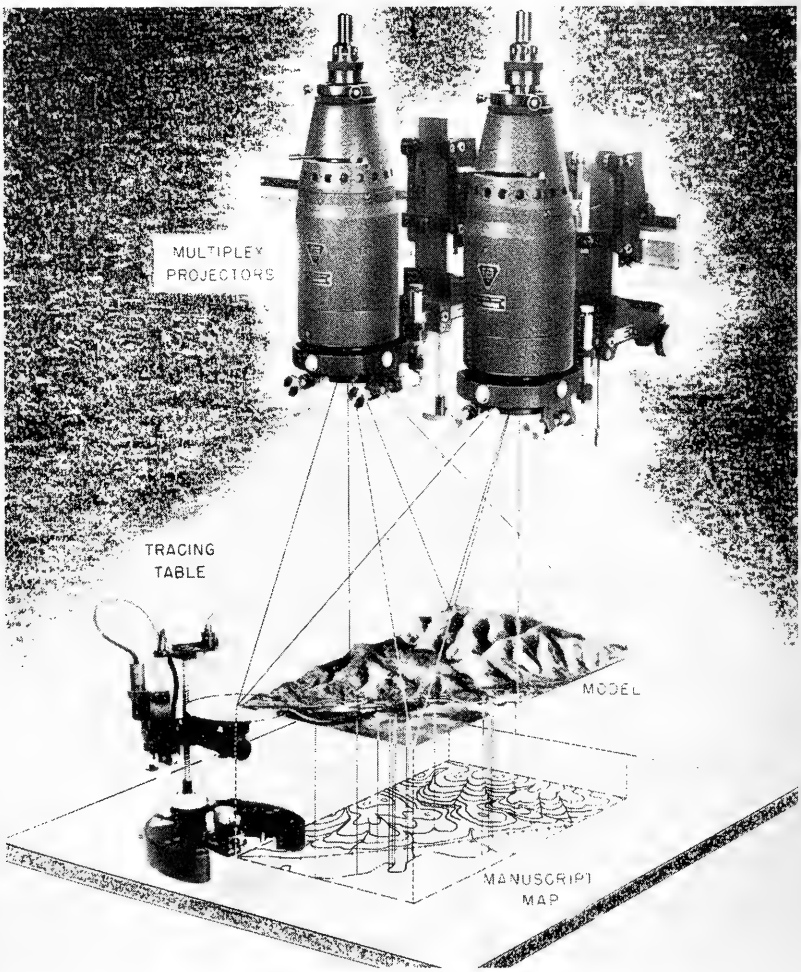
were first obtained for charting purposes by U. S. Navy ships conducting surveys along the Pacific Coast of Mexico. The year 1919 marked the first use of aerial photographs for charting by the Oceanographic Office. Although the early use of photographs was, of course, limited by the state of technological development of aircraft, cameras, films, and plotting equipment, the use of photogrammetry for certain data collection and measurement purposes is taken for granted today as being the most economical, efficient, and rapid method available.



Shorelines and coastal features are charted from aerial photographs.

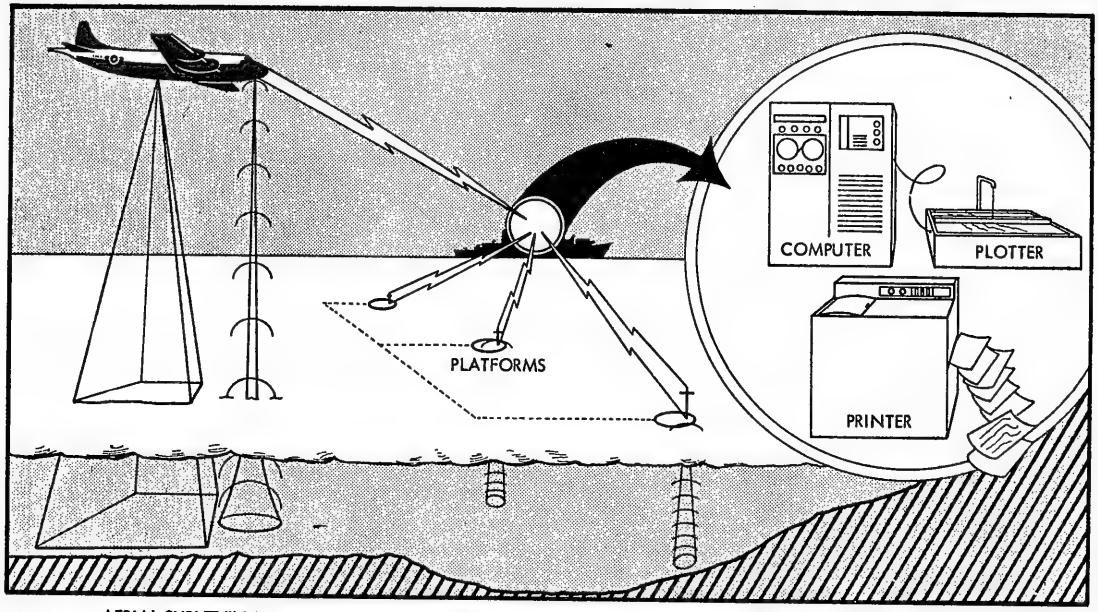
Photogrammetry is the best method of obtaining the topographic information required for nautical charts and has replaced the ground surveying method used almost universally just a few decades ago. The aerial photograph is also the best source for relative positioning of coastal and offshore detail, island groups, and other terrestrial or marine features visible on the photograph. Whereas black and white or panchromatic photographs were used almost exclusively until recently, the newly discovered advantages of using color and infra-red photography for special purposes have added a new dimension to photogrammetry. Additional hydrographic, topographic, and oceanographic data can now be recorded on film for mapping, charting, and other scientific purposes.

In the field of hydrography, the use of aerial photography extends from planning for oceanographic survey operations to determining water depths if water transparency and bottom contrast permit. It is anticipated that color aerial photographs, as well as satellite photography, will play an increasingly important role in the more rapid and comprehensive charting of coastal hydrography.

SURVEYING THE DEPTHS (BATHYMETRIC SURVEYING)

Controlled surveys of the oceans at great distances from shore are extremely expensive, and such precise, detailed surveys are necessarily limited to special high priority projects vital to the country's defense. Many gaps in our knowledge are being filled, however, by other means.

Present knowledge concerning the topography of the sea floor—considerably greater than that of only a few years ago, although admittedly less than desired—has been gained only through the close cooperation of many organizations and interested observers. Ships of the Navy, the Military Sea Transportation Service, the Coast Guard, and the merchant marine annually contribute millions of miles of sounding data in the form of a continuous bottom profile of their tracks throughout the world. Evaluating these, comparing them with other tracks of the same area, and integrating them with knowledge from precise surveys are continuing tasks necessary for producing and maintaining the best possible charts of the oceans. The Naval Oceanographic



Artists conception of Advanced Hydrographic Survey System (HYSURCH).

Office has the responsibility along with that of maintaining a Bathymetric Data Library for the Department of Defense. This probably makes it the world's largest repository of bathymetric data.

The ability to conduct precise surveys in the oceans far from shore has been a reality only in the past few years. Limiting factors, such as unsuitable echo-sounders and the surveyor's inability to position his survey vessel with sufficient accuracy, precluded the performance of precise surveys. Increased submarine activity and other vital defense measures forced the solution of these problems; as a result, the United States now has precise self-contained inertial navigation systems, many world-wide nets of long-range electronic positioning systems, and a capability for positioning relative to orbiting satellites. These, along with advances in echo-sounding and precision depth recorders, have permitted the Navy to extend its precise surveying into all the world's oceans. With new multiple-beam sonars, surface survey vessels can chart the sea floor much quicker and in far greater detail. To obtain still greater detail in water of great depth it is necessary to get closer to the bottom through the use of towed underwater devices or underwater survey platforms. Research and development effort in support of oceanographic operations is now being emphasized.

Development of an advanced hydrographic surveying and charting system has been initiated. A design study is being conducted by the Experimental Astronomy Laboratory of the Massachusetts Institute of Technology. This study will indicate the most effective means of increasing the rate of hydrographic data acquisition and will result in a preliminary design for a prototype system. This design will be based on a shipboard command/control concept for hydrographic and topographic (coastal) data acquisition, correlation, compilation, reproduction and dissemination. The system will be composed of an aerial survey subsystem, a hydrographic survey subsystem, and a shipboard cartographic compilation and reproduction subsystem.

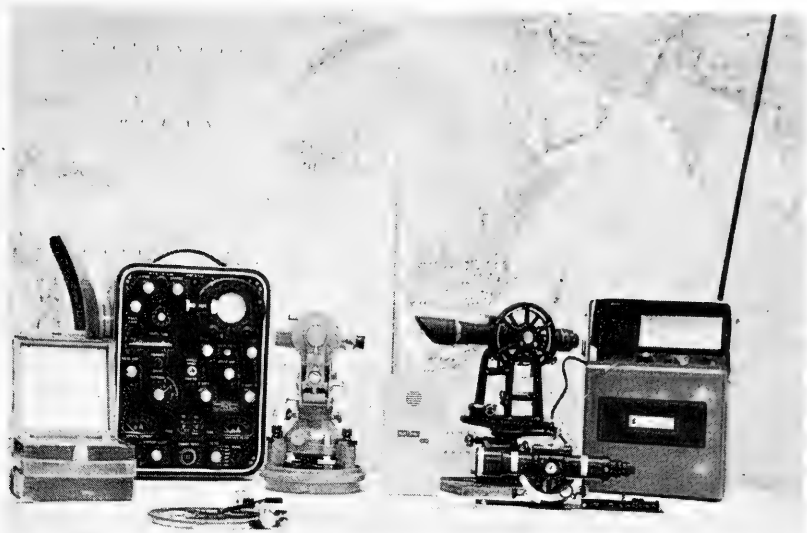
GEODETIC SURVEYING

Little publicized and often misunderstood outside the scientifc community is the amount of precise and detailed work necessary

to provide the geodetic support which must precede all surveying of the oceans. Data collected at sea is of little value unless the surveyor knows his precise position at the time of its collection. Merely knowing the survey vessel's position relative to adjacent land masses is no longer enough, and accurate distances and directions to points on the earth's surface, often thousands of miles away, must be determined. Geodetic support for ocean surveys and associated projects of the Department of Defense is provided by the Naval Oceanographic Office.

In support of these surveys, extension of geodetic control into the oceans is usually accomplished by the use of both long-range and short-range electronic positioning systems, including LORAN-C, LORAC, OMEGA, DECCA HI-FIX, and RAYDIST. However, merely possessing the power supply plus the system transmitters and receivers falls far short of having an accurate and reliable positioning capability. The shore-based transmitters must be tied geodetically to existing control points in the area by established standard land surveying techniques such as triangulation, trilateration, or traverse, using precise theodolites, tellurometers, and electrotapes. In the remote regions where many Navy surveys are conducted, finding, recovering, and evaluating control points present many problems; in many cases markers for such points have been destroyed. Where previous land surveys have not been conducted, a comprehensive geodetic survey must be performed which includes establishing an astronomical origin and determining deflection of the vertical values to relate this remote area properly to the rest of the world. When the system transmitters are positioned and the system is operating, it must be precisely calibrated. Following this, system coordinates must be converted to geographic coordinates to be overprinted on navigational charts. Users must be advised of the system's capabilities and limitations.

Among the many Department of Defense projects given geodetic support have been the Southwest Pacific Geodetic Survey, the Navy's Navigational Satellite Program, the Mediterranean Salvage Operation (unarmed nuclear weapon recovery off Spain), and the establishment of DEW LINE, AUTEC, and both the Atlantic and Pacific Missile Test Ranges. The many field oper-



Tools of the geodesist.

Construction of hydrographic signal on a remote island in the Pacific Ocean.

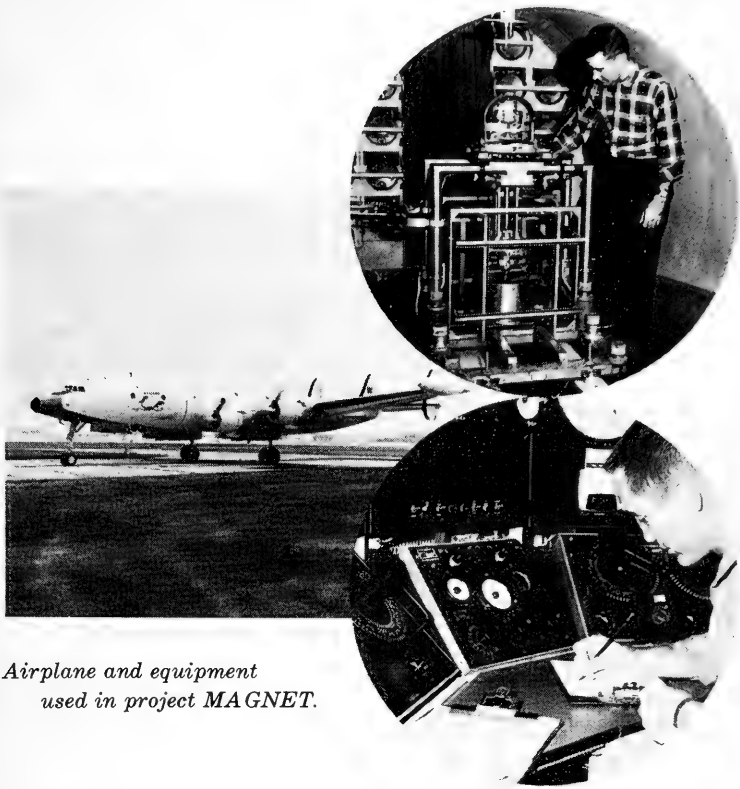
ations have contributed greatly to a continuing search for more exact knowledge concerning the size and shape of the earth and the location of points on its surface.

The future in this field appears exceptionally bright. Navigational and geodetic satellites developed under Navy contract are now operational. Their use has revolutionized the science of geodesy, allowing fulfillment of a longtime dream of geodesists to relate all points on the earth's surface to one reference point—in this case, the center of the earth. Several such satellites are now circling the earth in orbits approximately 600 miles in space. By knowing the orbital parameters of the satellites and by receiving radio signals from them, the geodesist utilizes the Doppler principle in determining their closest points of approach. From this information, a precise position is defined.

Satellites have also proved quite successful for their original purpose of "positioning at sea". Although here the situation is more complex and underway measurements have presented some problems, by programming information in addition to the orbital parameters into the satellites and by retransmitting this to ships equipped with Doppler receivers, an accurate position can be obtained from only one pass of the satellite. This technique has been operational for some time and has provided suitable positioning control for surveys conducted beyond the limits of existing LORAN-C net. A recent Navy decision to make this technique available for general navigation purposes will unquestionably improve the navigational control of merchant ships and in turn make them more valuable for collecting oceanographic data.

MAGNETIC SURVEYING

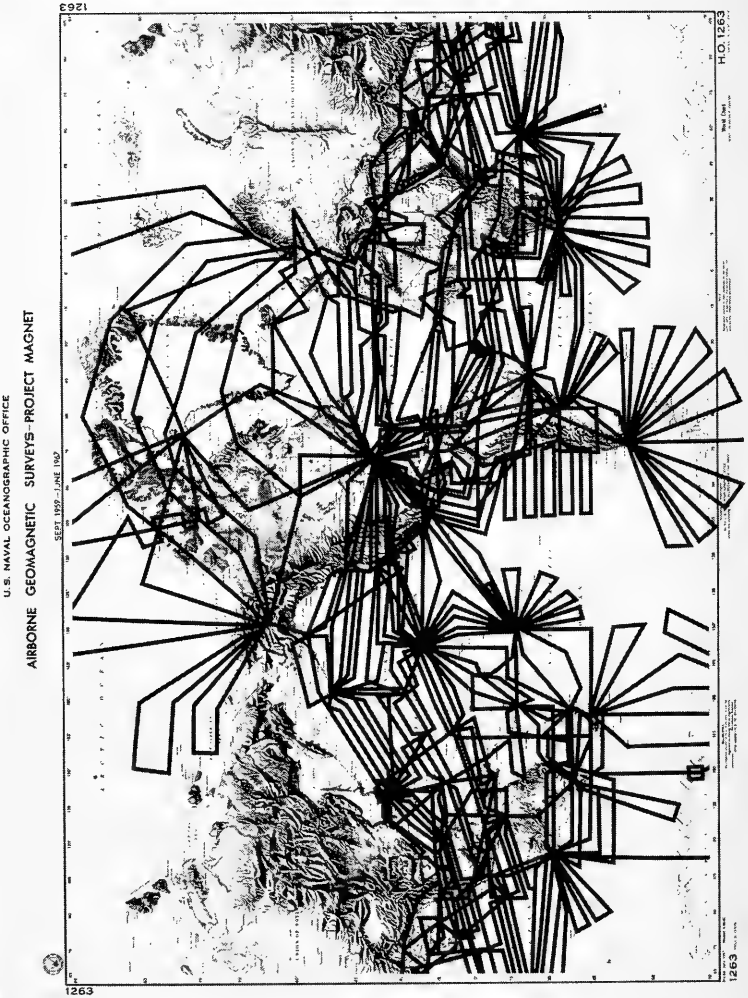
In 1953, the Naval Oceanographic Office inaugurated Project MAGNET, an airborne geomagnetic survey of the accessible ocean areas. Replacing specially constructed wooden ships that formerly collected magnetic data in the oceans, the project has dramatically increased the amount of data collected. It has allowed collection of data in polar regions where little concerning the field had been previously known. Currently, the project has two aircraft, an NC-121 Constellation and an NC-54 Skymaster, conducting systematic and continuous world-wide surveys, generally flying along



Airplane and equipment used in project MAGNET.

east-west lines spaced approximately 200 miles apart. Averaging well over 200,000 nautical miles of track annually, the planes gather data necessary for the construction of reliable navigational and world isomagnetic charts. In addition to measuring the magnitude and direction of the earth's changing magnetic field, scientists simultaneously measure cosmic radiation emanating from outer space which enables them to describe the earth's field at great distances from the earth.

