The

U.S. GLOBAL OCEAN

SCIENCE PROGRAM

A Strategy for Understanding

the Role of the Ocean in Global Change

October 1987

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U.S. GLOBAL OCEAN SCIENCE PROGRAM

A STRATEGY FOR UNDERSTANDING

THE ROLE OF THE OCEAN IN GLOBAL CHANGE

A Report to the Ocean Principals

U.S. GOSP Interagency Working Group

October 1987

Preface

The enclosed interagency report: "The U.S. Global Ocean Science Program" represents the first stage of a coordinated, federal agency, strategic planning effort. The planning began in November 1985 in recognition of the urgency of describing and understanding the central role of the ocean in global change and the multiple effects of the ocean on our society. The planning is timely because of the existence of new insights and the application of new measurement and computing technology to global ocean processes. To carry out the effort, the Ocean Principals agreed to coordinate the development of a national plan for ocean sciences. The goal of the plan was to maintain and strengthen U.S. leadership in ocean science and technology and to develop stronger international cooperation.

Planning during the following year in the federal agencies and in the ocean research community culminated in a workshop held at USGS Headquarters in Reston, Virginia on November 6 and 7, 1986. The workshop included representatives from federal agencies and the academic research community. From the workshop, a statement of opportunities and plans was developed that was presented to the Ocean Principals on February 18, 1987. The statement outlined a strategic planning context for a U.S. Global Ocean Science Program.

In response to the statement, the heads of the involved agencies requested the National Science Foundation to convene an interagency working group to develop the overall goals and objectives and identify specific scientific components of a U.S. Global Ocean Science Program. In the course of this planning the group was also to develop recommendations on steps needed to begin to implement the program. The planning was to be carried out in the scientific context of active national and international planning for studies of global environmental change.

The report presented here is the first stage of that planning effort. It presents the rationale for the U.S. Global Ocean Science Program, identifies the necessary components of science and technology, lays out the required actions for the short term, provides for continuing coordination, and estimates the level of effort, over a 7-year period centered upon FY 1989, required for the Program's success. The report, which will be updated annually, provides an interagency strategic planning mechanism that allows individual agencies to present a coordinated program structure for FY 1989.

U.S. Global Ocean Science Program

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EXECUTIVE SUMMARY

The U.S. Global Ocean Science Program is an interagency effort to assess and understand earth's last frontier: the global ocean. The program has been developed in recognition of the fact that, as in all frontier exploration, the nation that explores and understands it earliest and best will benefit most. We know that the ocean plays a central role in global change: It interacts with the atmosphere to cause changes in seasonal weather patterns, and it is the principal driver of long-term climate change. The ocean is a critical source of mineral and energy resources as well as a fertile field for fisheries, yet is subject to extensive waste disposal. As a maritime nation, we have always seen the ocean as key to our national defense. Thus, assessment and understanding of the global ocean and its boundaries have been and should continue to be a national priority.

The nation is ready to carry out this global program. Satellites, supercomputers, and other new ways of observing and modelling the ocean are at hand. The opportunity, however, puts the U.S. at a crossroads in ocean science. Historically we have been the world leader in this field; but our leadership is diminishing as our investment declines and the investment of other countries grows aggressively. We face a global challenge and we have an unprecedented opportunity: to use our technology and knowledge to move boldly ahead in ocean science.

The goal of the U.S. Global Ocean Science Program is to describe and understand more fully the interactive physical, chemical, geological, and biological processes within the global ocean that contribute significantly to the regulation and condition of the earth's global environment and to understand changes, both natural and anthropogenic, in the ocean that affect the health of that environment.

Specific objectives include: understanding ocean processes and their effects on global weather and climate; understanding both the natural variability of the global ocean and that due to man's activities, so that the ocean may be used effectively with minimal adverse impact; assessing and managing our coastal oceans and exclusive economic zone; and assuring national security interests and the safety of vessels and life at sea.

The program strategy used to address these issues divides the U.S. Global Ocean Science Program into five major science and three major infrastructure components:

- Global Ocean Structure and Dynamics
- Global Climate: Atmosphere-Ocean Interaction
- Global Ecosystems and Productivity Processes
- Global Ocean Lithosphere and Geoprocesses
- Coastal Margins and Polar Oceans Processes
- Technology for Global Measurements
- Facilities and Centers
- Data Management Systems

The U.S. Global Ocean Science Program requires cooperation among federal agencies because ocean processes transcend state and national boundaries and the related issues cut across agency responsibilities. Studies of the ocean are too long-term for the private sector, and too important to the nation's security and future strength to leave leadership to others. No single agency can marshall all the resources needed to gain a fully comprehensive understanding of the ocean and its role in the earth system. Thus, we must look to a collaborative and cooperative arrangement. The context of global environmental change and the need for interagency cooperation are the overarching rationale and driving force for the U.S. Global Ocean Science Program.

In this context, for each of the science and infrastructure components of the program, the Federal agencies including the National Science Foundation, the National Oceanic and Atmospheric Administration, the Department of the Navy, the National Aeronautics and Space Administration, the United States Geological Survey, the Environmental Protection Agency, the Department of Energy, and the Department of State have developed plans that will be coordinated by an interagency working group. This group will represent those agencies with major roles in the U.S. Global Ocean Science Program as well as those that will collaborate in particular components. Specific agency contributions to each component and plans for coordination are summarized in the report. FY 1989 actions required for the Program's success are identified, and a 7-year level of effort centered on FY 1989 is estimated.

U.S. Global Ocean Science Program

1. Opportunity and Challenge: the U.S. Global Ocean Science Program

In every scientific field, major advances in understanding are driven by new technology that provides a clearer view and different perspective of nature at work. When these advances have an impact on pressing economic issues, major national benefits can accrue.

Today we are offered such an opportunity at Earth's last frontier: the global ocean. New instruments, whether satellite-borne, in the ocean, or on the sea floor give us a capability to understand the role of the ocean in the total earth system. Supercomputers and communications technologies link scientists and sources of data so that models of ocean, atmosphere, and sea floor processes can be constructed to provide the basis for better prediction. With the opportunity now offered by new technology and new insights into ocean and seafloor processes, we are ready to accept the challenge of assessing and understanding the global ocean and its role in global environmental change. The payoff will accrue in basic scientific knowledge, in improved national security, and in economic development.

