Chapter 4

Selected National Programs

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Chapter 4
Selected National Programs

Four national programs are presented in detail in this chapter because they represent the institutional and technological opportunities and problems facing Federal efforts in oceanography today.

Two of the programs are major new ocean program initiatives that will depend on the development of large, new technology systems. The Ocean Margin Drilling Program (OMDP) is a scientific endeavor unique for its private industry support. The National Oceanic Satellite System (NOSS) combines civilian and military operational goals with related scientific investigations.

The remaining two programs will incorporate a mixture of conventional technology already in use plus advanced technologies tailored to research needs. Both programs have been mandated by Congress. The Federal program in fisheries and other living resources has been in existence for some time, but has recently been directed to focus its research more directly on resource management problems. The Federal program in climate research, when fully operational, will attempt to provide climate information and prediction services.

OCEAN MARGIN DRILLING PROGRAM (OMDP)

A program of new marine geologic investigations to gain knowledge of the nature and origin of the Earth began detailed planning in fiscal year 1981. Undertaken by the National Science Foundation (NSF), this $693 million, 10-year drilling program is a new thrust to investigate the geology of continental margins and ocean crust using deep-ocean drilling. (Some of the margin regions, which are the borders between continental shelves and the deep ocean, could contain substantial oil and gas resources in addition to valuable geologic information; but very little evidence of this possibility has yet to be collected.) Major ocean technology development, particularly in the early stages of the program, will be necessary to develop the deep-drilling equipment and techniques for accomplishing the OMDP science goals.

In some ways, OMDP is an extension of NSF's Deep Sea Drilling Project (DSDP), that has been in effect since 1968. That program, which may be terminated in fiscal year 1982, has resulted in considerable scientific accomplishments. The many boreholes that were drilled have yielded major scientific knowledge about the nature of the surface features of the Earth, the chronology of tectonic and environmental events, the nature of natural disasters, and the geological framework in which economic concentrations of resources are located. Equally important are the technological advances made in the recovery of soft sediments from the ocean floor. A hydraulically driven piston-coring device (the Hydraulic Piston Corer) was developed that has successfully recovered continuous sequences, hundreds of meters long, of undisturbed ocean-floor sediment. This device could open the way to a whole new series of studies on the:

- evolution of global climate, measured on time scales of a decade to millions of years;
- evolutionary development of marine plankton during the last 10 to 15 million years;
- sedimentary structure of deep-sea fan deposits, which are the most probable reservoirs of any deepwater hydrocarbons; and
- suitability of various types of deep-sea deposits as repositories for nuclear waste.

OMDP itself has resulted from years of planning by Government-sponsored committees. Planning began in 1973 and continued through several conferences and NSF reviews in the late 1970's. Finally, at an NSF-sponsored meeting in Houston, Tex., during March 1980, scientists and engineers from academic institutions, petroleum companies, and Government agencies developed an initial plan for a model ocean margin drilling program. That plan is the principal basis for NSF's present OMDP.[1]

Program Plan

Scientific objectives stated in the plan are to investigate:

- passive and active continental margins;
- the Earth's crust beneath the deep ocean; and
- the deep-sea sediments which could yield historic environmental information on the Earth, especially those at the opening of the Atlantic Ocean and the Gulf of Mexico.

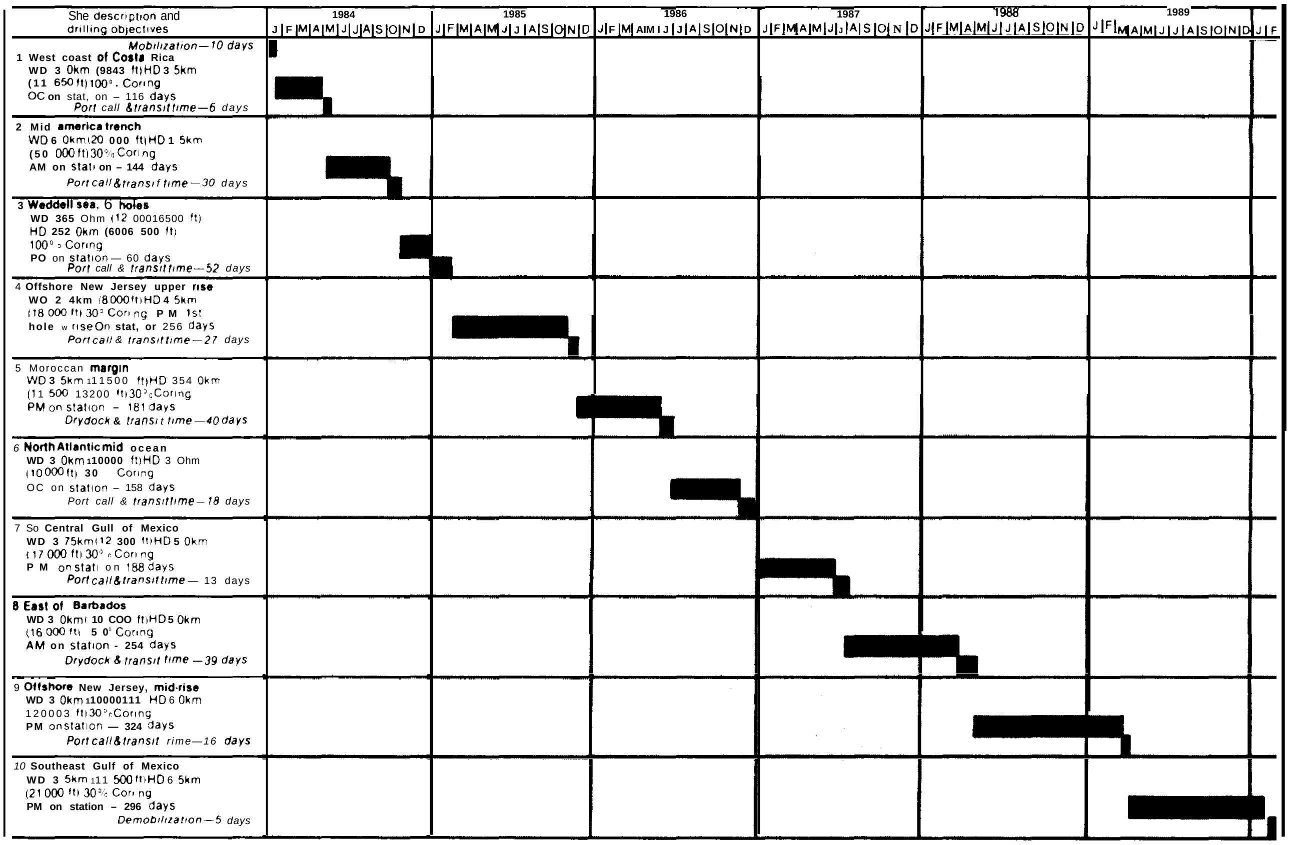
Meeting these objectives involves drilling 15 holes at 10 sites (fig. 13). Two sites will be in the Pacific Ocean; one will be in Antarctica's Weddell Sea, and the rest will be in the Atlantic Ocean and the Gulf of Mexico. The deepest hole (in the southeast Gulf of Mexico) in the model program will be about 21,000-ft below the sea floor in about 11,000 ft of water. OMDP's plan allots 4 years for drilling preparation and 6 years for actual drilling. Furthermore, it presents an initial estimate of operational and program-site costs.

Technology

The technology plans include the conversion of the Government -owned *Glomar Explorer* to a deep-drilling ship and the development of a riser

[1]For a detailed discussion and analysis of the Ocean Margin Drilling Program and all references to other reports, see OTA technical memorandum, *Ocean Margin Drilling*, May 1980.

Figure 13.—Ocean Margin Drilling Program Plan



Notes. WD-water depth, HD-hole depth below sea floor. OC-ocean crust objectives, AM-active margin objectives, PO-paleo oceanography objectives, PM-passive margin objectives Coring percentages shown are for hole depths below 20-inch casing "

SOURCE OMDP overview, NSF, June 30, 1980

system* (fig. 14) for controlled drilling in up to 13,000 ft of water and down to 20,000-ft below the sea floor.

Since this drilling technology has not been developed, OMDP requires a significant element of technology development. The 12, 300-ft riser pipe required for the deepest margin sites is about twice the depth of existing technology, therefore, a major effort will be needed to develop the riser and the entire deep-drilling and well-control system. Basic designs of the system, to be prepared during fiscal year 1981, will need careful evaluation.

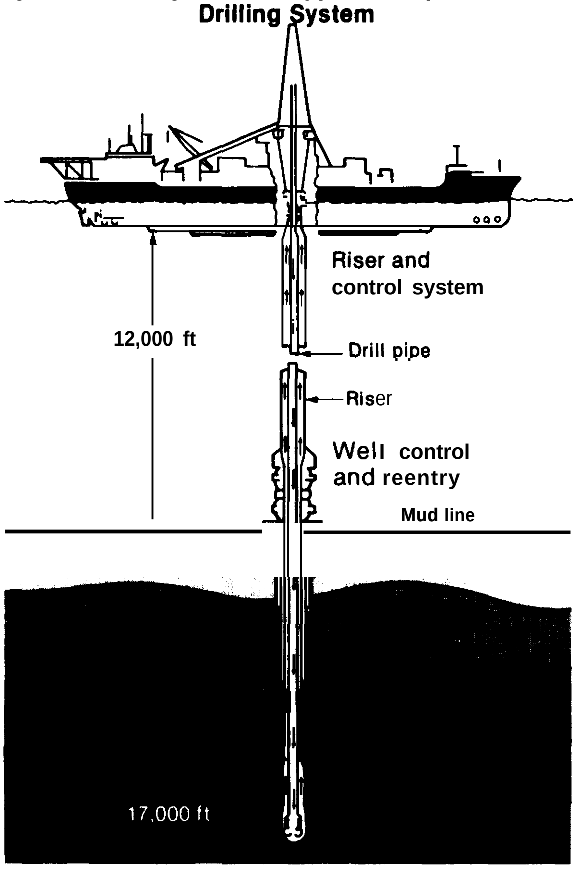
* **A riser is a large-diameter pipe. extending from the sea floor to the dri II ing ship on the surface, through which the drill pipe is inserted. The riser acts as a conduit for drilling fluid, which, after being pumped down the pipe flows back up to the ship between the pipe and the riser. The riser is also used to help control pressure in the wel I and to su pport blowout prevention.**

Since the technology is uncertain, so are the cost estimates. Because extremely deep holes are very costly, the sites must be selected with great care and attention to engineering conditions as well as to scientific objectives.

Budget

It is planned that the program will be jointly funded by the Federal Government (NSF) and the petroleum industry, each sharing 50 percent of the cost over the 10-year period. By November 1980, eight major petroleum companies had agreed to participate and support the first year's efforts. The total budget for the 10-year program is now estimated at $693 million with the Federal Government share at $346.5 million.

Figure 14.—Diagram of a Typical Deep-Water Riser Drilling System



SOURCE Project Contributions Program Review for Director. NSF. presented Apr 3, 1978 Deep-Sea Drilling Project, IPOD

Table 29 illustrates the proposed budget from fiscal year 1981 to fiscal year 1990 for the program and divides it into major components of ship conversion, vessel operation, ship operation management, scientific operations, advisory and management support, systems support, and science programs. The budget includes a 10 percent per year inflation factor for each year beyond fiscal year 1981; thus a considerable portion of the $693 million total budget is for inflation. During fiscal year 1981 the total program budget will be refined, based on system designs and plans to be prepared. A major commitment will be made with approval of the fiscal year 1982 budget because that is when the ship conversion and large expenditures will begin (see fig. 15 for major program milestones). Since the ship conversion and riser-development cost estimates could escalate substantially when a final design is completed, they must be evaluated prior to the decision to proceed with hardware contracts. During 1980 some cost estimates for the ship and riser were made that were almost double the budget figures. These discrepancies have not yet been reconciled by NSF, so the status of budget changes, or tradeoffs if one component cost escalates, is now uncertain.

Table 29.—Proposed Ocean Margin Drilling Program Budget—Fiscal Year 1981-90
August 1,1980 (million of dollars)

Activity	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Total
Ship conversion and riser development. . . .	$ 2.0	$20.5	$46.0	$36.0	0.0	0.0	0.0	0.0	0.0	0.0	$104.5
Vessel operations.	0.0	0.0	0.0	24.0	$48.3	$53.2	$58.4	$64.2	$70.5	$ 2.0	320.6
Management of ship operations.	0.0	0.0	0.0	5.0	9.9	10.9	12.0	13.4	14.8	1.0	67.0
Scientific operations . .	0.0	0.0	0.6	3.0	5.5	6.1	6.7	7.3	8.0	2.7	39.9
Advisory and management support.	1.5	1.5	1.4			1.6	1.8	1.9	2.1	2.3	16.9
System support contractors	2.0	2.0	2.0	2.4	2.7	2.9	3.2	3.5	2.4	2.0	25.1
Science programs.	4.5	8.0	10.0	11.0	12.1	13.3	14.6	16.1	19.2	10.0	118.8
Total.	$10.0	$32.0	$60.0	$82.7	$80.0	$88.0	$96.7	$106.4	$117.0	$20.0	$692.8

NOTES: This August 1, 1960 budget reflects:
a) A start-up or orientation of the SIC in late fiscal year 1961.
b) Mainly a design effort by the SIC in fiscal year 1982—long-lead hardware procurement limited to approximately $12 million.
c)Ship completion date, April 1964.
d) Fiscal year 1961 Government funding $5 million and 1962 Government funding $16 million.

SOURCE: National Science Foundation.

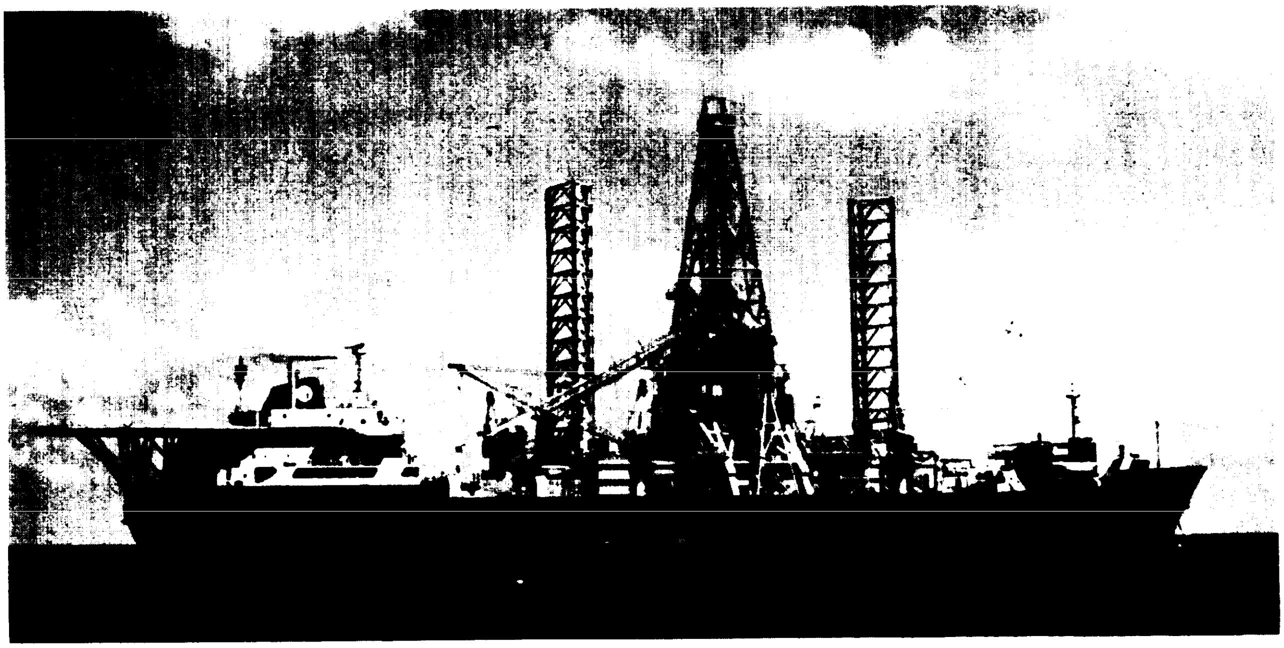


Photo credit' U.S. Navy

Glomar Explorer, a 52,000-ton, 620-f t-long ship, originally built by the Central Intelligence Agency to recover a Russian submarine, is proposed to be converted for the Ocean Margin Drilling Program

Program Management

NSF has successfully directed DSDP for the past 10 years, using oceanographic institutions to manage the scientific effort. The proposed management structure for OMDP relies on DSDP staff, a systems support contractor, science support contracts with Joint Oceanographic Institutions (JO I), Inc., and a future systems integration contractor. The systems integration contractor will be selected after the program has been specified in sufficient detail and formal invitations to bid are evaluated. This contractor will have major project responsibility, including the design, construction, and operation of the drilling system.

In addition to the basic program management, NSF plans to establish outside groups to advise both the director and the OMDP team. A program advisory committee will be comprised of representatives from industry (40 percent), academia (40 percent), and the public sector (20 percent). The Marine Board of the National Research Council has already selected a smaller advisory group from among those who served on its deep-ocean drilling, 1978-79 committee. Navy will be called on for its expertise in ship conversion inspection and supervision. Additional consultants from Government and industry will be used as required to assist various facets of the program as it develops.

