Chapter 1
Summary and Findings

OVERVIEW

In the past two decades oceanography has yielded a treasure of knowledge about the ocean and its resources. Once viewed as relatively static, the ocean is now seen as a dynamic environment actively affecting climate, geology, food and resource supply, and environmental quality. Continued research and monitoring of the ocean to understand further its influence on the Earth has become a vital endeavor.

Oceanography itself is a large, diversified field of investigation, encompassing many disciplines. In this report, the term *oceanography* includes all of the federally supported activities (except classified military work) that involve collecting data about the oceans and conducting experiments in the oceans. These activities range from standard surveys needed for producing maps and charts, to data collection on the sea surface or above for weather predictions, to basic research or experiments conducted by universities and Federal agencies on marine biology, chemistry, geology, geophysics, meteorology, and physical oceanography.

Determining how to manage such oceanographic activities, however, involves considerations not present 20 years ago. For, in addition to new information, the thrust in oceanography has generated new programs and technologies, dramatically changing the practice of ocean science and data collection. Scientists no longer work in isolated groups, using simple equipment. Instead, research teams from Government, industry, and academia share information gathered from technologies ranging broadly in complexity from sample bottles to satellites. Oceanographic programs now require long-range planning, considerable funding, sophisticated data management and analysis, specialized personnel, and coordination of effort among agencies whose program functions and needs frequently overlap. Increasingly, oceanographic research involves international cooperation particularly in global monitoring efforts such as those needed for climate studies.

Federally funded ocean research is conducted by private research institutions, universities, and Federal agencies — all with varying goals and functions. These organizations use a variety of oceanographic technology, defined for this assessment as stations, vehicles, instruments, and equipment used in oceanography. This includes completely engineered systems, innovative technologies, and new inventions as well as adaptations of equipment originally developed for other fields.

This report details the OTA assessment of present capabilities and future needs for federally funded ocean research, surveying, and monitoring. The assessment focuses primarily on the programs of the eight Federal agencies most actively engaged in oceanography, and it addresses the problems of effectively and economically using and maintaining appropriate oceanographic technology.

To complete the assessment, OTA requested that each Federal agency engaged in oceanographic research provide a description of its present programs, budgets, and plans, particularly as they related to providing technology for oceanographic research and data collection. The responses from these agencies provided the necessary information base for this assessment. Subsequent analyses of technologies and selected national programs provided the assessment findings and identification of issues.

Some agencies were not included in the assessment—in particular, the U.S. Army Corps of Engineers and the Maritime Administration in the Department of Commerce. The missions of these two agencies were considered of only marginal relevance to the principal subjects addressed. Although the Corps of Engineers was not covered in the program discussions, some of its work is noted in this report where appropriate. Military systems and classified information were not covered at all. The following sections are summaries of and findings from each of the major chapters in this report. The summaries highlight important topics discussed later in detail, and the findings are from the analyses performed during this assessment. References and other documentation appear in the subsequent chapters.

AGENCIES, PROGRAMS, AND BUDGETS

Summary

To conduct systematic and reliable oceanographic studies, the Federal Government has a sizable investment in programs and supporting technology. At present, the Federal ocean effort consists of approximately 90 programs conducted primarily by the following eight Federal agencies:

- U.S. Coast Guard (Department of Transportation),
- Department of Energy (DOE),
- Department of the Interior (DOI),
- Environmental Protection Agency (EPA),
- National Aeronautics and Space Administration (NASA),
- National Oceanic and Atmospheric Administration (NOAA) (Department of Commerce),
- National Science Foundation (NSF), and
- U.S. Navy (Department of Defense).

The oceanographic programs conducted by these agencies receive varying levels of emphasis. To simplify a review of the large number of ocean programs, OTA has classified them into nine broad categories according to their primary emphases:

- ***Technology Development*** programs created specifically to provide technological support to Federal programs in oceanography, including the design, construction, testing, and deployment of hardware and other equipment.
- ***Ocean science*** programs to advance scientific knowledge.
- ***Weather and climate*** programs dealing with the collection and analysis of oceanic and atmospheric data.
- ***Energy and mineral resources*** programs to explore and develop nonliving natural resources for the ocean.
- ***Environmental quallity*** programs to improve or enhance the quality of the oceans, Great Lakes, and coastal regions.
- ***Fisheries resources*** programs to develop food resources from the oceans and the Great Lakes.
- ***Public service*** programs organized especially to communicate with the public and to assist the public in the solution of ocean-related problems, including marine safety.
- ***Managemen t and enforcementt*** programs to manage or assist in managing marine resources or to enforce laws and regulations pertaining to the coastal and ocean environments.
- Agency ***support*** programs to support either the efforts and missions of the agency in which they are located or the efforts of other Federal agencies,

Since many programs perform tasks outside their primary missions, a single classification does not always adequately represent a total program. For example, some agencies support general technology development efforts, while others, like the U.S. Navy and U.S. Coast Guard, have strong technology development programs which are directed only toward their own mission needs.

The interdependence of programing and technology creates problems for Federal agencies when programs identify needed technologies that require many years of development to become operational. Such long leadtimes mean that agencies need to engage in long-range planning for research and to demand close cooperation among prospective technology users.

Estimated **Expenditures of Federal Marine Programs: by Agency–by Category-Fiscal Year 1980**
(in millions of dollars)

	Agency								
Category	Coast Guard	DOE	DOI	EPA	NASA	NOAA	NSF	Navy	Total
Agency support	—	$ 2	$ 70	$ 4	–	$ 68	–	$139	$283
Energy and mineral resources		43	44	—	—	—	—	—	87
Environmental quality	$ 1=	18	4	28	–	20	–	–	206
Fishery resources	—	—	12	—	—	45	—	—	
Management and enforcement	477	—	41	—	—	130			648
Ocean science	—	—	—	—	—	4	$106	88	198
Public service	686	–	19	—		214	—	—	919
Technology development	59	–	–	–	$24	13	–	10	106
Weather and climate	—	—	—	—	—	20	–	–	20
Total	$1,358	$ 63	$190	$ 32	$ 24	$514	$106	$237	$2,524

SOURCE: Office of Technology Assessment

Through the review and budget process, Congress exercises its authority to continue support of ongoing programs, to redirect Federal efforts, to initiate new programs, and to discontinue existing programs. In fiscal year 1980 the total Federal expenditure for ocean programs studied by OTA was $2.5 billion. Three agencies–Coast Guard, NOAA, and Navy– accounted for over 80 percent of that total. Based on funding, the principal program areas of emphasis for each agency appear to be as follows:

- Ž Coast Guard — public service, management and enforcement;
- DOE — energy and mineral resources, environmental quality;
- EPA —environmental quality;
- DOI — agency support, energy and mineral resources, management and enforcement;
- NASA — technology development;
- Navy —ocean science, agency support;
- NOAA — public service, management and enforcement, weather and climate, fisheries resources, agency support;
- NSF— ocean science.

Findings-Agencies, Program, and Budgets

- The 90 programs in the total Federal ocean effort are often scattered among different agencies whose missions or goals appear very similar. Overlap and duplication of effort does occur in some areas OTA has studied and is very difficult to identify.
- Of the total Federal expenditure of $2.5 billion for the ocean programs studied by OTA, 30 percent was spent for the technology, science, and applied research programs that this report addresses.
- With the exception of technology in the military sector and of satellites in NASA, development of new technology that can be used by a wide range of users in different programs and agencies is not focused in any one agency.
- There is no consistency among agencies in their plans for future program or capital expenditures. Some agency plans include an inflation factor, and some do not. Some agencies plan for possible future technology needs, while others do not include any new expenditures in their plans until a new item is firm. Some program plans include substantial contingencies and related activities, while others do not.
- From the information on future plans for technology and oceanography, provided to OTA by the eight agencies surveyed, OTA identified only two new initiatives — the Ocean Margin Drilling Program and the National Oceanic Satellite System–which include plans for substantial technology and funding requirements. Other proposed programs, like the climate program, have yet to establish such requirements, but must nevertheless be considered when planning future budgets.

TECHNOLOGY

Summary

Oceanographic research is complex, and no single technology system is best suited for its tasks. Thus, a combination of types of systems and techniques is usually the best approach for collecting ocean data and for conducting research experiments.