The U.S. Global Ocean Science Program describes a Federal plan to assess and understand this last frontier. In recognition of the breadth of agencies and disciplines involved, the plan has been developed by an interagency group. It appears now in recognition of the fact that, as in all frontier exploration, the nation that explores and understands it earliest and best will benefit most.

This report establishes the goals, objectives, and components of the Program, and illustrates how these will be coordinated. The aim of the report is to set the scientific and technological context for agency programs and plans and to identify specific actions required in the near and far term if the Program is to succeed.

2. The Rationale: Importance of Understanding the Global Ocean

Our knowledge of the global ocean with its coastal and polar margins has expanded dramatically in recent years, bringing insights about the ocean and its role in the complex processes that govern the nature and health of our planet. For example, today we know that the ocean interacts with the atmosphere to cause changes in seasonal weather patterns. It is the principal driver of longer-term climate change. The ocean is a critical source of mineral and energy resources and a fertile field for fisheries. As a maritime nation, we have always seen the ocean as a key element in our national defense. Most of the world's commerce is transported by sea. Better understanding of ocean processes will result in savings associated with improved shipping practices and the protection of vessels and life at sea. We do not have sufficient description or knowledge of ocean processes to enable us to address these major issues adequately. The U.S. Global Ocean Science Program is aimed at expanding our knowledge of this last global frontier to allow us to resolve these issues.

Last Frontier

The depth, breadth, and complexity of the global ocean, covering over 70% of earth's surface, have challenged our ability to explore, measure, and comprehend its governing processes and to predict its behavior. But today, technology has evolved to the point where we can examine the ocean on a global scale and study the role it plays in the total global earth system. We are also beginning to comprehend the changes mankind is making on the global environment. The little understood physical, chemical, biological, and geological processes at work in the global ocean and their interaction with the other components of the earth system are vital elements in the exploration and understanding of this last frontier. These interactive processes produce our climate, are responsible for the distribution of fishery, mineral, and energy resources, and are essential elements in national security and waste disposal.

Changing Climate

Changes in climate are a critical factor governing life on Earth, and the ocean plays a key role in such climate changes. Describing and understanding short-term, atmosphere-ocean processes like El Nino can have immediate economic impact. Agricultural production, and therefore our food supply and economy, is directly affected by both short and long-term climate variations. Understanding the role of the ocean and its high-latitude sea-ice cover in long-term changes in climate, especially those related to changes in atmospheric gases like carbon dioxide, are critical for developing a predictive capability so that we can project how best to minimize long-term effects on our society.

Oceanic Crust

Global solid earth processes determine the distribution of mineral and energy resources. These processes are often revealed best beneath the ocean where surface erosion and other processes are not present and where geological structure is in many cases simpler than continental crustal structure. Thus, through increased knowledge of the structure of the earth's crust beneath the ocean, the oceanic crust, we will gain new understanding of the processes that generate volcanoes, earthquakes, and tsunamis, and that are responsible for the distribution of mineral and energy resources. The majority of the earth's remaining unexplored giant oil fields lie beneath the ocean. The processes leading to the evolution of the continental margins are critically important to understanding the distribution of the basins most fertile for exploration.

New Economic Considerations

The coastal ocean, with its complex land/sea interactions, provides most of our fishery resources. Its shallow shelves contain energy resources important to the U.S. economy and security. Because of this, coastal states around the world have assumed new responsibility in the coastal ocean by proclaiming Exclusive Economic Zones (EEZ). The U.S. EEZ is nearly equal to the land area of the nation. By the year 2000, 75% of the U.S. population will live within 50 miles of the ocean, making increased demands on estuaries and coastal resources. Moreover, changing processes in the coastal regions also affect the global ocean, providing a boundary condition.

National Security

Mastery of the sea is essential for national security. The strategic and tactical emphases of maritime defense have become fully global with new geopolitical and technical developments. Thus the global ocean environment is a major critical factor in national security. The ocean is the Navy's operating medium and a barrier for protection. Yet our knowledge base is poor. As we improve our understanding of processes and their variability in the ocean and at the sea floor, the Navy will better be able to exploit the ocean to advantage. In addition, the sea floor promises to be an important source of strategic minerals, another aspect of national security.

Waste Disposal

The ocean is the ultimate sink for land, water and many atmospheric discharges. Moreover, as waste disposal sites are filled on land, the ocean is being used increasingly for direct disposal. Protecting the ocean and its food and cultural resources requires an understanding of chemical and biological interactions, the transfer of contaminants through food chains and their fate in the oceanic system. It also requires a much better understanding of the geological and geophysical processes at the sea floor to define the stability of these regions for potential permanent waste sites.

Summary

The broad rationale described above reflects our current awareness of the importance of the global ocean to many of the nation's affairs. The program developed here builds on this rationale and on new developments in science and technology to provide the optimal interagency program for achieving an appropriate U.S. role in the necessary assessment and understanding of the ocean.

3. New Developments: Where Do We Stand Today?

Historic Leadership

The U.S. has long been a maritime power. Since World War II, U.S. oceanographers have led the world in ocean science. This position of leadership is beginning to bring the nation major benefits, such as weather and climate prediction, the ability to explore and develop offshore energy and mineral resources, and increased understanding of the ocean as an operating medium for the U.S. Navy and merchant marine.

Leadership Diminishing

Our nation's lead is growing smaller due to our own lack of major new investment and the continued aggressive position taken by our principal trading partners. For example, Japan and France have each built deep-diving submersibles that can reach most of the sea floor. The U.S. ALVIN, the only deep-submersible widely available to the U.S. research community, can reach only about one-half of the sea floor, and is restricted to working on continental margins or mid-ocean ridges. U.S. oceanographers seeking to carry out major programs in the polar regions have had to look to non-U.S. ships: either the new West German or USSR research icebreakers. Both France and the United Kingdom operate marine multichannel survey systems that are vastly superior to those available here. On shore, laboratories and analytical instruments at U.S. universities are aged and many can no longer provide students with training in modern technology. Without action, we will lose our competitiveness.