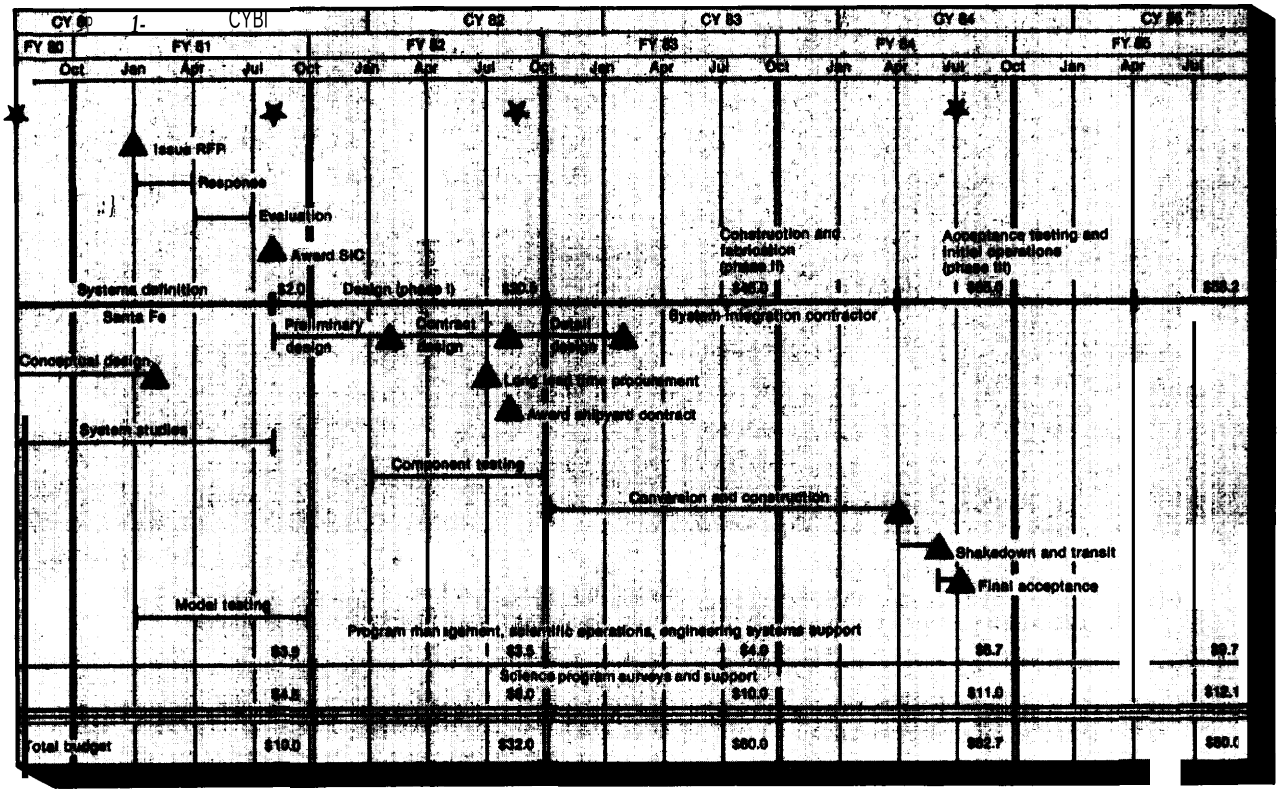
Analysis of OMDP

Objectives

Many scientists believe that the recently developed plan contains many worthwhile scientific objectives and that the chosen drilling plan and sites encompass significant scientific investigations that are in keeping with past committees' recommendations. Whether scientific objectives can be achieved from the holes drilled and information collected will depend, in large part, on the capabilities of the technology developed. Engineers have estimated a 50-percent probability of completing all the planned holes. However, some deep holes may not be completed as planned because of the uncertainty associated with deep-drilling in as yet untried geologic envi-

Figure 15.—Major Program Milestones and Budget—Proposed Ocean Margin Drilling Program, National Science Foundation

15 August *1980*



- Major program decision points

SOURCE National Science Foundation

ronments. As the technology is developed, better estimates of success probabilities for each hole can be made, but it is likely that some deep-drilling goals will not be reached.

Program Plan

Many scientists agree that the present OMDP is probably the broadest scientific program that could be put together using the *Glomar Explorer* in an industry -academia-Government cooperative venture and is worthy of complete support. They believe that the scientific objectives are of high priority and that if the petroleum industry provides 50 percent of the funds, the program will be a bargain for science. Some claim that even allowing for the predicted chances of technological failure, each hole or site will offer partial answers to many of the questions asked. They also note that much of the success of past deep-sea drilling has been from unanticipated results.

However, many scientists believe that OMDP may not be the best, the most appropriate, nor the most important scientific program that could be proposed for exploring the ocean floor.

There is wide agreement, even among those who support the present program, that more emphasis on geophysical surveys is needed. While funds are reserved for such surveys and support, a detailed plan for a science program is still in the planning stage. The plans are under development by JOI, Inc., who has an established scientific advisory committee and several planning advisory committees to consider the outstanding scientific problems and necessary studies. The committees are analyzing all existing geologic

Photo credit Woods Ho/e Oceanographic /nsfItut/on

Core samples from deep-sea drilling

and geophysical data available in order to recommend where new surveys are most critical.

Because scientists disagree on the program's goals and scope, it is important that the future peer review process for the scientific program be more explicitly defined. This process is now being developed by NSF. Since the holes, sites, and objectives are likely to change as the technology and plans are developed, additional review will be necessary to assure broad support and proper attention to high-priority scientific problems.

In addition, the most advanced state-of-the-art geophysical surveying methods and experiments will eventually be needed. The National Academy of Sciences (NAS) report, "Continental Margins Geological and Geophysical Research Needs and Problems" (known as the "Bally" report), recommended that academic institutions have at least one modern, thoroughly equipped, state-of-the-art geophysical surveying vessel, as well as supplementary equipment aboard existing oceanographic ships for conducting multiship surveys. Such technology is not now included in OMDP and will probably need to be funded from other sources.

Until the Explorer is ready to begin drilling, the selection of sites and holes will remain flexible. The drilling plan proposed during March 1980 was based on existing knowledge. Additional surveying, both within and without this program, will change concepts and drilling sites. To this end, the primary scientific task for fiscal year 1981 will be the synthesis of existing geological and geophysical data in 11 geographic regions targeted as candidate drilling areas. These regional syntheses will form the foundation on which the science" program will be developed. However, the capabilities of the *Explorer* technology and the funds available will have the major influences on any changes to the science program.

Anticipated Technological Problems

In reviewing the effort that will be required to develop the technology for meeting the present OMDP goals, heavy reliance was placed by OTA on an April 1980 report entitled "Engineering for Deep-Sea Drilling for Scientific Purposes, " by the Marine Board of the National Research Council. That report and the OTA technical memorandum on ocean margin drilling may be referred to for more detailed evaluations of future problems associated with OMDP.

An effective drilling system for the ocean margins will include a large number of complex and interrelated components. Most system elements will probably require some modification from present practice to perform at the extreme water depth and penetration goals of the program. Problems caused by drilling in unknown environments with untried technology may cause engineers and scientists to compromise as the program proceeds, thus lowering OMDP scientific objectives. Figure 16 outlines the extent of

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Figure 16.—Deepwater Drilling Technology/Water Depth Spectrum

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Riser:	Extended casing	[illegible]	[illegible]	[illegible]
[illegible]	N/A	[illegible]	[illegible]	[illegible]
BOP:	Surface	[illegible]	[illegible]	[illegible]
BOP control:	[illegible]	[illegible]	[illegible]	[illegible]
Wellhead foundation:			[illegible]	[illegible]
Well control:	Surface choke adequate	Deepwater kill procedures required	[illegible]	[illegible]

Key: U - Undeveloped; D - Developed but not field tested; E - Extension of existing technology; F - Field tested.
.Solution dependent on casing program and feasibility of extending drilling shallow hole without riser.

SOURCE. National Academv of Sciences, Marine Board, National Resource Council, "Engineeri Q for Deep Sea Drillinq for Scientific Purposes," Washington, D C "1980

present development for major equipment and indicates future technology development needs.

Some petroleum company participants in OMDP are concerned that the cost estimates are too low or that the chances of reaching all the deep holes are not good. It appears, in general, that industry participants will force future decisions on realistic technology development goals and cost estimates.

Industry Participation

The potential of oil and gas resources in the continental margins is subject to much speculation, but competent geologists claim that these areas hold significant promise. OMDP would help establish better scientific information on which to base further speculation on hydrocarbon resources. In fact, the U.S. Geological Survey (USGS) expects to benefit from OMDP in its efforts to evaluate long-range oil and gas potential in offshore regions. As designed, however, OMDP falls short of a logical oil and gas exploration program. Some petroleum companies claim that they are not participating in the program because it is not directed more toward assessing commercial resources.

Eight out of seventeen petroleum companies that were invited to sign an agreement to support the first-year OMDP efforts have agreed to do so. While there will not be a severe financial burden on these participating companies during the first year, greater industry participation will be needed in subsequent years when a much higher level of funding is necessary. A concern of some industry participants is the manner in which most companies commit funds to the program. In general, the funds that each of the companies would commit would be funds reprogrammed from present industry R&D budgets. Thus, there is concern that participation in the NSF program would preclude other research and exploration projects. Some nonparticipating companies are keeping close watch over the program; and, if the program benefits change, they may decide to join.

The companies that OTA surveyed expressed a variety of reasons for participating. Some that did not have extensive technology development programs themselves felt that technology developments would be the principal benefits. Some foresaw benefits related to the science of sedimentary geology. Very few felt that there were specific, substantial benefits to industry; however, they felt that there would be long-term intangible benefits, similar to those from DSDP, from new ideas generated by program results. None of the companies felt that information on potential commercial resources would be a great benefit.

Program Management

OMDP is a major increase in funds and complexity from previous efforts, and thus the capability and appropriateness of NSF to manage it is subject to question. Several concerns that have been noted include: whether NSF can effectively manage the considerable technology development work, whether the extra funds needed for technology would be taken from other needed programs, whether the possibility of finding oil and gas resources should involve the Department of Energy (DOE) or USGS more directly, and whether technology needs overshadow science needs.

Three major aspects in managing the program are operations, science, and technology development. Scientists are concerned about the current emphasis on the operational and technology development aspects. The initial plan developed in March 1980 did not win wide support from the basic research community. One reason may be that earlier expectations cannot be met within the financial, time, and engineering constraints faced by the project. A more detailed, overall management plan for science, which spells out the responsibilities and authority of NSF, industry, JOI, Inc., and the panels, may answer some of these concerns.

Alternatives to the Present OMDP Plan

In April 1980, OTA convened an advisory panel of academic scientists to explore possible alternatives to the present OMDP plan. Most alternatives suggested by the panel focused on the scientific efforts and recommend a delay in developing the technology, and thus the very deep drilling. While these alternatives lack the scientific variety of the present plan, they suggest focusing on a few principal areas of research. Most advocate using the NAS Bally report, which is broadly supported as addressing important problems, for initiating a program. Some advocate making a direct connection between specific science goals and national needs for future oil and gas resources.

The principal elements in an alternative approach with a greater science focus would be to:

- plan and conduct extensive geophysical surveys as the initial effort and to delay decisions on the technology and operations for very deep drilling;
- identify targets that are within the capability of existing technology for the early drilling efforts;
- define the goals of the very deep-drilling phase after the initial work is completed, assuming that substantially improved technology is developed by that time by industry; and
- seek broad scientific support before each phase of the program for specific program plans commensurate with the size of *the* effort.

Although some of the petroleum companies may be more willing to support this alternative approach, others may not – particularly if drilling is proposed in water depths of less than 6,000 ft. Some companies prefer that only industry exploratory drilling be permitted in water depths that are within existing oil and gas leasing regions.

With the above alternative approach, technology would be developed at a dower pace to minimize risks at each step; thus, also making it possible to estimate more accurately the cost at each phase. Less funding would be required in the early years of the program, and the decision to spend more money for a drilling ship might be delayed. Furthermore, more emphasis would be placed on geophysical studies and less on developing hardware.

Industry and some academic scientists advocate the need for a greater understanding of potential hydrocarbon resources in offshore continental margins. The present OMDP offers very little opportunity for assessing commercial resources. Although some petroleum companies want the Government to refrain from direct participation in oil and gas exploration, there is some support for an alternative program that would include some Government and industry cooperation in assessing commercial resources.

Thus, a second alternative approach would probably contain the following elements:

- The petroleum industry would take the lead in planning and conducting a program to assess the commercial resources on the U.S. Continental margins.
- The Government would offer incentives to allow industry funding of the program.
- Scientific studies would be conducted both as an adjunct to the industry program and separately in those areas not covered by industry.

With such an approach, a new science plan would have to be developed in conjunction with an industry plan. Industry would then probably assume the large financial risks and the responsibility for developing the advanced drilling and well-control technology. The budget and technology development of the Government in OMDP would thus be substantially reduced. It is not certain whether the *Glomar Explorer* would be the appropriate vessel for this approach. This approach would also require substantial changes to the existing offshore oil and gas leasing practices, including the probable offer of very large lease-blocks for commercial exploration and development.

NATIONAL OCEANIC SATELLITE SYSTEM (NOSS)

A major new effort in satellite oceanography, NOSS, was scheduled to begin in fiscal year 1981 and continue to fiscal year 1991. The new administration has recommended a substantial budget cut and delay. Jointly sponsored and funded by the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and Navy, NOSS consists of an orbiting spacecraft and dedicated ground control and data processing systems that will collect and deliver remotely sensed data about the global ocean to Navy and NOAA centers. Although primarily an operational demonstration satellite, NOSS will allocate 25 percent of its payload for research experiments. Therefore the satellite will be both a prototype for a future operational system and a station for some ocean research and experimentation.

Satellite systems like NOSS could become important tools for oceanography because satellites can provide wide-area coverage of the ocean surface in a single observation and can observe areas that are infrequently attended by other stations. At present, meteorological satellites provide only limited capability to measure the ocean. One research satellite that has some ocean research capabilities within its mission is *Nimbus-7,* which was designed for experiments in both pollution-monitoring and oceanography and has pioneered technologies for all -weather coverage. However, more experimentation will be necessary to determine the utility of such satellite data for specific ocean research programs.

NOSS follows several early satellite missions that provided oceanic data *(Skylab* and GEOS-3). However, these data were usually outside of the main purpose of the missions. The first satellite with a specific ocean research mission was *Seasat-A*. *Seasat-A* was dedicated to pioneering new microwave and radar remote sensing for oceanography, and was launched in June 1978 with a sensor complement that included one passive and three active radars: a radar altimeter, a synthetic aperture radar, a radar scatterometer system, and a passive scanning multichannel microwave radiometer. These sensor systems acquired real-time data for ocean-surface winds and temperatures, waveheights, ice conditions, ocean topography, and coastal storms. The spacecraft completed a scan of the globe about once every 36 hours, providing extremely high-resolution geophysical data. *Seasat-A* failed prematurely in October 1978 due to mechanical problems, after completing 31A months of a projected 1 -year research mission.[2] The cost of the *Seasat-A* experiment was about $100 million. This included no provision for a ground-based data system to process data at the rate it was acquired aboard the spacecraft.

In early 1978 some planning studies were conducted by NASA to define a *Seasat-B* follow-on research spacecraft to *Seasat-A*. However, NASA, Navy, and NOAA concluded that there were fundamental flaws in the design of the *Seasat-A* data processing system and in the spacecraft itself. They could not immediately agree on requirements for a follow-on ocean-oriented research satellite beyond those originally submitted for *Seasat-A*, *Nimbus-G*, *Tiros-N*, and *Landsat*. Planning continued throughout 1977 and early 1978, but no funding proposals for a new start for an oceanographic satellite were requested until requirements for NOSS were defined. [3]

NOSS Program

The NOSS program is currently in the planning stage. The three agencies that support the program are working together at all levels. During 1980, the Office of Management and Budget (OMB) approved a resource apportionment among the three agencies as follows: Navy (50 percent), NOAA (25 percent), NASA (25 percent). A reassessment of the levels of participation will be made by the three agencies prior to the decision to proceed beyond the alternate-concept-study phase now underway.

Launch of the first NOSS spacecraft by the spaceshuttle was originally scheduled for the

'U .S. Department of Commerce, National Aeronautics and Space Administration, Department of Defense, *NOSS, National Oceanic Satellite System*, Washington, D. C., Mar. 23,1979.

³S. W. McCandless,"An Analysis of the National Oceanic Satellite System, " discussion paper prepared for OTA, April 1980.

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). A fully operational system would presumably follow if the demonstration program proves successful.