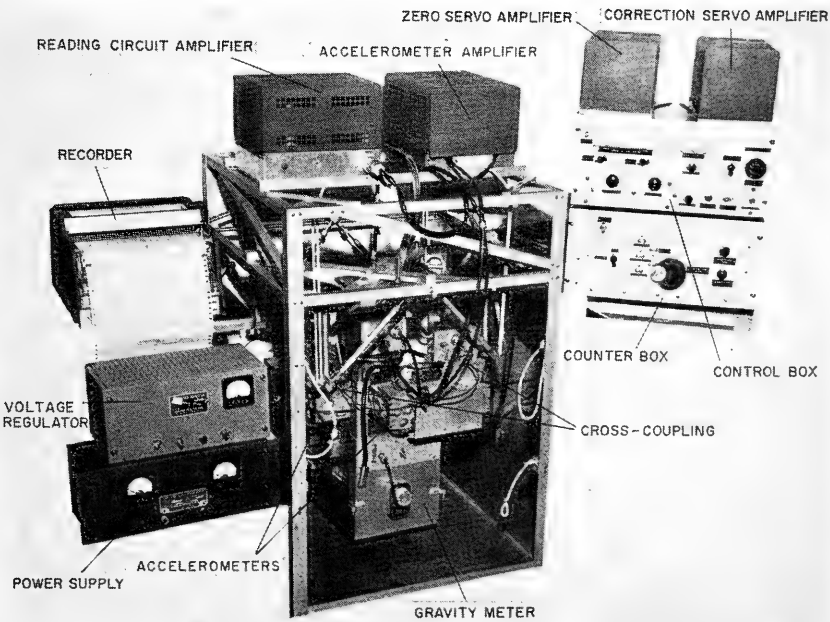
Since the development of this airborne capability, the two aircraft have been in great demand to support many special scientific projects. Among the more recent of these are extensive fine-grain surveys (5-mile track spacing) of the Norwegian Sea, the Reykjanes Ridge, the Eastern Continental Margin of the United States, and a 100-mile strip across central United States (a contribution to the USGS continental survey program), which have provided valuable data on the nature and composition of the



Survey lines flown under project MAGNET.

earth's crust. Also, because of the experience gained in developing this airborne capability, Navy geophysicists have helped improve techniques for magnetic detection of submarines and have assisted in resolving magnetic anomaly problems of the Strategic Air Command.

To supplement Project MAGNET's collection of magnetic data, nearly all Navy deep-water survey ships tow magnetometers, allowing a direct comparison of magnetic data with the bathymetric and gravity measurements taken simultaneously. These efforts have not only added considerably to the amount of data describing the sea's magnetic field, but have also proved valuable in developing techniques for locating submarines and sunken ships, as demonstrated in finding the remains of the THRESHER. Recent experiments aboard the ALUMINAUT indicate the feasibility of similar operations close to the sea floor, using underwater vehicles.



Shipboard equipment used in measuring the force of gravity.

The Oceanographic Office maintains a Magnetic Data Library for the Department of Defense and makes this information available to the scientific community in a variety of formats at a nominal cost. Project MAGNET data are available in microfilms of the original data collection tapes or in special publications giving total magnetic intensity, magnetic declination (variation), magnetic dip, horizontal intensity, and vertical intensity values at closely spaced intervals throughout the world.

Techniques for improvement of the measurement, analysis, and display of the earth's magnetic field are under development. Models are being developed for upward extrapolation of the magnetic field. The accuracy of the spherical harmonic surface at sea level has been verified from the data incorporated in the 1965 World Variation Charts. Spatial coherence of short-period variations in the magnetic field is being tested by simultaneous records made at two or more stations. Finally, a geological interpretation of the total magnetic field data collected along the east coast of the United States is underway in cooperation with the U. S. Geological Survey.

GRAVITY SURVEYING

For many years the Navy's gravity collecting capability consisted of land meters used by geodetic parties supplemented by gimbal-suspended spring-balance meters in submerged submarines. Taking submarine gravity measurements around remote islands and combining these with gravity measurements and astronomical observations ashore was virtually the only method of tying these islands geodetically to the rest of the world. Later, underwater meters set on the bottom in the relatively shallow off-shore waters filled the void between the submarine and land measurements, allowing more precise positioning. These methods are also used extensively for delineating the geologic structure of the earth's crust and the investigation of possible oil and mineral deposits. Underwater meters placed on the bottom give measurements comparable to land meter accuracies; Navy geophysicists in cooperation with the Army Map Service recently used them in a gravity survey of Lake Superior.

In the 1950's, as a greater knowledge of the earth's gravity field became increasingly important for the refinement of inertial

guidance and navigational systems and for studies concerning the ocean bottom's geologic structure, Navy support was instrumental in the development of gravity meters capable of making accurate underway measurements at sea from surface ships. At first, meters suspended in gimbals proved successful only if sea conditions were favorable, but mounting meters on stable platforms now allows continuous underway measurements of gravity to an accuracy of ± 5 milligals (1 gal is an acceleration of 1 cm per sec^2) or better, even in rough seas (up to sea state 5). This new system, combined with a better positioning capability, allows the underway collection of gravity data by surface vessels in all the world's oceans. The Naval Oceanographic Office now has five surface ships and one submarine collecting gravity data continuously along with other oceanographic data.

As these new meters do not measure absolute gravity but only the "difference in gravity" between two points, extensive surveys were conducted using underwater meters set on the bottom to establish precise calibration and test ranges in the approaches to San Francisco, Norfolk, and Newport, R. I. Running the meters over these ranges prior to and following the surveys permits accuracy requirements to be met.

Submarine used in oceanographic surveying.

Because of the high cost of these new meters and deep-water surveying in general, most Navy gravity projects are conducted to meet military requirements, but upon occasion purely scientific efforts are supported. One such effort was the recent gravity survey in the vicinity of New Guinea by the University of Hawaii's Institute of Geophysics. Shipboard measurements by the USS WANDANK and the HMS DAMPIER obtained off-shore data for a study of the area's geology. Also, because of the Navy's world-wide survey efforts—including land measurements by PROJECT MAGNET—considerable support has been given to establishing both the European and North American Calibration Lines and to other international cooperative efforts to establish a world-wide network of gravity base stations.

The Navy is participating in the Department of Defense project for development of a helicopter gravity collection system. Test equipment has been selected and the test, plans for which are well underway, will be carried out jointly by the Army, Navy, and Air Force.

SURVEYING THE OCEANS (OCEANOGRAPHIC)

GEOLOGICAL FORMATIONS

The shape and character of the sea bed affect the conduct of naval operations in many ways. The performance of long range sonars is degraded if bottom reflected echoes are absorbed in sediments at great depths. The risk to minesweepers detonating enemy magnetic mines in shallow water increases and the efficiency of sweeping decreases where the electrical resistivity of the bottom forces the magnetic sweeps to be brought closer to the mines. Mine-laying activities must take into account the likelihood of mines sinking into the bottom or being covered by shifting sediments. Emplacement of cables and equipment on the ocean floor requires knowledge of bottom topography and of sediment bearing strength. Finally, search and rescue operations for submarines or other lost objects are affected profoundly by the kinds of bottom features in the search area and by the tendency of sediments to cloud bottom waters when disturbed, or to bury objects and resist their extraction. Observations of properties of the sea floor determining these operational conditions are included in the survey programs of the Oceanographic Office.

Surveys to support mine warfare operations are carried out in bays and estuaries, extending outward from the coast to depths of some thirty fathoms. Working either from survey ships or from Fleet mine craft, the oceanographers collect sample cores of the bottom and make laboratory analyses of them to deduce sediment strength and stability. Suitability of the ocean floor for sweeping magnetic mines is determined by measuring electrical current flow between towed conductors.

Features that are further offshore, those of the continental slopes and the offlying plains, are increasingly difficult to survey as depths increase. The slopes are now understood to be regions where rugged topography may be the rule rather than the exception, but means of mapping details of their hills and canyons fifty or even a hundred feet across are not yet operational. To provide increased readiness for search and salvage operations, and to

Bottom-coring operations from U. S. N. S. Bent.

support design and construction of bottom installations, operational methods of mapping and probing deep features are being developed. Deep-towed echo sounders and side-looking sonars are in testing and the Oceanographic Office is experimenting with deep submersibles bearing metric camera systems. Use of deep submersibles is particularly enhanced by the ability of the oceanographer to make on-the-scene judgments on best places to probe or sample sediments, an operation now done blindly from surface ships.

Although attainment of any substantial capability to make detailed bottom surveys in deep water is some years away, the

Oceanographic Office is proceeding rapidly to map regional features of broad expanses of the sea bed across more than ten million square nautical miles of the North Atlantic and North Pacific Oceans. Directed primarily to finding variations in acoustic properties of the bottom, this program makes use of a spectrum of observations to determine limits of the ocean's physiographic provinces. Some 160,000 nautical miles of sub-bottom profiles have been recorded already. These profiles are examined in conjunction with concurrent geomagnetic observations, supplemented by analyses of ocean bottom cores ranging to 30 feet in length. This information has provided a basic understanding of the geologic history and structural processes of the regions studied. Such understanding makes it possible to map acoustic properties of the bottom by a sampling process far more economical than the detailed survey that would otherwise be required. These sea-floor surveys, done from both Navy and contract ships, are providing systematic information that not only is vital to Fleet operations but also will be highly significant to future minerals search and exploitation operations.

CURRENTS

Naval interest in ocean currents traditionally has centered on their navigational effects. Navigators' reports of set and drift, accumulating by the thousands since Maury's initiation of the program, have outlined the general trends of the major surface currents. Such reports continue to be made to the Oceanographic Office and are of value in helping to define seasonal variations of practical interest to navigators, despite the relative crudity of the observations. The coming of automatically recording current meters attached to deep-moored buoy arrays has now made possible more precise measurements of currents at the surface and at depth. Deep currents can also be measured by meters hung from drifting buoys or by neutrally buoyant targets tracked by surface ship sonars.

The Oceanographic Office measures oceanic currents either to support specific operations, such as the Palomares bomb recovery, or to help derive a better understanding of the dynamics of the sea. The longer-range sonars now used by the Fleet are affected

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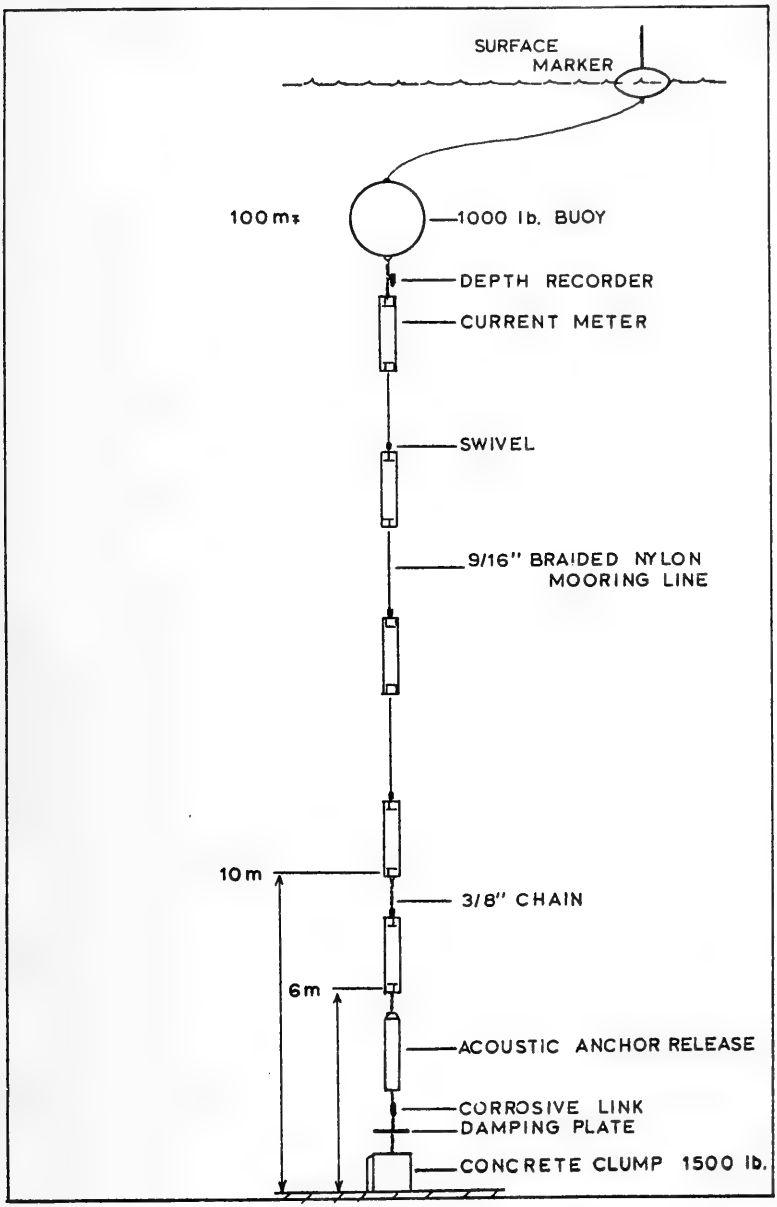
Launching of self-positioning buoy array.



Multiple depth current measuring system.

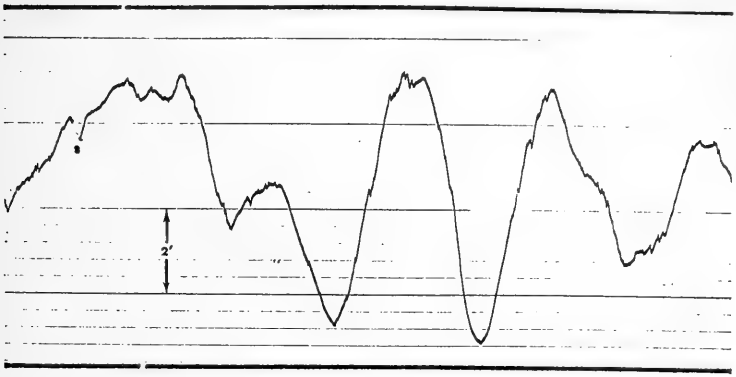
significantly by dynamic changes in location and characteristics of oceanic water masses—changes that could be traced better with adequate data on currents. At present, however, obtaining accurate current information in deep water is so expensive in time and resources that relatively few measurements are made. In one instance, the Oceanographic Office is installing a complex, moored current meter array in the Bahama Atlantic Undersea Test and Evaluation Center range to help define the dynamic situation there. In another, the Office installed five deep-moored current arrays in "Navy Acre", a one-degree rectangle between Bermuda and Cape Hatteras. Current observations were taken for more than a month for comparison with currents computed from temperature and salinity data. Additional comparisons in the forthcoming interagency cooperative Barbados project in the West Indies will help establish the operational need for deep ocean current observations.

WAVES

Wave observations in the past have consisted of random ship reports of visually observed sea conditions. These wave data are not only inaccurate but provide little knowledge of more sophisticated wave characteristics such as spectral components, period of maximum energy, or directional behavior. Wave instrumentation has now been developed which provides continuous measurement of the sea surface from both ship and aircraft. This wave information is more accurate and infinitely more complete than visual observations.

The airborne wave meter utilizes a radar altimeter device to acquire an actual profile of the ocean's wave structure. Flying at 500 feet the Anti-Submarine Warfare Environmental Prediction Service aircraft can obtain 1200 NM of wave data, or the equivalent of 120 ship reports in 8 hours. Surveys of wave conditions generated by a unidirectional steady wind have produced excellent wave spectra at varying fetch distances and duration times.

Additional wave data are obtained from a wave sensor installed on ARGUS Island near Bermuda. This installation has permitted the study of storm waves of a height not normally measured by ships at sea.



Portion of wave record from laser sea and swell recorder.

A sonic echoing device mounted on the bow of a ship has also been used to record waves continuously. This system automatically compensates for the ship motions and can measure waves from 0.5 to 40 feet in height.

At present the bulk of wave observations used in synoptic applications are visual in nature. These are being replaced by the more reliable, instrumented measurements which will permit us to predict wave conditions in the much more sophisticated format required for military operations.

PHYSICAL AND CHEMICAL PROPERTIES

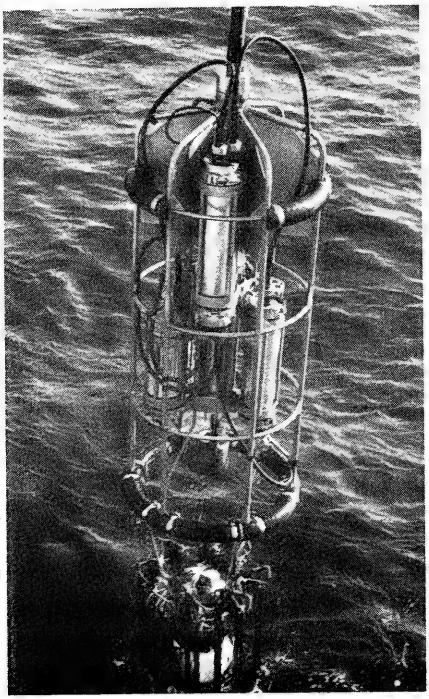
In keeping with its predominant influence on sonar behavior, water temperature is the ocean property most widely measured and exploited by the Fleet. More than 5,000 bathythermograph (BT) lowerings are made every month, primarily by Navy ships supplemented by Coast Guard and other ships. Each lowering, usually to depths between 400 and 900 feet, produces a temperature profile whose values are reported by radio. These data are the prime input used by the Oceanographic Office and the Naval Weather Service in deriving daily maps of near-surface sonar propagation conditions.

By stopping to lower precise thermometers or electrically recording thermistors, Oceanographic Office survey ships observe temperatures to greater depths than are obtainable by the BT.