Federally supported technology systems used in oceanography include:

- ships
- submersibles
- remotely operated vehicles
- buoys and moored systems
- equipment and instrumentation
- satellites
- aircraft
- oceanic data systems

Ocean research covers such a broad spectrum of activities that no logical generalizations can be applied when comparing the suitability or cost effectiveness of different technologies. Therefore, various ships, other vehicles, and instrument systems can only be evaluated in the context of specific research tasks to be accomplished.

A few concepts regarding various technologies can be explored, however, when comparing scales of space and time, when comparing research experiments to routine data collection, and when comparing basic research to applied research.

Ships are the only general-purpose vehicles for carrying oceanographers to sea to conduct experiments. They are both transport vehicles and floating laboratories, with living accommodations for scientists and crew. They are necessary for taking physical and chemical samples of the ocean, the sea floor, and the biota; for deploying instruments in the ocean environment; and for collecting data over a large ocean area, as in making subbottom profiles of the geology beneath the sea floor. In addition, ships are used to implant and support other vehicles, submersibles, data buoys, remotely operated stations (fixed or floating), and diving systems.

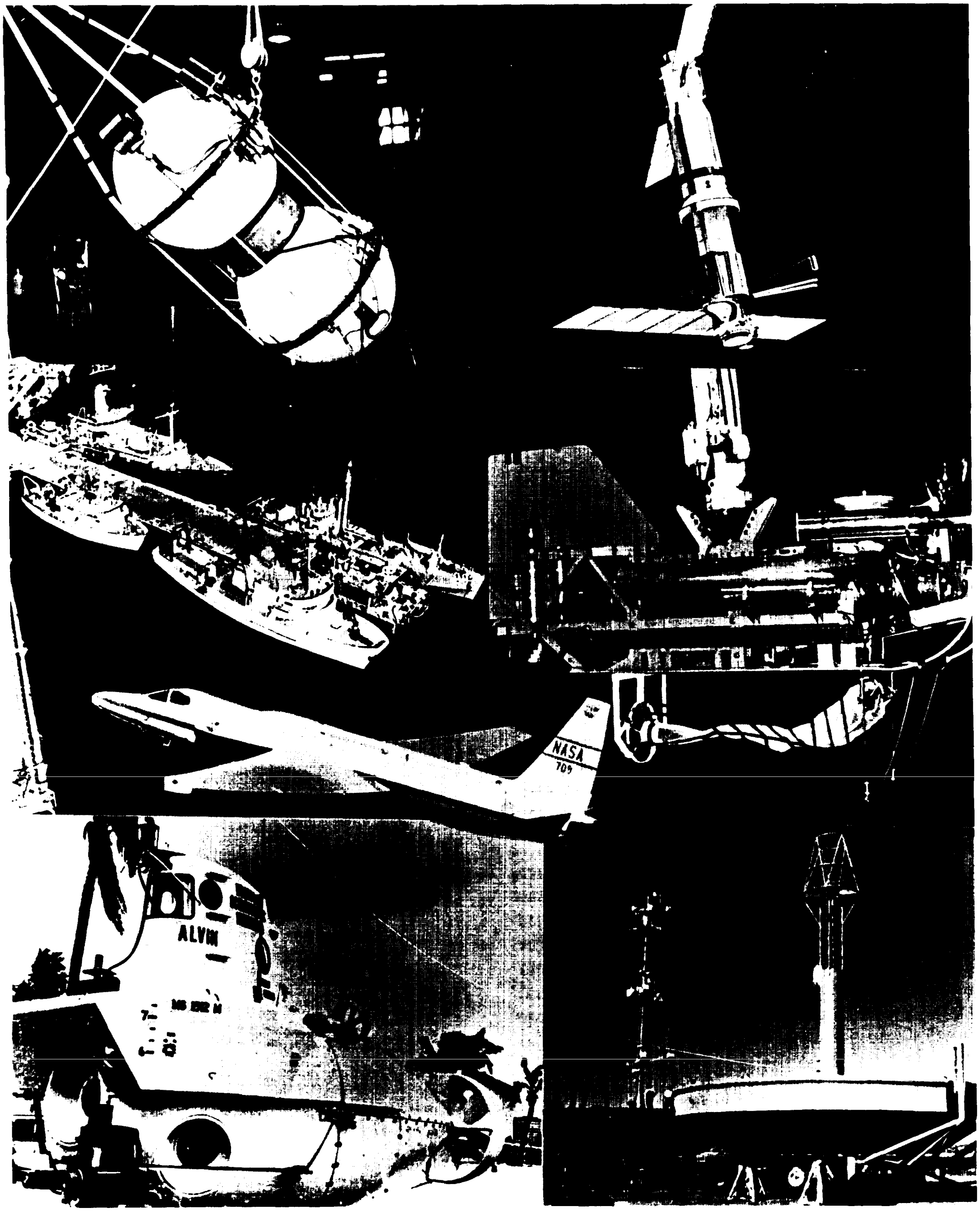
The federally supported oceanographic fleet of about 80 ships is comprised of a variety of types and capabilities and is supported by many agencies and programs. It is a fleet in name only because the ships have a variety of operating systems and their categories of use are usually not interchangeable.

Submersibles are vehicles that can carry a few scientists and instruments to the ocean bottom. They are invaluable for conducting experiments where human observers "on the spot" in the ocean are most important. In the past decade, submersibles were considered the most promising research tool of the future and much successful research was done with them. Today, only one manned, deep-diving submersible, the *Alvin, is* federally supported for nonmilitary research but studies of future submersible needs are underway.

Remotely operated vehicles (ROVs) cover a variety of unmanned, underwater vehicles controlled from the surface. They are used for many specialized tasks and are recently becoming of increasing value for oceanographic research and monitoring.

Buoys and moored systems capable of unmanned data collection are used most often when instruments must be placed in the ocean to collect data at and below the surface over a long period of time. They are thus invaluable for certain kinds of meteorological and oceanographic observations. Self-sustained, special-purpose buoys and moored systems have at times been developed as the principal technology for a research program, while in other cases they are part of the more standard oceanographic equipment and instrumentation carried aboard research ships.

Oceanographic equipment and instrumentation include many kinds of items, from shipboard-installed equipment and portable instruments handled from ships to permanently mounted sensors aboard buoys and other stations. Shipboard equipment includes winches, cables, cranes, and laboratory facilities. Multipurpose research ships, contain a combination of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fixed equipment, permanent instrumentation, and special instruments for each experiment. Single-purpose data buoys have built-in permanent instruments and data-handling systems.

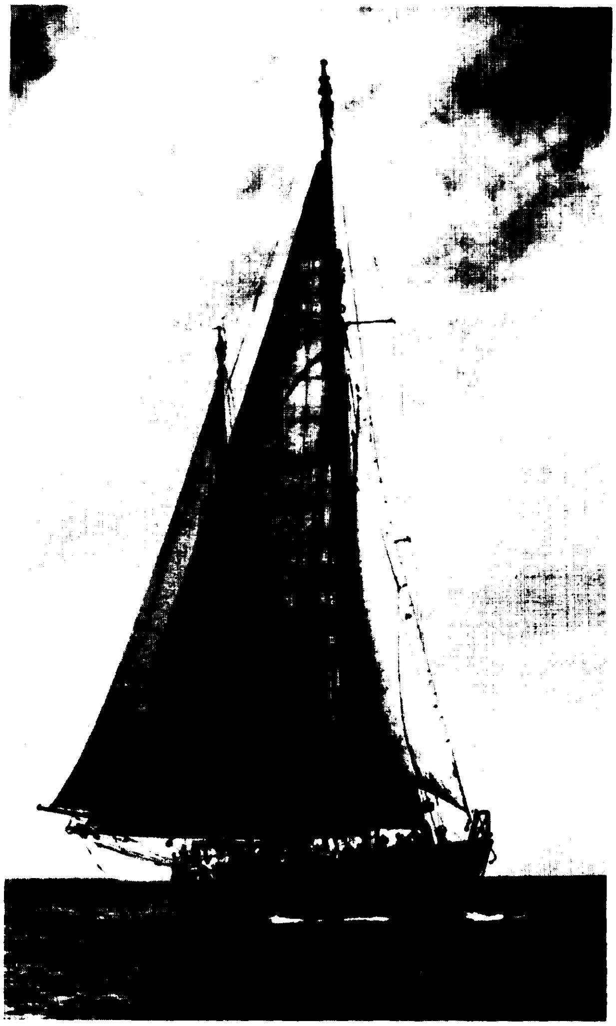
Thousands of separate oceanographic instruments are in use today. Standard shipboard instrumentation includes navigation equipment and some meteorological and standard ocean parameter sensors. Because many ships, such as those of the academic fleet, are now used by scientists for a large variety of research projects, it has become prudent to provide guidelines for standardization of some equipment and onboard data systems.