Budget

NOSS program budget estimates submitted to Congress in 1980 included the costs for the development of the prototype, the launch of two satellites, and the continuing operations through a 5-year demonstration period from fiscal year 1986 to fiscal year 1991. The flight segment of the program will cost an estimated $240 million to $350 million. Additional funds budgeted for instrument development ($125 million to $150 million), ground support ($175 million to $210 million), and science evaluation and other support ($40 million to $50 million) bring the total to $700 million to $900 million.[4] These costs do not include costs for secondary data distribution and for satellite communication such as a Western Union TDRSS (Tracking and Data Relay Satellite System) satellite data link, needed for the current concept. All of these estimates are in current (fiscal year 1981) dollars and contain no allowance for inflation. If inflation at the rate of 10 percent per year were added to the above, NASA estimates the cost would increase to $1 billion to $1.4 billion. Table 30 provides a fiscal year 1981 estimate of program costs. Table 31 provides an NOSS-funding profile by agency by fiscal year.

[4] U.S. Congress, House Committee on Science and Technology, Subcommittee on Space, Science, and Applications, *NASA Fiscal Year 81 Authorization*, 96th Cong., 2d sess., February 1980.

Table 30.—NOSS Program Cost Estimates (in millions of dollars)

Base program		$580-760
Flight segment	(240-350)	
Instruments	(125-150)	
Ground segment	(175-210)	
Science and evaluation	(20-30)	
Support (shuttle)	(20-20)	
STS tariff		75-85
Management and other support		45-55
Total[a]		$700-900

[a] Excludes funding for TDRSS services.

SOURCE: National Aeronautics and Space Administration, 1980

Mission Goals

Principal goals for NOSS include the attainment of global, all-weather coverage and near-real-time processing and distribution of oceanic data for diverse but important activities such as weather forecasting, climate research, sea-ice forecasting, ocean-wave forecasting, and ocean acoustic-propagation predictions. The most important data products from NOSS will describe the following oceanic parameters:

- *Global Winds.* – Measurements of all-weather, near-surface windfields are necessary for nearly all operational ocean activities (weather forecasts, fisheries monitoring, military operations). These data provide a basis for waveheight-prediction models and will be useful for climate-prediction purposes.
- *Waveheights.* –These data will be useful for correcting wind/wave models and for making direct sea-condition predictions. In turn, these data can be used for real-time ship routing and for selection of optimum conditions for undersea missile launching.
- *Sea-Surface Temperature.* – All-weather measurements of sea-surface temperature can be used to locate ocean frontal zones for antisubmarine warfare, fisheries, and long-range weather forecasting.
- *Chlorophyll Concentrations and Optical Coefficients.* — Measurements of surface chlorophyll concentrations may allow observation of plankton and assist in pollution research. Optical properties of the near-surface water and atmosphere may provide visibility correction factors useful for military operations.

NOSS Users and User Needs

The primary use of the data collected by NOSS will be for Federal agencies with operational missions. Secondary uses of the data will be for Federal research, and for scientific and commercial applications. A TriAgency Mission Needs Statement has been written that identifies requirements of each funding agency for global oceanographic data; sufficient oceanographic data within the territorial waters of the United

Table 31.—Funding Profile by Agency by Fiscal Year[a] (fiscal year 1981 dollars in millions)

	1981	1982	1983	1984	1985	1986	1987	1988-91	Total
NASA	6	34	47	43	30	19	—		179
NOAA	4	11	29	49	48	32	16	28	217
DOD	12	40	7	89	77	50	16	29	386
Total	22	85	149	181	155	101	32	57	782

[a]Preliminary planning estimates only —TDRSS charges not included

SOURCE National Aeronautics and Space Administration

States; and a capability for real-time, rapid high-volume processing and distribution of remotely sensed oceanographic data.[5]

Navy needs global monitoring of oceanographic conditions in real-time to provide timely, accurate oceanographic predictions on a global basis to its operational fleet of surface ships, submarines, and aircraft. NOAA justifies its need for satellite oceanic data to support its four major missions in fisheries management; coastal zone management; mapping and charting; and, most significantly, weather services which will benefit directly from the data to be collected. NASA's interest in NOSS relates to NASA's role in the expansion of global environmental knowledge, in its studies of space activities for peaceful and scientific purposes, and in the useful application of space science and technology.

Civilian considerations, economic benefits, and operational data requirements are also claimed as major justifications for NOSS. Proof-of-concept and research demonstrations from NASA's Seasat project and from other Government projects (Defense Meteorological Satellite Program, Tires, Nimbus, GEOS, and Landsat) have shown applications for civilian users that include offshore oil and gas developers, the fishing industry, the maritime industry, and the oceanographic research community.

Even though civil-sector needs are widely referred to in NOSS program justifications, civilian users have only recently been asked to contribute suggestions. This fact has spurred these users to organize and state their focused interests in NOSS. Although major benefits are attributed to civilian users, the Federal agencies managing NOSS cannot be as responsive to research and commercial users as the users would like when civil user needs conflict with agency mission needs.

During 1980, NOAA held a series of five 1-day regional conferences around the United States to inform potential users about NOSS and to encourage their participation in the development of the program. The conference objectives were to obtain comments from users on priorities and requirements for NOSS data and to develop methods of participation. The participants in the workshops expressed the following concerns in a NOAA draft report of the workshop results:

- Support in the user community for NOSS is tempered by previous experience with existing satellites. Specifically, the length of time to receive data and information has been too long, and the data are not consistent in format and quality.
- A data distribution system that works should be in place prior to launching NOSS. Availability of *Nimbus-7* sensor data in conjunction with ongoing marine experiments would significantly enhance NOSS statements on the capabilities and validity of satellite-derived data.
- Suggestions were made to include near-real-time wind, wave, ice, and water-mass data from NOSS on a time base comparable to that of data available from other environmental satellites.
- There should be "focused points of contact" in NOAA with whom users can interact in lieu of the present system in which five different NOAA components have responsibilities and information.
- Before investing in equipment necessary for using NOSS, certain users want assurances

[5]National Oceanic Satellite System Steering Committee, *Major System Acquisition Tri-Agency Mission Need Statement, National Oceanic Satellite System*, Washington, D. C., Aug. 20, 1979.

that similar satellite systems will operate after NOSS.

- The research users are concerned with the lack of sufficient computer capabilities to support planned NOSS research. At present, no facility can handle the large volume of data sets that will be generated. A national facility for interactive processing of NOSS data is a high-priority requirement among research and development users.[6]

NASA, which has been most sensitive to civil-sector needs in the past, has been assigned responsibility to foster scientific interest in NOSS. This role may be difficult because some scientific interests are in conflict with certain operational objectives. Payload space reserved for science and archival data files can and will be used for scientific purposes; however, it is not likely that basic orbital parameters and design configurations will be changed to accommodate science needs. It may be difficult to protect and preserve even the payload reserved for research if overruns occur and if payload, volume, and power needs grow.

Moreover, concern has been expressed by those who are not a part of the triagency team that a single NOSS demonstration project will not satisfy all of their needs. As a result, NASA is studying various supplements and alternatives to NOSS, including other research satellite projects which, if funded, would provide more comprehensive data. These project proposals are described later in this report.

Key Features of NOSS

NOSS includes two spacecraft and a complete ground system for receiving and processing data from each satellite sensor and for supplying that data to primary networks for handling and storage in both Navy and NOAA. This ground system is at least 25 percent of the total system cost and a major portion of the program's hardware. The entire NOSS system will be designed with at least a 5-year lifetime so that replacement and repair will be minimal.

[6]U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Earth Satellite Service, *Report of the Conference On the National Oceanic Satellite System*, September 1980.

The sensors that have been proposed for the NOSS satellite are based on operational needs identified by Navy and NOAA with special consideration to those sensors that have had successful previous development and testing. The following NOSS sensors, that have had varying amounts of testing on previous satellites, will be used:

- ***radar altimeter (ALT).*** — Developed and tested on *Seasat-A, GEOS-3;*
- ***coastal zone color scanner (CZCS).*** — Developed and tested on *Nimbus-7;*
- ***large antenna multichannel microwave radiometer (LAMMR).*** — Adapted from the scanning microwave radiometer that was used on *Nimbus-7, GEOS-?;* and
- ***radar scatterometer (SCATT).*** — Developed and tested on *Seasat-A.*

A variety of orbits for a satellite such as NOSS can be chosen, including polar, near-polar (Sun-synchronous), and low-inclination orbits. The orbit inclination angle to the Equator can vary, depending on the satellite's altitude, the desired instrumentation swath, the sensor suite, and the mission objectives. The nominal inclinations for each kind of orbit and the logical orbit selection as a function of the primary mission measurements are summarized in table 32. For instance, if monitoring ocean color is a primary mission requirement, a Sun-synchronous orbit must be used to provide constant Sun-angle light reflections. On the other hand, if polar ice coverage is of primary importance, a polar orbit is required for optimum coverage.

A near-polar, Sun-synchronous orbit has been selected for NOSS spacecraft. This orbit is a compromise based on an evaluation of the most important operational needs for ocean coverage and the optimum operating conditions for all of the sensors. The indications are that while useful data coverage of ice conditions can be made from the near-polar Sun-synchronous orbit selected for NOSS, open-ocean circulation will definitely require a satellite in a low-inclination orbit like that of *Seasat -A.*[7]

[7]National Aeronautics and Space Administration, *National Oceanic Satellite System (NOSS) Orbit Selection and Coverage Study Report*, Washington, D.C., Aug. 14, 1980.

Table 32.—Comparison of Orbit Selections—Oceanographic Satellites

Measured parameter	Polar 87 °-93”	Near-polar Sun-synchronous 970-990 (NOSS planned orbit)	Low inclination 105°- 1150 (Seasat orbit)
		Inclination to Equator	
Winds	x	x	x
Waves	x	x	x
Sea-surface temperature	x	x	
Ice edge	x		(a)
Polar ice dynamics	x	(a)	—
Color (chlorophyll) coastal area	—		
Circulation (deep ocean)	–	(a)	(b)

x = optimum coverage
[a]Less than complete coverage
[b]Requires a large spacecraft for Optimum coverage

SOURCE Off Ice of Technology Assessment

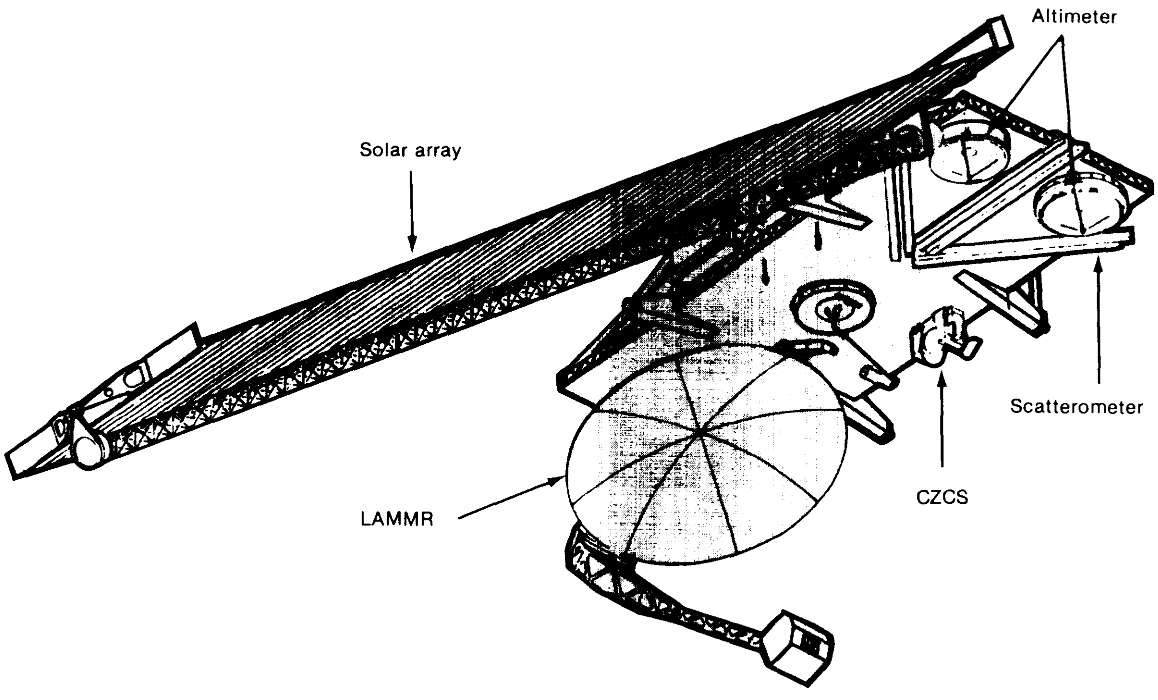
System Description

A series of studies of alternative concepts and configuration are now being performed by contractors to define the final NOSS design. Elements under consideration in these concept studies include the optimum use and deployment of ground systems (including the location of the primary processing facility) and the methods to accomplish a 5-year systems lifetime having a greater than 95-percent availability. The selection of the orbit and sensors, fixed prior to initiation of these studies, will not be part of the alternative concepts to be evaluated.[8]

Figure 17 illustrates the NASA/Goddard Space Flight Center conception of the NOSS

[8]U. S. Department of Commerce, National Aeronautics and Space Administration, Department of Defense, *NOSS, National Ocean Satellite System*, Washington, D. C., Mar. 23, 1979.

Figure 17.—Goddard Concept of NOSS Spacecraft



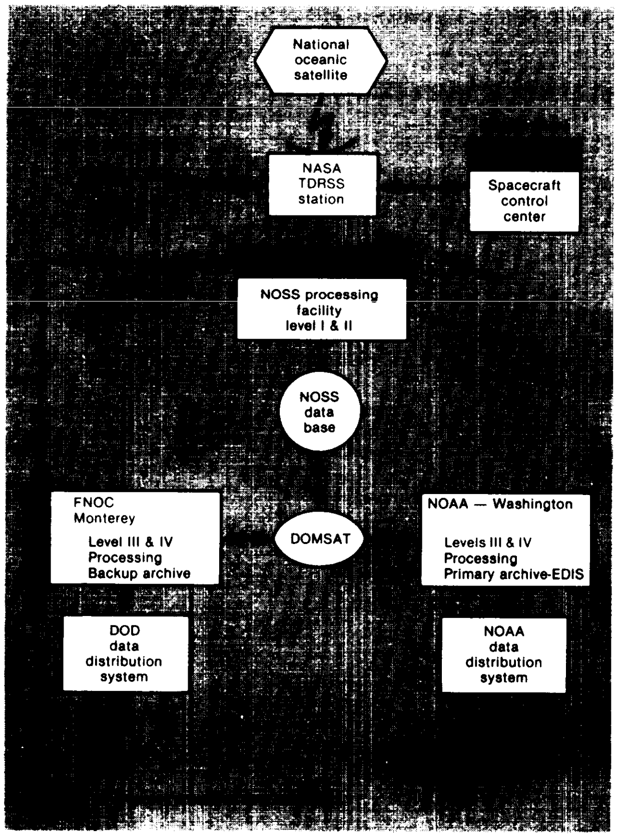
SOURCE National Aeronautics and Space Artmlnistratlon spacecraft. The spacecraft sensors and the shuttle launch and retrieval are considered part of this package.

The basic elements of the ground segment, shown in figures 18 and 19, will include system control, data processing, and distribution. System control is where all major spacecraft and data decisions are made and where complete information on the status of the entire system is available.

An important functional part of the ground system is the ability to perform near-real-time processing. Such processing of raw NOSS data will take place initially in the primary processing facility, which will:

- *ingest raw output* data from all sensors and tracking aids, such as positioning and timing information, and engineering data important to sensor calibrations (level O);

Figure 18.—NOSS Functional Diagram



SOURCE National Aeronautics and Space Administrat!on

- create preprocessed sensor data records (level I); and
- *create geophysical* data records (level II).

The computer programs (algorithm specifications) necessary to convert the raw sensor data to geophysical quantities such as windspeed, waveheights, and surface temperatures will be provided by the Government to the mission contractor who will operate the primary processing facility. Distribution of level I and II NOSS data from the primary processing facility will be restricted to the primary users — NOAA and Navy. Further data dissemination will be implemented by NOAA, but is not designated as part of the NOSS program per se.

From Navy and NOAA, NOSS outputs will then be sent to facilities for storage and for further processing and distribution (respectively level III and IV). The archival subsystem will be responsible for the storage, production, and maintenance of all data and data products and for a current data directory.