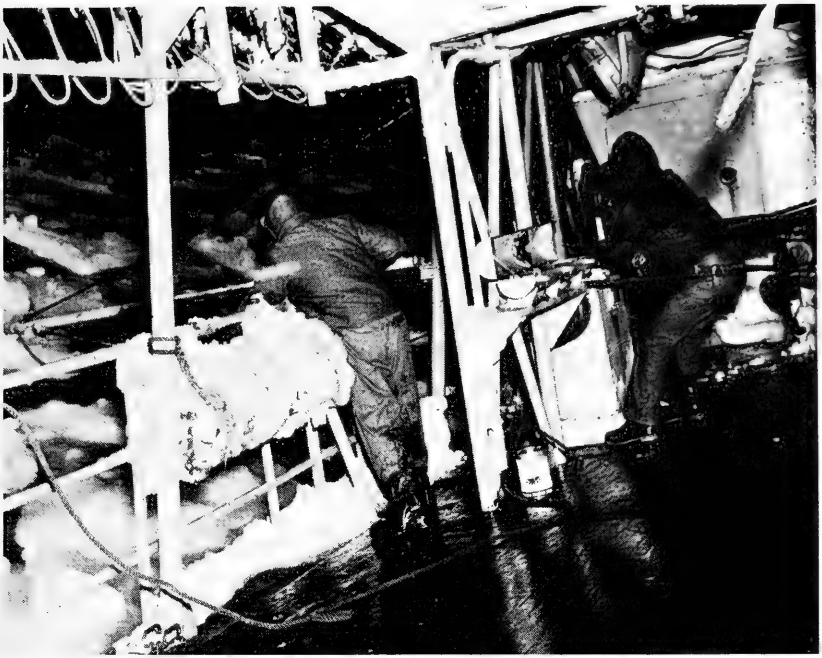
At such ocean stations, Nansen bottles also collect actual sea water samples that the oceanographers analyze for salinity, which also affects sonar conditions. Other observations of concern to Fleet operations are made of water color and clarity, both affecting the visibility of submerged submarines and mines.

The Oceanographic Office also collects data on nutrients and the dissolved oxygen content of the oceans. Such data not only are of scientific importance in identifying and following movements of water masses but also are becoming of increasing value for locating commercial fishery areas. The Office occupies more than 900 ocean stations a year from tropic to polar waters, wherever its own oceanographic ships are assigned or where its scientists are embarked on Navy or Coast Guard ships of opportunity.

Data of fisheries significance are also observed from the aircraft used by the Oceanographic Office to scan sea surface temperature. The boundaries of varying water masses so mapped—for example, the limits of the Gulf Stream—tend to govern the movements of tuna and other fish. A cooperative program with



Instrument package for measuring temperature, salinity, and sound velocity.

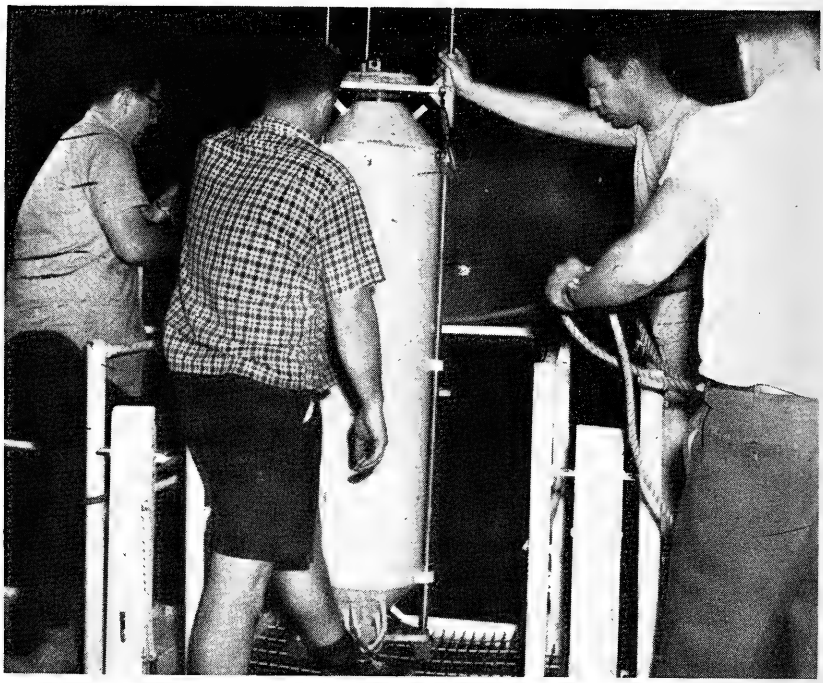


Oceanographic operations in ice-infested waters.

the Bureau of Commercial Fisheries will facilitate making such information available to U. S. fishermen.

The distribution of certain artificial radioisotopes, resulting from nuclear events and deposited on the sea surface as fallout, has been under study since early 1965. In addition, the analysis of trace elements related to these radioisotopes is being carried out to understand more fully the processes regulating the distributions of these chemical constituents in the various ocean reservoirs.

As part of the overall program of chemical and radiochemical investigations, the Navy, under a cooperative agreement with the U. S. Atomic Energy Commission, acts as a consultant and tests and evaluates systems utilizing radioisotopes in the marine environment. Those systems that are presently under study are the Deep Water Isotopic Current Analyzer (DWICA II), the Nuclear Sediment Density Probe and an *in situ* oxygen analyzer.

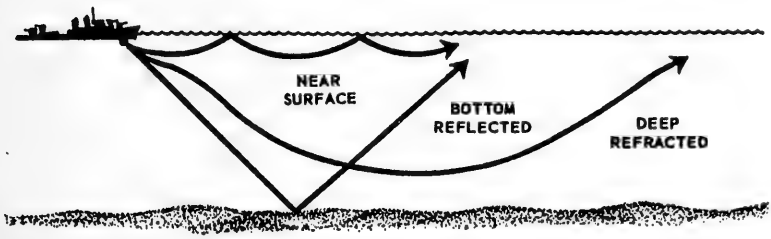


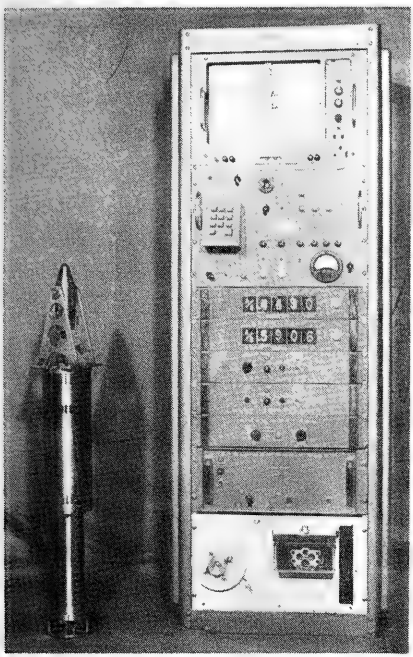
Preparing to obtain a large water sample for radioisotope determinations.

Upon the completion of such studies and depending on the conclusions reached, the systems are placed in a fully operational status or are modified for better compatibility with oceanographic survey applications.

SOUND PROPAGATION

New Navy weapons systems and operating needs have created unprecedented demands for rapid, oceanwide environmental measurements. To meet these needs, the U. S. Navy has commenced extensive surveys to obtain acoustical, oceanographic, and geophysical data in areas of strategic importance. A secondary objective, important to the Navy's immediate operational capability and to long-range research, is the efficient and systematic collection, compilation, and presentation of oceanographic and geophysical data.





Sound propagation paths are determined by use of modern instruments.

Energy from a sound source in the near-surface region of the ocean follows many diverse paths, which may be generally grouped into the following modes of propagation:

1) Surface duct—sound which travels in the near-surface region.
2) Bottom bounce—sound which is reflected off the ocean floor.
3) Convergence zone—sound which travels along a deep refracted path.

Older types of sonar relied entirely on the surface duct or direct mode of sound propagation. Thus, much of the environmental data

collected in the past have dealt mainly with the near-surface sound velocity structure of the oceans and the effects of surface backscatter of sound. Newer sonars use all possible modes of sound propagation, and as a consequence have made us aware of the extreme sparsity of subsurface environmental data. To provide this urgently needed information, the Navy has both stepped up its own effort and has contracted with commercial exploration companies for surveys of all critical areas. Over 5 million square miles of ocean have already been surveyed, with vast areas of the Atlantic and Pacific Oceans programmed for early effort.

In order to obtain a broad sampling of the ocean with a minimum of ship time, these surveys depart from the conventional survey of intersecting grid lines and make a statistical sampling of physiographic provinces of the sea floor. The basic hypothesis in this type of survey is that the ocean is divisible into provinces, so that a limited number of samples within each province will be sufficient to define the characteristics of the province as a whole.

As previously described, other types of supporting environmental information are required to define adequately and predict acoustic characteristics such as the nature of the ocean bottom and its material, structure, and topography. Sound velocity profiles through the entire water column, either measured directly or calculated from water temperature and salinity, are also collected on all surveys to define propagation paths. Special procedures to measure sound scattering by marine life also are established.

Oceanographic and acoustical information collected on all surveys is stored in data banks after processing and analysis, where it is available to all qualified personnel for further study.

MARINE LIFE

Because some marine organisms habitually adhere to submerged objects in the shallow water zones of the oceans, the Navy has undertaken studies designed to investigate their geographic and seasonal abundance. The study of fouling organisms, begun in 1956 with a biological survey of the approaches to Chesapeake Bay, has since expanded in scope to include nine localities, six of which are outside the continental limits of the United States.

Test panels used to determine season of setting and rates of growth of fouling organisms.

Eight nearshore fouling sites are under study at present. About three years of data will be collected at each site. Fouling study projects are being planned for at least two additional sites in 1968. The results of fouling studies at seven localities have been completely or partially reported.

The marine fouling program should eventually improve our understanding of the geographic distribution of fouling communities and the ecological relationships of individual species within these communities. A more immediate goal is the determination of approximate seasonal occurrence and growth rate of attaching organisms for selected localities. From this information, predictions can be made concerning the operational efficiency of underwater equipment as it is affected by marine fouling.

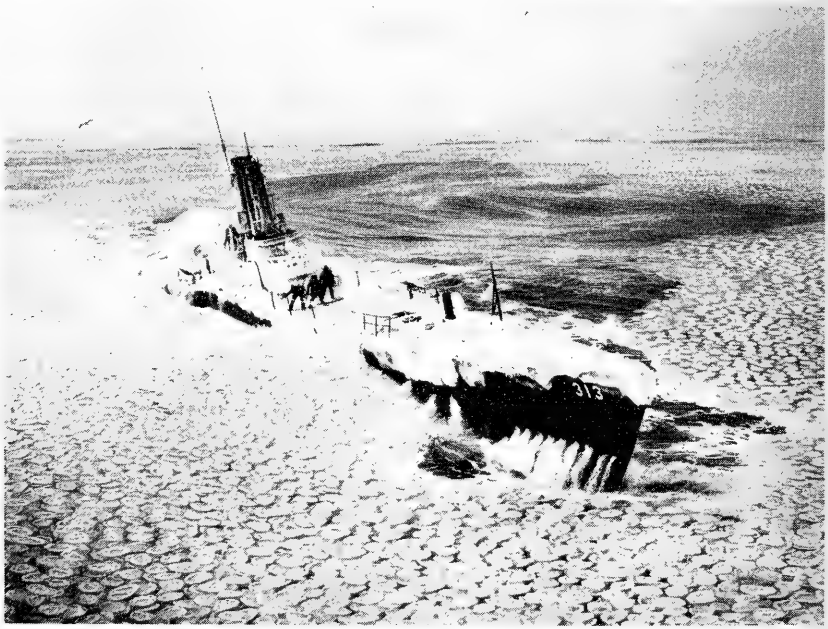
Fouling data are available from many world areas based upon cumulative and qualitative studies made of test surfaces placed in these areas. General information as to the thickness and type of fouling also has been compiled from actual measurement of fouling on installations in many areas. These data have been studied and predictions of fouling for many ocean and harbor areas have

been based on this information. At present, the data mentioned above are being compiled and charted on a world-wide basis giving representative foulers and their predicted concentrations. The fouling data are also being reduced to a common system for world-wide interpretation.

In connection with the studies on radioisotopic and stable trace element distributions in the marine environment, studies are being conducted on the mutual relationship between the organisms collected and their environment.

ICE

Sea ice data collection a few years ago was limited primarily to reports from shore stations and ships conducting research and resupply operations. This approach, of course, resulted in only a few sea ice observations for relatively few locations. In order to develop a synoptic observational capability in areas of concern, the Naval Oceanographic Office implemented an aerial ice observing program in the early 1950's. This program is now



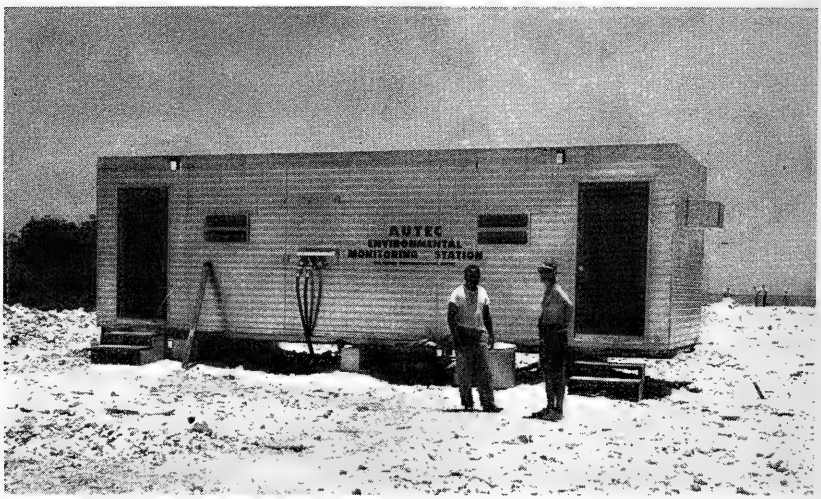
Ice and waves hinder submarine operations in subarctic waters.

Ice features and ice-coverage are charted by icebreakers and aircraft.

providing synoptic ice reports over large areas of the Arctic and Antarctic for use in preparing forecasts in support of surface and subsurface naval operations. About 500,000 miles of ice reconnaissance are now flown each year, providing an average of 18,000 observations made in accordance with a detailed numerical code. Satellite pictures of sea ice, showing such gross features as ice boundaries and major open-water features, are being used experimentally by ice forecasters. Improvements in methods of obtaining data and in interpretation techniques within the next few years should greatly enhance our knowledge of ice distribution, movement, disintegration, and formation.

RANGE SURVEYS

Oceanographic survey operations in support of the Navy's underwater range programs began in 1961 with project AUTEC (Atlantic Undersea Test and Evaluation Center), followed in 1962 by the first of two surveys for the St. Croix Range. Subsequent surveys were conducted for underwater tactical ranges in Kauai, Hawaii (1964) and Vieques, Puerto Rico (1967). These fine-grained surveys require very precise navigational control and



Oceanographic operations headquarters for the Atlantic Undersea Test and Evaluation Center.

new observational techniques. Coordinated, closely spaced bottom samples, underwater photographs, and depth soundings provide information necessary for the routing of submarine cables and design of bottom structures. Collection techniques have only recently been augmented by the use of deep submersibles in the AUTEC and St. Croix ranges. Ranges with critical needs for real-time environmental data, for example, AUTEC Weapons Range, require permanent buoy arrays which transmit data to a shore facility for direct input to computers.

The scope of oceanographic support required for range development and operation will doubtless increase as range facilities are expanded. More abundant and accurate oceanograpic data will be required during some range tests in keeping with the increasing environmental sensitivity of newer generation weapons or detection systems. To meet this challenge, future range surveys will make greater use of submersibles and buoy technology.

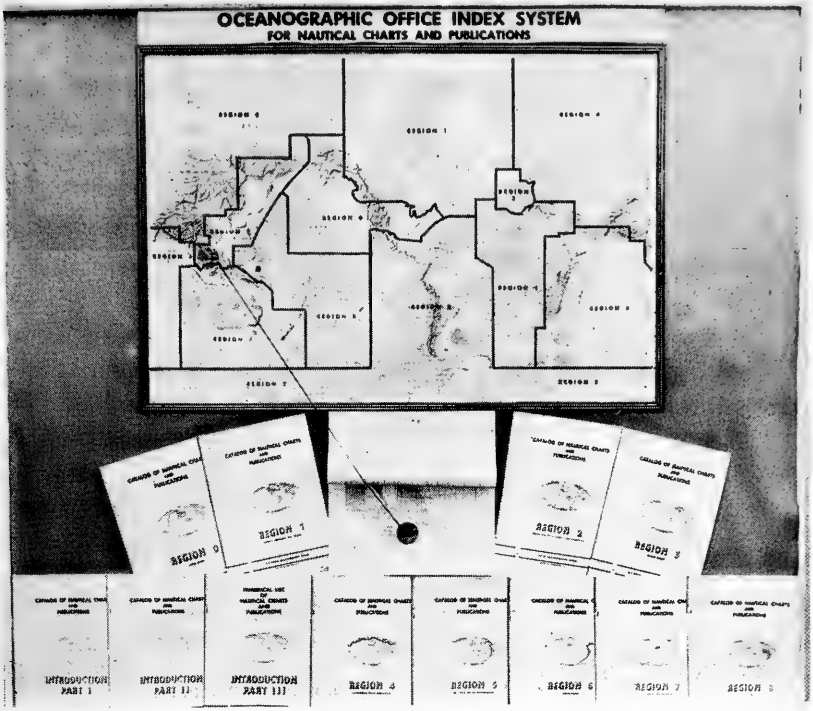
Many of the tools and techniques developed for range support surveys will find application elsewhere in the marine sciences. For example, fine-grained bottom survey methods can be related directly to ocean mining and problems in search and recovery. Equipment developed for range monitoring can be applied to larger ocean areas for a better understanding of the ocean's "weather" patterns. Finally, the wealth of experience that will accrue from the installation, operation, and maintenance of various underwater equipment will be invaluable to commercial and other nonmilitary interests as they develop their maritime activities.