Satellites provide worldwide coverage of ocean surfaces and can provide data on a timely basis. Limited at present to covering sea-surface phenomena, new satellite instruments will give more comprehensive and accurate information. Certain surface phenomena related to large-scale ocean processes, sea-surface data on a global grid, and other large-scale ocean research can only be accomplished at reasonable cost by satellite. As valuable ancillary tools, satellites are routinely used for navigation and data-transmission purposes.

Aircraft are used less in ocean research, but their coverage and speed of data taking are valuable for laying a line of air-droppable instruments, detecting ocean pollutants, measuring gravitational and magnetic fields, measuring sea-surface conditions with high resolution, investigating hurricanes, and conducting research on marine mammals.

Oceanic data systems include the data handling, archiving, processing, and disseminating networks that now provide services to Federal agencies and other users. Most oceanographic data from satellites, ships, buoys, and other sources are archived by NOAA's Environmental Data and Information Services. The recent large flow of satellite data into the existing system has called attention to the growing problem of providing modern technology and adequate management systems for the handling of oceanic data.

This report does not cover certain categories of ocean technology that either are not a significant part of existing Federal programs or are ancillary to this study's focus on major systems used in the field. Some examples of such ocean technology which may be significant to many future programs are sail-powered ships, satellite data telemetry and communication systems, satellite navigation systems, and computers. Studies within the agencies and the National Academy of Sciences/National Research Council address future needs for these technologies.



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Findings-Technology

- Ships are the vehicles from which most research on the ocean has been conducted. The addition of new ways to examine the ocean has not replaced the need for ships, but has instead identified new and more productive ways to use these vessels.
- The Federal research and survey fleet is facing a shortage of ship operating funds. Fuel, maintenance, and overhaul costs are all escalating rapidly. NSF may be forced to reprogram capital funds to operating accounts and/or to lay-up more ships now in the academic fleet.
- There is a general erosion of capabilities in the Federal fleet which will probably continue in the future. The number of ships in the fleet is decreasing, and ships are not being adequately maintained or upgraded. The erosion of capability is most apparent in deepwater academic ships but extends to all vessels and affects their general condition and the instrumentation and equipment on board.
- Over the next 20 years, the Federal fleet of about 80 ships will require replacement or major rehabilitation. The replacement cost for these ships is about $1.5 billion in 1980 dollars. The two largest fleet groups are the NOAA fleet and the academic fleet, which is operated by various oceanographic institutions. The NOAA fleet is generally older and may require earlier attention to replacement or rehabilitation.
- Many ocean research programs require cooperative efforts between countries and thus coordination of capabilities. The total number of oceanographic ships operated by other countries is difficult to determine precisely because many are used for several other purposes. However, OTA has determined that together the U.S.S.R. and the United States operate about 60 percent of the total oceanographic research and survey ships in the world. Only the Russian fleet equals that of the United States in number of ships, and in fact, exceeds it in number of large ships.
- It appears that, in the future, increased attention will be given to remotely operated and other unmanned vehicles, buoy systems and moored systems, as appropriate, for many specialized ocean data collection and monitoring tasks. New data links with satellites are making buoys and moored systems more useful. Advanced buoy- and moored-system technology, developed within several research programs, could be even more widely used by the mission agencies.
- Instrumentation for oceanography and data collection is generally good especially for those programs that have supported its development and use over long periods of time. Increasing sophistication and reliability of microelectronic technology holds promise for improved instrument systems.
- There are no dedicated oceanographic satellites in orbit today that provide coverage of the world's oceans with modern sensors. *Seasat*, an oceanographic research satellite launched in 1978, lasted only 3 months. The *Nimbus* series of research satellites that provides coastal zone ocean data is being phased out. If the new NOSS program is supported as planned, only part of the *Nimbus* and *Seasat* capabilities will be reinstated.
- Aircraft continue to be used for specialized ocean data collection and surveying in certain programs. Some remote sensors, when used in local areas, are more effectively employed by aircraft than by satellite.
- Existing oceanic data systems are not meeting the research needs of many oceanographers. New satellites and other remote-sensing systems with large data volume potential will make this problem more critical in the future.

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CRITICAL REVIEW OF SELECTED NATIONAL PROGRAMS

This assessment has identified for special analysis the following four national programs that are representative of the institutional and technological opportunities and problems facing Federal efforts in oceanography.

- Ocean Margin Drilling Program (OMDP)
- National Oceanic Satellite System (NOSS)
- Federal Program in Fisheries and Marine Mammals
- National Climate Program

Two of these – OMDP and NOSS – are major new ocean program initiatives for fiscal year 1981. The drilling program is principally a scientific endeavor with unique private industry participation. NOSS combines the operational needs of military and civilian satellite mission agencies with related scientific investigations. Both programs involve large, new technology systems.

The other two programs exist by congressional mandate. The first, the Federal Program in Fisheries and Marine Mammals, has been in place for a long time, but new legislation has forced its research to be directed more toward resource management problems. The second, the National Climate Program, has been recently directed by legislation to address national needs for delivery of a climate prediction capability and public services that result from that capability. The technology required for each program is a mixture of conventional systems in use for a long time and new developments. The latter could significantly advance future research.

Many other national programs, such as those in marine pollution, offshore energy development, or ocean minerals, could be addressed in a similar manner, and it is hoped that this review will help identify a useful structure for future analyses.

Ocean Margin Drilling Program

Summary

To gain more knowledge of the nature and origin of the Earth, NSF has begun an important new $700 million, 10-year scientific program of marine geologic investigations. This effort, known as the Ocean Margin Drilling Program (OMDP), resulted from years of planning and evaluation by academic and Government-sponsored committees. It is both a continuation of deep-ocean drilling under NSF's Division of Earth Sciences and a new thrust to investigate the geology of continental margins and ocean crust where very deep drilling is necessary to penetrate unknown regions. Some of the margin regions that are the borders between Continental Shelves and the deep ocean might contain substantial oil and gas resources, but sufficient evidence has not yet been collected to confirm this.

The success of OMDP is contingent on major development of advanced ocean technology, such as deep-drilling, coring, and well-control techniques and hardware. It will be necessary to focus a considerable effort on technology development in the early stages of this program in order to assure that its science goals can be accomplished.

Early planning for an ocean margin drilling program began in 1973 and continued with the Conference on the Future of Scientific Ocean Drilling held in Woods Hole, Mass., in 1977. In 1978 an NSF advisory group reviewed the scientific merit of an ocean margin drilling program, and in 1979 an NSF blue-ribbon committee addressed the national interest in such an effort. More recently, at an NSF-sponsored meeting in March 1980, an initial ocean margin drilling model program plan was developed. That plan is the basis of NSF's OMDP. Scientific objectives stated in the plan are to investigate: 1) passive and active continental margins, 2) the Earth's crust beneath the deep ocean, and 3) the deep-sea sediments.