Economic Competitiveness

The global challenge and the national opportunity are especially clear today. Our nation is facing aggressive competition from other countries, and we are in danger of losing our scientific and technical leadership with consequent loss of economic competitiveness. We must be able to reliably assess resources available in the ocean and at its boundaries to balance the efforts of other nations who aggressively explore their EEZs and the global ocean. The next generation of developments in ocean science could lead to improved predictions of seasonal and longer term changes in climate and weather predictions, thus helping to protect the nation's agricultural production and permit the nation to better protect life and property . The President's 1987 State of the Union address and the FY 1988 Budget submitted to Congress in January 1987 underscore this need. The FY 1988 Budget is aimed at providing Federal support for the generation of new knowledge and the provision of an effective and timely transfer of this new knowledge to specific applications. A "global geosciences program to understand the earth, its oceans, and its atmosphere as a unified system" was specifically noted. The U.S. Global Ocean Science Program has been developed to provide a rapid follow-up of that lead.

4. Recognition of Urgency: Why Now?

At certain times, developments in basic understanding and technology come together to produce dramatic advances. Such a breakthrough is now possible in ocean science. A major increase in global geosciences research with an interdisciplinary approach exploiting new technology will produce a tremendous increase in our understanding of how the earth operates as a system. This is nowhere more evident or more applicable than in the ocean.

Technical Readiness

The task is to assess and understand the ocean on a global scale. We are now prepared to do this, because we have capabilities not available earlier. For example, new satellite-borne instruments permit global observations and provide a capability to describe and understand the role of the ocean in the total earth system. New instruments in the ocean and on the ocean floor and new chemical techniques measure processes more precisely and over longer periods than ever before. Supercomputers now allow us to assimilate and study the enormous quantities of data from these systems. New communication technologies can link satellites, ships and instruments at sea, and scientific laboratories to provide real-time interaction as well as cost-effective data collection.

World Climate Research Program

The new technology has provided a basis for new international programs. The most recent of these, the World Climate Research Program (WCRP) began in the early 1980s with new in-situ and satellite measurement techniques. The WCRP is aimed at understanding long-term weather variability and climate change. In recognition of the central role of the ocean in these processes, the WCRP has a focus on the interaction of the ocean and the atmosphere with emphasis on tropical interactions (the Tropical Ocean Global Atmosphere program - TOGA) and on global ocean circulation (the World Ocean Circulation Experiment - WOCE). In addition, the WCRP will continue to study the processes which control the energy budget and the exchanges of energy and water within the global climate system. These programs, for which the U.S. is providing major resources, provide a context for much of the U.S. Global Ocean Science Program.

International Recognition of Global Change

Issues of global environmental change will necessarily require emphasis on a broader range of disciplines than those covered in the World Climate Research Program. In September 1986 the International Council of Scientific Unions approved a new report on the International Geosphere-Biosphere Program: A Study of Global Change. This new program (IGBP) will be aimed at describing and understanding the interactive physical, chemical, and biological processes that regulate the total earth system, the unique environment it provides for life, the changes that are occurring in the system, and the manner by which these changes are influenced by human actions. The IGBP builds on the global and international programs typified by the International Geophysical Year, the

International Biological Program, the International Lithosphere Program, and the now active World Climate Research Program. The IGBP will study such phenomena as acid deposition, ozone depletion, and greenhouse effects, all of which reflect highly coupled systems of oceanic, atmospheric and terrestrial processes. The international Joint Global Ocean Flux Study (JGOFS), aimed at understanding oceanic biogeochemical cycles and budgets and the factors that control long-term chemical and biological dynamics on global scales, will make major contributions to the IGBP. JGOFS, which will have significant U.S. participation, is currently in the planning stages under the auspices of the international Scientific Committee for Oceanic Research (SCOR).

International Cooperation: Programs and Partners

It is clear from the development of these international programs that the international community of atmospheric and oceanic scientists has come of age. In addition, we have seen that in such programs as the international Ocean Drilling Program, it is now possible to have significant partnerships between the U.S. and other countries. By participating in these international programs, we leverage our own investments, and thus make it possible to address these global issues. One of the purposes of the U.S. Global Ocean Science Program is to help identify and facilitate such international cooperation and management arrangements.

A Human Resource Base

The nation's most effective long-term response to the challenge of an international knowledge- based economy is an educated human resource base. Investing in research is an effective way to provide educated scientists and engineers and to transfer technology from research projects to industrial practice. The US has an effective ocean research community now, and technology transfer has worked reasonably well, but this community needs to be substantially enlarged to meet the needs of understanding the global ocean and its role in global change.

The Federal Response

The President's FY 1988 Budget and previous budgets have responded to the general recognition that the U.S. must increase its investments in basic research now to develop and expand technologies that can help bolster the nation's economy. A vital part of that investment has been in the ocean sciences, and the return on the investment is becoming apparent in terms of improved scientific understanding and ocean technology. A continuing focus on ocean research through the FY 1989 and later budgets can ensure that the benefits of scientific advances in exploiting the ocean and its resources flow to the U.S.

5. Evolution of the Interagency Program

Background - The Foundation

For the past several years, informally through the Ocean Principals group and formally through various Committees of the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET), the relevant agencies have loosely coordinated programs that address global ocean science. Long-range planning efforts for new programs and for facilities such as ships and satellites have been developed by individual agencies and various advisory groups. Notable among these are the NSF Long-Range Plan for Ocean Sciences, NASA's plan for Oceanography from Space, the UNOLS and Navy ship replacement plan, and NOAA's Ocean Climate Research Plan. All of these help set the stage for the coordinated, interagency U.S. Global Ocean Science Program.

Interagency Approach

The Federal agencies have different, but related, needs for understanding the global ocean to meet their mission responsibilities. No single agency, however, can marshall all the resources needed (people, dollars, and capital assets) to gain a comprehensive understanding of the global ocean. If we are to effectively advance our knowledge, then we must do so in a collaborative and cooperative arrangement. The U.S. ocean research establishment is a unique and highly productive mix of universities, industry, federal agencies, and government laboratories. All sectors have important roles in providing and exploiting new technology and ensuring the availability of new scientific advances to the nation. Moreover, ocean research is properly a major responsibility of the federal government. Ocean processes transcend state and national boundaries, are too long-term for private sector investment, and are too important to the nation's security and future economic strength to leave leadership to other nations. The U.S. Global Ocean Science Program includes strong participation from all of the federal agencies with major ocean science interest and responsibilities. Certain agencies such as NOAA, NSF, NASA, Navy, DOE, and USGS are major participants in the Program, other agencies such as EPA and Department of State anticipate collaboration and participation in specific elements of the Program that relate to each of their missions and activities.