CHARTING THE OCEANS FOR SAFE NAVIGATION

NAUTICAL CHARTING

For the past 130 years the U. S. Navy has been producing nautical charts on a world-wide basis in order to secure maximum navigational safety for ships of the Navy and merchant marine. The earliest charts were made from exploratory surveys of a reconnaissance nature. Through the years the charts have been considerably improved to meet the growing needs of modern shipping by the addition of more accurate, detailed sounding data obtained by electronic surveying systems, by the extensive use of aerial photography for the interpretations of land masses and coastal configurations, by the application of geodetic control positioning for more precise navigation, and by improvements in cartographic presentation and reproduction methods. The requirements of safe navigation govern the selection of nautical chart content, detailed portrayal of which is commensurate with the scale and purpose of the chart. First emphasis is given to the most important features of the chart, namely, the soundings and depth curves by which the main characteristics of the configuration of the ocean bottom—sunken rocks, wrecks, and other obstructions and dangers to navigation are charted in detail. Current and tidal data are included. Symbols are employed to portray submarine relief for features such as coral and rock reefs, shoals, banks, etc. Abbreviations for bottom sediment characteristics, such as mud, sand, shell, etc., are shown. Also portrayed are principal aids to navigation such as buoys, lights, lightships, daybeacons, and radio beacons. Aids with their identifying characteristics must be charted so that they can be readily identified without confusion to the chart user.

Topographic detail shown on nautical charts is compiled in accordance with the needs of the mariner, an accurate delineation of such detail being useful for fixing positions at sea. Extensive use is made of Navy and other aerial photographic surveys for compilation and revision of topographic detail. Coastlines, important rivers, contours, spot elevations, and other topographic



The catalog of Nautical Charts and Publications provides the essential selection for the seafarer.

details are shown to convey to the navigator a general idea of the configuration of land areas within visual or radar distances of the coast.

The amount of detail applied to a nautical chart and the method of presentation employed are dependent upon the scale of the chart and the purpose for which it is constructed. Nautical charts are published to established specifications, and are classified into four general categories: (1) port and harbor charts; (2) harbor or coastal approach charts; (3) general or coastal charts; and (4) ocean sailing charts.

The Navy is charged by law with providing nautical charts at various scales for all the sea lanes and for all foreign coasts and ports of the world which are essential to marine navigation and other national interests. The implementation of this requirement involves not only the production of charts initially but the continuing maintenance of all nautical charts to

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insure safety of navigation. This maintenance is accomplished by the issuance of daily radio messages, weekly printed Notices to Mariners, periodically revised chart printings, and when necessary, new charts or publications or completely revised chart editions.

Over 4000 standard nautical charts are on issue by the U. S. Naval Oceanographic Office. Most of these charts are based on U. S. Navy surveys and various foreign chart sources. To provide more timely service and the latest available information to the mariner, more and more charts are being issued as modified facsimile reproductions of foreign charts. These reproductions are published under bilateral agreements with foreign hydrographic offices.

The standard nautical chart program as now scheduled through Fiscal Year 1973 calls for the publication of approximately 400 new charts and nearly 800 new editions. These figures do not include modified facsimiles made of foreign charts for geographical areas of particular U. S. interest. The immediate program is concentrated largely on the production of charts for use by U. S. Forces in Southeast Asia. In addition, some large-scale charts are programmed for ports in South and Central America being surveyed under the Harbor Survey Assistance Program, while others are being produced to reflect hydrographic surveys carried out in recent years by U. S. Navy ships in foreign waters elsewhere in the world. The remaining charts will provide coverage needed to fulfill Navy and merchant shipping requirements throughout the world, including Antarctica.

A number of special version nautical charts are produced. Many of these are standard charts to which Fleet operating areas, anchorage berths, military grids, territorial sea limits, navigational lattice lines, radar calibration grids, or other special operational information have been added. Nautical charts, regardless of scale or type, are the *sine qua non* of further ocean exploration and exploitation, inasmuch as they provide the basic framework on which such activity is planned and executed.

Nautical charts and related publications published by the Oceanographic Office are listed in H. O. Publication 1-N, Catalog of Nautical Charts and Publications. This publication is issued in the form of ten separate geographic regional catalogs and three

introductory catalogs, which index and give essential information on the products available.

AERONAUTICAL CHARTING

Since the beginning of Naval aviation, the Navy has had the responsibility for meeting the operational navigational charting needs of Naval aviators. This responsibility is fulfilled by producing aeronautical charts, furnishing flight information and air intelligence data, and providing special services necessary to support U. S. Naval air activities.

As early as 1918 the Naval Oceanographic Office produced a series of "Naval Operating Charts" designed for use by aircraft and airships patrolling maritime airspace to protect shipping from possible raids of hostile submarines. As a result of the introduction of new navigation and tracking devices for antisubmarine warfare operations, more sophisticated cartographic products have been developed. For example, the automatic Dead Reckoning Tracing system used on certain types of Navy aircraft generated the development and production of special charts designed for use in conjunction with this equipment. Approximately 125 of these special charts have already been produced, and additional coverage is planned to provide for future needs.

Aeronautical navigation charts evolved from early requests for special charts to support such special Navy missions as the first trans-Atlantic flight in May 1919 by Lieutenant Commander Albert C. Read in the flying boat NC-4 and the MacMillan-Byrd expedition to the Arctic in 1925. To satisfy the continuing operational need for air navigation charts on medium and long-range oceanic flights, the Navy developed several series of aeronautical charts. An example is the V30 air navigation chart series first designed and produced in 1942 to provide world coverage of aeronautical plotting charts for Naval air operations in both theaters of the war. This series today consists of 104 charts, which are designed for plotting to an accuracy of one nautical mile and for rapid computation of courses and distances. They are constructed on the Mercator projection at a scale of 30 nautical miles to the inch (at the mid-latitude of each chart). This series has been redesigned to meet the needs of modern air-

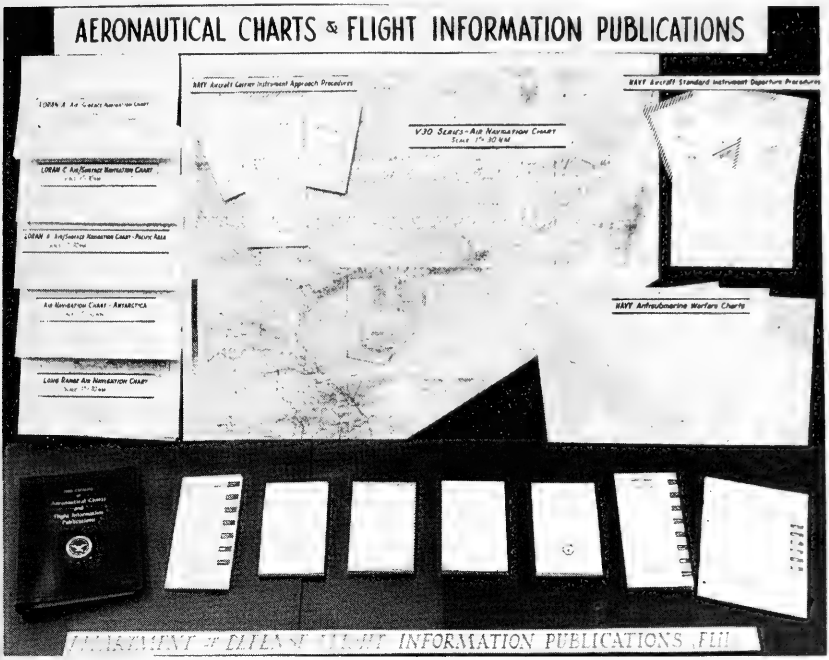
craft and is supplemented by additional charts of various scales to provide coverage for special Navy missions.

At the beginning of World War II, the first hyperbolic line-of-position electronic navigation system, Loran A, was developed and implemented, and the VL30 series of charts, among others, was produced for air and surface use throughout the world. Since then, new charts have been developed and produced to keep abreast of the requirements generated by both expanded Loran coverage and implementation of such new navigational systems as Loran C and Omega.

Air navigation charts are also produced to support special projects, such as Operation "Deep Freeze". The Naval Oceanographic Office has also responded to the unique needs of Naval aviation activities through its production of special charts for training, search and rescue, and special operations. In addition to producing new charts as required, the Oceanographic Office maintains, and has on general issue, some 500 different aeronautical charts in carrying out its mission in support of Naval aviation and the overall Department of Defense mapping and charting program. Approximately one-fourth of these charts provide Loran rate information for Loran navigation by both air and marine users. Nearly all Navy aeronautical charts are on sale to the general public.

FLIGHT INFORMATION AND PUBLICATIONS

An additional major area of responsibility in support of Naval aviation is that of furnishing Navy flight information and air intelligence data for incorporation in Navy and Department of Defense publications. These publications provide essential flight information for planning, enroute, and terminal phases of Navy, Army, and Air Force air operations. The Navy prepares aircraft instrument approach procedure charts, portraying the flight maneuvers and related procedures required for approach and landing under instrument weather conditions at all Navy, Marine Corps, and Coast Guard air activities. A comparable service is provided for aircraft instrument departure procedures. Information pertaining to the flight operational capability of Naval and Marine



Essential tools for safe aircraft navigation.

Corps air facilities throughout the world is furnished for publication in a variety of Department of Defense flight information publications.

Since 1920, the Navy has been furnishing to aviators and others concerned with navigation, information on such subjects as land and sea landing areas, air routes, airspace restrictions, air traffic procedures, hazards to air navigation, and electronic aids to navigation. One means of providing this service is through a world-wide communications network linking Naval and Air Force air facilities. This system, identified as the Notice to Airmen (NOTAM) system, provides for immediate transmission of flight advisory information. The Oceanographic Office monitors all Navy input into this system.

Approval of the aircraft instrument approach and departure procedures established for Navy and Marine Corps air activities, worldwide, is made by the Oceanographic Office. Some 1200 such procedures are processed annually. An associated service

provided is the participation in formulation of the design criteria for establishing safe, efficient, and standardized aircraft terminal procedures.

To ensure that existing aeronautical chart and flight information products are accurate, current, and in the most usable format, continuing liaison is maintained between the chart producer and operational commands in the Fleet. All requests or indications of new or updated user requirements are reviewed and analyzed, followed by product or service development and evaluation. The previously mentioned special series of anti-submarine warfare charts was developed in this manner.

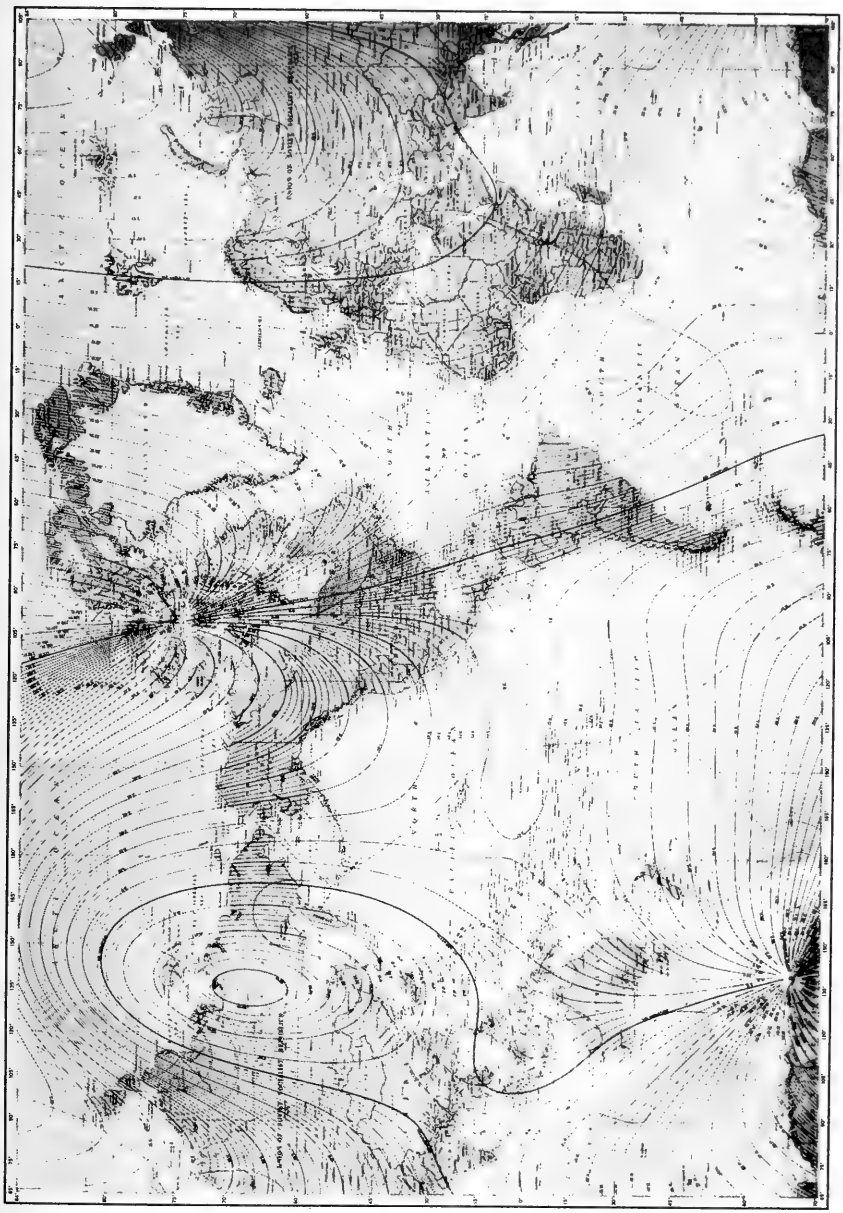
Close liaison is maintained with domestic and foreign mapping and charting agencies, as well as operational users, in an effort to standardize format, content, and production techniques. This effort is directed toward inter-changeability of products and elimination of duplication.

WORLD MAGNETIC CHARTING

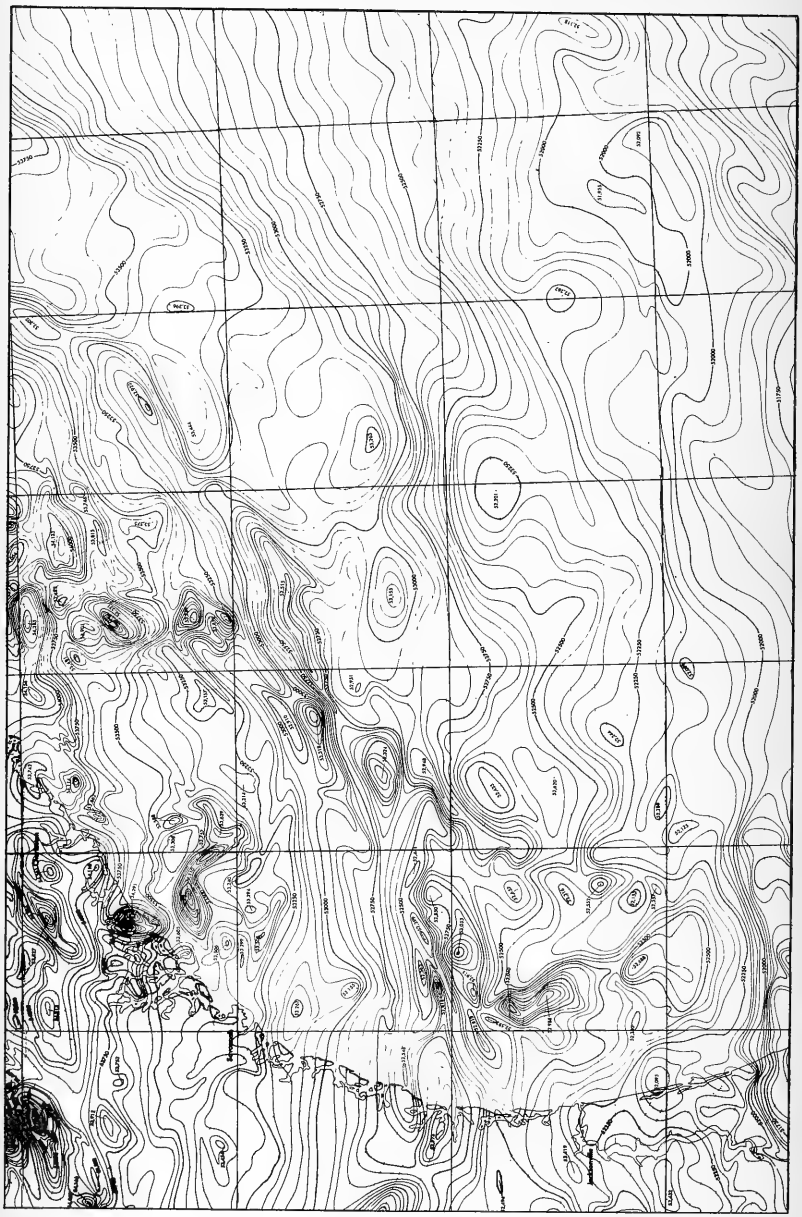
Although some knowledge of the elementary principles of magnetism existed earlier, considerable interest and concern have been manifest in magnetic information since the time of Columbus. Since then, maritime nations have zealously and continually acquired magnetic data, primarily for use in publishing world magnetic charts for the benefit of navigators.

The first attempt at oceanic magnetic surveying was made by the British astronomer Edmund Halley, who observed magnetic variation in the Atlantic in 1698–1700. Halley published his first chart in 1701 and erroneously believed that he could obtain the longitude of a ship at sea by comparing his chart with the observations made on board the ship.