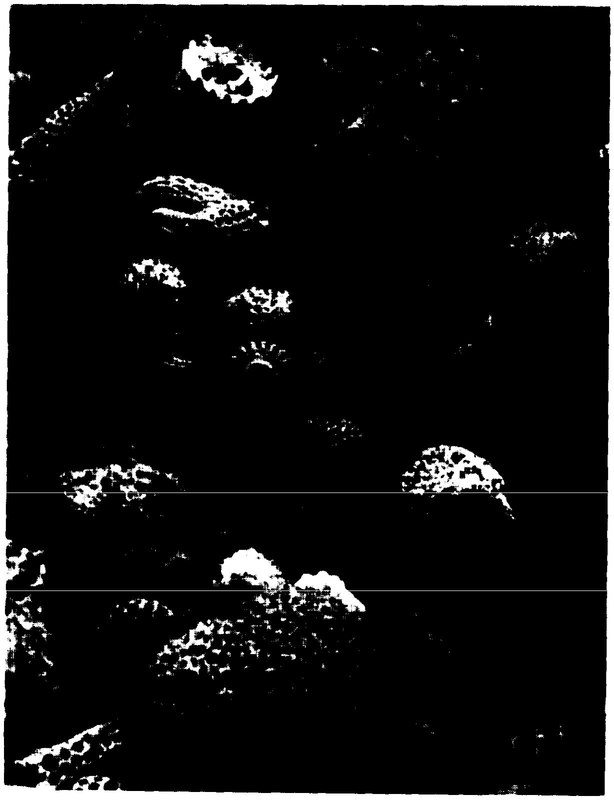
The model program allots 4 years for preparation and 6 years for drilling. It also presents an estimate of program costs. The program includes 10 sites and 15 holes, the deepest of which (Southeastern Gulf of Mexico) is about 21,000-ft below the sea floor in about 11,000 ft of water. Two model sites are in the Pacific Ocean, one is in Antarctica's Weddell Sea, and others are in the Atlantic Ocean and the Gulf of Mexico.

As planned, the program will be jointly funded by the Federal Government and the petroleum industry, each sharing 50 percent of the costs over the 10-year period. Several major petroleum companies expressed interest in participating and, by October 1980, eight had agreed to fund the first year's planning effort. The technology plans include both the conversion of the Government-owned *Glomar Explorer* to a deep-drilling ship as well as the development of a riser system* for controlled drilling in maximum water depths of 13,000 ft and in maximum depths below the sea floor of 20,000 ft.

Findings

- NSF and other Federal agencies have stressed the unique nature of OMDP as a basic science effort with industry support and cooperation. Many oceanographic institutions are also participating in the planning and future management of science work.
- Technology is not yet developed for controlled drilling 20,000-ft beneath the ocean bottom in 13,000 ft of water, and engineering studies predict many technological difficulties. The technological uncertainty of such deep-ocean drilling may preclude completion of some of the planned deep holes. Engineers and scientists will likely have to make compromises as the program proceeds, resulting either in lowering of the scientific objectives or in significant cost escalations.
- By July 1980, cost estimates for ship conversion and riser development had already increased substantially from those proposed earlier in the year. The OTA analysis highlights concerns that funds to cover the future additional costs to develop deep-drilling technology might be diverted from OMDP science or from other NSF ocean science programs.
- NSF has successfully directed the deep-sea drilling project over the past 12 years, using an established oceanographic institution to carry out the day-to-day management. However, OMDP involves a major funding increase and a new thrust in technology development from previous efforts in deep-sea drilling. Thus, OTA questions the capability and appropriateness of NSF to directly manage the more complex OMDP. The questions include whether NSF is the most appropriate organization to manage the considerable technology development work, whether aspects of the oil and gas resources should dictate more direct involvement by DOE or U.S. Geological Survey (USGS), and whether the science benefits are overshadowed by the technology development benefits.
- A more sharply focused science program with fewer options than the present plan is advocated by several industry and academic scientists contacted by OTA during its preparation of a technical memorandum on this subject in May 1980. These scientists suggested alternatives that might result in lower initial costs and a postponement of the decision to fund major technology developments. Many of these alternatives include an approach to identify first those drilling targets that are within pres-

*A riser is a large-diameter pipe, extending from the sea floor to the drilling ship on the surface, through which the drill pipe is inserted. The riser acts as a conduit for drilling fluid, which is pumped down the pipe and flows back up to the ship between the pipe and riser. The riser is essential for controlling pressure in the well and for supporting blowout prevention.



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ent technical capabilities. Other alternatives involved a greater emphasis on hydrocarbon resources (thus increasing industry involvement), but would probably require considerable changes in Government practices in leasing offshore lands for oil and gas exploration.

National Oceanic Satellite System

Summary

A major new 10-year effort, the National Oceanic Satellite System (NOSS), was scheduled to commence in fiscal year 1981 but the new administration has recommended a substantial budget cut and delay. Funded jointly by NASA (25 percent), NOAA (25 percent), and Navy (50 percent), this program is designed to collect and deliver synoptic* global measurements of the ocean to Navy and NOAA centers using an orbiting spacecraft, ground control, and data communication and processing systems.

NOSS is designed to demonstrate an operational capability for global, all-weather ocean coverage with real-time data processing and distribution that may presage a series of oceanographic satellites in the future. Synoptic ocean-surface data from NOSS could have significant value in future programs of worldwide weather and climate forecasting, measurement of ice cover, measurement of surface waves and currents, forecasting of sea conditions, observations of surface pollutants or chlorophyll, and other oceanic observations.

NOSS has a planned 5-year demonstration period. Launch of the first NOSS spacecraft from the space shuttle was scheduled for the third quarter, fiscal year 1986. Once the spacecraft and ground systems are operational, a second satellite will be launched (within approximately 6 to 12 months).

NOSS's satellite will carry four basic sensors. The technology for each of these has been developed and tested in previous research satellites, *Seasat* and *Nimbus*. They are: a radar altimeter to measure sea-surface height accurately and thus provide observations of waves and sea state; a radar scatterometer to observe windspeed and direction at the sea surface; a microwave radiometer to measure sea-surface temperature; and a color scanner, which can observe different pigmentation at the sea surface and, in turn, distinguish optically between concentrations of certain substances such as chlorophyll. These sensors, plus the data handling and processing network, will produce pictures, charts, and other forms of information to be used by Navy and NOAA to analyze and forecast weather, sea, and other environmental conditions globally. Researchers outside of Government and industry will also have access to the observations and data. The systems for providing these data products, however, are in the process of being detailed by

* A comprehensive and broad view of the whole.