An Interdisciplinary and International Context

The strategy outlined here is consistent with the evolution of the IGBP to study global environmental change. Fundamental to that program is the concept that no single part - oceans, atmosphere, land and biota - can be understood adequately without study of the other parts. For example, we know that the ocean influences the atmosphere and land, and that only by studying these parts simultaneously can we fully understand the ocean itself. The scientific community and the federal agencies have responded to the need for interdisciplinary planning by developing new integrated programs. NSF has a new initiative in Global Geosciences, NASA plans a program in Earth System Science, NOAA plans an accelerated program in global climate change, and ONR has begun a series of interdisciplinary research initiatives impacting global understanding. The U.S. Global Ocean Science Program presented here builds on these programmatic themes to provide a context and ocean science focus for these broad agency actions.

6. Goal, Objectives, Components, and Coordination

Goal and Objectives

We have a new challenge to understand the global ocean, and we have a new national opportunity to maintain world leadership role. Recognizing the challenge and opportunity and with the firm foundation that has been developed, we can establish a sharp focus for the interests and needs of all the major agencies involved. The purpose of the U.S. Global Ocean Science Program is to provide a focus and overall context so that the total can be greater than the sum of the parts. The overall goal of the Program has been arrived at by mutual agreement of the interagency group and is the following:

> *To describe and understand more fully the interactive physical, chemical, geological, and biological processes within the global ocean and at the ocean boundaries that contribute significantly to the regulation and condition of the earth's global environment; and to understand the changes, both natural and anthropogenic, in the ocean that contribute directly to the health of the global environment.*

The specific objectives of the Program derive directly from the overall goal and the program rationale and are aimed at both science and resources:

- To understand the physical, chemical, and biological processes at work within the ocean and their effects on global weather and climate, and to assess the changes caused by mankind in the global ocean.

With this global description and understanding, we can expect:

- To use the ocean more effectively as a source of food, energy, and mineral resources with minimal adverse effects on the environment,
- To better assess and manage our coastal ocean, our Exclusive Economic Zone, and future coastal development,
- To ensure the safety of vessels and life at sea,
- To protect national security interests, and
- To identify and control those human activities such as certain waste discharges which will irreparably damage renewable resources.

Program Strategy

In order to meet its goal and objectives, the U.S. Global Ocean Science Program uses a strategy of identifying science and infrastructure components, each of which has a single unifying theme. Agencies contribute to each component with individual agency programs and with complimentary contributions to interagency programs. Identification of critical needs, gaps, and potential overlaps is the responsibility of an interagency working group that provides an overview of the entire program. This document is the first stage in that process.

Components of the Program

The science aspects of the U.S. Global Ocean Science Program are divided programmatically into five science components which will have interlocking parts:

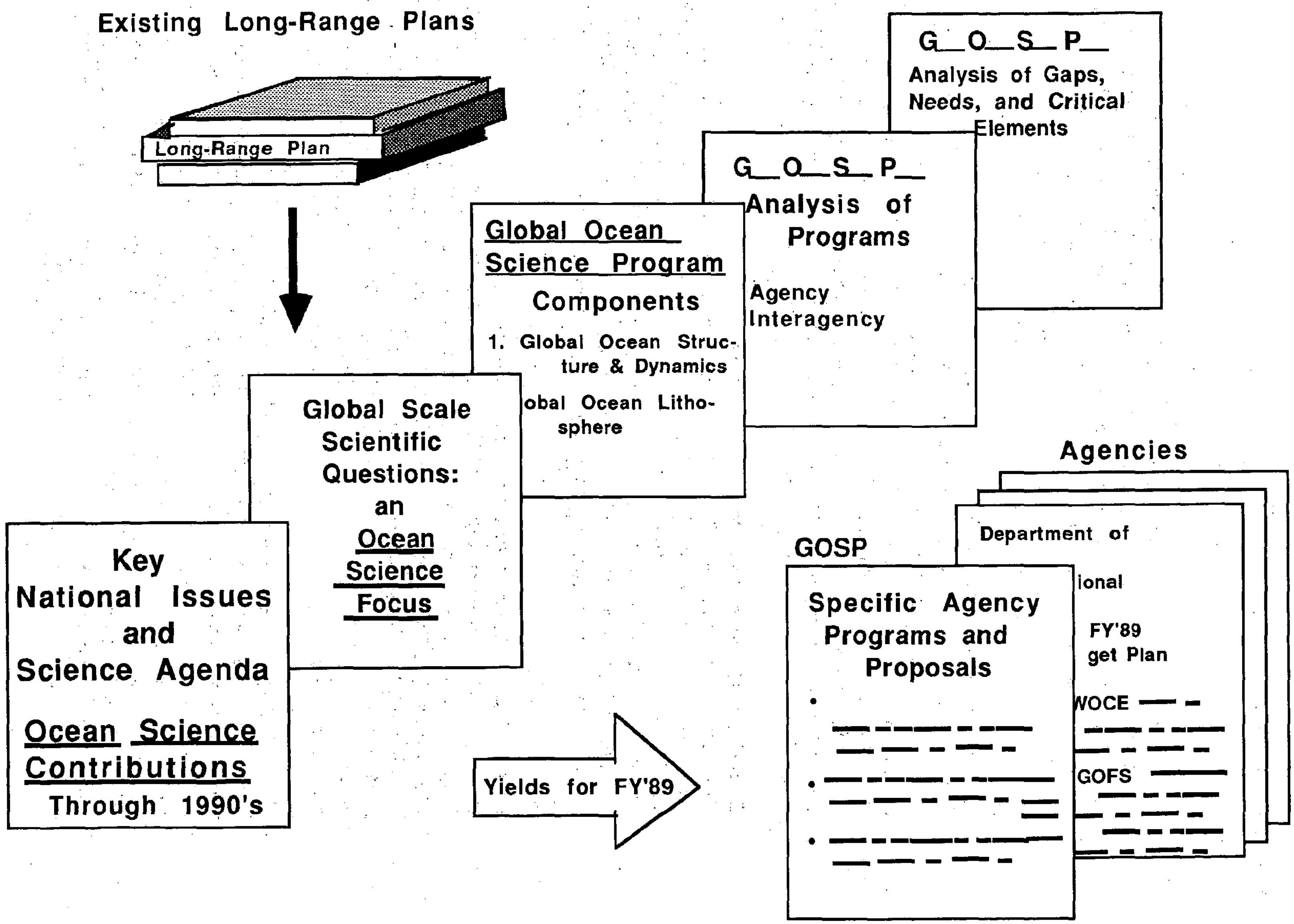
- Global Ocean Structure and Dynamics
- Global Climate: Atmosphere-Ocean Interactions
- Global Ecosystems and Productivity Processes
- Global Ocean Lithosphere and Geoprocesses
- Coastal Margins and Polar Oceans Processes