The United States collection of world magnetic data dates back to the U. S. Exploring Expedition of 1838–1842, under the command of Navy Lieutenant Charles Wilkes, but it was not until 1881 that collection of such data was undertaken on a large-scale, continuing basis. All wooden ships of the U. S. Navy were requested to make and report magnetic observations for the purpose of producing a chart showing the declination of the compass throughout the oceans of the world. The first such chart was published by



World Chart of Magnetic Declination (H.O. 1706, Epoch 1965)—a product of the cooperative efforts of the Navy and Department of Commerce.



Geomagnetic field along part of the eastern continental margin of the United States as determined from fine-grained survey.

the Navy in 1882.

With the passing of the years, the scientific study of the earth's magnetic field was recognized as being of major importance. One component, the variation, or magnetic declination, of the earth's magnetic field, is displayed on all nautical and aeronautical charts. Other components needed for purposes of compass adjustment and compensation, degaussing, magnetic guidance, and numerous other military, commercial, and scientific uses, are charted in a series of world charts.

Production of world magnetic charts by the Navy stems directly from its basic mission. The series of charts provides comprehensive information on each magnetic element, namely, dip or inclination (I), horizontal intensity (H), vertical intensity (Z), total intensity (F), and magnetic variation (or declination) (D). Each chart, in addition to displaying isopleths of the charted element, also contains isoporic or annual change lines which make possible correction for epochs other than those for which the isomagnetic lines are shown.

Under contract with the Navy, the U. S. Coast and Geodetic Survey compiles world magnetic charts incorporating data from Project MAGNET. These charts are then published by the U. S. Naval Oceanographic Office. The magnetic information for the 1965 epoch charts was compiled by analytical techniques, using modern high-speed computers in place of former graphic methods. A more accurate and more scientifically acceptable portrayal of the strength and direction of the geomagnetic field resulted.

At the present time, 29 magnetic charts are published by the Navy and are on sale to the public. Because of the constantly changing nature of the earth's magnetic field, new editions of charts showing magnetic declination are published every five years; new editions of charts showing magnetic inclination, horizontal intensity, vertical intensity, and total intensity are published every ten years.

SPECIAL PURPOSE CHARTS

The tremendous increase in activity in the marine sciences and in the sophistication of weapons systems and military operations has created an unprecedented demand for various types of special

purpose charts. In this category are charts which have been constructed on special projections to facilitate great circle tracking and quick visual determination of azimuth and great circle distances, position plotting sheets for all world areas, maneuvering boards and radar plotting sheets, star charts, time zone charts, world charts, coordinated series of charts for command and control purposes, small boat charts, strategic planning and plotting charts, and charts designed expressly for hydrographic and oceanographic survey plotting.

The Navy, through its automated cartographic production system, has pioneered in the mass production of most of the aforementioned charts. Computer programs have been developed to permit rapid and precise construction of such charts on any of over thirty different projections, each possessing unique qualities for various needs. Charts on the azimuthal equidistant projection, for example, permit depiction of the entire earth on a single sheet, and are particularly useful in communications studies. Thus, if a chart is constructed with a selected geographic coordinate or city at its center, the great circle or true distances and azimuths from this point, to any other point on the earth's surface, may be rapidly determined by inspection. The Oceanographic Office has produced over twenty such charts, and more are programmed.

Great circle tracking charts comprise a second important group of special purpose charts. These charts are constructed on the gnomonic projection and permit rapid determination of the great circle track or shortest route between any two points on a given chart. Although originally designed about 1884 to enable navigators to plan their routes, the charts have been found invaluable tools in tracking ships and other craft.

A total of 72 great circle tracking charts are on issue and available to the government and private individuals and institutions. In addition to providing a quick tracking capability, the charts show important reference detail such as coastline, principal islands, cities, navigable rivers, bathymetric curves at 1000 fathom intervals, important depths, names of principal bathymetric features, and other specialized information of value to either operations or planning.

Perhaps the largest group of special purpose charts in number is the precise positioning sheet. Such sheets are specially con-

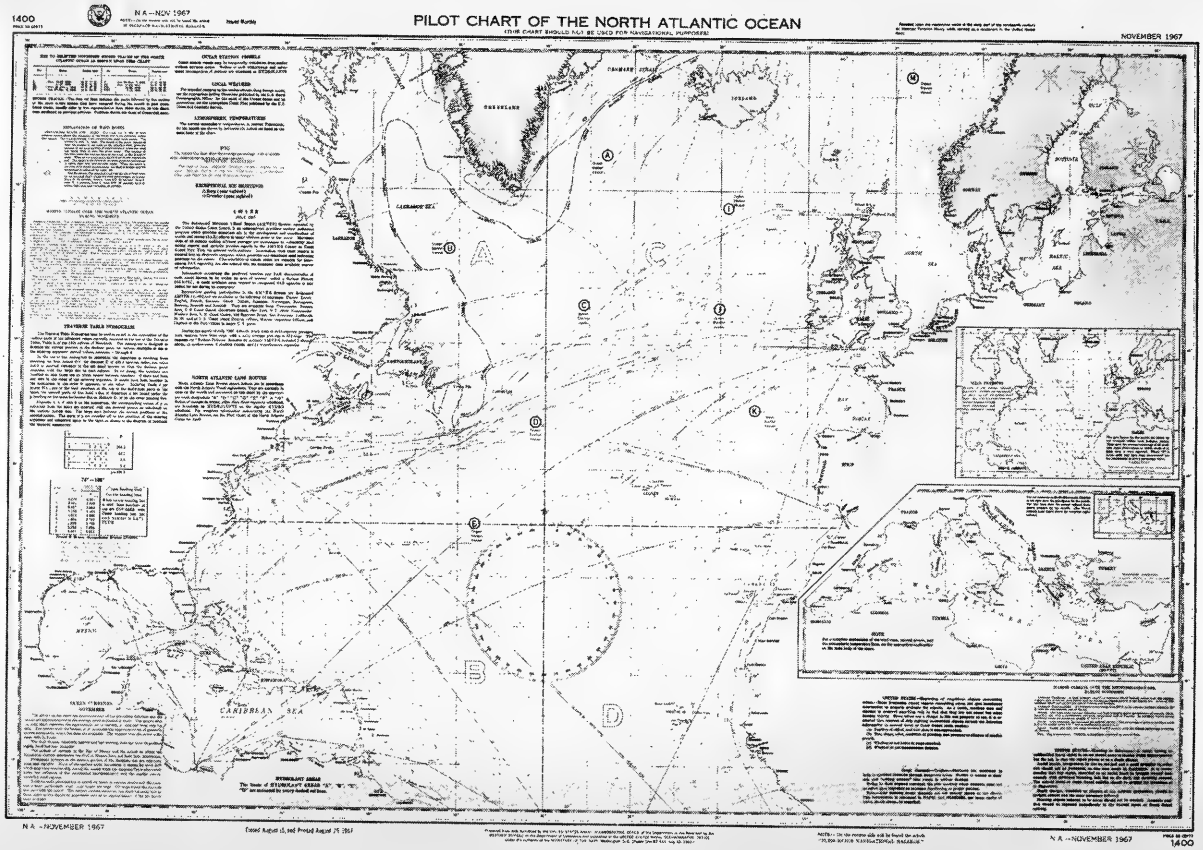
structed for individual geographic areas for precise hydrographic or oceanographic surveying; ship or equipment positioning, installation, or recovery; and related operations and planning. The simplest type of sheet—the optical plotting chart—permits determination or recovery of position by visual reference to established shore stations, and the azimuth readings and azimuth lines which are shown on the chart. Most precise positioning plotting sheets, however, are produced for use with electronic navigational systems.

Electronic positioning plotting sheets, constructed at very large scale, are used to record oceanographic and hydrographic observations and to locate or recover underwater objects. Navigational lattice overprints are included on these charts for the particular electronic navigational systems being used, including Loran A, Loran C, LORAC, DECCA, RAYDIST, and LAMDA. Charts on which field observations have been plotted become a primary source of new standard nautical chart revision or construction data.

Perhaps the best known special purpose charts provided by the Oceanographic Office are the Pilot Charts. These present to the mariner and scientist a summary of oceanographic, meteorological, and navigational information needed to assist in planning operations in the North Atlantic and North Pacific Oceans. For other major ocean areas, the information is published in atlas form.

Pilot Charts, first published in 1847 as Maury's "Wind and Current Charts", are the exchange medium for the wealth of marine information collected through the years by the Navy and the Weather Bureau. The Pilot Chart of the North Atlantic Ocean was first published as such in 1883, that of the North Pacific in 1894. Pilot Charts are published monthly; in addition to the chart itself, each contains a timely article of professional or technical interest on the reverse side. A different article appears each month, and subjects covered include biological oceanography, Arctic ice and its drift, subsurface navigational hazards, shiphandling, the Gulf Stream, and numerous other topics of marine interest.

General development maps, for areas such as the McMurdo Scientfic Station in Antarctica, have been photogrammetrically



One of the oldest and yet most popular products of the Oceanographic Office.

compiled. Large scale photogrammetric compilations have been prepared for many special uses, including the selection and development of a suitable site and the installation of a desalination plant on the Naval Base in Guantanamo, Cuba. Currently, general development maps of a number of naval bases are being produced to aid in the future planning and development of the bases.

Only a few of the many types of special purpose charts issued by the Oceanographic Office have been described in the foregoing paragraphs; all pertain directly to Navy missions and maritime operational needs. Despite the large increase in the number and quantities of such charts produced, requirements continue to grow. It is to be expected that special purpose charts and graphics will play a greater and greater role as the oceanographic programs of the Navy and the nation move forward to greater accomplishment.

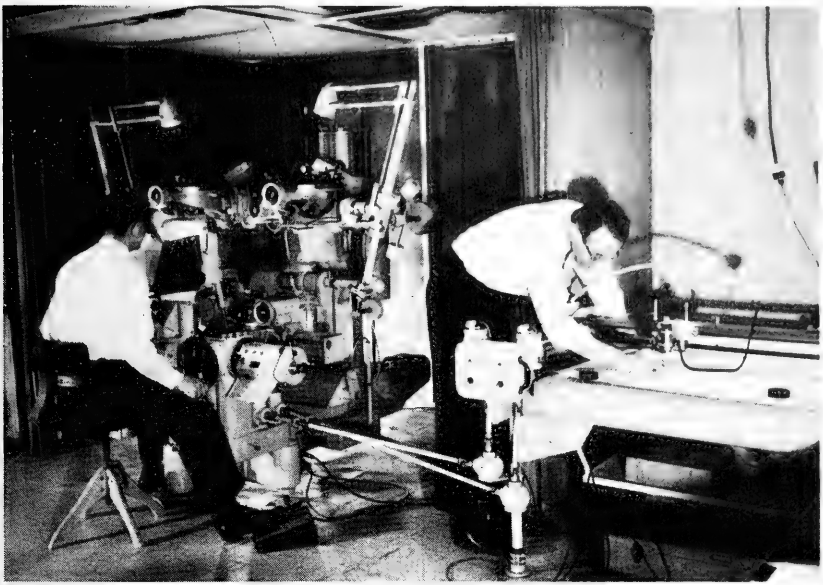
AUTOMATION OF CHART PRODUCTION

The solution to an ever increasing demand for charts lies in the employment of high speed computers and other precision devices in automated cartographic production. Today the photogrammetrist has instruments at his disposal that can record values to the nearest micron. He also has computers to assist him in establishing supplementary control or in calibrating his cameras. For the future, automated systems utilizing aerial photographs may well perform the greater part of the work required in coastal chart construction and in chart revision. Recent technological advances in echo-sounding equipment and automated techniques for collecting and processing data—many of which are already operational—have considerably speeded up the conducting of surveys by eliminating former time-consuming manual methods. A finished chart is now available soon after completion of the field survey. For example, modern computers process the data and feed it to mechanical plotters which plot up to 28,000 accurately positioned soundings in an eight-hour day compared to 300 by former manual methods.

The initial steps to automate cartographic production in the Oceanographic Office were taken in 1960, when development was

Fine skills of yesterday — — —

— — — are giving way to modern automated instruments.



High precision stereoscopic plotting systems are used by the Naval Oceanographic Office to compile data from aerial photographs.

begun on a precision automatic digital coordinatograph system. The first such system was placed in operation in the Naval Oceanographic Office in June 1963. The system is capable of drawing, scribing (engraving), or photographically exposing continuous straight or curved lines; printing numerical data with a mechanical print head; and photographically exposing alphanumeric data on large sheets of sensitized film. Information processed by the plotter system may be in the form of computer-prepared magnetic tape (used 95 percent of the time) or punch paper tape. The system may also be controlled from a keyboard input unit. An integral part of the system is a director unit, which controls the coordinatograph and the operations of its interchangeable instrument heads in response to information fed into it. The plotter operates on the principle that any curved line that can be described by a mathematical equation can be automatically produced by the system. The final output of the automatic plotter system consists of an inked plastic or paper sheet, a photographic film, or a scribed negative. The charted detail is plotted and delineated at a speed and to a tolerance that

cannot be matched by manual construction methods.

In the four years that the automatic digital coordinatograph system has been in operation, a large library of computer programs for different types of cartographic functions has been developed.

Computer programs are in use for the following:

Construction of all types of electronic navigational position lattice systems, both hyperbolic (LORAN, etc.) and circular (Shoran, etc.) plotting sheets.

Construction of over 30 different map projections.

Annotation and plotting of soundings resulting from hydrographic surveys based on ship-furnished information and electronic lattice system control data. These data are processed through special control survey and edit programs, which automatically plot the soundings in their proper latitude and longitude position and annotate the correct depth in fathoms and feet.

Plotting and scribing of geographic shoreline and other map features and using the photo-projector head for annotating position of cities.

Delineating the major great circle sailing routes and underwater cable routes of the world; the production of magnetic variation and declination charts of the world.

Scribing of various metric plotting grids and military reference grids for overprinting on nautical charts.

Computer programming techniques can produce as many as twelve chart originals in eight hours, completely plotted, scribed, and ready for photo-lithographic production. Stops are required only for changes in scribing materials and magnetic tapes. In the 4 years the plotter has been in operation, over 7000 individual original drawings and color separation originals have been produced.

The automatic cartographic capabilities of the Naval Oceanographic Office have been recognized throughout the world. Numerous requests for automatic services have been filled from other domestic government agencies, private institutions, and foreign governments. Broad guidance, production assistance, technical information, and computer program documentations have

been supplied freely to others developing similar capabilities.

Two additional automatic cartographic production systems are scheduled for installation in late 1967. These systems will provide more advanced capabilities, making it possible to place names and symbols in any desired position automatically, using various type sizes and styles. Digitizers will provide the capability of storing cartographic source data in such a manner that it can be readily retrieved from a library file, processed by a computer, and graphically produced on the coordinatograph within a matter of minutes. These new cartographic systems will greatly increase both output and quality of the finished products. Future plans will provide a color separation capability whereby each color plate of a printed chart can be digitized, recorded, and stored for chart compilation or revision.

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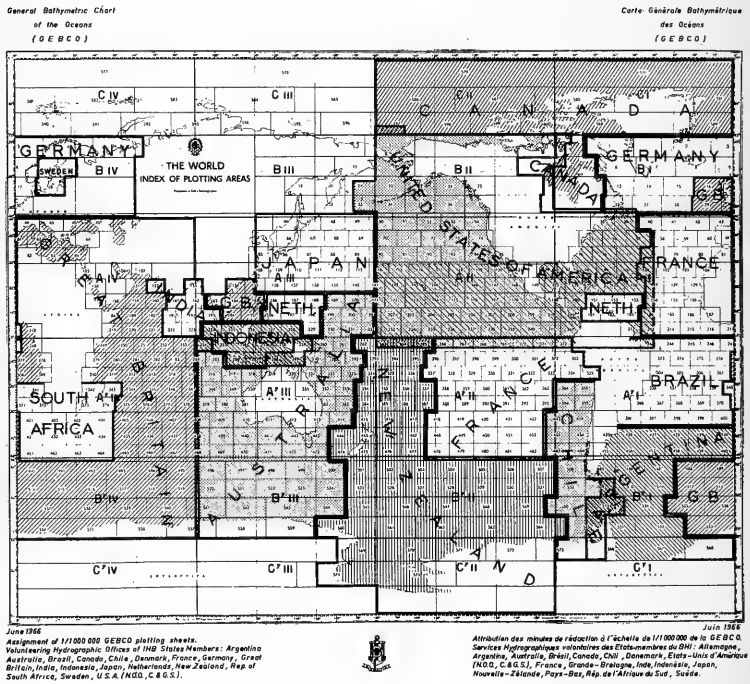
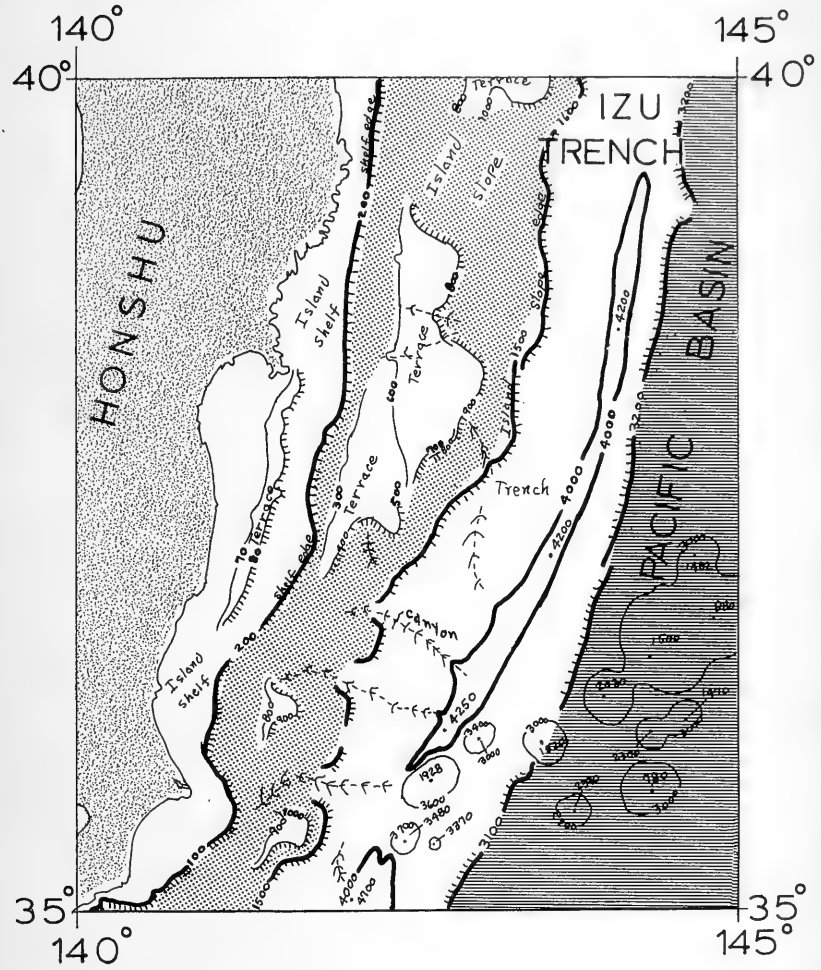
DESCRIPTION OF THE MARINE ENVIRONMENT AND OCEANOGRAPHIC PROCESSES

BATHYMETRY

In 1965 the Naval Oceanographic Office was designated as the official Department of Defense repository for bathymetric data. Data obtained in the field must be translated into products useful to the operating forces, merchant marine, and others with requirements. This consolidation of bathymetric information permits translation and application of immediate survey data in the light of all applicable information contained in this extensive archive. The location and description of submarine physiographic features are indispensible to surface or submarine navigation;



The U. S. Navy is a principal contributor to the General Bathymetric Chart of the Oceans sponsored by the International Hydrographic Bureau.