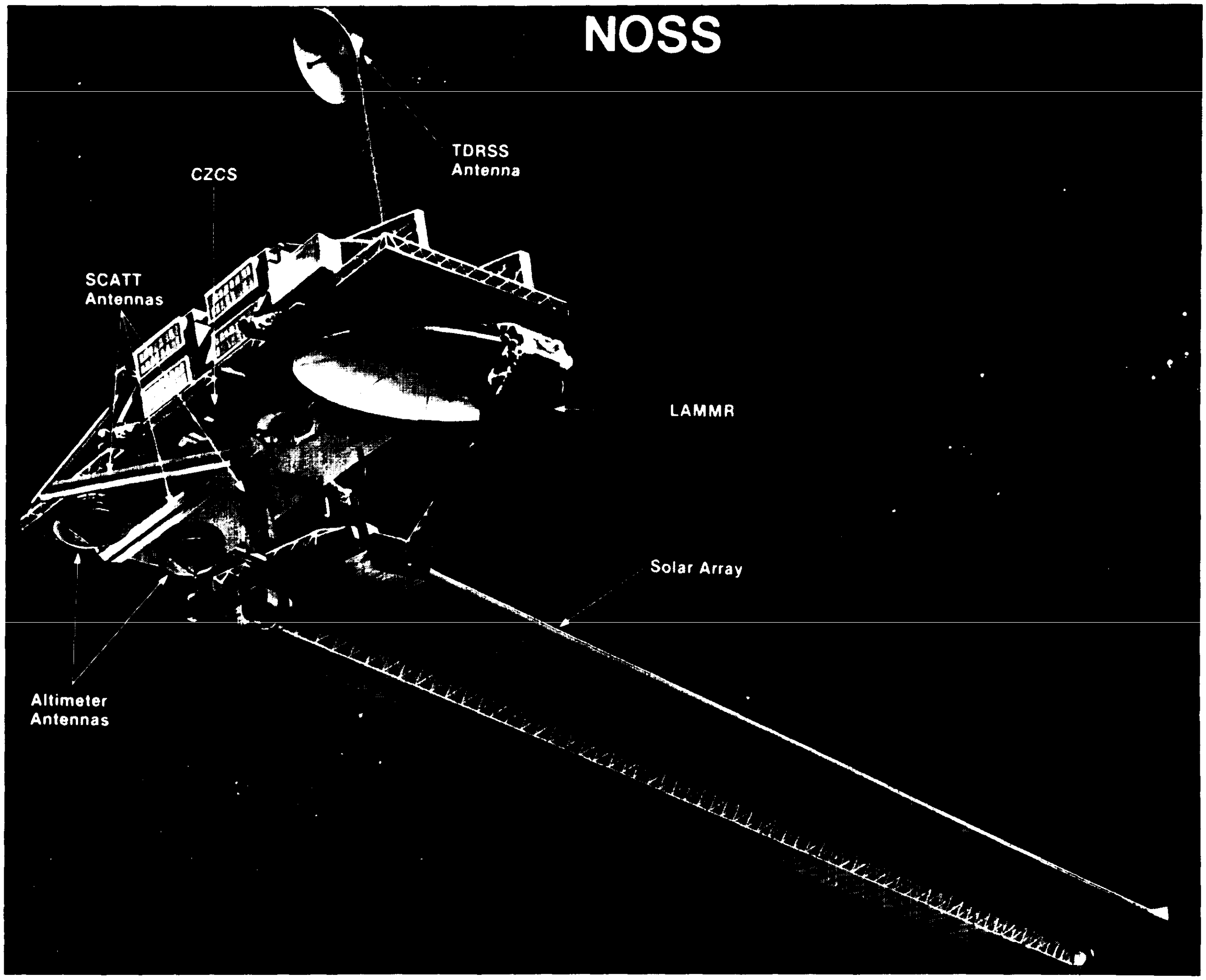

Photo credit National Aeronaut/es and Space Administration

An artist's drawing of the proposed National Oceanic Satellite System. The sensors will provide observations of waves, sea-surface temperature, surface winds, and particles in surface water over the global oceans

the agencies and are only partially included in the program cost.

The total cost of the NOSS program from fiscal years 1981 to 1991 is estimated to be $700 million to $900 million and includes the cost of a planned demonstration period. Since some additional agency costs are not included, such as that for end-user data distribution, the total system costs may approach or exceed $1 billion. These estimates, in fiscal year 1981 dollars, contain no allowance for inflation.

Findings

- NOSS is a major new program in satellite oceanography. If successful as a "limited operational demonstration," it may be the first generation in a series of satellites for collecting global ocean data in the 1990's and beyond.
- NOSS differs from other satellite programs in that it has all-weather capabilities and uses sensors not used by operational meteorological satellite programs,

- The cost of the NOSS 10-year program, jointly funded by NASA (25 percent), Navy (50 percent), and NOAA (25 percent), is estimated at about $800 million. However, NOSS alone will not provide all the satellite oceanic data required for research and operational purposes, A complete program of satellite oceanography will cost much more.
- The primary operational use of NOSS will be to improve global weather and sea condition prediction for Navy and NOAA weather service. If successful it will provide global, all-weather, synoptic ocean measurements of winds, surface waves, and sea-surface temperatures.
- Three basic NOSS sensors will provide the required operational data on winds, wave-heights, and sea-surface temperature. They are the scatterometer, the altimeter, and the large antenna multichannel microwave radiometer (LAMMR). The scatterometer and altimeter are proven technology while the LAMMR requires development.
- The coastal zone color scanner is one NOSS sensor without a clear, direct use in Navy or NOAA operational programs. Instead, for these two agencies, the scanner's chlorophyll and water-clarity measurements will be more important for research programs. These research programs will include evaluation of whether this sensor can obtain adequate measurements through clouds (prevalent in coastal areas), how chlorophyll data can be used to indicate biological productivity, and how water-clarity measurements can aid other research.
- NOSS's program office has conducted studies to determine an optimum orbit for the satellite, given NOAA's and Navy's stated data needs and given the four sensors selected. However, no detailed mission analysis has been prepared that compares the value of other research needs to NOAA and Navy requirements or that considers alternative orbits, sensors, and data systems. The ongoing contracted studies of alternatives to NOSS will not consider these major options to the planned system.
- The research mission of NOSS is limited, and secondary to the stated agency operational missions. Only part of the past research satellite (Seasat and *Nimbus)* capabilities of several years ago will be reinstated with NOSS.

Fisheries and Marine Mammals Research

Summary

The large and diversified Federal Program in Fisheries and Marine Mammals is directed principally by the National Marine Fisheries Service under NOAA at an annual cost of $50 million; selected aspects of the program are directed by the Fish and Wildlife Service of the Department of Interior at an annual cost of over $10 million.

Fisheries. — The Federal fisheries program is directed toward conserving and managing U.S. fisheries stocks, as mandated by the Fishery Conservation and Management Act of 1976. The Act, in an attempt to alleviate overfishing of certain stocks, extended U.S. jurisdiction over fisheries to 200 miles from the coastline and specified the establishment of Regional Fishery Management Councils to allocate and conserve fish resources for future use. The councils prepare management plans based on scientific information principally furnished by the Federal Government about species that are or may be harvested. The process of supplying this information focuses and directs much of the present and future fishery research in the United States.

The National Marine Fisheries Service within NOAA conducts fishery research through observation and monitoring of stocks, monitoring of commercial and recreational harvesting, investigation of fish behavior, and of environmental and other influences. The work is carried out at fisheries research laboratories using the 10 NOAA fisheries survey vessels and other ships that are chartered when needed. The work at sea involves sampling of stocks and analysis of results by technologies that are basically adaptations of fishing gear or biological oceanography. New technologies are periodically tested by the fishery researchers, and some development work is supported at individual laboratories.

Marine Mammals. –The Federal program in marine mammals focuses on conserving marine mammal populations by limiting harvest and by researching and ensuring conditions that will provide maximum productivity of various species. Research expeditions using various technologies and methods are necessary to count species whose behavior and habitat are more variable than those of fish. Present marine mammal research and technology are adapted from experimental programs or from other fields.

The following findings are based on analyses of the status and trends found mainly in NOAA's program in fishery and marine mammals research and on analyses of the possible future programs related to krill resources in Antarctica.

Findings

- The 1976 legislation has shifted attention to management problems and socioeconomic factors at the expense of fishery sciences and research. Future research and technology needs are thus being shaped by the more immediate needs of the fishery managers.
- Present technology for gathering stock assessment data on fisheries is adequate for most current, high-priority monitoring programs, More data on actual fish harvesting (catch-data) are needed by fishery managers, but the limitations on getting these data are institutional, not technological. The possible future need for more research-ship time to cover assessment of new stocks could be met by additional chartering and by upgrading existing ship capabilities.
- The one new technology with the potential to improve future stock assessment capabilities is acoustic measurement. While similar technology is used for military purposes, considerable development and applications testing is required to transfer the best techniques to the stock assessment problem. NOAA has not yet bridged the gap between experimental acoustics and engineering development of an operational system.
- Satellite remote sensing of ocean-surface conditions has not proven useful for stock assessment. Some satellite measurements of surface chlorophyll or temperature may provide indirect evidence of biological productivity and be useful for more basic research.
- New technology for efficient harvesting, reduced waste of catches, better safety, improved processing, and other factors of fish utilization could aid the development of new fisheries by U.S. fishermen. Some of these technologies are now being used by foreign fishermen in the U.S. zone. Some are necessary to make products acceptable to the U.S. market. The Federal Government has paid little attention to this research in the past.
- *Krill.* – Research on Antarctic krill is now basic and exploratory. Much more basic research is needed on krill lifecycle, growth, and behavior. Comprehensive survey techniques for data collection, evaluation, and reporting must be developed and standardized to better understand the role of krill in its ecosystem. It is probably premature to establish a major stock assessment program for krill until more harvesting tests are monitored and more basic research is done.
- *Marine Mammals.* – The Federal Government must invest major funds if it is to comply with many of the specifications of the Marine Mammal Protection Act of 1972. Past funding limitations have constrained methodological research and technological development; slowed data acquisition, analysis, and distribution; and created shortages of necessary equipment and manpower. A major technological difficulty is the current lack of suitable, well-designed survey ships and aircraft for large-scale surveys.

National Climate Program

Summary

The ability to forecast climate on a seasonal, annual, or longer-range basis requires not only an understanding of the effects of the ocean on climate, but also information from global monitoring of selected oceanic parameters over many years.