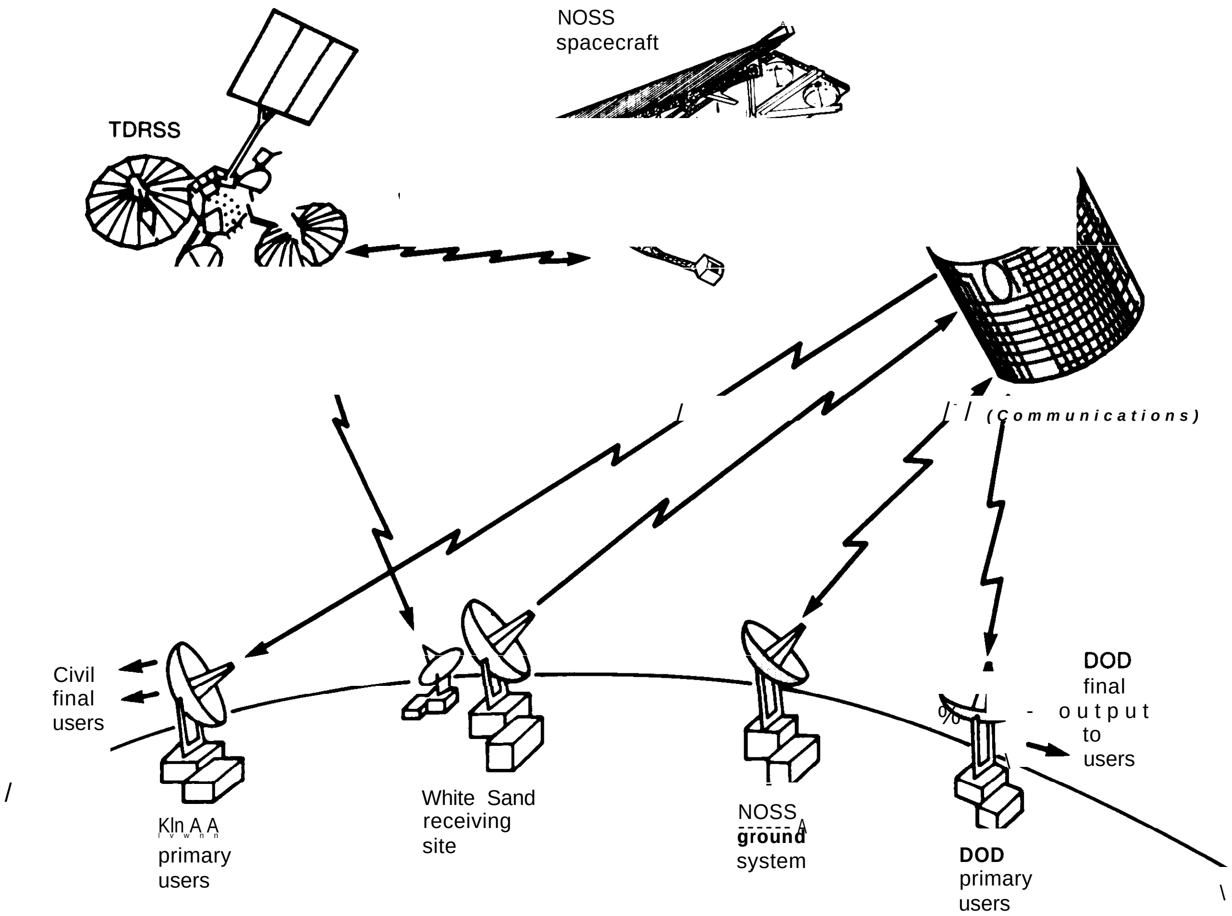
NOSS Status

Planning for NOSS began in the fall of 1977 when NASA, Navy, and NOAA met to discuss the need for operational remote sensing of the ocean environment. These three groups formed a triagency program management group to which there have been few changes in composition and structure since its inception. When this structure was originally conceived, the Jet Propulsion Laboratory (JPL) continued its *Seasat* role as project manager, however, this assignment was shifted by NASA management in early 1979 to the Goddard Space Flight Center because of the Center's operational experience and involvement with the Tires weather satellites.

The following is a brief listing of NOSS program milestones that have already occurred:

1. *January 1978:* program structure established.
2. *March 2978:* objectives defined and approved.
3. *April-June 1978: NOSS* working group in place at JPL, conducting feasibility analyses.

Figure 19.—NOSS End-to-End System



SOURCE National Aeronautics and Space Administration

4. *June 2978:* study results presented to steering committee.
5. *July-September 1978:* revisions to and finalization of four-volume set of study results; synthetic aperture radar removed from NOSS payload.
6. *March 1979:* Goddard Space Flight Center chosen as lead NASA center for NOSS.
7. *August 1979:* release of Request for Proposal (RFP) to begin a major procurement for the total NOSS.
8. *January 1980: six* contractors responded to the NOSS' RFP to perform concept-definition studies.
9. *August 2980:* four contractors selected for concept definition.

A total systems procurement for NOSS is proceeding within the three funding agencies. The general OMB policy that has been applied to NOSS procurement is to contract for missions, not equipment, thereby encouraging innovation and conceptual competition to promote exploration of alternative flight and ground systems that will be compatible with Government-furnished sensors. The major objective of this type of procurement is to foster competition between concepts throughout the entire acquisition process, ensuring that a range of appropriate tradeoffs of performance, cost, risk, and schedule are considered.

Needs and objectives require a mission contractor to:

- furnish a NOSS flight segment, except for sensors, including satellite systems and spaceshuttle interface and checkout system;

- furnish a NOSS ground segment from communications interface to primary users;
- provide overall systems operation for 1 year; and
- furnish plans for the following 4 years of operation.

Original plans called for a total systems procurement for NOSS to be initiated during 1981 and a contractor selected by 1982.

Concurrent with the main contractor's effort, procurement of the four NOSS sensors would begin. NOSS sensors will be provided as Government-furnished equipment to the NOSS contractor selected. Three of the four sensors, ALT, CZCS, and SCATT, will be sole-source procurements because they are nearly identical to the *Seasat* and *Nimbus* instruments and they are being purchased from the same contractors. LAMMR, the longest lead-time sensor, will be competitively procured.

The program milestones that follow the concept-definition studies span 10 years: 5 years until the launch of the first satellite system and 5 years of planned system operation.

Analysis of NOSS Program

At present, satellites appear to be a promising, but limited, research tool for oceanography. Because past oceanic satellite observations have been inconsistent in quality and inadequate in coverage, the merged, high-quality oceanic data sets with long-time histories required for some research are deficient. The measurement capabilities to be provided by NOSS will only partially solve this problem.

Measurement Goals and Expected Performance

The performance goals and present estimates of system capability for NOSS are shown in table 33. NOSS will meet many but not all of the stated goals that were established as long-range goals for an operational system. Some of the goals will require multiple satellites performing simultaneously in complementary orbits to achieve the temporal coverage indicated, as well as sensor technology advances to achieve the accuracies noted.

Based on the *Seasat-A* and *Nimbus-7* results, NOSS capabilities appear to be reasonable and achievable, with the possible exception of LAMMR performance. This sensor has not yet demonstrated its capability. Figures 20 through 23 describe the performance and capabilities of each NOSS sensor.

System/Mission Design. –The potential contribution of NOSS to operational needs is significant. The contribution to research will depend on many factors. NASA has concluded that no single system can satisfy all the requirements for satellite oceanography. Combining data from various satellites with in situ data will be necessary. To handle data from both operational and research satellite systems as well as from many other stations will require a cooperative program with participation from the oceanographic community and NOAA. More than just archival services will be required. The data management system must be capable of extracting and combining data from several sources, thus preventing a possible problem in data handling and formatting in addition to requiring funding for satellite hardware.

A concern of the oceanographic research community and commercial users is that NOSS may be the only oceanographic satellite authorized as a new start in this decade. The research payload for NOSS has not been defined at this time. The academic community has some concern that a loss of research payload will result from inflationary costs and weight-budget overruns during NOSS program development. Research needs that require hardware systems other than NOSS may not be met until the 1990's. Two major experiments — e.g., the Ice and Climate Experiment (ICEX) and the Topography Experiment (TOPEX), that require new hardware or platforms have been proposed by NASA and the research community, but budgets for these experiments have not been submitted to Congress for authorization.

ICEX Science Applications Working Group was established in February 1979 to consider research needs for the mid- 1980's in satellite sens-

Table 33.—NOSS Operational Geophysical Measurements

	Goals		Expected NOSS system capability		
Parameter	Accuracy	Resolution	Accuracy	Resolution	Instrument
Wind					
Speed	2m/s	25km	+/- 2m/s or +/- 10%	17km	LAMMR
Speed			+/- 2m/s or +/- 10%	50km	SCATT
Speed (Nadir only).			+/- 2m/s or +/-10%	12km	ALT
Direction.	10°	50km	+/- 20	50km	SCATT
Sea-surface *temperature*					
Global.	1.00 c	25km	+/- 1 .5" c	25km	LAMMR
Local.	0.5° c	IOkm	* 2.00 c	1.Okm	CzcsIII
Waves (sea state)					
Significant wave height	0.3m	25km	+/- 0.5m or 10%	IOkm	ALT
Direction.	10°	25km	—	—	—
Ice					
Cover	150/0	20km	& 150/0	9km	LAMMR
Thickness.	2m	50km	2 2m	9km	LAMMR
Age	New, 1st yr, multiyear	20km	1st yr, multiyear	9km	LAMM R
Sheet height	0.5m+/-2m change	IOkm	+/- 2m change	10km	ALT
Water-mass definition					
Chlorophyll	Within factor of 2	0.4km	Within factor of 2	1.Okm	CZCS/ll
Turbidity	Low, medium, high	0.4km	Within factor of 2	1.Okm	Czcs/II
Horizontal **surface** *currents*					
Speed	5cm/s	20km	+/- 15cm/s	50km	ALT
Direction.	10°	20km	+/- 20°	50km	ALT

SOURCE: Off Ice of Technology Assessment

ing of ice parameters for ice processes research, climate studies, resource extraction, and polar ocean operations. The study group responded with a satellite concept similar to NOSS that would be flown in a polar orbit within 30 of the pole. The satellite system would include special altimetry and radar systems to map ice elevation as well as telemetry links for locating and transmitting buoy data. It is not clear yet whether NASA will propose a new start for ICEX or will try to accommodate these needs in an operational NOSS.

TOPEX is an experimental spacecraft concept that is being developed to determine global geostrophic (density balancing) circulation of the oceans. NOSS will not be capable of providing the proper altimetry coverage from a Sun-synchronous orbit to perform the precision ocean-surface topography needed for TOPEX. To obtain accurate orbit and geoid information required for making precision altimetry measurements, TOPEX may use an orbit inclination (105 °to 1150, similar to that of *Seasat*. TOPEX is being proposed as a new start in fiscal year 1983 for launch in fiscal year 1986 by NASA.[9]

Orbit Selection Tradeoffs. –A report prepared by NOSS' program office in August 1980 details how the satellite orbit was selected. The analysis was based on each funding agency's stated needs or measurement goals (as shown in table 33) and on the requirements of the four basic sensors selected. The analysis does not consider major variations and deep-ocean circulation measurements, nor does it consider any alternatives in sensor complement.

NOSS' orbit was selected on the basis of operational user needs (the Federal TriAgency Team), with secondary consideration for other scientific research and commercial applications. The need for a Sun-synchronous orbit for NOSS

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'National Aeronaut ics and Space Adm inistrat ion, *Oceanic Processes Progra m Status Report Fiscal Year 1980,* Washington, D. C., July 1980.

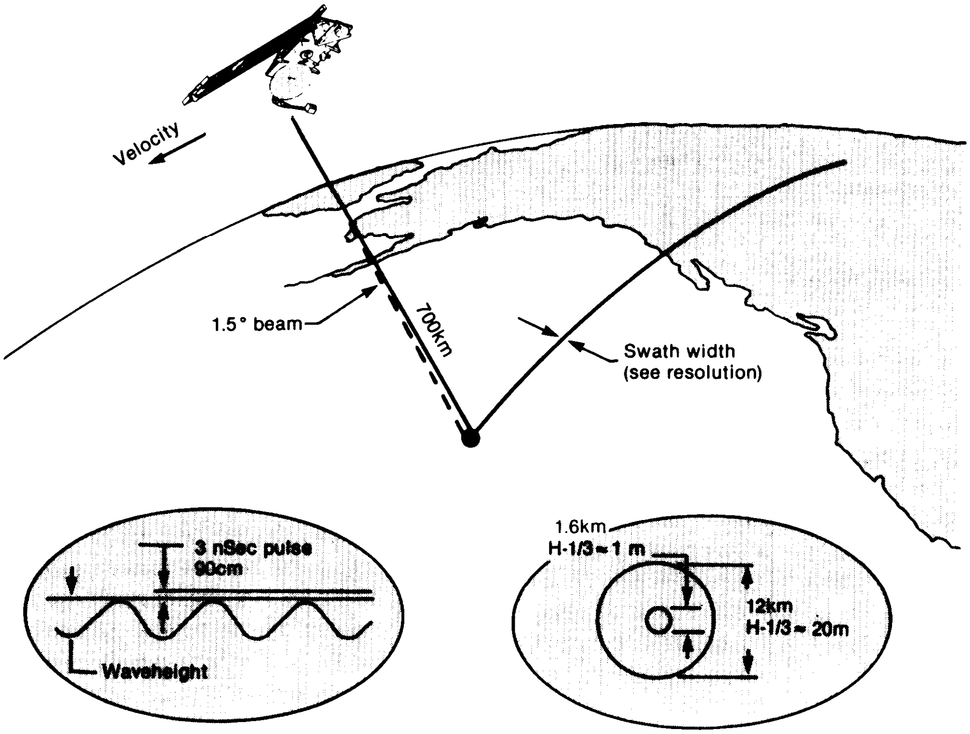
[10]National Aeronautic-s and Space Admi n istra t ion, *National Oceanic Satellite System (.%'0.7S) Orbit Selection and Coverage Study Report*, Washington, DC., Aug. 14, 1980.

Figure 20.–NOSS Altimeter

The NOSS altimeter (ALT) is a short-pulse, fixed-beam active microwave **sensor that operates at 13.5** GHz. It **makes precision measurements of significant waveheight in the range 1-20m. ALT surface topography data can be processed to derive ocean-surface current and icesheet height along the satellite ground track.**

Predicted altimeter capability

Parameter	Range	Accuracy	Resolution
Satellite altitude	700km +/- 15km	10cm	—
Ocean waveheight	1 to 20m	0.5m	< 10km
Surface currents	15 to 250cm/s	15cm/s	< 10km
	O to 3600	20”	



Waveheight measurement

Foot print

SOURCE. National Aeronautics and Space Admlnlstratlon

was partially driven by the requirement for a CZCS. CZCS is the one sensor that can operate only in visible-light bands and thus requires a Sun-synchronous orbit (97 °to 990 inclinations). Other NOSS sensors do not require a Sun-synchronous orbit because they use all-weather microwave radiometers. The NOSS ALT, for instance, works best in orbit inclinations that improve geodetic information (66 °to 1080, by permitting north-south and east-west component derivations.

Data taken in a Sun-synchronous orbit will not have a diurnal variation because only conditions at a single local time will be observed. This result can be good or bad depending on the user’s point of view. Moreover, this orbit renders some of the sensors less than optimally effective. In coastal

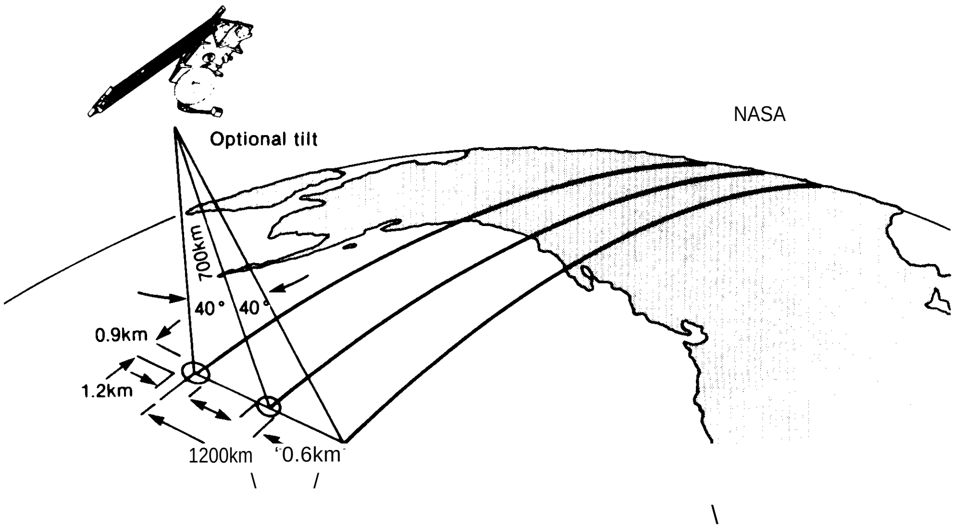
Figure 21.–NOSS Coastal Zone Color Scanner/2 (CZCS/2)

The purpose of the CZCS/2 is to measure the abundance or density of chlorophyll at or near the sea surface. This will reveal the abundance of phytoplankton or planktonic plants which contain chlorophyll and are at the bottom of the oceanic food chain. The CZCS/2 maps the location and measures the density of the plankton on a temporal or time scale, providing information to marine biologists and the fishing industry.

Additional objectives of the CZCS/2 are the measurement of sediment in coastal waters, diffuse attenuation coefficient, and the measurement of sea-surface temperature. The temperature measurements can detect cold water upwelling, which frequently provides the nutrient necessary for plankton "blooms."

Predicted NOSS system capability

Sea-surface temp.	Sensitivity	Range	Accuracy	Resolution
Local	1.00 C	– 2 to 35° C	2.0° c	0.8km
Water-mass definition				
Chlorophyll	10% (mg/m^3)	0.1 to IOOmg/m^3	Within factor of 2	0.8km
Diffuse attenuation Coefficient (K)	O. Olin-'	O to 6m^{-1}	Within factor of 2	0.8km



SOURCE National Aeronautics and Space Administration

areas, the signal strength will be marginal. The signal bandwidth of chlorophyll and sediment measurements by CZCS overlap causing interpretation difficulties. Moreover, algorithms to map concentrations of chlorophyll are not yet fully developed. Therefore, even if the concentrations can be measured, NOAA, the primary user of the data, has not demonstrated how the measurements will be effectively used to support its operational programs.