Bathymetric provinces in one section of the Western Pacific Ocean as derived from geological data and bathymetric surveys.

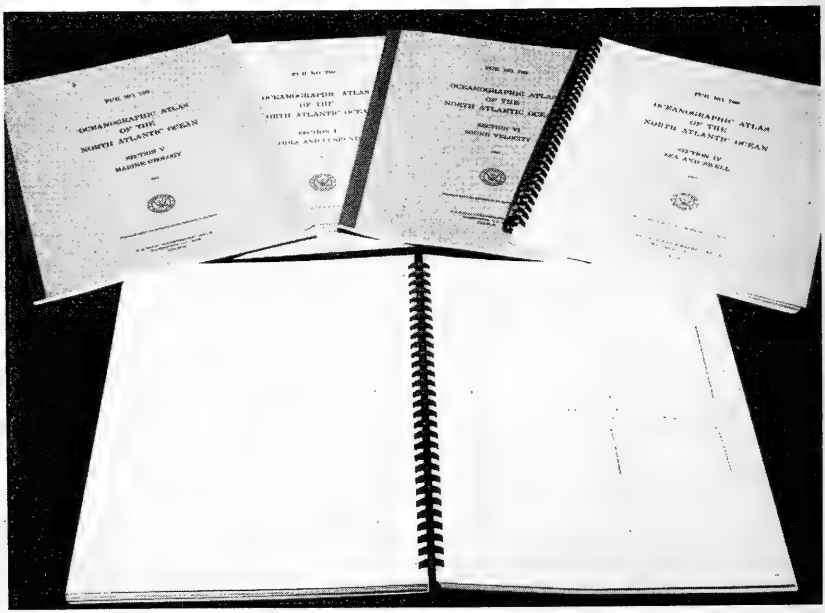
to an understanding of oceanic, longshore, and tidal current patterns; to prediction of acoustic energy and its transmission through the crust; and in determining reasons for interruptions in sound channels. Therefore, bathymetric charts of the world's oceans are prepared at various scales and at various isobath intervals, and studies of the sea floor are made to determine provinces of similar structure, for example, basins, ridges, and rises, as well as direction and degree of slope.

Bottom Contour (BC) charts are available for approximately 94 areas covering large portions of the North Atlantic and North Pacific Oceans. A transition is being made from the BC series of charts to an HO/BC series, which should provide more up-to-date bathymetry and expanded coverage.

Because of its vast bathymetric data holdings, the Navy is one of the principal contributors to the General Bathymetric Chart of the Oceans, a program of the International Hydrographic Bureau to produce up-to-date charts of the world's oceans. Responsibility for providing data for particular ocean areas was assigned to its 40 members, and the Navy, in addition to satisfying its own responsibilities, has helped many member nations in meeting their commitments.

MARINE GEOLOGY

The composition and physical characteristics of sediments and rocks affect the absorption, reflection, and scattering of acoustic energy. Also, a knowledge of the type and distribution of sedi-



New Oceanographic Atlas, being produced serially, gives latest information on the physics, chemistry, biology, and geology of the oceans.

ments, rocks, and habitats for bottom-dwelling organisms permits estimation of biological noise and magnetic background, in the absence of direct observation and measurement of these factors. The selection of sites for submarine instrument arrays or minefields is dependent upon knowledge of the form and composition of the bottom.

Studies are made of various ocean areas showing the relief of the ocean bottom, the materials covering it, and the nature of the crustal and subcrustal layers beneath the sea floor. Also, earthquakes, volcanic eruptions, and tsunamis are charted in an effort to determine their effect on the marine environment and on military operations. A Navy study of St. Paul Rocks was used as background material in planning the MOHOLE project; marine geology studies were important factors in the search for the submarine THRESHER and for the lost nuclear bomb off Palomares, Spain.

A file of about 150,000 descriptions of bottom samples is continually being enlarged and is currently being automated. Files on volcanic activity and tsunamis are also maintained. Future plans call for procedures to retrieve required data for specific places on demand.

CURRENTS

The U. S. Navy has had a long-standing interest in ocean current data for use by the defense establishment and the merchant marine. As previously described, formalized work in systematizing current observations dates back to Lt. Maury's "Wind and Current Chart of the North Atlantic", published in 1847. This early effort has evolved into modern-day Pilot Charts, published in cooperation with the U. S. Weather Bureau, and many other publications. Detailed and accurate current charts and atlases are required not only by the Navy in its operations in war and peace but also, under the statutory mission of the Navy, for the merchant marine.

Major publications issued during the past few years are the tides and currents section of the Oceanographic Atlas of the North Atlantic Ocean and the Environmental Atlas of the Tongue of the Ocean. Several smaller oceanographic publications have been issued covering ocean currents in such localities as the Arabian

Sea and Northwest Indian Ocean and in the vicinity of the Japanese islands and China coast. A technical report describing the major current systems of the North and South Atlantic is in press. Seasonal charts of the major current systems of the world have been updated with new information.

Future requirements call for more observations and analyses of subsurface currents and the application of computer techniques for more sophisticated analysis of the numerous surface current determinations.

WAVES

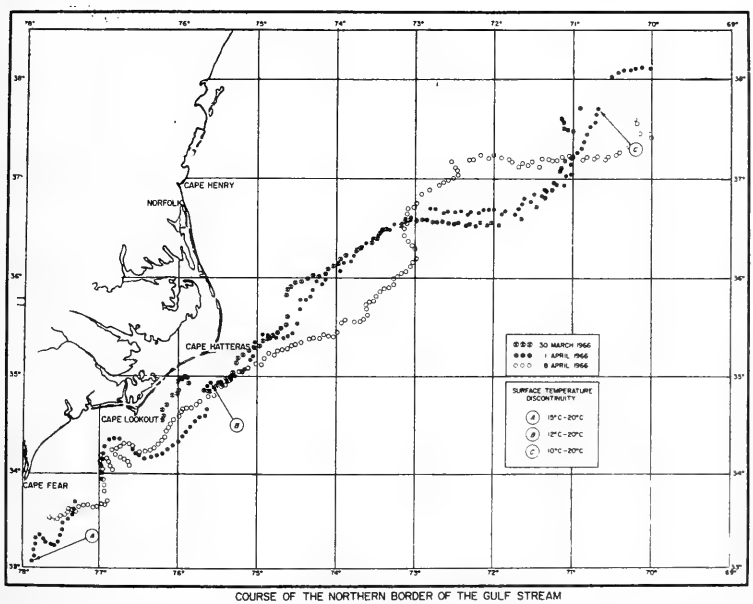
Severe seas and high swell can hinder nearly any naval operation. It is imperative, therefore, to have the most accurate, quantitative description that is possible of the distribution of wave heights over all ocean areas. Subsurface wave motion and surf conditions are important derivatives of surface waves. The best available information on waves is contained in the sea and swell section of the Oceanographic Atlas for the North Atlantic Ocean. Numerous studies have been made of particular ocean areas to provide information on such wave processes as generation, propagation, refraction, decay, filtering, and subsurface pressure fluctuations for use by the Fleet, various government agencies, and marine engineers. Digests of wave statistics have been prepared to aid in the routing of ships.

PHYSICAL AND CHEMICAL PROPERTIES

With the increasing sophistication of naval operations and equipment, knowledge of the physical properties of the oceans becomes increasingly important, not only in actual naval operations but also in the development and testing of new weapons systems. Also, before environmental prediction and surveillance systems can be perfected, the operating environment must be described statistically.

In the past few years the Oceanographic Office has produced atlases, studies, and reports containing detailed analyses of the physical properties of sea water, both horizontally and vertically, for such diverse areas as the North Atlantic Ocean (Oceanographic

Infra-red sensors show the boundary of the currents, leading to— — —



COURSE OF THE NORTHERN BORDER OF THE GULF STREAM

— — —charted movements of the northern border of the Gulf Stream.

Atlas of the North Atlantic Ocean, Physical Properties), the Sea of Okhotsk, Southeast Asian waters (Temperature, Salinity, and Density of the World Seas: South China Sea and Adjacent Gulf), the coast of Brazil, and the Tongue of the Ocean (Environmental Atlas of the Tongue of the Ocean). In addition, considerable technical and advisory assistance has been given to nondefense agencies, government contractors, and foreign oceanographic activities.

With the increasing use of continuous oceanographic sensing and recording devices, the problem of automatic data processing will become more acute. Additionally, satellite oceanography may provide simultaneous, large area coverage heretofore unavailable to the physical oceanographer.

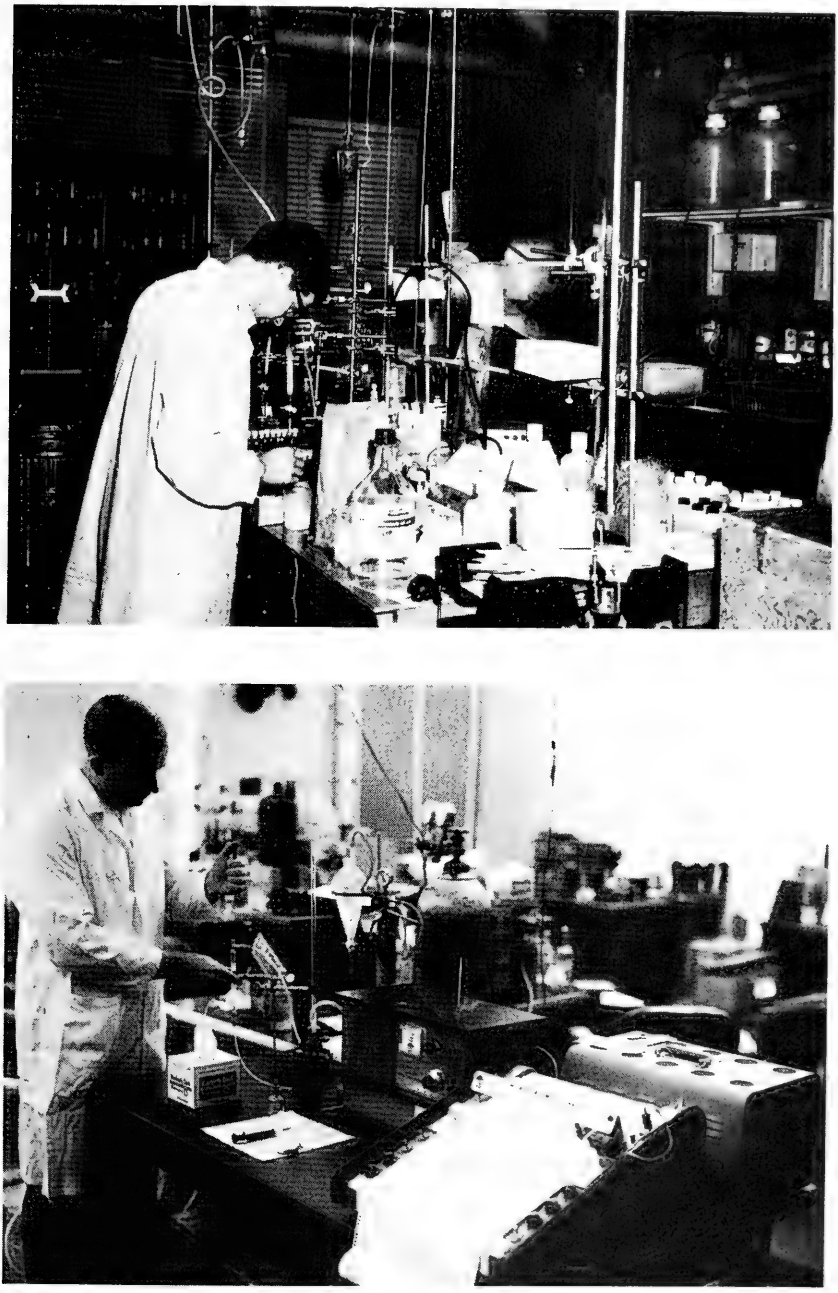
SOUND PROPAGATION

In order to achieve a better understanding of the acoustic structure of the North Atlantic Ocean, aproximately 23,000 sound velocity profiles have been analyzed. The results are contained in the Oceanographic Atlas of the North Atlantic Ocean, one section of which depicts the sound velocity structure by season from the Equator to 68°N. A similar analysis is underway for the North Pacific Ocean.

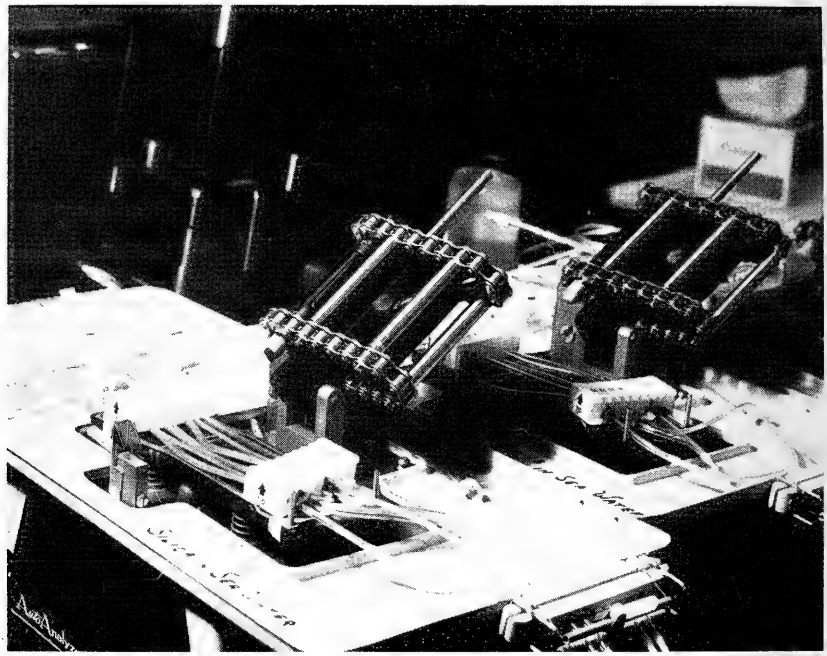
MARINE LIFE

Many types of marine organisms have detrimental effects upon naval operations, equipment, and personnel. In response to naval needs, studies have been made of particular ocean areas concerning marine biological influences on military operations. A large repository of pertinent biological information useful in both military and nonmilitary fields now exists at the Naval Oceanographic Office.

Many studies have been made and consultative services provided on subjects such as the following: dangerous and poisonous marine organisms capable of inflicting injury; bioluminescent organisms that may produce strong illumination at night; boring organisms capable of destroying marine structures; fouling organisms and vegetation capable of inhibiting the movement or operation of



Laboratory work underway at the Naval Oceanographic Office.



Modules for the automatic determination of nitrate, phosphate, and silicate in sea water.

ships and equipment; distribution and nature of the deep scattering layers (DSL); and plankton, fish, and mammals capable of interfering with underwater acoustic listening or ranging.

Future cooperative work with nonmilitary agencies such as the Bureau of Commercial Fisheries will contribute to studies aimed at devising methods of increasing fish catches and automation of the processing, storage, and retrieval of the diverse data required.

SEA ICE

Since polar operations are now of strategic interest to the national defense, information on the occurrence and nature of sea ice and icebergs is mandatory. Although synoptic ice forecasting is required for high latitude resupply, surface, and subsurface operations, the analysis and presentation of historical data provide the mariner with planning information on seasonal accessibility of ports influenced by ice, as well as the general navigability of polar and subpolar waters.

The Oceanographic Office recently has made many studies of ice occurrence and thickness, as well as port conditions, for such regions as the Baltic Sea, Denmark Strait, Sea of Okhotsk, and the Antarctic. It has compiled a section on sea ice for inclusion in the Oceanographic Atlas of the North Atlantic Ocean.

Voluminous files of ice data have been accumulated, and efforts are being made to adapt the contents to machine processing. In addition, increasing use of polar observations by satellites is expected to enhance the capability for furnishing descriptions and data for larger areas.