If we can achieve major advances in our understanding of each of these component areas, then we will begin to have the understanding we need to make a major step towards our goal of describing and understanding the ocean; its role in global environmental change; and the specific objectives listed previously. However, it will not be possible to mount the associated science programs without simultaneous improvement in the infrastructure to support these programs. In order to fulfill the goal and hence to meet the objectives, we need global measurement systems in place; we need communication networks that can deliver data as required to researchers and operational users in government, private industry, and academia; and we need to develop and validate models that can use the new global data sets. Thus we also identify the infrastructure components of the Program:

- Technology
- Facilities and Centers
- Data Management Systems

Support in these areas will ensure that we have the necessary instruments, that basic facilities are in place, and that new data sets can be handled efficiently. The science and infrastructure components together with the coordinating mechanism make up the heart of the U.S. Global Ocean Science Program. Below we describe the overall aims of each of the components, address the vital issue of manpower needs, and identify the coordination mechanism. In the next section, we will identify critical elements of each of these, and show how these can be met with on-going programs and new proposals. The following diagram illustrates this approach to developing the interagency plan.

Planning Strategy for the U.S. Global Ocean Science Program



Science Components

Global Ocean Structure and Dynamics
This component must develop a quantitative description and understanding of the global ocean with emphasis on relating ocean circulation to driving forces and boundary conditions, developing and validating predictive models, understanding internal dynamics and mass and energy transfers, and relating scales of motion and mixing from small to large. The World Ocean Circulation Experiment (WOCE), sponsored by the WCRP, is a key element here.

Global Climate: Atmosphere-Ocean Interactions
This component must develop a quantitative understanding of air-sea interactions with emphasis on understanding the role of the ocean in global climate, determining the transports of heat, momentum, energy, moisture, and chemical substances through the interface, assessing climate-related feedbacks among ice, ocean, and atmosphere, and understanding near-surface and deeper processes that affect biological and chemical exchanges, abundances and distributions. The Tropical Ocean-Global Atmosphere (TOGA) program, sponsored by the WCRP is a key element.

Global Ecosystems and Productivity Processes
This component must develop a quantitative understanding of ocean ecosystem dynamics on a global scale, including biological productivity, recruitment processes, and the full food web; and of the physical, chemical, and biological processes important in affecting the origins, distributions, and variability of oceanic biological and chemical species. The Global Ocean Flux Study (GOFS,) now being planned, is a key element. A new Global Ocean Ecosystem Dynamics (GOED) program will be proposed here.

Global Ocean Lithosphere and Geoprocesses
This component must develop a quantitative understanding of the ocean lithosphere. The emphasis is on determining geologic structure and on describing and understanding geoprocesses ranging from the upper lithosphere, ridge crest, and hydrothermal venting processes to those controlling the structure and shape of the seafloor and continental margins. The program will aim to understand the influence of these geoprocesses on the global ocean environment and the production of energy and mineral resources.

Coastal Margins and Polar Oceans Processes
In order to understand global phenomena, this component must develop a quantitative understanding of those critical processes that occur in coastal and polar regions. The emphasis is on the role of the coastal ocean in global ocean climate, in biological productivity, in biogeochemical cycles, and in geological processes. The coastal component of GOFS, under active development, is an important element. The component includes consideration of the effect of high latitude processes (such as bottom water formation) on global ocean circulation, on climate variability, on gas and chemical exchange, and on renewable and non-renewable resources.

Infrastructure Components

Technology

Here we look to new in-situ techniques and instruments, new supercomputers and communication technologies, and new satellite-borne instrumentation. There have been great strides in the past decade, but we need now to apply the technology on a global scale. Examples of needs include development of "smart" CTDs, pop-up drifters, "intelligent" collecting nets, automated systems for long-term data collection, and new satellite instruments.

Facilities and Centers

Ocean science, as all U.S. science, suffers from a lack of adequate facilities ranging from platforms (ships, moorings, island and coastal stations, satellites) to laboratories to large specialized facilities. Special needs include modernizing the federal and the academic fleet, providing access to modern physical, chemical, and biological laboratories, and supporting special large facilities such as satellite systems and accelerator mass spectrometers.

Data Management Systems

Traditional oceanographic data systems have depended on individuals or individual institutions for maintenance and support. Today, with enormous amounts of new data coming in from a variety of new instruments, and with much more likely from new satellites that will come at the end of the decade, more formal arrangements are required. This topic is one of much interest among the federal agencies; one very successful management arrangement has been developed by NOAA's National Oceanographic Data Center (NODC). This joint arrangement between NODC and one or more oceanographic institutions has the advantage of providing expertise from both sides in science and data; more such imaginative arrangements need to be considered.

Manpower Requirements

As we approach each of the initiatives in the US Global Ocean Science Program there is a need to attract the research capability of the best students and scientists available. Manpower is a critical requirement, and we must support innovative concepts to achieve our technical goals. In order to attract the best students into earth sciences and ocean sciences in particular, we need to support the development of exciting new educational programs including field work for students at all levels. This is best done by the agencies working together with the academic oceanographic community. Joint industry programs that allow students real hands-on experience are also available. These issues need to be more fully explored and an education initiative developed for early funding. An example is the ONR program to apprize professors from leading undergraduate colleges and universities of scientific opportunities in oceanography that are available to students.