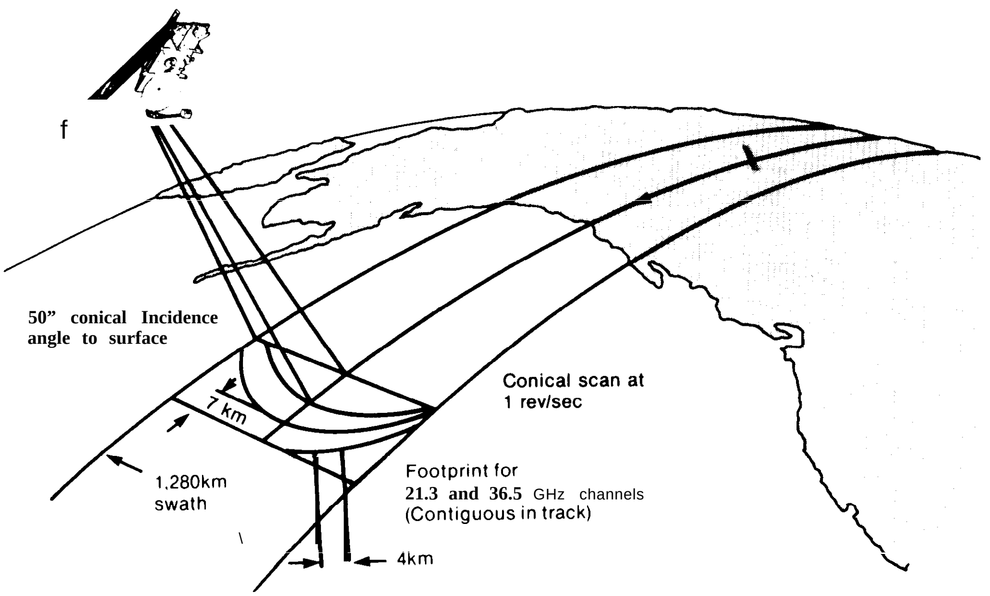
Selection of a Sun-synchronous orbit has some benefits, however, NOSS will require less time-correction of data to aline with the format of meteorological data products from both Navy and NOAA because it will use the same standard

Figure 22.–NOSS Large Antenna Multifrequency Microwave Radiometer (LAMMR)

The LAMMR is a passive multichannel microwave radiometer that provides high-resolution radiometric brightness temperature maps of the Earth's surface and atmosphere at multiple frequencies in verical and horizontal polarization.

Predicted LAMMR capability

Parameter	Range	Accuracy	Resolution
Sea-surface temp.	– 2 to 35° c	1 .5° C	25km
Sea-surface temp.	– 2 to 35° c	2.5° C	16km
Oceanic windspeed	O to 50m/s	2m/s	20km
Sea-ice coverage	o to 1000/0	15 "/0	9km
	New to multiyear	New, 1 yr., multiyear.	
Water vapor-integrated			
Atmosphere water-vapor content	O to 6gms/cm²	0.2gm/cm²	9km
Liquid water	O to 100mg/cm²	4mg/cm²	9km



SOURCE National Aeronautics and Space Administration

worldwide reference based on Greenwich Mean Time. Another benefit is that the near-polar NOSS orbit ensures better ice coverage than does a low-inclination orbit similar to that of *Seasat.*

Technology Readiness/Sensors. –The effectiveness of the entire NOSS depends substantially on the capability of the sensors to produce accurate and reliable oceanic measurements. In general, the sensor technology is well-founded, with a few exceptions.

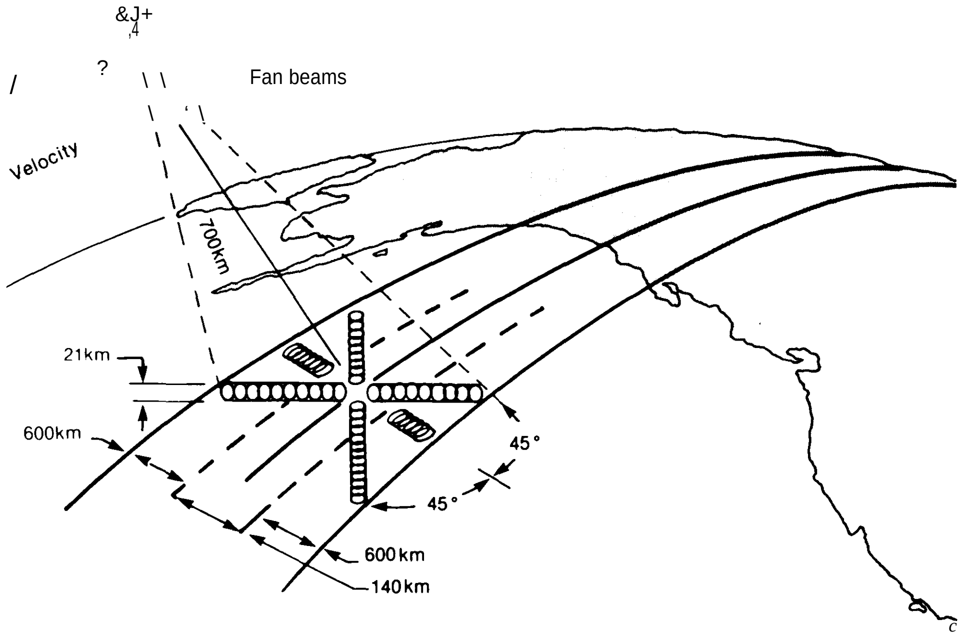
Of the four primary sensors on the NOSS spacecraft, LAMMR is classed as a major new sensor development, while the three remaining sensors are modifications of prototype sensors that were flown either on *Seasat-A* or on *Nimbus-7.* Thus, LAMMR does not have a concrete performance history at the same level as that of the other NOSS sensors. It is an improved version of the scanning microwave radiometer on *Seasat* and *Nimbus* that provided data with up to 1.50 C accuracy.

Figure 23.–NOSS Scatterometer (SCATT)

The NOSS Scatterometer (SCATT) is a long-pulse scanning active microwave radar at 13 to 14 GHz that provides measurements of radar backscatter coefficient from which the synoptic scale, ocean-surface vector winds are inferred. The physical basis for this technique is the Bragg scattering of microwaves from centimeter length capillary ocean waves.

Predicted NOSS/SCATT capability

Wind	Sensitivity	Range	Accuracy	Horizontal resolution
Speed	1.5m/s	O to 50m/s	2m/s	50km
Direction	200	0° to 360°	20°	50km



SOURCE National Aeronautics and Space Administration

The synthetic aperture radar (SAR) was removed from the NOSS program by NASA in the fall of 1978. The reasons given for its removal were that its high data rate and experimental nature prevented its operational use and that its cost would be too high. Recently, completion of *Seasat* studies have shown that while resolution of the open-ocean data from the SAR is good, lack of sea-truth and inadequate position information make it very difficult to interpret SAR output. Those who disagree with the agency decision to shelve SAR point out that all of these problems could be solved. Thus, although NASA has indicated research needs for an ocean-observing SAR sensor in a near-polar orbit, it stresses that improved interpretation of SAR imagery and near-real-time data distribution would be prerequisites for SAR use. SAR is proposed as part of NASA's 15-year objectives and may eventually be launched in a civilian oceanographic satellite.

Recent development has indicated that the use of multiple sensors, possibly on multiple satellites, to estimate one parameter could substantially improve the capability of remote-sensing systems. Significant improvement of some measurements, such as sea-surface temperature, will require in situ measurements in conjunction with satellite measurements.

Technology Readiness/Ground System. – The most important concern about NOSS' ground system is the acquisition, management, and distribution of the acquired data. The processing and communication transfer and the archiving of data is not limited by technology. NOSS civilian-user data distribution plans are currently being developed by NOAA.

Because of the concerns of many potential satellite data users, NOAA is now planning for the development of a data system to process and handle NOSS data for end-users, both inside and outside of the Federal agencies. This system will not be part of NOSS' program as such, but will be designed to make NOSS measurements widely available and to produce useful products for Government research labs, universities, private industry, and the oceanographic community in general.

The two general classes of distribution systems that may be utilized are systems of distribution to standard user terminals and of distribution to other computer installations. One class is that of data distribution to NOSS user terminals via standard dial-up or permanently connected commercial telecommunications services. The second class of data distribution is a computer-to-computer service that can be tailored to support the transfer of data between NOAA and end-user computer installations.

The Navy Fleet Numerical Oceanography Center (FNOC) in Monterey, Calif., is making progress with the problem of processing and distributing oceanic data from satellites that will be directly transferrable to the NOSS program. FNOC along with NASA operates a satellite data distribution system demonstration project for commercial users in accordance with a memorandum of agreement between NASA and the Department of Defense. Likewise, NOAA is handling sea-surface temperature data from *Tiros-N*. The amount and complexity of the coded NOSS datastream, however, require a much bigger processing effort than that of any current effort. This aspect of the NOSS program will be the responsibility of NOAA.

Nearly two decades of environmental satellite missions and technology has produced some valuable data. However, information of value to many users has been difficult, if not impossible, to obtain in the past. In the regional NOSS user conferences conducted by NOAA, users expressed the opinion that a major success for the NOSS program may lie not in creating NOSS, but rather in creating a national oceanic data system with compatible data formats from various stations.

NASA has also identified the high-priority need for an oceanic data system, not now part of the NOSS program, that could foster research associated with remotely sensed parameters from many data sources, including NOSS, *Seasat*, *Nimbus*, *Tiros*, and GOES. Data would be far more useful and usable by scientific and commercial users if it were processed in both a near-real-time as well as a retrospective mode, with data products and data links available on-line from a computer rather than through hard copy only.

FISHERIES AND LIVING RESOURCES RESEARCH PROGRAM

The Federal Government has an ongoing, sizable investment in programs and supporting technology designed to study and manage living marine resources. The technology required for the programs is unique and is a mixture of conventional systems which have been in use for a long time and new developments which could significantly advance future research.

OTA's study of both programs and technology includes a comprehensive analysis of marine fishery management, fishery research, and stock assessment. In addition, it covers specific problems associated with the krill fishery* in the Antarctic[11] and with the implementation of the Marine Mammal Protection Act (MM PA) of 1974.

OTA study highlights are presented here, more detailed information is available in the complete study version, being issued by OTA as a working paper. [12]

The Fishery Conservation and Management Act

Most of the coastal countries of the world have asserted authority over fisheries within a 200-mile-wide exclusive economic zone bordering their coasts. This action was taken in the United States by means of Public Law 94-265, The Fishery Conservation and Management Act (FCMA) of 1976.13 Under FCMA, which became effective March 1, 1977, a clear Federal authority was established over a fishery conservation zone defined as the area between the outer limit of State authority (usually 3 miles) and 200 miles from the coast. Foreign fishing is now allowed in the zone only under permit and in accordance with management plans. To monitor compliance with the Act, observers are often placed onboard foreign vessels, and frequent radio reports of foreign catches are gathered. However, to what extent the United States should allow foreign fishing inside its 200-mile zone continues to be a subject of debate, and recent proposed legislation calls for gradually phasing out foreign fishing in the U.S. 200-mile zone.

With FCMA, the United States brought under its management about 10 percent of the conventional ocean fishery resources of the world. This decision caused a dramatic increase in U.S. commercial catches that had remained about level for the preceding three decades. In 1970, for instance, the world commercial catch totaled 59.7 million tonnes; 7.4 million tonnes of this amount were caught within the U.S. 200-mile coastal zone 1imit by both U.S. and foreign fishermen. The U.S. commercial catch alone in 1970 was 2.9 million tonnes. [15] By 1980 the U.S. catch had increased to 3.5 million tonnes, reflecting both the restraints placed on foreign fishing and the increased opportunities for U.S. fishermen to seek stocks which had been almost exclusively fished by foreign fishermen. [16]

In addition to extending U.S. fishing opportunities, FCMA established principles of fishery management and a system of Regional Fishery Management Councils to meet the demand for

* Krill are shrimp-like crustaceans, 4- to 6-cm long, which are widely distributed around Anarctica and inhabit an area about 5,300,000 square nautical miles. In contrast, the U.S. Continental Shelf fishing area is about 800,000 square miles. In part of the area, krill form dense aggregates called "super swarms, " which are the object of the fishery. Krill are the major food source for baleen whales and other marine mammals, fish, and birds in the region.

[11] Takeyuki Doi, Takehiko Kawakami, "The Estimation of Krill Abundance in the Antarctic by Analysis of Echogram," *Biomass* 2(5): 1.11, 1980,

[12] College of Fisheries of the University of Washington, OTA Working Paper on "Fishery Research Technology," including manuscripts from a conference, Seattle, Wash., Apr. 21.24, 1980.

[13] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *The United States Marine Fishery Resource, Marmap Contribution No. f,* John P. Wise (cd,) (Washington, DC.: U.S. Government Printing Office, 1 974).

[14] U.S. Congress, Senate, *American Fisheries Promotion Act,* H. R. 7039, 96th Cong., 2d sess. (Washington, DC.: U.S. Government Printing Office, 1980).

[15] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *The United States Marine Fishery Resource, Marmap Contribution No. J,* John P. Wise (cd.) (Washington, D. C.: U.S. Government Printing Office, 1 974).

[16] US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Fisheries of the United States, 1979,* April 1980.

better information on which to base the management of both U.S. and foreign fisheries. This demand was the result of research findings that previous management was not as effective as possible. The Act required the regional councils to develop management plans according to the following requirements:

- Each fishery in the United States that comes under the purview of the law must be managed for optimum yield, defined as that amount of fish "which will provide the greatest overall benefit to the Nation, with particular reference to food production and recreational opportunities. "
- Optimum yield must be calculated by first calculating maximum sustainable yield and then modifying that figure by ". . . any relevant economic, social, or ecological factor. "
- Planning for the attainment of optimum yield must be specified in a fishery management plan.
- Fishery management plans must contain:
  — specifications of conservation and management measures applicable to the fishery;
  — a description of the fishery, including number of vessels, type and quantity of gear, the species of fish involved and their location, management costs, actual and potential revenues from the fishery, recreational interests, and extent of foreign fishing and Indian treaty fishing rights;
  — an analysis of present and probable conditions of maximum sustainable yield and optimum yield and a summary of information to make such a specification;
  — the capacity of U.S. fishing vessels; and
  — various specific data from the fishery.
- The acceptability of a plan must be tested against national standards that specify that the plan be consistent with:
  –preventing overfishing while sustaining optimum yield;
  — using the best scientific information available;
  — management of stocks throughout their ranges and in close coordination with interrelated stocks;
  — conservation and management measures that promote efficiency in utilization of fish;
  — conservation and management measures that consider variations and contingencies among fisheries, fisheries resources, and catches; and
  — conservation and management measures that minimize costs and prevent duplication.

Fishery Management

Prior to FCMA, any management of domestic U.S. fisheries was primarily handled by the States. Few of these States had the data on offshore stocks needed to support management of these fisheries, and yield concepts were not widely accepted. A review in the early 1970's of U.S. ocean fishery resources and management revealed that many of the 31 most important fish species or species groups, most of which comprised many stocks, were being managed inadequately. Of those groups that were being managed, few were managed with a yield objective, with the exception of those subject to an international agreement.

Now, the task of managing the domestic ocean fisheries is a very large one. The fishing area adjacent to the United States consists of the Outer Continental Shelf and the upper part of the continental slope out to a depth of 300 fathoms. This area, almost all of which is within the 200-mile zone, amounts to about 800,000-square nautical miles, or an equivalent of about 30 percent of the land area of the United States.

A review that was made just after FCMA was passed listed species that were thought to be overfished or in danger of being overfished in the U.S. fishing area. Those species endangered primarily by foreign fishing totaled 15; by a combination of foreign and domestic fishing, 12; and by domestic fishing alone, 7.[17]

[17] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, *Report to the Congress on Ocean Pollution, Overfishing, and Offshore Development, July 1974 through June 1976*, 1976.

The development of fishery management plans to prevent such overfishing is a lengthy process, requiring from 14 to 32 months to complete.[18] If a Fishery Management Council is amending a previous plan –and amendments of at least a minor nature may be expected annually — it is necessary to restart part or evaluate all of the planning process. In the plans not only the requirements of FCMA must be met but also those of the Endangered Species Act, the National Environmental Policy Act, MMPA, the Coastal Zone Management Act, and various other administrative directives.

Not the least of the problems of developing the management plans is the requirement for information based on research. Special demands on the research base occur when the councils consider all of the alternative regulations of quota, gear, area, season, and size of fish. A further demand is the preparation of the environmental impact statement required for each fishery management plan under the National Environmental Policy Act of 1973. As a result, the 76 plans that were in some stage of development by the end of 1979, only 12 were implemented by the end of 1980, and of these, 7 are plans that involved foreign fishing.[19] Furthermore, each plan that has been implemented is subject to annual review and revision, a lengthy process that will probably continue.