PREDICTION OF THE MARINE ENVIRONMENT

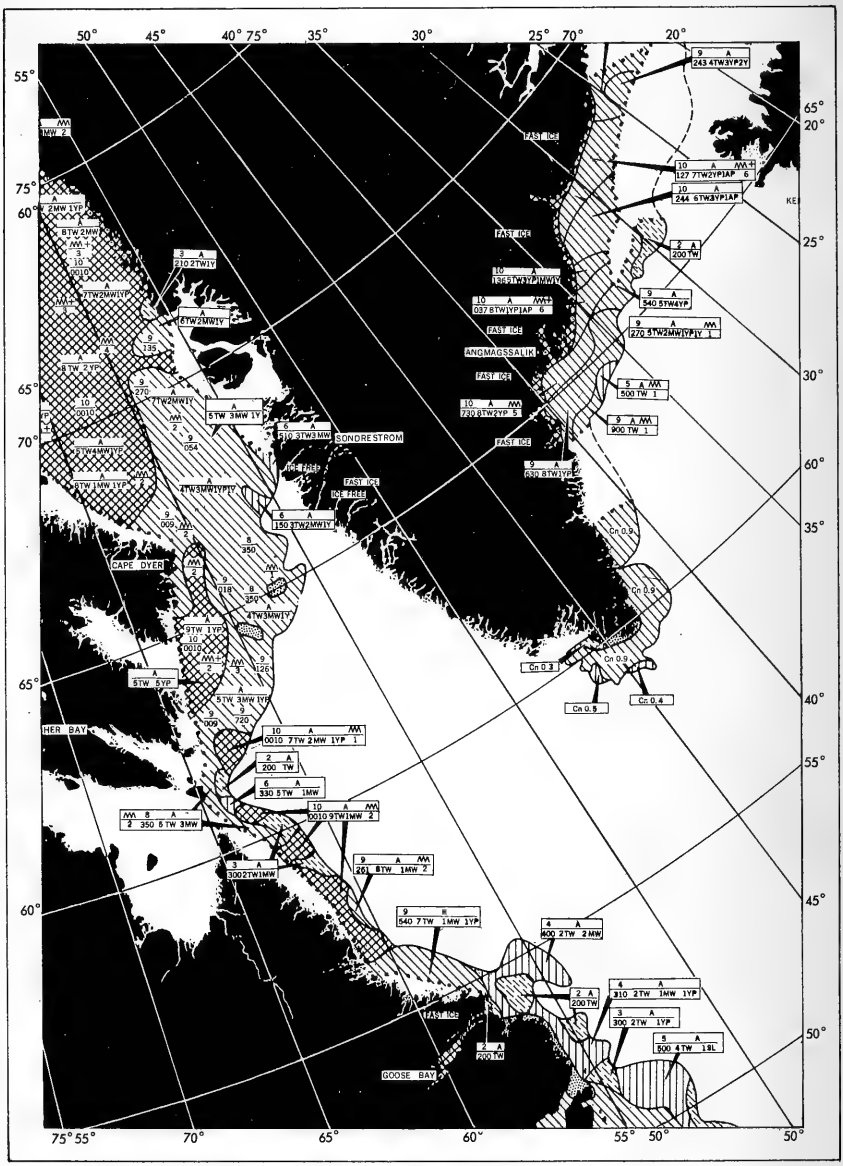
In order to plan and execute naval operations effectively, prediction capability is required for such environmental factors as sea ice, which is a formidable hazard to shipping in arctic and antarctic regions; high ocean waves, which endanger the safety and reduce the speed of ships; and thermal structure of the water, which affects ASW capabilities. The Naval Oceanographic Office is engaged in developing methods of predicting environmental conditions and, in turn, together with the Naval Weather Service, applying these techniques to naval operations.

During the late 1940's and early 1950's, ships operating in the arctic sustained considerable sea ice damage. To reduce this hazard, the Naval Oceanographic Office instituted an experimental ice observation and prediction program in 1952 and 1953. Synoptic ice observations are now acquired by ice reconnaissance aircraft operating throughout most of the North American Arctic, the adjacent Arctic Basin, and selected antarctic areas. Sea ice reports are also furnished by ships and helicopter crews, and satellite pictures are being used experimentally for studying gross features, such as major ice boundaries and large open water features. Ice forecasters analyze these observations and furnish synoptic-type ice predictions covering large regions so that ships and submarines can select areas or tracks most suitable for their mission. The ice prediction service has greatly reduced the amount of ice damage to ships. It has also reduced the amount of ship-time required to complete naval assignments in these remote areas. Short term predictions are primarily the responsibility of the Naval Weather Service Command, while the Naval Oceanographic Office prepares forecasts for 15 day periods and longer.

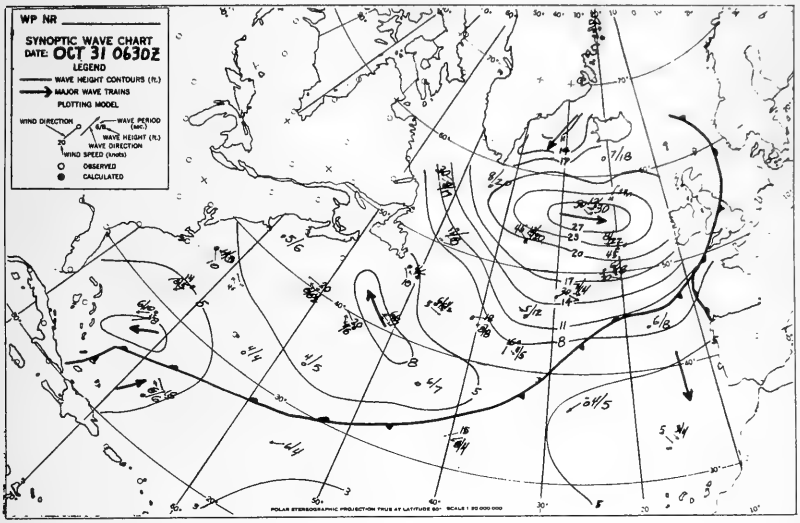
Sea ice observational techniques are continually being improved, and more synoptic ice data are becoming available each year. Satellites will eventually provide more daily data on ice concentration and movement needed for accurate analyses and predictions. New ice forecasting methods and more knowledge about ice formation, behavior, and deterioration will lead to improved support for planning and conducting surface shipping and submarine under-ice operations.

Since the synoptic approach to ice observing and forecasting had proved successful in the early and mid-1950's, oceanographic forecasters began to explore other phases of oceanographic forecasting that could be of value to the Navy. Ocean waves, especially high seas, had always plagued naval operations and merchant shipping. Both commercial and military ships for years had reported ocean wave conditions in the six-hourly synoptic weather reports transmitted by radio to forecasting facilities. No procedure, however, was available for showing wave conditions synoptically for an entire ocean. In 1954, forecasters constructed the initial synoptic wave charts, showing wave height contours for the entire North Atlantic. By 1956, synoptic and prognostic wave charts were being transmitted to the Fleet via radio facsimile.

From this has grown the oceanographic prediction program which has received the highest praise to date, the Optimum Track Ship Routing (OTSR) program. OTSR techniques were developed by scientists of the U. S. Naval Oceanographic Office in 1956-57. Predicted wave charts made it possible to use wave forecasts in routing of ships along tracks of maximum operational efficiency. Ocean currents and surface winds are also considered in determining the fastest and/or safest track. The program was made fully operational by the Naval Weather Service in August 1958. Fleet Weather Central Alameda is responsible for OTSR in the Pacific Ocean and is currently providing service to an average of 2,000 ships per year. Recently, Fleet Weather Central Guam began OTSR services to assist in handling the overload from Alameda. In the Atlantic Ocean area, Fleet Weather Facility Norfolk provides OTSR services to an average of 800 ships per year. The program is provided ships controlled by the Military Sea Transport Service (MSTS) as well as to Fleet units; it serves to reduce average transit times significantly by avoiding the rougher sea and higher wind areas. Additional benefits have been realized from reductions in ship and cargo damage and in passenger and crew discomfort. Commander MSTS reported a savings of $500,000 in tanker operations because of reduced time at sea during the first year of OTSR services; 655 ships were provided the services. In addition, cargo and passenger ships also averaged savings of $100,000 each in fuel costs due to lessened steaming time. Although not computed in dollars, savings also



Example chart of observed ice conditions.



Charts of wave heights and directions of movement provide essential information for ship routing.

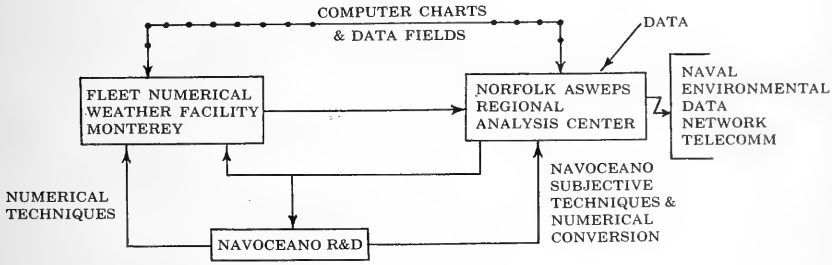
were experienced in shipwear, storm damage, and cargo damage due to faster, smoother, and safer crossings.

Thermal structure analyses and predictions for use by antisubmarine warfare forces appeared to be the next area for oceanographic forecasters to pursue, since temporal and spatial changes in the ocean environment were known to influence sonar capabilities. It was envisioned that analyses and predictions of these changes would be of value to ASW planners and tactical commands. Sea surface temperature and layer depth analyses of the western North Atlantic commenced in 1957. The value of these two charts, plus others, was recognized immediately by ASW forces. This initial effort was formalized as the ASWEPS program in 1959.

The term ASWEPS is an acronym for Anti-Submarine Warfare Environmental Prediction Services. The program is designed to provide surface and sub-surface oceanographic forecasts for use in ASW planning and tactical decision making. ASWEPS rapidly rose in popularity and was elevated to an operational oceanographic prediction system in 1966. The Naval Weather Service is the operator of ASWEPS, having been tasked to expand oceanographic services fleet-wide and later to place into worldwide

Chart of sea surface temperatures and layer depths.

operation an improved ASWEPS. Fleet Weather Facility Norfolk is the regional center assigned responsibility for conducting the initial ASWEPS program for specified areas of the Atlantic Ocean. Ten Environmental Detachments adjacent to the western Atlantic Ocean also participate directly in the initial ASWEPS program. Much of the analytic work at Norfolk is accomplished first by manual processing techniques; as computer techniques are certified the shift from manual to machine methods will be made. Following is a diagram showing the processes and activities involved:



Depending upon the type and the application intended, FLEWEAFAC Norfolk products are promulgated by facsimile, radio teletype, or mail. Eight different types of charts are promulgated on a daily basis, and five additional products are currently provided upon request. Most of the latter are classified products for special operational use. An East Coast tieline, controlled by Norfolk, is maintained between stations extending from Brunswick, Maine, to Key West, Florida, to pass oceanographic products as well as meteorological products to those stations. Each supports Fleet forces operating from that station. Operational oceanographic support programs are being enlarged to match the Norfolk programs at the following locations:

U. S. Fleet Weather Central Rota, Spain,
U. S. Fleet Weather Central Alameda, California,
U. S. Fleet Weather Central Pearl Harbor, Hawaii, and
U. S. Fleet Weather Central Guam.

Computer program development/responsibility for these latter activities is assigned to Fleet Numerical Weather Facility

Monterey, California. Computer programs are continually reviewed and updated to incorporate successful advancements from various R&D efforts.

Environmental and sonar range prediction is now used effectively by ASW commands; however, further improvements are anticipated. Planned instrumentation for ships, aircraft, and buoys will greatly enhance the quality and quantity of synoptic oceanographic observations within the next few years. Development of new and revised forecasting models will be accelerated through the use of computers as more synoptic environmental data become available. Investigations are now underway regarding the effects and prediction of the environment on shallow-water ASW. The biological false target problem is being evaluated with the intention of developing a biological false target prediction capability.

Although ASWEPS is designed and used primarily for ASW purposes, several side benefits are being derived from the program. Through the Bureau of Commercial Fisheries, for example, fishermen are making use of ASWEPS predictions by fishing in regions of optimum temperature conditions. Some fishery groups have increased their catches four-fold through the use of the environmental charts.

Fleet Weather Centrals provide various additional types of operational oceanographic support. These are:

General Fleet Support, which include sea height forecasts, high seas warnings (areas in excess of 12 feet), and sea surface temperature patterns as well as Optimum Track Ship Routing.

Amphibious Operations Support, which includes wave and swell forecasts, surf and littoral current forecasts.

Anti-Submarine Warfare and Submarine Operations Support, which includes sound velocity profile forecasts, temperature vs depth profiles, mixed layer depth forecasts, and sonar forecasts in ocean areas not covered by the ASWEPS program.

Mine Warfare Support, which includes wave, swell, and current forecasts.

Polar Area Operations Support, which includes ice forecasts

Space Vehicle Recovery Operations and Search, Rescue and Salvage Operations Support, which includes sea condition forecasts and current forecasts.

Sea Surveillance Operations Support, which includes sound velocity forecasts, sound ray path forecasts, wave and swell forecasts, and ice forecasts.

Some of the foregoing support is developed by use of computer programs. As time and computer program developments allow, more specific support for the Operating Forces will be provided. Additional data for all oceanographic parameters are needed to realize the successful employment of such programs. The product list which depicts the computer program efforts of Fleet Numerical Weather Facility Monterey is quite long. Programs there include wave analyses and forecasts; ocean thermal structure analyses; analyses and forecasts of sea surface temperature, mixed layer depth, sonic layer depth, thermocline magnitude and gradient, transient thermoclines, and temperature at standard depths; "Zoom" programs (detailed small scale features); temperature and sound speed profiles; plus sound propagation loss, convergence zone range, and other sonar forecasts.

For the future, a corps of highly motivated scientific personnel within the Naval Weather Service Command and the Naval Oceanographic Office are working toward the development of more extensive programs to better satisfy Fleet requirements. Additionally, they are striving to develop new programs to automate existing manual data processing programs in order to provide completely tailored products for the Operating Forces.

Oceanographic survey operations require many types of ships. U. S. N. S. Bent, center above, is one of the Navy's newest oceanographic survey vessels.

SUPPORTING SERVICES

SHIPS AND AIRCRAFT

Nineteen Navy surface ships, a submarine, and four airplanes are assigned fulltime to the collection of oceanographic, hydrographic and other related geophysical and meteorological data. These include 4 AGOR class ships utilized by Navy Labs and the Naval Oceanographic Office in support of their programs. Also included are 15 AGS class ships operated by the Military Sea Transport Service and appropriate Fleet Commands which perform both oceanographic research and hydrographic survey functions. The aircraft, Projects MAGNET, BIRDS EYE, and ASWEPS are operated by Air Development Squadron Eight located at the U. S. Naval Air Station, Patuxent River, Maryland. This constitutes one of the largest oceanographic fleets in the world. It is being modernized by the replacement of older ships, not particularly well suited for oceanographic surveys, with new ones specifically designed and instrumented for oceanographic work.

In addition to the fulltime fleet, other ships are under contract to the Navy for special oceanographic projects. Still other ships of the Navy and the U. S. Coast Guard are used on an opportunity basis to obtain oceanographic information to meet the defense requirements of the Nation.

The five aircraft of Weather Reconnaissance Squadron FOUR (VW-4), the "Hurricane Hunters" for the Atlantic Fleet, and the eight aircraft of the Airborne Early Warning Squadron ONE (VW-1), the "Typhoon Trackers" for the Pacific Fleet, provide timely meteorological information supporting oceanographic operations, particularly in the area of predictions. Ice reconnaissance in support of MSTS operations in the Baffin Bay and Bering Sea operating areas is performed by Patrol Squadron aircraft.

CALIBRATION RANGES AND FIELD GROUPS

Calibration ranges for sea gravity meters have been established in cooperation with the U. S. Coast and Geodetic Survey in the

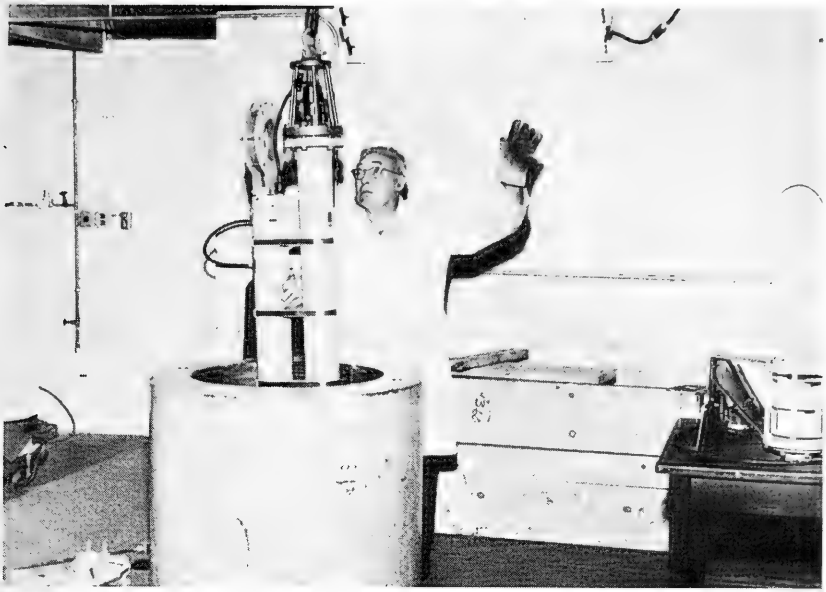
Gravity meter being lowered to the seabed to obtain measurements in establishing gravity range.

Chesapeake Bay and off the coasts of California, New Jersey, and Rhode Island. These ranges are used to calibrate the total gravity meter systems as installed and operated aboard ships. In addition, the Navy has cooperated in establishing land gravity meter calibration ranges in North America and Europe.

A Pacific Coast Support Group has been established by the Naval Oceanographic Office at San Diego to provide logistic, operational, and technical support to oceanographic operations in the Pacific Ocean. Fulltime oceanographic representatives are maintained at Honolulu and Norfolk to provide continuing close liaison with the Fleet Commands and the Submarine and ASW Forces. In addition, a team of scientists, engineers, and technicians is assigned to Vietnam to solve the special oceanographic and charting problems arising there.