Precisely how the oceans affect future atmospheric conditions is not known. It is known that the oceans are a major heat-energy source for the atmosphere, that the oceans absorb and release carbon dioxide (CO_2), and that air-sea interactions play an important role in climate dynamics.

Scientists around the world have been studying aspects of the ocean's role in climate and can predict some climatic fluctuations over land based on variations in conditions in the oceans. During the 1980's scientists will begin a global effort to understand climate dynamics. The National Climate Program plan and the World Climate Research Program are parts of this effort.

In compliance with the National Climate Act of 1978, Federal agency scientists have proposed a variety of planning and feasibility studies and field experiments to determine what factors control climate and to determine how best to study the ocean's role. These studies are generally not adequately funded for technology development. Moreover, since the National Climate Program is in its initial stages, there is no well-defined, broad statement of its technology requirements, although present programs are doing the scientific planning necessary for the establishment of such requirements. Substantial increases in technology funding for climate studies will probably be required by the mid- to late 1980's if the research plans gain agency and congressional support.

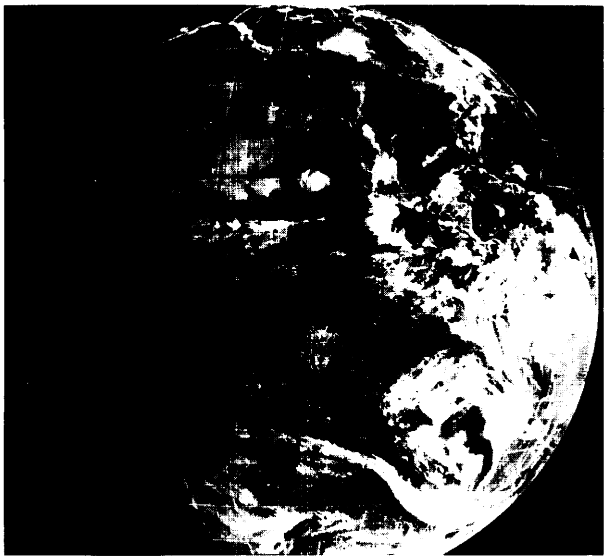

Photo credit: National Oceanic and Atmospheric Administration

The full Earth disk, with the Western Hemisphere artificially outlined for reference, shows global weather patterns from a geostationary satellite

The National Climate Program is managed by the individual agencies that have climate research activities. While the National Climate Program Office was established to coordinate these interagency activities, it does not presently have sufficient resources to effect this coordination and to initiate action to fill the inevitable gaps between the diverse agency programs. It also lacks overall authority to direct a coordinated research program.

On an international level, the World Climate Research Program is expected to provide the required degree of coordination among countries. The U.S. interest in an international research effort was expressed in the National Climate Program Act of 1978. As the needed research is more specifically defined, both costs and benefits of these efforts can be evaluated.

Findings

- Because climate research is still in the planning stage, there is no comprehensive statement of its technology needs. However, there are ocean technology needs in communication and data processing that, if met, could play a major, immediate role in understanding climate dynamics.
- One or more dedicated centers and a dedicated computer for the collection, processing, and distribution of future climate-related data would lead to a much improved capability to analyze climate dynamics.
- A mix of sensors and vessels, such as ships-of-opportunity, * drifting buoys, and arrays of moorings, will be needed to measure oceanic heat storage. This mix will necessitate an expanded and improved data collection and coordination system.

*Commercial ships or other vessels not normally engaged in oceanography but which can be used to make routine measurements or launch automated sensors.

- Four general areas of technology needs for future climate research are listed below, along with examples of specific technology development or use that appear to be of highest priority based on OTA's analysis of program needs.

  1. *Stations:*
     - –Organization of a worldwide ships-of-opportunity data collection program, including a satellite data network and centralized data-processing center.
     - –Substantial improvements and cost reductions in expendable buoys and probes.
     - –A commitment to long-term, moored stations. (Many of the existing long-term stations, on which much of our current knowledge of ocean climate is based, are being closed for economic considerations.)
  2. *In situ sensors:*
     - – *New* types of upper-ocean-current sensors that would be used to collect data to evaluate the manner in which the ocean moves heat from the tropics to the high latitudes.
     - – Improved, cost-effective sensors for measuring temperature, salinity, and velocity from fixed moorings.
     - – Improved, cost-effective sensors for measuring profiles of ocean temperature, salinity, and velocity as part of the worldwide ships-of-opportunity program.
     - – New technology for measuring the humidity content in the atmospheric boundary layer near the ocean surface.
     - –Sensors that measure various trace gas constituents such as $C0_2$.
  3. *Satellite sensors:*
     - –Technology for measuring the global windfields, useful for describing and predicting the oceanic variations that can affect atmospheric changes. (It may be possible to make the necessary measurements using satellite instrumentation such as that proposed for NOSS.)
     - –Satellite capability to determine surface currents and precipitation on the time and space scales appropriate to climate.
     - –Satellite systems that transmit in situ measurements using the same data stream as measurements from satellites themselves.
  4. *Data management:*
     - – The anticipated flood of data from satellite sensors will require major efforts to upgrade data management and handling capabilities to retain existing satellite data, to merge historical data of various types with satellite data, and to provide easy and economical access to data bases.

ISSUES

Whether new oceanographic research programs can gain adequate support for needed technology depends not only on the program needs, but also on whether the technology itself has adequate support. For many oceanographic programs adequate mechanisms have not been developed to satisfy technology needs through either the adaption of existing technology or the development of new technology. It is very difficult to provide technological support for science programs when the science has broad or diffuse goals and objectives.

Four important issues concerning Federal activities in technology and oceanography have been identified through this assessment. These issues cover subjects of significant controversy about how technology is provided now or how it may be supported in the future to meet diverse Federal goals and missions in oceanography. They cover overall institutional considerations and technological subjects. The issue discussions provide a basis for congressional actions such as oversight, budget review, or new legislative initiatives.

The issues are, briefly:

1. ***Ocean Technology Development. –*** Whether a larger and more centralized ocean engineering effort within one or more Federal agencies would significantly

improve future ocean technology development.

2. ***Oceanic Data Systems.*** **–** Whether the growing need to handle and distribute increasingly large volumes of oceanic data to a variety of users can be met effectively within existing agencies or will merit some new institutional arrangement.
3. Ships. –Whether the unique capabilities of the Federal fleet of research and survey ships will be adequately maintained or improved in the future.
4. ***Satellite Oceanography.*** –Whether the benefits of a major new thrust in satellite oceanography warrant the substantial funding and long-range planning entailed in establishing and maintaining such programs.

Ocean Technology Development

Issue

There is no effective and comprehensive nonmilitary effort to plan and coordinate the development of new technologies that would advance many major Federal ocean programs. A strong, centralized ocean technology organization has been proposed by several past studies, but many researchers and administrators strongly oppose such a concept. However, most agree that ocean engineering capabilities are inadequate and that important technology development work is not receiving needed attention in some key Federal agencies.

Discussion

The extent to which ocean engineering capabilities within nonmilitary Federal agencies can be improved and to which ocean technology development can be made responsive to Federal ocean program needs will depend on future institutional changes. At present, Navy and Coast Guard have substantial ocean engineering efforts directed toward their own operational missions and related research. NASA conducts significant technology development programs, but its mission is basically to transfer space-related technologies, when developed, to other agencies. NOAA and other agencies develop some technologies, but their engineering development efforts do not often even meet their own program needs.

Numerous studies have proposed establishing a more capable ocean technology organization within the Federal Government. Proposals have ranged from "centralizing the technological development programs and projects of all civil agencies in a single organization" to simply establishing "an interagency coordinating unit" to aid in the transfer of technology among agencies. Two reports that are often cited for recommending a central technological organization are the "Panel Reports of the Commission on Marine Science, Engineering, and Resources" of 1969 and the 1974 National Advisory Committee on Oceans and Atmosphere report, "Engineering in the Ocean. " Another, the September 1980 report, "Federal Ocean Engineering, " by the Committee on Atmosphere and Oceans, recoin-mended establishing a Federal ocean engineering strategy group to foster communications and to focus Federal technology development work on some key neglected areas, such as polar and deepwater research.