Coordination

The U.S. Global Ocean Science Program will continue to be coordinated through an interagency working group which will periodically review agency initiatives and interagency programs in the context of this and other global planning efforts. The interagency group will analyze and identify needs, critical elements, and gaps in cross cutting analyses. Individual agency representatives on the group will be responsible for integrating the needs of the U.S. Global Ocean Science Program into each year's budget planning process.

Within the Federal Government, the interagency group will look to the Ocean Principals and the FCCSET Committee on Earth Sciences for guidance. Input from the academic and industrial communities would come through individual agency advisory committees, the National Academy of Science and the National Academy of Engineering. Specific actions for FY 1989 are identified in the next section of this plan. In addition, the interagency group will be responsible for taking the long-term view of the Program's needs, and ensuring that the right pieces are in place in each agency for the Program's long-term success.

The following section and diagram summarize the major components of this plan and their integration.

Summary

U.S. Global Ocean Science Program: Components

Global Ocean Structure and Dynamics

To describe and understand the global ocean emphasising:

- Circulation, driving forces and boundary conditions
- Predictive models
- Internal dynamics, mass and energy transfers

Global Climate: Atmosphere-Ocean Interactions

To understand air-sea interactions emphasising:

- Role of the ocean in climate and hydrologic cycles
- Transports of heat, momentum, energy, moisture, and chemical substances through the interface
- Climate-related feedbacks
- Chemical and biological exchanges and distributions

Global Ecosystems and Productivity Processes

To understand oceanic ecosystem dynamics on a global scale emphasising:

- Productivity, recruitment, food web
- Origin, distribution, variability of species
- Chemical and biological exchanges and distributions

Global Ocean Lithosphere and Geoprocesses

To understand the ocean lithosphere emphasising:

- Geoprocesses of upper lithosphere
- Influence on environment, mineral resource distribution

Coastal Margins and Polar Oceans Processes

To understand effects of coastal margin and polar oceans on:

- Global climate, circulation, and productivity
- Biogeochemical cycles, geological processes
- Renewable and non-renewable resources

Technology

To develop the necessary new in-situ techniques and instruments emphasising:

- Measurements of large scale systems
- Potential real-time monitoring

Facilities and Centers

To provide capital infrastructure including:

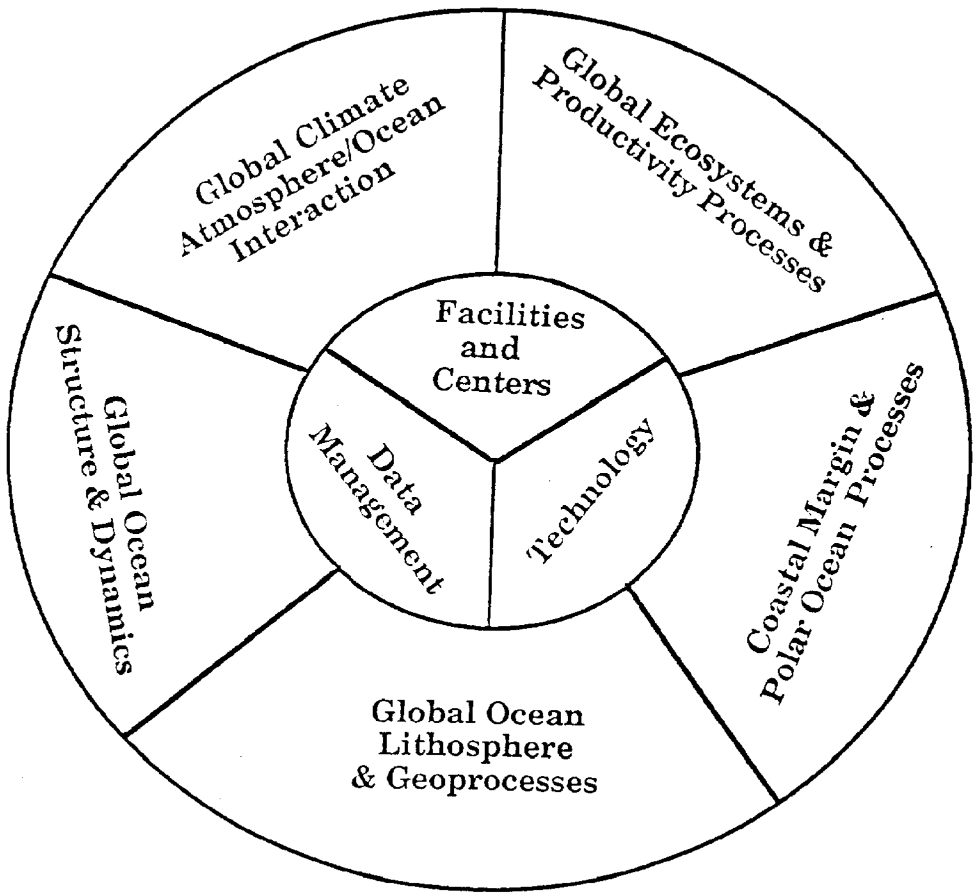
- Platforms
- Laboratories
- Specialized measurement facilities such as satellite systems

Data Management Systems

To provide data handling schemes for global data sets including:

- New techniques for data management
- Data Networks linking institutions
- New joint Federal/University/Industry arrangements

U.S. Global Ocean Science Program: Components



7. Specific Agency Contributions and Required Actions

The Global Ocean Science Program involves coordinated activities by several agencies in both the science and infrastructure components. As part of the planning for the Program, the interagency group has looked carefully at on-going and proposed interagency and agency activities in each of the Program components to identify specific needs, critical elements, and gaps that have not yet been addressed. From these, specific FY 1989 requirements have been identified. Even with these required actions, however, not all the gaps are filled. A summary of unfinished business is therefore also provided. This will be a long-term program. For illustration of the continuing effort required, an assessment of the current and recommended level of effort from FY 1986 through FY 1992 in each of the components has been developed to show the support that these components will need to make the Program successful.

Global Ocean Structure and Dynamics

In this component the Program requires a broad range of research and technology aimed at describing the physics of global circulation. Studies in this component will interact closely with studies in the climate and ecosystem components, and will require infrastructure support in technology (ocean instruments), facilities (operational and research satellites, accelerator mass spectrometer), and data management (new joint institutes).