Fishery Research and Stock Assessment

Much fishery research is directed at the problems of managing fisheries, of managing human use of the aquatic environment in which fish live, and of growing fish as a domesticated crop. Now, because of the present capability of overfishing almost any valuable and unmanaged fishery resource, the demand for research to guide management decisions is increasing. Such research includes biological, physical, chemical, mathemat-

Photo credit National Ocean/c and Atmospheric Administration

Monitoring of commercial catches is an important factor in fishery stock assessment and in developing fishery management plans

ical, oceanographic, economic, and other studies as may be necessary.

Many management successes have occurred with fish stocks that were top predators in their ecological niche or with stocks that did not have a strong interaction with other stocks. In such cases if the fishery harvests a good portion of the stock each year, the relationship between the size of the stock and the amount of fishing is satisfactorily predictable. With stocks that are major prey species, fishing may cause only a minor part of the mortality and have an unpredictable relationship to the size of the stock. This assumption is also true of stocks that are short-lived and subject to highly variable survival because of environmental changes.

Particularly important to successful management is fishery stock assessment that includes studies that describe the stocks, assess their abundance, and measure the impact of the fishery on them. Out of a total research budget of about $44 million in fiscal year 1979, the National

[18] U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Operational Guideline for the Fishery Management Plan Process*, 1979.

[19] U. S, Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, council memorandum, vol. 3, No. 12, December 1979.

Marine Fisheries Service (NMFS) allocated about $32 million to such stock assessment activities. Added to this was about $10 million for the operation of the fishery research vessels by the National Ocean Survey in support of the stock assessment activity. These amounts have probably not changed much in fiscal year 1980 or fiscal year 1981 except for adjustments for inflation.[20]

To assess a fishery stock, the stock must first be defined. A stock, defined in FCMA as "a species, subspecies, geographic grouping, or other category of fish capable of management as a unit, " is ideally an intermingling group of one species, but many fisheries catch mixed species, and it is the activity of a fishery that must be managed.

After being defined, the stock is described according to where it lives, where it migrates; if and how it schools; when, where, and how it spawns; how fast it grows; how old it gets; and other aspects of its biology. Such information provides a base for management plans and estimates of abundance. Given the abundance and the amount of fishing effort over a period of time, it is possible to estimate the mortality rate. Given the growth rate, it is possible to estimate not only the effects of fishing on the stock, but also the level of sustainable yield.

Assessing fish stocks involves evaluating fish at all growth stages. Especially critical to the size of a fish stock is the environment of larvae. Normally, fish eggs are produced by the hundreds of thousands or millions by each female, and the larvae have a high mortality rate. Because larvae of most commercial species are freely drifting animals only 4- to 7-mm long (about 1/4 inch), measuring deviations from the norm that will eventually change the size of the stock is exceedingly difficult.

Many other variables also make measuring fish stocks a challenging task. Most fish are distributed in a patchy way over wide areas and migrate seasonally between spawning and feeding grounds. Many behave differently in different hours or seasons. Since the fish population can vary in size and location as well as from human influences, it is hard to locate and count fish, and it is hard to separate human influences from natural variability. Moreover, all fish change in their vulnerability to fishing or sampling gear as they grow from larvae through the juvenile stage to adults. Any mesh in a net will let small animals go through, and no net can be pulled fast enough to capture all of the swiftest and largest fish. No fishing gear is completely nonselective, no sample. can be completely unbiased.

A consequence of the complexity of these variables is that stock assessment depends not only on rigorous methods, but also on experience and judgment. Predicting the abundance of fish is, in some ways like predicting the weather, political elections, or other mercurial events. The reliability of the prediction is a function of the time between the collection of data and the predicted event.

The basic data for predicting yields must include an estimate of the abundance of the stock and the capability of the fishery to catch it. Estimates of both can be obtained from the fishery data and can be quite accurate for the older age groups in the catches. But the fishery has no prior experience with the age group just being recruited to the fishery, and this group may be a large fraction of the stock. A prediction of the abundance of the recruit group must be made from known relationships and measurable environmental factors, both of which can be highly variable. Data from the catches of special nets used by research vessels or from the spawner-recruit relationship must be used in predicting the fishery catch. Direct measurements of the ratio of recruits to adult fish have been made by acoustics for one species, but it is not clear that such research work could be developed into operational systems by NMFS.

Technology

The validity of the stock assessment also depends on the quality and quantity of basic data. The most important data source is the fishery fleet itself. It is vital to the whole management process to have information on the catch and fishing effort by time, species, size of fish, area,

[20] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Stock Assessment Activities Within the National Marine Fisheries Service*, June 1980.

and gear. Such information provides not only an assessment of the capacity of the stock to sustain the catches, but also an assessment of the capability of the fleet to make the catches.

A complimentary and, in some respects, superior source of information is from surveys by research vessels. Such surveys can provide unique information through the use of special gear and by operation in areas not normally fished by the fleet. The surveys can also provide less biased samples of abundance and a greater opportunity for biological studies of the catch. The surveys are expensive, and they cannot provide the assessment of the capacity of the fleet to make the catches.

Fishery research vessels must be able to handle fishing equipment, the fish that are caught, and oceanographic instruments. Handling large fishing gear such as trawls and seines requires major structural and power arrangements. Handling the catch requires deck space for sorting, laboratory space for studying, and storage space. These requirements mean that other ocean research vessels are usually ill-suited for fishery research; although the navigational equipment, laboratory space, and accommodations may be similar.

The fishery research fleet of nine vessels (with the recent addition of the *Chapman)* is operated for NMFS by the Office of Fleet Operations of the National Ocean Survey of NOAA. The budget

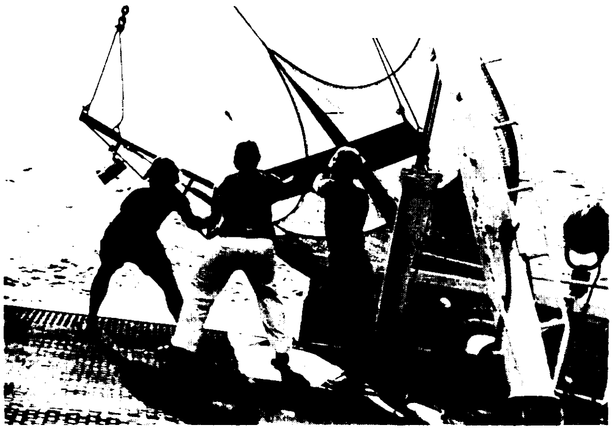


Photo credit Woods Ho/e Oceanographic /nstltuflon

Scientists bring a sampling net aboard a research vessel. Fisheries surveys require careful sampling of stocks during different stages of growth

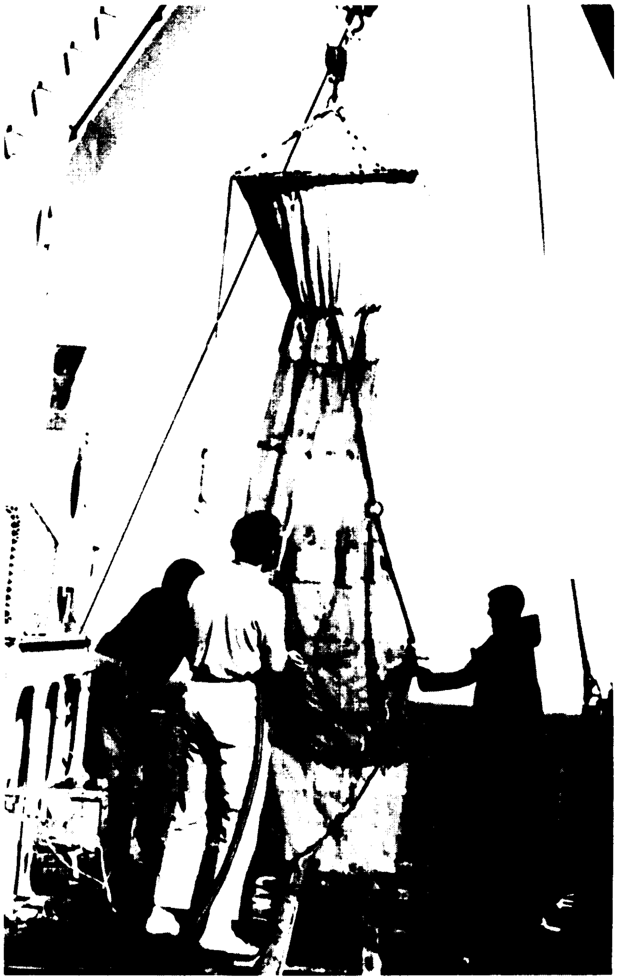


Photo credit Scr/pps /nsfltullon o/ Oceanography

Oceanographers aboard a Scripps research vessel wash down meter net to concentrate marine organisms in the cod end

for the operation of the fisheries vessels for fiscal year 1981 is about $10.2 million, or about one-fourth of NOAA’s fleet budget. This sum provides about 2,000 days of sea time. In addition, NMFS budgets about $2 million for vessel charter and about $250,000 for operations of small vessels. About 90 percent of the ship time supports the resource assessment program.

Foreign fishery research vessels have recently assisted with stock assessment surveys and have added about 400 sea days to U.S. research-vessel capability. This activity has continued under FCMA because it aids in the determination of catch allocations for foreign nations, but it may

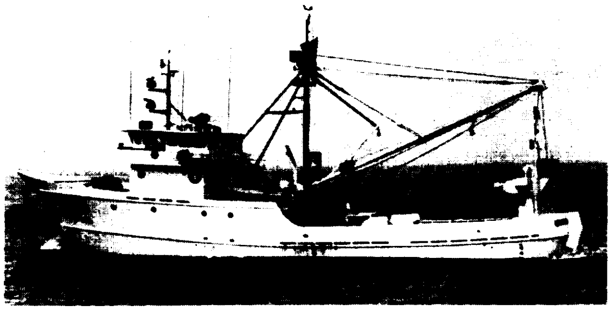


Photo credlf National Oceanic and Atmospheric Administration

National Marine Fisheries Service's 127-ft *Chapman*

not continue much longer. Table 34 lists actual and planned ship days for NMFS research for each ship of NOAA's fleet and for other vessels. Table 35 shows the breakdown of NOAA fleet-support costs by vessel and category for fisheries research in fiscal year 1981.

A method of assessment that is rapidly increasing in effectiveness is acoustic remote sensing from survey ships. Instruments with satisfactory range, sensitivity, and stability have been developed to detect fish to within 1 km from a ship. The instruments cannot identify fish by species,

Table 34.—NMFS Research Sea Days Support—Fiscal Years 1979-81

Source	1979	1980 (projected)	1981 (estimated)
NOAA fleet			
Albatross IV	213	240	250
Delaware II	246	240	250
Oregon II	250	235	250
Jordan	202	232	250
Cromwell	242	250	250
Freeman	138	130	130
Cobb	166	166	166
Oregon	196	189	—
Murre II	145	140	140
Chapman	—	100	250
Kelez	—	30	30
Other	49	30	30
Charter vessels	471	700	700
Foreign ships	400	450	450
Program boats	400	400	400
Other[a]	100	130	150
Totals	3,218	3,662	3,696

aDonated commercial vessel, research contract, etc

SOURCE. National Marine Fisheries Service

except in certain cases, nor can they assess the abundance of fish very close to the ocean bottom or to the ocean surface. Although acoustic methods have not been widely applied to fishery management problems, such applications are advocated by those in academia and in industry who have studied the problem .21 One benefit of effective acoustic techniques over net-sampling techniques would be a reduction in ship time. It may thus be desirable to invest in such technology development if its benefits appear substantial. The technology development work could be greatly enhanced by encouraging technology transfer from agencies like Navy, which uses acoustics extensively for different problems.

Locating fish through aircraft or satellite observations of ocean-surface conditions such as temperature, currents, salinity, or chlorophyll (which may indicate productivity) has been useful occasionally for locating surface fish, especially certain tunas that follow productive ocean currents or temperature boundaries. This method is not effective for the many fish that live below the surface where conditions are more unpredictable and are different from surface conditions. Another disadvantage is that coastal zones which contain most fisheries also have the most cloud cover, a phenomenon that hinders the effectiveness of many satellite sensors.

The usefulness of satellite or aircraft observations of ocean-surface conditions for the purpose of predicting the abundance of a stock has yet to be demonstrated, but such observations are being used by many researchers as part of their research on the ocean. These observations are especially important for providing nearly simultaneous information on the surface conditions over the entire range of a stock.

Future Fishery Research and Development

Stock assessment research has been driven and shaped by the needs of the fishery managers. The major need, as noted previously is for better in-

[21]U.S. Department of Commerce, National Oceanic and Atmospheric Administration, "Ocean Acoustic Remote Sensing Workshop, Summary Report, " VOI. 1, March 1980.

Table 35.—Cost Estimate for NOAA Fleet Support of FCMA-Related Research— Fiscal Year 1981
(in thousands of dollars)

	Operations	Percent	Maintenance/ repair	Management/ overhead	NMFS total	FCMA[a] (MARMAP) total
Northwest Region						
Freeman (52°/0)	$ 942	13.1	$ 375	$ 217	$ 1,534	$ 1,335
Chapman	893	12.4	355	205	1,453	1,264
Cobb	382	5.3	151	88	621	540
Murre II	228	3.2	91	53	372	324
Subtotal	$2,445	34.0	972	563	3,980	3,463
Southwest Region						
Cromwell	880	12.2	349	202	1,431	1,245
Jordan.	1,046	14.6	417	242	1,705	1,483
Subtotal	1,926	26.8	766	444	3,136	2,728
Northeast Region						
Albatross IV	1,088	15.1	432	250	1,770	1,540
Delaware II	854	11.9	340	197	1,391	1,210
Subtotal	1,942	27.0	772	447	3,161	2,750
Southeast Region						
Oregon II.	876	12.2	349	202	1,427	1,241
Grand total.	$7,189	100.0	$2,859	$1,656	$11,704 *	$10,182

[a]FCMA (MARMAP) sea days amounted to 87 percent of all NOAA fleet support for NMFS research in fiscal year 1979

SOURCE National Marine Fisheries Service

formation on a large number of stocks that have not been managed as rigorously as required under FCMA. This need for information is ongoing since management plans are reviewed and changed annually. It is an extraordinarily complex need because each stock varies significantly.

Fishery research contributes not only to Federal management, but also to fishery development. FCMA promotes domestic, commercial, and recreational fishing and encourages the development of fisheries, such as that of bottomfish off Alaska, which are currently underutilized by U.S. fishermen.

The stock assessment information, when suitably presented as forecasts, provides the fishing community with indispensable information on the quantity of each stock that may be caught and on the amount of fishing that the stock can tolerate without depletion. In addition, the observations of foreign fishing can provide similar information on the stocks not being fished by U.S. fishermen. Such information is vital for planning the construction and operation of fishing vessels and processing plants.

Krill Research

Many distant-water fishing nations have shown great interest in Antarctic krill as a major potential source of food for animal and human populations because of its wide distribution, its abundance, and its accessibility, Other nations, including the United States, are interested in the key role krill plays in the Antarctic ecosystem. Because of the speculative nature of information about krill's standing biomass, productivity, and commercial harvest, and because of the issues surrounding the potential impact on the Antarctic ecosystem of an expanded krill fishery, some nations argue for caution in proceeding with commercial development of krill. Under domestic legislation and as party to the Antarctic Treaty and other international agreements, the United States shares a scientific and political interest with other nations in promoting scientific investigations and the conservation and management of krill resources in the southern oceans.[22]

[22]U.S. Department of State, *Final Environmental Impact Statement for a Possible Regime for Conservation for Antarctic Living Marine Resources*, June 1978.

Conventional fishing technology is well-suited to exploit krill's "super swarms. " Over the years, improvements in locating and catching techniques have apparently made it possible to take large catches at moderate costs. The 1979 combined catch was probably over 100,000 tonnes. Projections show a 1985 commercial harvest of 2-million to 4-million tonnes, which will not exceed 50 million tonnes by the turn of the century .23

Although krill are believed to be an immense protein source, U.S. fishermen have not been interested in actively exploiting it. Unlike countries with large, idle, long-range fishing vessels that have pushed for exploitation of krill, the United States does not have such vessels. At present, U.S. fishermen do not see any economic advantage in leaving their domestic fishing operations to fish krill in the Antarctic. The frontrunners of krill exploitation will probably be the Communist bloc countries, Japan, and perhaps, ultimately, Chile,[24] The United States does, however, have an interest in the key role krill plays in the Antarctic ecosystem. Krill, more than any other single species of zooplankton in other ocean ecosystems, is an important link between phytoplankton and higher trophic forms. Whales and other marine mammals, fish, and birds of the area feed on krill. [25]

The Marine Mammal Program

Protection of marine mammals is addressed in MMPA which declares that stocks of marine mammals should not fall below a level "which will result in the maximum productivity of the population or the species, keeping in mind the optimum carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element."[26] It is difficult not only to define this goal scientifically, but also to obtain enough scientific information about these species to carry out the provisions of MM PA.