INSTRUMENTATION

The Oceanographic Office operates a complete test, calibration, and repair facility for oceanographic instruments. Because of



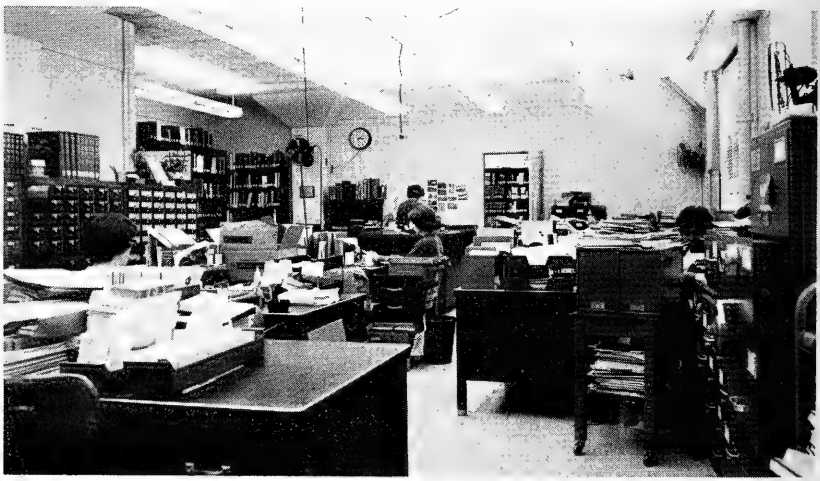
Preparing to test oceanographic instrument under pressure.

Calibration of reversing thermometers.

the large number of ships instrumented for oceanographic work and the diversity and complexity of the devices used, this is the largest and most complete facility of its kind.

LIBRARY

Established in 1871 with the approval of the Secretary of the Navy, the Oceanographic Office Library has nationally and internationally recognized resources relating to the marine sciences. The present collection, the most comprehensive in its subject area within the Department of Defense, consists of over 100,000 current and retrospective publications collected from world wide sources, with new information being added daily. About 700 periodicals are received regularly by the Library. There are also special collections of all Office publications, of all publications issued by the International Hydrographic Bureau since its founding in 1921, and of foreign sailing directions since 1920. At least 30 percent of the Library's holdings are obtained from sources outside the United States. Library services are available, not only to personnel of the Oceanographic Office, but also to others on a need-to-know basis. There is an active interlibrary loan service. Translations of selected foreign oceanographic publications are prepared, and



Still growing at a rapid rate, the library of the Naval Oceanographic Office is the largest of its kind within the Department of Defense.

copies supplied to other oceanographic institutions on an exchange basis.

The chart library, which serves as the Department of Defense Nautical Chart Library, houses perhaps the largest and most up-to-date collection of nautical charts in existence for the oceans and the foreign waters of the world. This working collection is used primarily as source and reference material in the compilation and revision of nautical and aeronautical charts and navigational publications.

Original manuscripts of all U. S. Navy hydrographic surveys dating back to the mid-19th century are available for reference at the National Archives in Washington, D. C. As a rule, the field survey sheets, or "smooth sheets" as they are commonly called, are on much larger scales than published nautical charts of the same area and show a greater degree of detail. They thus provide an invaluable unpublished data source for research and ocean engineering and development purposes.

COMPUTER PROCESSING OF DATA AT NAVOCEANO

The main computers within the Naval Oceanographic Office are an IBM 7074 with 10,000 words of core memory and a CDC 3100 with 16,000 words of core memory. Smaller specialized computers include a CDC G15D with drum memory for low volume geodetic problems, a CDC 8090 used principally to tape weather data from a teletype circuit, and a TRW 130 (AN/UYK) for checking out shipboard programs. Computer systems of other activities which are used regularly by NAVOCEANO are IBM 7090/7094, CDC 3800, and CDC 1604. Other specialized outside equipment, such as the SC 4020 Cathode Ray Plotter, is used for several projects.

A number of CALCOMP general purpose plotters and a Benson-Lehner plotter are used for many applications. For automated high precision charting, a large Concord Control Plotter is available.

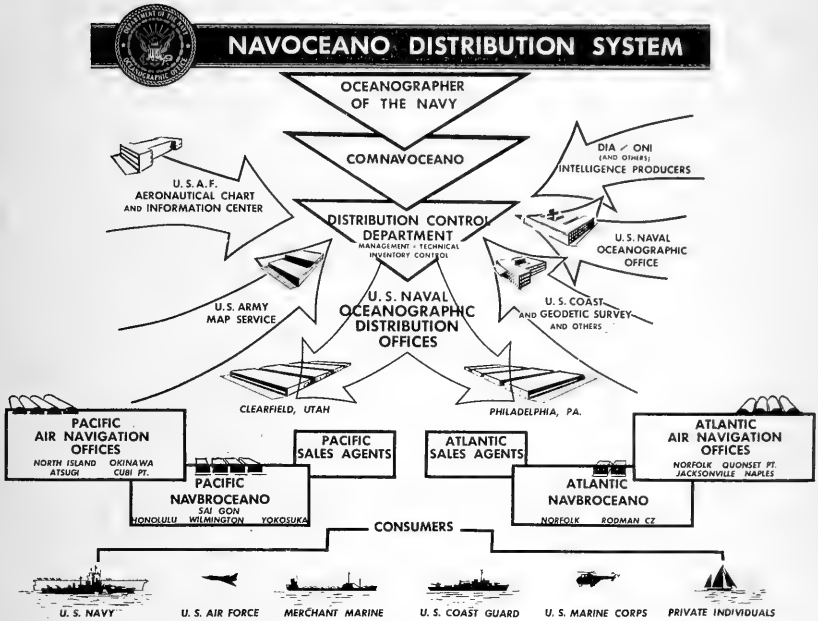
Computer programming is provided by staffs of mathematicians, analysts, and programmers for both in-house and shipboard systems. Open shop instructions are given to scientists and engineers who wish to program in FORTRAN. A library of

Computers are increasingly used in oceanographic operations.

standard general purpose programs or subroutines and other software packages is maintained by a systems staff.

PRODUCT DISTRIBUTION

The Naval Oceanographic Distribution System operates under a direct delegation of statutory mission through the Secretary of the Navy to the Commander, Naval Oceanographic Office. The objective of the distribution system is to provide the Fleet with all required mapping, charting, geodetic, and oceanographic publications produced by the Department of Defense agencies, the Coast and Geodetic Survey, the Coast Guard, and selected foreign countries, and at the same time make Navy products available to the merchant marine and other users.



Distribution system of the Navy for oceanographic charts and publications.

To accomplish this objective, a worldwide system consisting of 16 field distribution points and more than 150 commercial sales agents has been established. Inventory management over the more than 90,000 different published items included in this distribution system is accomplished by use of Automatic Data Processing equipment and Automatic Digital Network (AUTODIN) facilities. As a result of agreements between the Director of the Defense Intelligence Agency, the Director of Naval Intelligence, and the Commander of the Naval Oceanographic Office in April 1965, responsibility for the inventory management and distribution of all finished intelligence materials to fleet units was included in this system.

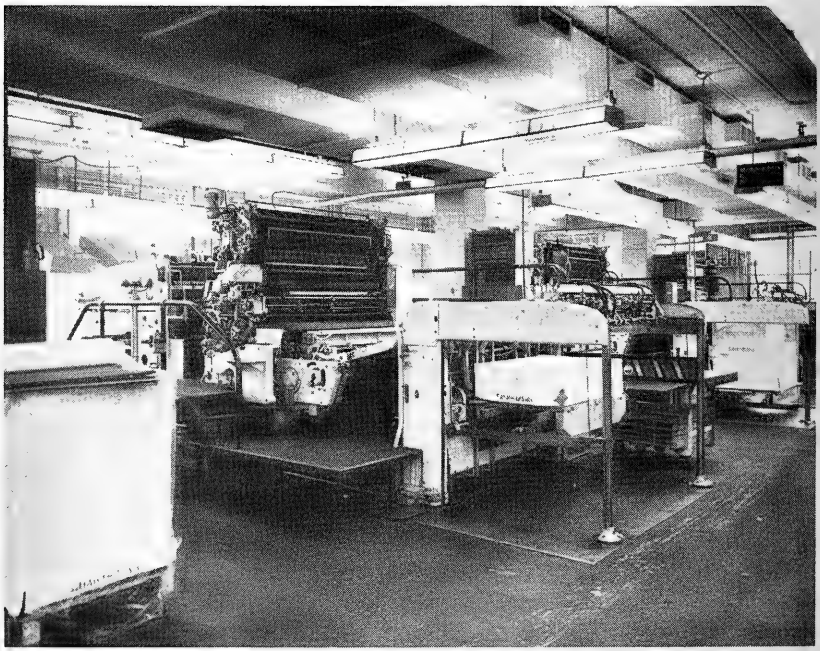
Research and development work, underway and planned, in support of the distribution system involves the greater use of miniaturization and automation, including a system of applying corrections to nautical charts by a screen printing process. In the field of operations research, plans provide for the devising of a transportation model to assure the most efficient and

economical redistribution pattern among the oceanographic distribution depots throughout the world.

LITHOGRAPHIC REPRODUCTION

Lithographic reproduction is no stranger to the Naval Oceanographic Office, having been introduced in 1835, and updated in 1885 when a printing press used to print "Notice to Mariners", and other urgent nautical information, was installed. In 1912, a press was installed which used zinc metal plates, incorporating chart images which were photographically transferred and affixed to the plate, hence the term "photolithographic plate". This press was then utilized to print multi-color charts.

Over the years, the Oceanographic Office has expanded its lithographic printing capabilities to where full-time use is now required of three single-color and five two-color high speed precision offset printing presses. A comparison of the capacity



Printing plant required to produce the oceanographic charts of the Navy.

in 1837, when fifty impressions a day per press was considered adequate, to the present capacity of one hundred and ten thousand impressions per day reveals the dramatic increase in the lithographic reproduction capability of the Office. A stringent quality control program is maintained to uphold the high graphic and editorial integrity required of products which are used to guide ships carrying valuable cargo on the oceans of the world.

In addition to the conventional printing capability noted above, and as a direct result of the Vietnamese military action, the Office has been called upon to expedite chart production even further. As a result, chart substitutes are being produced, using pseudo color separation techniques in combination with more conventional procedures. These charts are now printed on a plastic base paper substitute and have been widely acclaimed by users.

A recently installed sixty-inch process camera together with four 48-inch process cameras make a very imposing capability. The vastly improved drafting and engraving techniques and materials and the acquisition of phototypesetting equipment have also contributed toward the dramatic growth in the printing of extremely accurate nautical charts and publications now issued by the U. S. Naval Oceanographic Office.

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INTERNATIONAL COOPERATION

We shall bring to the challenge of the ocean depths —as we have brought to the challenge of outer space —a determination to work with all nations to develop the seas for the benefit of mankind....

—President Lyndon B. Johnson

In carrying out its mission of surveying and charting the seven seas, the U. S. Naval Oceanographic Office is in an ideal position to promote international cooperation and to strengthen international good will. In fact, the successful accomplishment of its mission is directly dependent on the strong, continuing ties established with the maritime nations of the world. The hydrographic and oceanographic data collected by the Office, and the charts, publications, and other products issued reflecting these data, have one main purpose—that of adding to man's knowledge of the oceans for the benefit of mankind.

International cooperation of a high degree is essential to the success of efforts such as Project MAGNET, where there must be assurance of adequate airfields suitably spaced throughout the world. It is essential to the conduct of oceanographic and hydrographic surveys of the high seas and foreign waters. It is particularly important to guarantee full exchange of hydrographic and navigational information required for the safety of life and property at sea. Finally, it is essential to the development of new products and new techniques.

At the international level, cooperation consists of active participation, consultation, and liaison with numerous international organizations. The Oceanographic Office is a leading participant in the work of the International Hydrographic Bureau in Monaco, which is one of the oldest international bodies and has been recognized as the principal coordinating force in international hydrography. Under the auspices of the Bureau, the principal nations of the world have launched a major drive to prove or disprove reported doubtful shoals throughout the oceans of the world and to add to the world's knowledge of the ocean depths by an international effort of bathymetric data collection, com-

pilation, and dissemination. Another major cooperative effort has been exerted through the International Oceanographic Commission. The Navy has also participated in major international programs such as the International Geophysical Year, the International Indian Ocean Expedition, and the International Cooperative Investigation of the Tropical Atlantic, among others. Less well known, but equally important, are the various cooperative enterprises undertaken bilaterally with the institutions of other nations.

In the field of hydrography the Oceanographic Office maintains a continuing program of chart and navigational information exchange with other nations. Under bilateral agreements, it conducts surveys of foreign waters with the participation of the host nations, thus adding significantly to international understanding, development, and progress. As of September 1967, bilateral facsimile chart reproduction agreements were in effect with twelve nations (Brazil, Canada, the Federal Republic of Germany, France, Great Britain, Italy, Japan, Mexico, the Republic of the Philippines, Portugal, the Republic of Korea, and the Netherlands); Harbor Survey Assistance Program agreements were in effect with five nations. Under the latter, harbor surveys are conducted jointly, not only for the purpose of producing improved charts for commerce and national economic development, but also to enhance the in-country hydrographic surveying capability.

Oceanographers from the Naval Oceanographic Office have participated in exchange of scientists agreements with the United Kingdom and Australia. Such exchanges of oceanographers have been mutually beneficial in the fields of long range sonar, oceanographic surveying, and oceanographic instrumentation. In this same vein the Naval Oceanographic Office annually conducts training for foreign military and civilian personnel. Hydrographic Engineering and Basic Oceanography are taught jointly as a one-year course while Applied Oceanography is a four-month course. During the past twelve years, 220 students from 35 foreign nations have graduated from these courses. Many graduates of this curriculum have risen to prominent positions in their own naval and maritime communities. The rapport this program has fostered between hydrographic

offices of the world and the resultant better working relationships attest to the success of this venture.

Considerable international cooperation exists within the sea ice program. In a special effort to assess the maximum ice budget through aerial and satellite reconnaissance surveys, Norwegian scientists participated in several U. S. Naval flights in early 1967. There has also been cooperation and exchange of data with West Germany and Japan. Interest in future programs has been expressed by Swedish, Finnish, and Canadian activities. Invitations to participate in aerial reconnaissances were extended to the Soviet Arctic and Antarctic Research Institute. Cooperation with Canada in its Polar Continental Shelf Project is planned.

International cooperative efforts are effected through the Department of State and coordinated as appropriate with other federal agencies with allied interests.

THE NATIONAL OCEANOGRAPHIC DATA CENTER

The National Oceanographic Data Center (NODC), administratively under the Naval Oceanographic Office, is a processing center and archive for the nation's oceanographic data. The concept of such a center of national marine data was developed ten years ago in response to the basic need for providing a focal point for collection and dissemination of marine data generated by a diversity of Government, academic, and private oceanographic activities—both national and foreign.

The Data Center, which opened in 1961, is sponsored by ten Federal agencies, including the Department of the Navy. It receives policy guidance from an advisory board composed of representatives of its ten Federal sponsors and the National Academy of Sciences. It is thus truly a national center, and its programs are based on nonmilitary as well as defense requirements.

The archives and services of the Data Center are important to the Navy in providing data describing the marine environment and marine phenomena.

Oceanographic (physical-chemical) station data and bathythermograph data are, at present, two of NODC's largest archive files. Elements included in the station data file are described in the Data Center's publication M-2, Processing Physical and Chemical Data from Oceanographic Stations. Charts displaying the location and number of station data observations in all ocean areas can be found in NODC's publication C-3, Inventory of Archived Data.

The bathythermograph data are stored as analog temperature-depth records. These are currently being digitized. The majority of the observations thus far digitized are for the Indian and North Pacific Oceans.

Also archived are drift bottle data, bottom sediment information, and marine biological observations. For other types of data, several information-retrieval systems are under development.

Requested material is normally provided on a reimbursable basis, but there is no charge for nonrecurring requests for small

amounts of data and information. In addition, visitors are welcome to use reference archives at NODC without clearance or charge.

Magnetic tape systems are designed for selective retrieval for three-dimensional space and time. An IBM 7074 and 1401 are being used at present. Data are available as machine printouts, punched cards, or magnetic tapes.

The Data Center provides data analysis and evaluation services tailored to the requirements of the requester. Information specialists search libraries to provide bibliographic references, abstracts, and documents. A number of bibliographies of interest to the Navy have been prepared.

The Data Center publishes a monthly NEWSLETTER which is available to those interested in the marine sciences. Other publications include oceanographic data processing manuals, catalogs of holdings, and some special publications such as data reports, atlases, and progress reports.

In return for receiving data recorded on standard forms, the Center returns data in the form if machine listings, including computed values when applicable. In addition, the Center enters into agreements to provide data of specific types and for specific areas in return for similar data. One of NODC's major activities is the development of systems for more efficient and rapid processing, archiving, and retrieval of marine physical, biological, geological, and geophysical data. Systems now in use include those for oceanographic station data, bathythermograph data (analog and digital), and certain marine biological and geological data. Systems are under development for estuarine and nearshore data; for marine chemical, biological, and geological data; and for data on subsurface currents.

EPILOGUE

The comprehensive oceanographic operations just described must be considered as efforts in support of a multitude of diverse goals, never as ends in themselves. Whether they result in new charts to help insure the safe passage of seaborne commerce or in environmental prediction to enhance the kill probability of our ASW forces, they are accomplished to meet a clear user requirement. As man rushes to exploit offshore resources, as new types of ocean craft are developed and standard vessels become larger, and as the weapons systems which enter the ocean environment become more powerful and sophisticated, these user requirements will become ever more demanding. The Navy's program in oceanographic operations stands ready to meet the challenge.

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