Critical Elements and Contributing Agencies

World Ocean Circulation Experiment (NSF, NASA, NOAA, Navy)
Tropical Ocean-Global Atmosphere Program (NOAA, NSF, DOE)
Global Sea Level Measurement Network (NOAA, NSF, DOE)
Research Satellites: Altimeter and Scatterometer (NASA, NSF, Navy, NOAA)
Research on Global Circulation (NSF, NASA, NOAA, Navy, DOE)
Research on Mesoscale Circulation (Navy, NSF, NOAA)
Global Chemical Tracer Measurements (NSF, NOAA, DOE)
Bilateral and Multi-lateral Programs (DOS, technical agencies)

Gaps

Further efforts needed in:

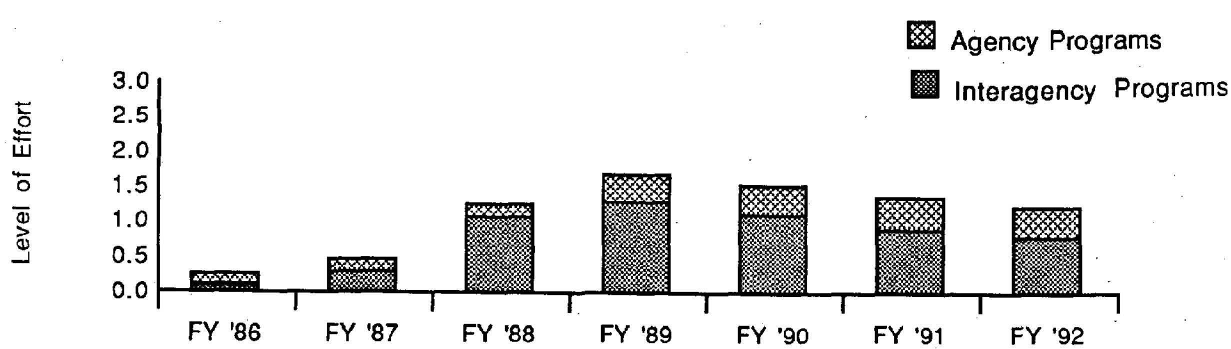
Fully Global in-situ Sea Level Network
NROSS for flight of scatterometer and other instruments not yet approved
International management arrangements for WOCE, JGOFS
Research ships, data management

FY 89 Actions Required

NSF: Maintain Global Geosciences growth (including Global Circulation, Climate and Productivity), advanced computing, data management
NASA: Maintain TOPEX, NSCAT (for flight on NROSS)
NOAA: Enhance large-scale ocean observing systems (including global sea level) and ocean circulation studies related to global climate change
Navy: Ship initiative, modelling and mesoscale processes, NROSS approval

Projected Level of Effort

The timing for this component is largely determined by the flight schedules of satellites. TOPEX/POSEIDON and NROSS are currently planned for 1991. There is a buildup to 1989, followed by a gradual decline since the next generation of technology will be developed by that time.



Global Climate: Atmosphere-Ocean Interactions

In this component the Program requires a broad range of climate-related research including the effects of air-sea exchange, ice interactions, the hydrologic cycle, and chemical and biological processes that affect climate. This component interacts with the Global Ocean Structure and Dynamics and the Global Ecosystem and Productivity Processes components, and will require support from each of the infrastructure components. Examples of such infrastructure are air-sea exchange instrument development, climate data management, and operational weather satellites.

Critical Elements and Contributing Agencies

Seasonal and Interannual Climate Research including Tropical Ocean-Global Atmosphere Program (NOAA, NSF, DOE)
Trace Gases (Climate/Air Quality)(NOAA, NSF, DOE)
Arctic System Sciences (ARCSS)(NSF, Navy, NOAA, NASA)
Research on Air-Sea Exchange/Marine Meteorology (Navy, NSF, NOAA, DOE)
Research related to the satellite wind scatterometer (NASA, NSF, Navy)
Climate Modelling Diagnostics and Data Management (NOSS, NSF, NASA, Navy)
Bilateral and Multi-lateral Programs (DOS, technical agencies)

Gaps

Further efforts needed in:

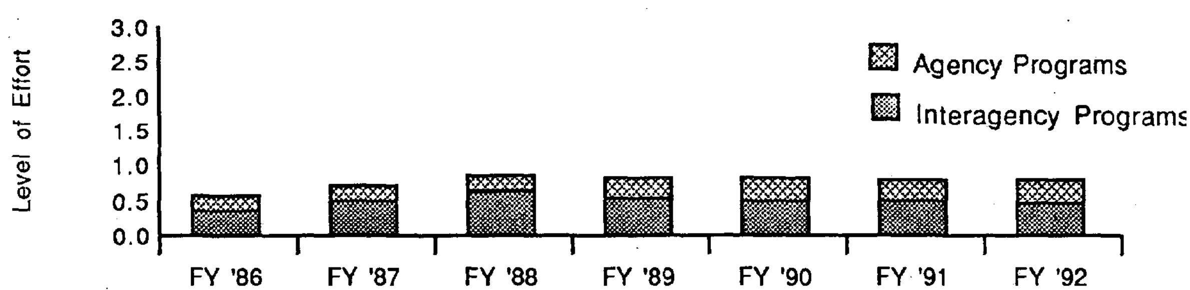
Sea Level in the Indian Ocean
NROSS (not yet approved)
Global Trace Gases Chemistry
Data Management for global climate studies

FY 89 Actions Required

NOAA: Maintain full TOGA program; accelerate work on global climate change including trace gas studies, historical climate proxy studies, climate modelling and diagostics, and data management
NSF: Maintain Global Geosciences growth (TOGA, WOCE, trace gases), advanced computing, data networks
NASA: Maintain NSCAT support, data management
Navy: NROSS approval, modelling, ship initiatives, bio-physical interactions

Projected Level of Effort

This component is underway. TOGA began in 1985. Tropical studies will enter a new stage in approximately 1991, when new global satellite data will be available for tropical winds and ocean currents. The level of effort is already close to maximum, building slightly to 1989 with the addition of initiatives such as paleoclimate studies after which it remains roughly constant.