Centralization of technology development within each agency or among agencies, is supported by some who claim that focusing more authority and funding in one office could alleviate the frustrating experiences of trying to initiate promising new techniques amid a bureaucratic maze of unclear authority, funding inflexibility, and a shortage of specific technical experts. Such centralization could theoretically:

1. Provide a technically superior organization that can direct the solutions to a wide range of problems associated with carrying out agency missions.
2, Provide the mechanisms and focal point for advancing ocean technology through grants and contracts and by use of the most qualified Government technical organizations.
3. Provide central budgeting and funding with major program line items for:
   –defined mission and program-oriented technological projects;

– projects that are needed to advance the state of the art; and
– projects that would help bring promising experimental equipment into routine use through engineering development.

Ocean technology developments must be tested at unique sea and shore facilities. Since these facilities are used intermittently, some savings could be made through use of more efficient and more centralized facilities or by combining organizations that need the facilities. Moreover, centralization of technology development may induce a more economic use of staffs that have specific and sufficient technology experience and of project management that has the expertise necessary to raise critical questions and to avoid large and expensive omissions.

Centralization of technology development can also have serious drawbacks. The user of the technology is generally concerned that the centralized organization will not give his problem the attention that it deserves. Also, with the funds not under his control, he cannot control project expenditures in the development and testing processes. If the technology development problem is removed from the organization that needs the equipment, there is a risk of not meeting the real needs of the scientist. Small engineering tasks may have high priority within a specific research project, but low priority within a central technology organization. Finally, there are concerns that a large organization cannot meet the needs of the various smaller organizations; that adequate funding will not be provided for each project when budget priorities are set; and that one office cannot provide for both direct mission support, and the development of more basic technology.

There are many ways that technology centralization can be accomplished. One would be to establish a central interagency organization. Many believe that this option would be worse than the existing system because no agency has developed the required expertise to be so designated. Another approach, intra-agency centralization, would be a scaling down of the central concept in that it would consider only an individual agency's technological needs. To a limited degree, many such offices now exist, although they do not all have the required staff capabilities. In NOAA, a new Ocean Technology and Engineering Service (OTES) has been established to centralize technology development, however, it appears that some of NOAA's technology needs, such as fishery technology, are not considered in OTES. In Navy, ocean technology is important — and often of differing character — in almost every segment of Navy's research, development, and test programs. Thus, each of these programs has an ocean engineering component. In many other agencies, centralization of ocean technology development is done generally by discipline or by specific mission.

Centralization of technology development by discipline occurs within several Federal organizations by grouping both personnel and facilities. For example, Navy's towing basin has served other Federal agencies. Similarly, the Sandia Corp. Laboratory conducts measurements of seismicity for DOE and other agencies. The submarine and manned-diving technologies of Navy have been shared with many agencies. NOAA has become a focal point for scuba and saturation diving for scientific purposes. In addition, all agencies have some technology development offices that serve the principal missions. In certain cases a technology development project is passed to another agency, certain ocean technology development activities of EPA are passed to NOAA for execution. But these established practices fall short of an effective technology development effort to meet important ocean science and monitoring needs in the future.

Short of a Presidential mandate, congressional initiatives may be necessary to make the needed institutional changes and improvements because interagency coordination on budgets and mission authority is difficult to achieve otherwise. For example, Congress could establish a central office to support future ocean technology development in one or more agencies with authority to provide the expertise and project management capabilities for specific missions or program needs, Through oversight, Congress could call for an evaluation of specific technology development needs that are not being met within the major ocean agencies by those ocean engineering offices now established. This evaluation would lead to the identification of neglected areas and priorities of programs for technology development. As another option, Congress could establish an interagency ocean engineering strategy group (as recommended by the Committee on the Atmosphere and Oceans) with authority for technology transfer and other productive coordinating functions.

There is no way to centralize technology development adequately to meet the individual needs of every program and agency. Direct communications between the programs needing technology and the developers of technology is most important. Flexibility in funding is also necessary for accelerating the innovation and bridging process of converting experimental equipment to operational systems. And of utmost concern is assuring the availability of highly qualified personnel in each department or agency for critical program assessment and for focusing on promising directions in technology development.

Oceanic Data Systems

Issue

Federal programs have not given adequate attention to the handling and distribution of oceanographic data, collected at great expense to the public. Large amounts of data are stored unused because their nonstandardized formats are incompatible with user needs and because they are difficult to retrieve from the archives. These difficulties hamper much oceanographic research. Accordingly, many researchers and private groups recommend that funds and plans for data management and distribution beyond the primary agency users be included in major data collection programs. At present, however, only primary data networks are included within specific programs.

Discussion

Although several Federal agencies are involved in the collection of oceanographic data, NOAA's Environmental Data and Information Service (EDIS) is the agency specifically created to maintain data and information for use by Federal, State, and local agencies and the general public, Most oceanographic data is archived in either the National Oceanographic Data Center or the Satellite Data Services Division, part of EDIS.

OTA has identified a growing need for more current, near real-time environmental data in almost all major ocean research programs. NOAA representatives have stated, however, that EDIS has the responsibility for supplying only retrospective data to users; it does not have responsibility for the distribution of real-time data. In essence, then, EDIS manages only the archiving of the data stream. The other agencies and contractors that originate the data have the responsibility for data documentation and quality control. As NOAA indicated:

> . . . problems are far greater in obtaining documented, quality-assured data from data originators than . . . in processing it into and out of archives.

Because planning and budgeting for both archiving and distributing retrospective data is not closely tied to similar planning for data acquisition, projects of major significance and cost have been funded without adequate resources for handling and distributing the resultant data. Then, the major question is: Who really should have the Federal responsibility for comprehensive oceanographic data management? At present, the NOAA archives seem to be unable to handle the present digital data stream from existing collection systems in a near real-time environment. New programs like NOSS that generate new data streams will only exacerbate this problem. In fact, NOAA is planning to implement a major new data management system as an adjunct to the NOSS program. Handling increased data volume requires new organizations and management methods for data cataloging, storage, archiving, processing, and distribution.

A related issue is defining the role of the Federal Government in providing services and software to make oceanographic data available to researchers in the scientific community, the commercial sector, and the general public. Future trends in data-processing technology indicate a large increase in the use of electronic data transmission, processing, and display. With only Federal archival and retrospective data responsibility clearly defined, there may be a gap in management responsibility which is filled on an uneven basis by each Federal agency with an operational mission.

Management systems and networks for future data handling could take various forms. A trend toward establishing regional data networks and distribution centers has been underway for some time by large, commercial firms for their own private work. It appears likely that regional networking of Federal oceanographic data systems may also be effective. If data management responsibility were centralized in one place, it might ensure easier planning and budgeting for future needs and might accommodate more effectively the needs of individuals and other small users. If data management responsibility and funds are not given to a Federal agency, this may be an incentive to commercial data networks or private institutions to operate data networks for a fee.

There are two steps that could be taken to make oceanic data systems capable of serving the growing user needs and of handling the growing data volume. The first step is assigning agency or program responsibility for comprehensive management geared to user needs. The second step is choosing a Federal, regional, or private data management system and upgrading it with modern technology for use as an oceanic data system.

Congress could initiate the first step by requiring that data management for all end-users be included in plans and budgets for major new programs, The second step could also be at the direction of Congress. For example, if the data management system choice were a major Federal system, Congress could provide NOAA with funds and added responsibility to establish a central Federal data network for all users of future oceanographic data. Otherwise, Congress could either establish regional oceanographic data networks for management and distribution of oceanic data outside of the Federal agencies or provide incentives for commercial data networks to be established for end-users.

Ships

Issue

The capabilities of the Federal fleet of research and survey ships will continue to degrade unless additional new funds are added or new, more efficient systems are devised to provide and operate these ships at less cost. Several years of debate have failed to resolve whether more centralized management systems with greater Federal control would produce savings so that capabilities could be maintained or enhanced, especially when funding does not match escalating costs.

Discussion

The future of oceanographic ships appears to be constrained by limited Federal funding for ship operation, rehabilitation, and replacement. Thus, it is important to consider whether a system can be devised to maintain fleet capabilities with less funding or whether increased funding must be provided to maintain adequate numbers of capable ships. It will always be necessary to provide some new funds to replace and refit ships and to upgrade equipment and instrumentation.