Surveying marine mammal populations is difficult because they combine the inaccessibility of most fish populations with the variability in behavior and habitat preference of most terrestrial mammalian species. [27] Surveys often range over large areas and a number of survey techniques must be designed, each with sufficient flexibility to adapt to the particular characteristics of individual species. Some species that concentrate seasonally in dense aggregations (California gray whale and northern fur seal) can be surveyed through efficient sampling devices. Other species (porpoise and harbor seal) that do not aggregate to such an extent require large-scale surveys to assess their population sizes. Although past survey methods have met with some success for a limited number of marine mammalian species, much additional research is needed to develop methodologies capable of satisfying the requirements of MM PA.

Technology Needs

In addition to the need for improved survey methodologies for marine mammal research is the need for development of new technology and the modification and/or acquisition of current technology.

Photo credit National Marine fisheries Service

Humpback whale

[23] D. L. Alverson, "Tug-of-War for the Antarctic Krill," *Ocean Development and International Law Journal* 8(2): 171-182, 1980.

[24] M. A. McWhinnie and C. J. Denys, *Antarctic Marine Living Resources With Special Reference to Krill, Euphausia Superba: Assessment of Adequacy of Present Knowledge*, report submitted to the National Science Foundation, December 1978.

[25] Scientific Committee on Antarctic Research (SCAR), Scientific Committee on Ocean Research (SCOR), Group of Specialists on Living Resources of the Southern Ocean, SCOR Working Group 54, *Biological Investigations Of Marine Antarctic Systems and Stocks (Biomass)*, vol. 1: research proposals, August 1977.

[26] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *The Marine Mammal Protection Act of 1972 Annual Report*, Apr. 1, 1977 to Mar. 31, 1978.

[27] L. L. Eberhardt, D. G. Chapman, and J. R. Gilbert, "A Review of Marine Mammals Census Methods, " *The Journal Of Wildlife Management*, vol. 43, No. 1, January 1979.

Photo credit Nat/ona/ Mar/ne F/sher/es Serwce

Research on marine mammals has led to development of tuna seine nets that allow porpoises to escape

Virtually all marine mammal surveys require some form of observer platform. Since the number of commercial harvesting vessels has been drastically reduced, a major source of cost-effective platforms has been curtailed. Hence, NMFS must rely more heavily on its own vessels to conduct marine mammal surveys, thus creating a serious need for more and better designed survey ships. Such ships should have long-range capability for operating in remote parts of the world. They should also be capable of visual searching, be equipped to gather both passive and active hydroacoustic data, and be able to accommodate helicopters which can be used to extend and augment surveys. Finally, for Arctic and Antarctic work, survey ships must be ice-strengthened. To date, lack of suitable survey vessels has hampered the Bowhead Whale and Cetacean Tracking programs in the North Pacific Ocean and in the U.S. Antarctic Program.

Aircraft are also needed, especially for large-scale surveys. As with ships, aircraft must have long-range capability. To survey porpoises in the eastern tropical Pacific Ocean, for example, survey planes are used to search as far as 1,500 nautical miles out to sea. Survey aircraft must be maneuverable enough to change altitude and course frequently so that observers can identify species, obtain more accurate counts, and take aerial photographs. Lack of suitable aircraft has, in the past, constrained the Tuna/Porpoise Program in the eastern tropical Pacific Ocean and the Bowhead Whale and Cetacean Tracking programs in the North Pacific Ocean.

In addition to observer platforms, marine mammal surveys require better use of aerial photography. The value of conventional photography has been established, especially for surveying large aggregates of animals, and attempts to employ ultraviolet and infrared photographic techniques have met with some success. Research is needed to improve the accuracy of these techniques and to make them cost effective.

Tracking of radio-equipped animals via aircraft or satellites has not been used to a great extent in marine mammal surveys. However, such techniques show considerable promise and should be addressed by future research.

Finally, updated navigational equipment on survey vessels and aircraft is needed for marine mammal surveys. Since many of these surveys are conducted far from shore, sophisticated navigational equipment is imperative for acquiring accurate distributional information on surveyed populations.

Analysis of the Fisheries and Living Resources Research Program

Fishery Management, Research, and Development

Although FCMA is obviously the beginning of major changes in fishery management in the United States, domestic fishery management is as yet little changed. It will be first necessary to complete fishery management plans for the many stocks identified as needing management, a task difficult to accomplish while keeping the already implemented plans under annual review and possible amendment. In addition, it is likely that some stocks, not yet identified as needing management, will at some time be more heavily fished and will then require management. Other stocks that are reduced in abundance due to unknown factors may also have to be brought under management quickly but workable techniques to deal with this situation are not yet available.

In addition to these longer range developments, improvements must be made in the current implementation of FCMA. These improvements include collecting better data on biological, social, and economic problems; improving the coordination with the States in regulations and enforcement; improving public participation and understanding; and speeding up the planning process.

Accurate and comprehensive catch data from U.S. fisheries is not now available, but technology does not appear to be the problem. Rather, improvements are needed in the institutional systems that have been established to collect the data, to verify its accuracy, and to provide managers with timely and reliable data-history and forecasts.

Fishery research needs will be met by extending and refining existing theory and technology to hitherto unmanaged stocks as they are brought under management. Generally, fishery research will be relatively routine, directed at monitoring and prediction. But familiar methods have been found wanting when applied to some important bottomfish stocks, which are complex mixtures of species, and to some very large herring and anchovy stocks. In these instances, a better understanding of the nonfishery factors is more essential and can be gained only by researching the ecological production processes. When conducted on a scale adequate to measure the environmental and the interspecies relationships, such research should be expected to be nonroutine, expensive, and lengthy.

Technology

It does not appear that any significant changes in the fishery research fleet will be necessary in the near future. However, maintenance and upgrading of ship equipment and instrumentation will be important if fishery research capabilities are to be maintained. Also, the present trend toward using more charter vessels to augment the Government fleet may be cost effective in the future. Many commercial fishing vessels have very modern equipment and can be chartered for research surveys during slack seasons.

There are some technology needs that accompany the development of new fisheries to ensure the safety and good quality of new products. Those species that are unfamiliar to U.S. fishermen require different handling and processing procedures. For example, many of these species are small and require different processing machinery and almost all must be prepared in a form suitable for different and highly competitive markets. The successful development of these resources by the United States will require very different technology for fishing and processing than that for the existing fisheries. Such technological development depends heavily on information about flesh quality and its chemistry, toxins, deteriorative processes, and on many other laboratory studies.

Krill Research

At this time, research on Antarctic krill is basic and exploratory rather than routine assessment. Ongoing multinational krill research efforts include surveys and explorations by the Soviets, Japanese, Poles, West Germans, and Chileans. The United States has not done as much scientific research on krill as these countries have, but could begin by sending more scientists on foreign research vessels. Long-term research programs should be developed, and existing international collaboration in krill research should be further expanded and intensified. Methods of survey techniques, data collection, evaluation, and reporting need to be developed and standardized. This involves collecting comprehensive catch-and-effort statistics and reporting them to the appropriate international agency.

For some purposes better results could be obtained by coordinating research programs with the commercial fisheries on krill than by deploying an independent krill assessment research vessel and program. NOAA claims that while it would be beneficial to coordinate research with commercial vessels to assess krill, a medium-to-large research vessel capable of polar operation will ultimately be needed for basic studies of polar marine life.

The Marine Mammal Program

Curtailment by MMPA of U.S. harvesting of many marine mammals has drastically reduced direct acquisition data on population sizes and auxiliary characteristics, such as age at maturity, sex and age distribution, fecudity, and survival rates based on catch-effort and mark-recapture procedures. In the absence of harvesting, therefore, marine mammal information must be acquired through scientific expeditions using alternate study methods like mark-resighting, sightings per unit effort, and direct counting. A major drawback to such methods is that often an unknown and inestimable fraction of the population is not visible; indices of abundance are all that can be reliably obtained from many such surveys. A major goal of future methodological research should therefore be to develop corrections for nonvisible population fractions so that estimates of total abundance can be made.

Meeting the research and survey requirements of MMPA will be costly. Funding limitations in the past have generally constrained methodological research and technological development; have slowed the acquisition of data, analysis, and distribution; and have created shortages of necessary equipment and manpower. Most marine mammal survey programs have been severely hampered by these limitations, and it is clear that if these programs are to improve to the extent required, a major increase in financial support is mandatory.

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THE CLIMATE RESEARCH PROGRAM

Basic understanding of world climate and the ability to predict climate changes do not exist now, but a major new research program to address this subject is urged by the National Climate Program Act of 1978. Such a program would involve major efforts by the oceanographic community in a series of large and definitive experiments, long-term data collection efforts, and theoretical modeling.

The detailed physics of the ocean-atmosphere-cryosphere interaction, now largely unknown, must be understood before reliable models can be constructed for estimating climate variability on seasonal, yearly, and longer time scales.[28 29 30 31 32]

The National Climate Program Act of 1978

The intent of the National Climate Program Act is to strengthen and improve the Federal research efforts to provide useful climate information and long-range forecasts to the public. In the past, climate research consisted of individual programs in agencies such as NSF, NOAA, and DOE whose goals were either to improve basic knowledge or to solve specific problems. The Act focused goals and efforts by calling for the establishment of a National Climate Program Office within NOAA. It called for the preparation of a 5-year plan to define the roles of the agencies and offices involved and to provide for program coordination.

The activities called for by the Act which are relevant to determining ocean effects on climate are:

- Assessments of the effect of climate on the natural environment, agricultural production, energy supply and demand, land and water resources, transportation, human health, and national security.
- Basic and applied research to improve the understanding of climate processes — natural and man-induced — and the social, economic, and political implications of climate change.
- Methods for improving climate forecasts on a monthly, seasonal, yearly, and longer basis.
- Global data collection, monitoring, and analysis activities to provide reliable, -useful, and readily available information on a continuing basis.

The Act also contains specific requirements for the participation by universities, the private sector, and others in applied research and advisory services.

Climate Program Status

The National Climate Program Office is now established and ongoing programs have been coordinated. During 1980, a 5-year plan[33] was prepared and reviewed by the Climate Research Board of the National Academy of Sciences.[34 35] The ocean research portion of the climate program is now funded at about $10 million annually. A significantly larger and more concerted effort will be needed if any near-term improvements are to be made in understanding world climate and in developing useful forecast abilities. Whether the present small group of ocean research projects develops into a major long-range program in the next several years depends on how clearly a plan can be stated, how specifically certain public benefits can be determined, and how

[28] GARP, *The Physical Basis of Climate and Climate Modelling*, publication No. 16, (Geneva: WMO, 1975).

[29] B. V. Hamon and J. S. Godfrey, "The Role of the Oceans," in *Climate Change and Variability, A Southern Perspective*, A. B. Pittock, et al. (eds.) (Cambridge University Press, 1978).

[30] National Academy of Sciences, Ocean Sciences Committee, *The Ocean's Role in Climate Prediction*, Washington, D. C., 1974.

[31] National Academy of Sciences, *Understa riding Climate Change*, Washington, D. C., 1974.

[32] National Academy of Sciences, Geophysics Study Committee. *Studies in Geophysics Energy and Climate*, Washington, D. C., 1977.

[33] U S Department of Commerce, National Oceanic and Atmospheric Administration, National Climate Program Office, *National Climate Program, Five-Year Plan*, Washington, D. C., 1980.

[34] National Academy of Sciences, Ocean Sciences Board, *The Continuing Quest, Large-Scale Ocean Science for the Future*, Washington, D. C., 1979.

[35] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, *An Ocean Climate Research Plan*, Washington, D. C., 1979.

much funding will be needed to provide those benefits.

Furthermore, while the 5-year National Climate Program Plan describes goals, experiments, and data needs, the plan has not addressed technology needs to any significant degree. For this major national research program, a strong technology effort is necessary. It will be important to anticipate critical technology needs if significant advancements in climate research are to be made.

Much of the technology (both new techniques as well as applications of existing techniques) to conduct climate experiments and to collect these data is not now in place. Some systems need to be developed, others need to be built and tested, and still others need to be operated and maintained over long time periods. The most critical needs known at this time for measurements are outlined here with their associated major technology needs.

Measurement Needs for Climate and Ocean Processes

The Heat Budget

The Earth's climate is controlled primarily by the amount of solar heat the planet retains and by the transport of that heat from one region of the globe to another by the ocean and by the atmosphere. The global atmospheric transport of heat is determined principally by the temperature differences between equatorial and polar regions. The oceanic transport of heat is determined in large part by the global distribution of wind stress.

The equatorial ocean regions receive and store a surplus of solar energy which the transport processes mentioned above eventually transmit to the polar regions.[36 37 38] A large portion of the heat which the atmosphere transports poleward is extracted from the ocean in the warmer latitudes through warming of the airmass just above the ocean surface and through exchanges of heat in the evaporation/condensation process. Processes important in the oceanic transport of energy include surface drifts, major polewards currents such as the Gulf Stream and the Kuroshio (off Japan), deep-return flows in the mid-ocean, and possibly oceanic eddies.

In the polar regions the ice cover affects global climate changes by reflecting a substantial percentage of solar energy and by providing insulation between the relatively warm polar waters and the much colder atmosphere. 39 40 Also, the relationship between solar energy cycles, the heat-transport processes, and icemelt and ice growth, adds further complexity to overall global climate forecasting.

Each of the oceanic processes that is involved in climatic interactions is a component of the ocean heat budget. The technology required for evaluating each of the heat budget components varies widely and ranges from the use of satellites, to the use of drifting ocean buoys, to the use of polar meteorological stations. In the following sections major components of the ocean heat budget are discussed briefly and are linked to the technology required to evaluate the associated oceanic mechanisms.

Incoming Radiation. – The energy from the Sun passes mostly through the atmosphere and is stored in the ocean at lower latitudes. In higher latitudes the radiation balance is negative and the Earth loses heat. Simple theoretical climate models suggest that small variations in the incoming radiation can have dramatic effects on the Earth's climate .41 These models also suggest that understanding and predicting climate change will require measurement of incoming radiation to a precision that is only now becoming available. Since such measurements will most

[36] GARP, *The Polar Subprogram,* publication No. 19 (Geneva: WMO, 1978).
[37] D. E. Trenberth, "Mean Annual Poleward Energy Transports by the Oceans in the Southern Hemisphere," forthcoming in *Dynamics of Atmospheres and Oceans*
[38] T. H. Vender Haar and A. H. Oort, "New Estimates of Annual Poleward Energy Transport by Northern Hemisphere Oceans," *J Physical Oceanography 3(2),* 1973, pp. 169-172.

[39] W. F. Budd, 'antarctic Sea Ice Variations From Satellite Sensing in Relation to Climate," *J Glaciology* 15, 1973, pp. 417-427.
40 National Aeronautics and Space Administration, Goddard Space Flight Center, *Proposed NASA Contribution to the Climate program,* Greenbelt, Md., July 1977.
[41] GARP, *The Physical Basis of Climate and Climate Modelling, publication No 16* (Geneva: WMO, 1975).

likely be made from satellites to avoid the biasing effects of clouds, water vapor, and other factors in the Earth's atmosphere satellite instrumentation must meet extremely stringent requirements.[42] For example, satellite instruments will have to be calibrated repeatedly to high accuracy in order to measure changes in incoming radiation from the Sun that are only a fraction of 1 percent of the total.

Storage of Heat in the Ocean. –The incoming radiation from the Sun is partially reflected by the clouds and by the ocean surface. The radiation energy that is absorbed by the ocean is stored for various lengths of time and is later either extracted locally by the atmosphere or carried by ocean currents to distant areas where it is released from the sea.

The Earth's temperature, on the average, is in equilibrium (about as much energy is radiated over a long period of time as is absorbed). The surplus heat gained in the tropics is carried by the atmosphere and the ocean toward the poles. Recent determinations of the Earth's heat balance from satellite measurements and from upper-air measurements, have shown that the ocean probably transports a large share of the heat needed for global balance.[43] At latitude 200 N., the ocean carries 75 percent of the total heat and the atmosphere carries only 25 percent. The amount of heat carried by the ocean decreases at higher latitudes. In the Southern Hemisphere the sparse data allows only the tentative conclusion that heat transport by the ocean is greater than that of the atmosphere up to latitude 300 S. and remains substantial even to latitude 600 S. 44

Simple measurements of the sea-surface temperature, at best marginal now, can provide fairly good estimates of the temperature throughout the ocean's upper mixed layer. However, the measurement of sea-surface temperature must be coupled with the measurement of the depth of the mixed layer in order to estimate the amount of heat stored. Furthermore, to qualitatively understand heat transport, other properties of the water column such as salinity and density must also be known.

At present, satellites do not yield an accurate measure of sea-surface temperature, and it appears that even in the future they will be unable to measure the depth of the oceanic-mixed layer. Such measurements at present are accomplished from drifting buoys, research ships, survey ships, naval ships, and ships-of-opportunity. New technologies which have been proposed for these measurements include the use of acoustics either from ships or from large arrays (acoustic tomography) and the use of aircraft-mounted laser systems. Expendable instruments that measure not only temperature but also salinity will probably be required for future climate-monitoring programs.

Horizontal Transport of Heat Within the Ocean. –Since heat is transported by ocean currents over relatively large distances, knowledge of currents is vital for determining the ocean's effect on the overlying atmosphere. The kind of current measurements required, however, are not easily made. In general, measurements of currents presently obtained from current meters, hydrographic surveys, and other instruments are point measurements of the currents and do not provide either the time or space coverage required for determining the mass and flow of near-surface ocean currents over time.[45 46 47] (The data do show, however, that there is strong variability of current flow on both the seasonal and interannual time scales.) New acoustic techniques have been proposed for these measurements, but much development work and experimentation will be necessary to validate these methods. A combination of sensors, including satellite-based radar systems and altimetry systems, coupled with ground-based observing systems (such as drifting buoys), measurements from ships-of-opportunity, island measurements of sea level, and vertical

[42] National Aeronautics and Space Administrate ion, Goddard Space Flight Center, *Proposed NASA Contribution to the Climate Program*, Greenbelt, Md., July 1977.

[43] Report of th, JCC/SCOR Specialists Meeting, *The Role of the Oceans in The Global Heat Budget*, 1978.

[44] D. E. Trenberth, op. cit.

[45] Center for Ocean Management Studies, *Ocean Research in the 1980's* (Kingston, R.1.: University of Rhode Island, 1977).

[46] Federal Coordinating Council for Science, Engineering, and Technology, A *United States Climate Program Plan*, Washington, D.C. , 1977.

[47] Roger Revelle, "Presentation of Report on the Pilot Ocean Monitoring Study (PO MS)," at Joint SCOR ' IOC Committee on Clima tic Changes and the Ocean (CCCO), 11th sess. , Miami, Fla., Oct. 15, 1979.

profiles of temperature and salinity, will be required to measure heat transport in the ocean.

The role of mesoscale eddies in effecting changes in ocean climate is not presently clear, but may be significant. Aside from determining their possible effects on driving the general circulation, it is important to determine the extent that eddy motions effect a net transport of heat in the ocean toward the poles.[48 49] Despite considerable investment in several large U.S. experiments, the role of these eddies in heat transport is not fully understood.

Air/Sea Heat Exchange. – There are several processes by which the ocean and the atmosphere exchange heat:

Back radiation. – Infrared radiation from the sea surface is a primary function of sea-surface temperature; however, the actual measurement of this variable, which is generally done by satellite, is influenced by the fact that clouds and water vapor in the atmosphere absorb and eventually reradiate the energy. Knowledge of cloud structure is required to properly estimate the back-radiation from the sea surface worldwide. Although the net radiation leaving the Earth can be determined, the amount of radiation leaving the ocean versus that remaining in the water-vapor field and transported to other parts of the globe can only be estimated.

Sensible heating. –Scientists can estimate the exchange of sensible heat (total heat content) between the ocean and atmosphere. To make these estimates, however, requires knowledge of the surface wind as well as that of the air-sea temperature difference (the most difficult of the two estimates because it is generally a small difference between two large numbers). Present satellites cannot determine precisely enough, either the sea-surface temperature or the air temperature in the boundary layer immediately above the ocean's surface. Satellite data may provide an indirect measurement of sensible heating, but the techniques are not yet proven.

Latent heat transfer. –To estimate the heat transferred from the ocean to the atmosphere (through evaporation) and from the atmosphere to the ocean (through condensation) requires a knowledge of the wind, the temperature, and the more difficult to measure moisture content of the air just above the sea surface. The technology necessary to carry out surface wind and temperature measurements is just being developed, but the technology to measure moisture content is not currently available. It is absolutely crucial to develop techniques to estimate the moisture content of the lowest 10 m of the atmosphere.

Precipitation. –Since the condensation of atmospheric water vapor results in precipitation, measurement of precipitation can indicate a component of the heat budget of the atmosphere. Over land, measurement of precipitation is made at meteorological stations. Over the ocean, there is no satisfactory way to measure precipitation from either existing or planned satellite systems. The best measurement now available is a crude measure by satellite of the rate of precipitation in given regions at given times. However, since most satellites pass a given area only twice a day, a rate measurement becomes of questionable value since the same rate does not apply during the 12 hours between passes.

Ice cover. – The lack of solar heat in the polar regions results in the growth of large volumes of sea ice on a seasonal basis. The resulting ice cover provides insulation which prevents evaporative, latent-heat processes from taking place.

Even satellite observations are inadequate for making polar ice measurements. Ice processes occur over both long- and short-time scales. Earlier *Tiros* satellite imagery and the later finer resolution *Nimbus* and *Landsat* imageries have been of limited use in delineating sea ice extent and morphology and in distinguishing snow from cloud cover. Synoptic data about polar ice can only be obtained with satellites that have nearly polar orbits. No existing satellites meet this need and much improved satellite sensors are needed for any future satellite system.

Development of a Measuring Strategy

In order to understand and monitor the processes of ocean/atmosphere interaction relevant to climate, it is necessary to carry out specific ex-

[48] Center for Ocean Management Studies, op. cit.
[49] Federal Coordinating Council for Science, Op. cit

Photo credit: Jim Broda, Woods Hole Oceanographic Institution

The ocean and atmosphere continually exchange energy in a way that has a lasting effect on global-weather patterns periments and to do long-term monitoring of critical processes. A major ocean observing system must take into account both the scientific understanding of the ocean's role in the climate system and the rapid changes in technology and in the needs for technology that come as the field develops. 50

A NOAA-sponsored study on the development of a system for ocean-climate monitoring is underway. This study will include technical planning and systems evaluation leading to the development of a global-monitoring system for climate studies. The immediate objective of this effort is the formulation of a strategy for system development that includes an assessment of how emerging technologies can meet monitoring requirements, a projected time-phasing of capabilities, an estimate of the time-phasing of costs, consideration of institutional factors (domestic and international) involved in a comprehensive ocean-monitoring activity, and the coordination with other ocean-monitoring activities.

As currently conceived, the observing system will evolve from existing and projected observational capabilities, including satellites, buoys, ships-of-opportunity, and island stations, into a systematic means of monitoring climatically significant ocean variables. Measured parameters will include surface temperature (air and sea), upper-ocean transport, sea ice extent, and upper- and deep-ocean circulation.

The first phase of this study, which began in earl y 1980, will focus on the problems of measuring the components of the regional heat budgets in the upper levels of the ocean globally in order to describe the annual and interannual variabilities. Supplementary objectives are to assess how to determine the uptake and redistribution of carbon dioxide in the ocean and to monitor the variability of selected key indices in deep water. It is expected that to achieve global coverage at a reasonable cost, the final long-range system will have to be based primarily on remote sensing from space, with in situ measurements and inference from modeling used to fill in gaps and to provide calibration benchmarks. Specific attention will be given to the problem of accurate statistical sampling.

A follow-on phase of the NOAA study will involve systems engineering studies to determine the most effective systems configurations and to perform detailed planning of systems development efforts. It is expected that each phase of the study will take approximately 1 year.

A second phase of planning for ocean monitoring for climate is the Pilot Ocean Monitoring Study (POMS), now in the planning stages.[51] POMS was proposed as part of the World Climate Research Program, which in turn is sponsored by the International Council of Scientific Unions and the World Meteorological Organization. Meetings were held in late 1979 and mid-1 980 by the World Climate Research Program and the Scientific Committee on Oceanic Research to set the goals of POMS. POMS planning meeting recommended that the following activities be carried out:

- Study the feasibility of conducting a basin-scale experiment to evaluate the poleward transport of heat in the atmosphere and ocean using a variety of techniques.
- Explore the feasibility and design of an experiment to determine the global ocean circulation using a combination of hydrographic methods and the geodetic/altimetric satellite techniques under development. A unique opportunity to use these techniques may occur during the latter part of the 1980's when a U.S. satellite, a European satellite, and a Japanese oceanographic satellite orbit simultaneously.
- Designate certain geographic lines in the ocean for continued long-term monitoring by POMS participants.
- Establish a theoretical oceanographic group to assist, interact with, and provide general theoretical expertise to the POMS study as required.
- Take steps to initiate vigorous technical interaction and exchange between laboratories, using buoys to facilitate development of

[50] National Academy of Sciences, Climate Dynamics Panel, U.S. Committee for GARP, *Elements of a Research Strategy for the United States Climate Program*, Washington, D. C., 1978,

[51] Revelle, op. cit.

oceanographically and meteorologically instrumented buoy systems suitable for POMS and corresponding satellite-data transmission links.

At the present time, active planning is going on in the United States, U. S. S. R., Canada, France, Federal Republic of Germany, the United Kingdom, and Japan to prepare for POMS. First studies such as the proposed North Atlantic Heat Flux and Storage Study, have already begun. Some simple monitoring systems such as island stations will also contribute, but they must be maintained and coordinated better than the existing systems.

Existing Technology for Ocean Experiments and Monitoring

Many technology systems are now in place or available for use in climate research and monitoring programs. Future climate research will be dependent on the following technological advances and continued support for these systems.

Stations. – Existing long-term oceanic data come from relatively few sources: coastal stations, island stations, ocean weather ships, and ships-of-opportunity. Since 1972, organized and expanded ships-of-opportunity programs have been contributors to a description of the climate system because of their good, long-term reliability. Furthermore, they have been used in several of the large-scale, long-term ocean experiments with increasing success. These systems take on greater significance now with the phase-out of the ocean weather ships. Aircraft-of-opportunity and satellites also have substantial potential for some surface measurements, but they have not yet been available on a routine, long-term basis.

Sensors. – Only relatively few types of measurements are available in any abundance or continuity in the climatic data base. One of the most used measurements is sea-surface temperature. Since post-World War II, this variable has generally been measured by ships' injection thermometers. Prior to that, bucket thermometers were used to obtain the data. Sea level, as measured at various tide stations, is another type of measurement that exists in abundance; but more long-term sea-level and bottom-pressure measurements are required to establish a climatic data set. In general, the measurements have been made with standard instrumentation that has not changed dramatically for many years.

There are now some regions of the world's oceans where short and intermittent time series of temperature, salinity, and water velocity as functions of depth can be constructed. These data have come from a variety of measurement techniques, such as measurement by Nansen bottle casts or by continuous-drifting instruments and current meters. The stability of temperature sensors used to collect this data is good, but the salinity sensors tend to drift. Thus, a stable salinity sensor is needed.

The time series referred to above come from point data. There are no good techniques existing now for the measurement of temperature and salinity over large volumes, although acoustical techniques hold promise here. Instruments that measure current velocity accurately over large volumes, especially near the surface and in the presence of wave motion, are another major need.

Other extremely useful measurements taken over the ocean are those pertaining to the windfield. Surface wind, as reported by ships-of- opportunity, is generally not measured from a ship's anemometers, but rather is based on visual estimates — e.g., relating sea state to the Beaufort scale. Nevertheless, these crude estimates have been of great help in a variety of research programs. Information on the wind strength at upper levels comes from standard radiosonde observations taken from islands, ocean and land weather stations, and currently from satellite soundings. The relationship of satellite-measured winds to actual surface winds is still not understood.

Some satellite data sets, extending back to the mid- 1960's, are presently being used in climate research. Among the most important sets are the estimates of cloud cover from reflectance data. The sensors that provide this information have changed considerably since satellites were first launched, and this change can create potential problems. Extensive study of satellite-sensed ocean parameters is required to understand fully how to interpret present satellite measurements, Moreover, satellite estimates of variables such as surface wind, sea-surface temperature, vertical temperature profiles in the atmosphere, upper-level winds, etc., are only just beginning to have the accuracy required to make them useful in long-term climatological studies. Unfortunately, most satellite data is discarded before it can be used in climate studies, a policy that severely hinders research.

Data Management Systems. – Most of the data collected by the methods indicated above are organized through different management and reporting structures. Eventually most of the data find their way to the National Climatic Center, where they become available to interested users. The mere mass of the data makes it difficult for the uninitiated to determine what is available.

Generally, the data in the Center are in their natural form. Most researchers would prefer to work with products such as monthly contour maps of the Pacific trade-wind fields. The development of such climatological products is largely the province of the individual researcher. While these products are sometimes available on request, they are not widely disseminated in the oceanographic community.

New Technologies for the Climate Research Program

The climate studies required by the National Climate Program Act of 1978 will require major new ocean programs that will in turn require new technology. Ocean programs currently planned for the 1980's are designed to meet the need for understanding climate processes, but are generally underfunded in the technology area.

To gain the technological capability to measure climate-related oceanic parameters, an integrated approach may be needed. Such an approach would take into account both national and international climate parameter-measurement capabilities, resources, and research programs. However, particular attention should be addressed to:

- the improvement of remote sensors proposed for the NOSS and other climate-proposed satellites,
- techniques for improving satellite sensor ground-truth,
- innovative, in situ measurement systems to provide integrated heat-flux data,
- techniques for gaining reliable oceanic and meteorological data on a real-time basis from the world fleets of research ships and naval vessels and from ships-of-opportunity, and
- techniques for gaining data from the polar regions.

OTA has identified the following technology needs for future climate research and monitoring of the ocean.

A Mix of Technologies. – One of the most important needs is for a variety of technologies to address the climate problem. Since almost all satellite systems sense only the skin of the ocean and cannot measure all quantities at the air-water interface that are required for the determination of the heat budget, it is apparent that space systems are not totally sufficient for studying the ocean's role in climate. Many other technologies must also be used such as instrument packages on ships-of-opportunity to collect surface-transfer measurements and upper-ocean temperature soundings. An expanded and improved ships-of-opportunity program should be developed to gather large-scale and long-time series of ocean data. Drifting buoys can be used to measure currents, sea-level pressure, sea-surface temperature, and other data. Research ships are needed to gather ground-truth data for complex satellite measurements and to perform process experiments. Subsurface moored instruments are required for determining vertical and temporal signals of relevant oceanic variables. Since the technology needs of the climate program are shared by many other oceanographic programs, these programs will also benefit from climate-related technology development.

Data Management and Computers. – Present data reporting methods tend to be slow and non-uniform and could be 1argely replaced in the future by a single data-retrieval system. The key to the system would be a reliable, inexpensive satellite data-relay link. With satellites as prime receivers and transmitters of climatological data from ships, islands, or other satellites, it should be possible to develop effectively a single climate datastream. Subsequent production of products for use by operational agencies, researchers, and others would then be a relatively straightforward matter. At present, the huge volume of climate data from satellites and from various other platforms is overwhelming and is poorly managed in available archives. It is critical, therefore, to invest in competent, well-managed data archives that will involve fifth- and sixth-generation computers to manipulate and retrieve the data base. The immense investment in satellites and other technology is wasteful unless the data base can be easily available for scientists and Government managers to use. In fact, many types of users will want access to both in situ and remotely sensed oceanic and atmospheric data. Data formatting, distribution, and management must be considered to provide an effective way by which the research scientist, the governmental climate-product packager, and the ultimate user can have timely access to the data at minimum cost.

A single data-management structure could coordinate and ensure the continuity of the ocean climate-data collection program. A large part of the job in monitoring climate is one of managing a wide variety of resources, institutions, instrumentation, and people. This management structure does not now exist. In addition to developing the management structure, there must be a long-term commitment to carry through the climate-monitoring program. Without this commitment, such long-term measurement programs should not be started.

Specific Major Technologies. – It is essentially impossible now to measure upper (top 100 m) ocean currents with accuracy. Present means of attempting the necessary measurements have serious flaws. Drifting buoys are not accurate due to windage. Line-of-sight radars are very useful only when mounted on land or on ship. Over-the-horizon radar are affected by ionospheric fluctuations which are poorly understood. Current meters are expensive and are unreliable due to wave contamination. Sea-surface slope from satellites yields information on the surface geostrophic components of the currents; but for the total surface current, one must also know the wind-driven component. If a new technology to measure ocean currents with 10-percent accuracy is developed, it will be a major breakthrough for ocean-climate research and for other important problems, such as the fate of pollutants (such as oilspills), fisheries management, rescue-at-sea maneuvers, and numerous military problems.

It is also essential for ocean-climate studies that the windfield be estimated over the ocean on a time scale of at least once a month and on space scales of 200 by 200 km. There are potential satellite systems to accomplish this such as the microwave scatterometer technique. However, the instruments involved have had limited ground-truth verification, and considerable research is required to ensure that their wind-velocity determinations are meaningful.

It is extremely difficult to estimate precipitation, an important part of the energy budget, over the ocean. Rainfall rates have been estimated by observing cloudtop height and density using visible and infrared radiation (on the assumption that thick, dense clouds rain more than thin clouds) and by observing radio energy emitted by liquid water (but not ice) at radio wavelengths near 2 cm. This latter method has an accuracy of around +/- 50 percent, with spatial resolutions on the order of 30 km. The accuracy of the radio technique is limited primarily by inadequate spatial resolution and by the uncertainty in present knowledge of the height of the freezing level and of the distribution of raindrop sizes. (The latter can perhaps be estimated from other satellite data; although this has not yet been done.) These techniques all require extensive verification. It is highly probable that a new, advanced instrument will be required for estimating precipitation.

It is generally believed that the latent heat flux (evaporation) is several times larger than the sensible heat flux. In order to estimate the latent heat flux, the sea-surface temperature must first be known and then the saturation water content, the windspeed, and the humidity or water content a few meters off the sea surface must be determined. Until reliable technology to measure remotely the humidity of the air near the sea surface is developed, scientists will not be able to calculate balanced heat budgets.