Management of federally supported ships entails not only operating and maintaining the existing fleet, but also planning the mix of the future fleet. At present, the Federal fleet includes ships designed for general-purpose (flexible) applications and for special-purpose tasks. The fleet is operated by organizations that have a variety of missions ranging from basic research to routine surveys.

In the present Federal fleet, a distinction can be made between ships that are operated directly by Federal agencies mostly for routine surveys or applied programs and those operated by academic institutions mostly for basic research. The agency fleets tend to have more centralized management within each agency. The academic fleet, on the other hand, has been subject to very little Federal control over operations; but some agencies, like NSF, have recently tried to plan

Photo credit Scripps Institution ot Oceanography

R/V *Alpha Helix,* owned by NSF and built in 1966, has recently been transferred from Scripps Institution of Oceanography to the University of Alaska. The ship is 133-ft long and can accommodate 12 scientists

and effect cost -saving changes in the fleet makeup.

There are several studies underway that will provide planning information on the future management needs for oceanographic ships. These include studies of the academic fleet by the National Academy of Sciences/National Research Council, two oceanographic laboratory groups, Navy, and NSF; studies of NOAA's fleet by NOAA; and studies of Navy's fleet by Navy. A study by the General Accounting Office (GAO) in 1978 identified a decline in capabilities and efficiencies in the Federal fleet and recommended that a single manager be designated or that a Government-wide fleet-allocation council be established. Accordingly, in mid- 1980, the Federal Oceanographic Fleet Coordination Council (a subgroup of the interagency Committee on the Atmosphere and Oceans) was established in response to GAO's recommendation and to that of several agencies.

Several groups are also pursuing certain aspects of regional operations for the academic fleet. NSF and Navy have stated that moves toward regional academic fleet operations should and will be encouraged. Some proposals for regional operating centers for new coastal research ships have been made; and cooperative operations of large, special-purpose ships, such as a geological/geophysical vessel, have been discussed.

Those who argue for more centralized management or Federal control over the oceanographic fleet claim that the result would save money because some functions could be merged and some operations would be more efficient. Thus, central fleet management could facilitate more accurate planning for future fleet makeup, in particular for replacement or refurbishment of ships. A specific long-range plan for ships to be retired and new ships to be built could be laid out and consistently followed if only one office were in charge.

However, oceanographers consider central management and control detrimental to the flexibility and individual project efficiency that is so important to basic research, and to some applied research as well. They view the present system of decentralized management and planning, particularly in the academic fleet, as more satisfactory for individual research needs as well as for agency and program missions. Some argue that flexibility must be maintained if the opportunities for new discovery associated with basic research are to be pursued. The cost-effective planning needed in central operations may not be possible in basic research; and some claim that the small, decentralized ship operators can, therefore, provide services at less cost.

These concerns about centralization are reflected in several areas. USGS and EPA, who now operate just a few ships, claim that they could not relinquish control of their vessels to another agency because of their unique program needs and unique vessel capabilities. In the academic community, serious conflicts exist over whether NSF or other agencies supporting basic science should have the authority to decide on the makeup or operations of the fleet as a whole. In addition, many scientists and Government agencies have recognized a growing need for polar research ship capabilities, but the mission agencies have not been able to consolidate their needs and bring together the resources and justification for a polar ship.

Many of the needed efforts to resolve this issue are already underway in the Federal agencies and institutions. If Congress wished to oversee and direct these efforts more carefully, it could call for the submission of ongoing studies of the fleets when the studies are completed, and it could request a consolidation of study recommendations from all agencies. This consolidation could be done by an existing interagency committee or by a White House office. As part of these efforts, Congress could request a projection of the costs of maintaining the U.S. oceanographic fleet capabilities under the present and any proposed system. The choice could then be to either provide sufficient funds or eliminate certain capabilities.

Finally, to assist coordination among agencies, Congress could establish and fund an interagency ship planning council with the authority to specify management and planning practices, a move which could reduce costs.

Satellite Oceanography

Issue

Major satellite systems for oceanography are being planned that could become the dominant thrust in ocean technology in the next two decades. NOSS is one part of this thrust; however, several additional systems will be needed to meet the range of operational and research goals now established. Many research programs and ocean-user groups, including scientists and industry, could benefit from oceanic satellite data, but only a few Government agencies acting together can now afford the very high costs of this technology.

Discussion

Satellite remote sensing could become the fastest growing segment of oceanography if certain agency plans are followed. NOSS, a proposed operational demonstration satellite system designed to meet the needs of Navy and NOAA for the collection of oceanographic data, may be the first of a new generation of oceanographic satellites. Twenty-five percent of the NOSS payload has been reserved for research purposes. Moreover, NOSS data have the potential to benefit a wide range of public and private applications by providing a long-term, synoptic, all-weather view of the ocean surface. If additional satellite programs follow NOSS, as many have advocated, the cost of oceanic satellite hardware and data systems for both research and operational users could be about another $1 billion in addition to the NOSS program.

The activities within the Department of Defense and NOAA that have considerable need for satellite oceanography are Navy and NOAA's National Weather Service (NWS). In Navy, the Fleet Numerical Oceanography Center provides near real - time synoptic ocean data for fleet operations because naval ships and weapons cannot operate effectively without current environmental information. In NOAA, NWS is expected to provide several services that rely on synoptic ocean data and routine weather forecasts. These data could be used for automated ship and aircraft routing, performance estimates for radar and sonar, and search and rescue operations. To accomplish these operational missions, meteorological and oceanographic forecast services over the oceans should be continually maintained. The information required range from complete satellite coverage data to subsurface measurements data from buoys, ships, and other stations.

A variety of important research programs could also benefit from satellite observations because some large-scale features of the ocean surface may be described adequately only by such remote sensing. Satellite data are useful for addressing problems relating to descriptions of the ocean's influence in world climate, observations of large circulation patterns, investigations of marine pollution, large-scale studies of oceanic productivity, and many other phenomena which occur near the sea surface. Those research projects that require observations beneath the sea surface will need additional tools and techniques that work in conjunction with satellites.

The extent to which satellites themselves will add new knowledge and thus justify very large costs is difficult to evaluate until more experience is obtained. A large investment in satellite oceanography in the future will probably draw funds and people from other programs of ocean observation or may make other methods, such as the use of surface and subsurface vehicles, more dependent upon work with satellites. In fact, many researchers believe that future uses of satellites will increase the need for ships to make surface-calibration measurements and other subsurface measurements not possible from spacecraft. In future debates over costs and benefits of satellite oceanography programs, researchers must consider both the intrinsic value of the programs as well as their possible effects on other ocean research technology.

Satellite systems, including ground support and data handling, require long development periods (5 to 10 years) before becoming operational. Consistent Federal support is necessary if the systems are to be useful to broad segments of public and private groups. Because of the large Federal support needed, long-range planning is also necessary. NASA has started a long-range planning process for satellite oceanography, and many other Federal agencies and private groups will probably participate in the process as it develops. Cooperative long-range planning is supported by many now working with the NOSS program, but is not supported by some researchers and agencies who wish to maintain the flexibility and uniqueness of their own programs. Some researchers also feel that new sensor development will be the key to future useful oceanographic measurements from satellites because NOSS-proposed sensors have limited capabilities.

While NASA has developed a broadly supported approach to the NOSS program to meet both the operational needs of Navy and NOAA, and the research needs of many users as well, agencies such as USGS remain convinced that a mission like that of a *Seasat-B*, which would be more research-oriented and limited in scope, would be preferable. Researchers also claim that major, long-range Federal support of satellite oceanography must await both the results of further experimentation with many techniques as well as the success of the NOSS prototype mission.

Because of the substantial funds required for a major satellite oceanography program, Congress will have a continuing interest over many years in plans, budgets, justifications, and possible alternatives. As with all major Federal efforts, the NOSS program will be subject to close congressional oversight. For such oversight it may be desirable to select each major program decision-point and evaluate specific cost and benefit justifications with the understanding that NOSS is just one step (a demonstration prototype) in a larger, satellite oceanography thrust. To assist this process Congress could call for a long-range plan for satellite oceanography, specifying research and operational program needs in each Federal agency and some optional methods of providing them, including nonsatellite means.