Global Ecosystems and Productivity Processes

In this component the Program requires support of a broad range of ecosystem research. Because of the importance of the physical climate system, this component must be carried out in the context of the Global Ocean Structure and Dynamics and the Global Climate components. This component will require support from the Technology component for new sampling and analysis instruments.

Critical Elements and Contributing Agencies

Global Ocean Flux Study (GOFS) (NSF, Navy, NOAA, DOE)
Global Ocean Ecosystem Dynamics program (NSF, Navy, NOAA)
Research related to satellite ocean color measurements (NASA, NSF, Navy, NOAA)
Physical/Biological interactions studies (Navy, NSF, NOAA)
Fisheries/Oceanography interactions (NOAA, NSF)
Bilateral and Multi-lateral Programs (DOS, technical agencies)

Gaps

Further efforts needed in:

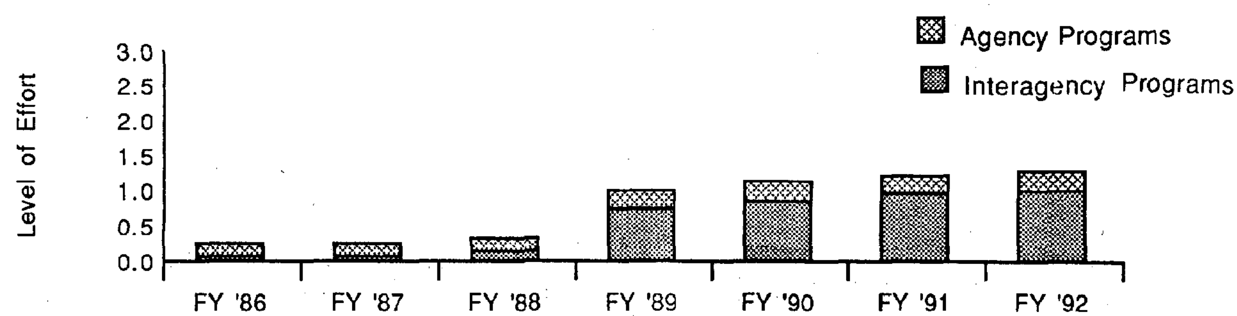
Satellite Ocean Color Instrument
NROSS (not yet approved)
Global Ocean Ecosystem Studies
New sampling techniques

FY 89 Actions Required

NSF: Maintain Global Geosciences growth (including JGOFS); Establish Global Ocean Ecosystem Dynamics program
NASA: Support Sea-Wifs ocean color instrument for flight on Landsat-6
NOAA: Support fisheries related oceanographic research and expand global marine ecosystem studies
Navy: Modelling, bio-physical interactions, increase in bio optics and particle dynamics. NROSS approval
DOE: Expansion of CO2 program to include biological interactions

Projected Level of Effort

This program is just beginning, and will depend strongly on the Global Ocean Structure and Dynamics and Global Climate components for basic physical and chemical understanding. Major funding begins in FY 1989 for field activities beginning in FY 1991 to coincide with the Global Ocean Structure and Dynamics component. Funding during the prior years is for process studies and technology development aimed at better global sampling of biota and processes.



Global Ocean Lithosphere and Geoprocesses

In this component, the Program requires a variety of measurements of the structure of the sea floor and continental margins to enhance our understanding of the global geoprocesses that control the solid, but dynamic, earth. This component interacts primarily with the Global Ocean Structure and Global Ecosystems components, through cross cutting interests in the chemistry at ridge crests, the paleoclimate aspects of global climate, (since the sediments record the history of global change), and programs in continental geology and geophysics. Infrastructure needs include long-term bottom observatories and satellite measurements of gravity and magnetic field.

Critical Elements and Contributing Agencies

Processes at plate boundaries and other active regions (NSF, USGS, NOAA, Navy, DOE)
Global network of seismometers (NSF, USGS, Navy)
Coastal Ocean geoprocesses (Navy, NSF, USGS, NOAA)
High Latitude Drilling (NSF, Navy, USGS)
Satellite measurements of Gravity and Magnetic Field (NASA, Navy, NOAA)
Bilateral and Multi-lateral Programs (DOS, technical agencies)

Gaps

Further efforts needed in:

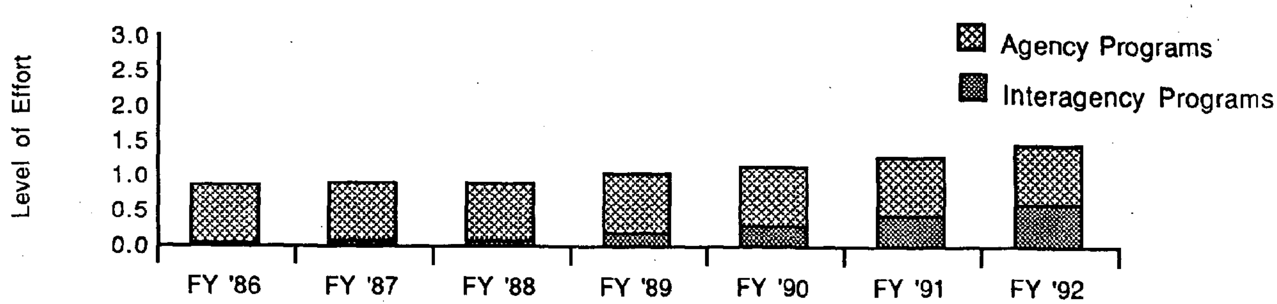
Ridgecrest processes, back arc spreading and vent program
Ocean Bottom Seismometers
Arctic Drilling
Coastal Ocean Dynamics and Fluxes
Satellite missions for gravity and magnetic field
Morphology of the floor of the global ocean

FY 89 Actions Required

NSF: Maintain Growth of Global Geosciences Program (includes Ridgecrest Processes and Vents Program)
Navy: Ship initiative, ULF/VLF, Increase in particle dynamics and ridge crest processes
DOE: Development of isotopic chemistry (young time markers)
NOAA: Expand studies of ridge crest processes, including the VENTS program
USGS: Multichannel seismic studies of the U.S. continental margin

Projected Level of Effort

This program, with major agency components such as the Ocean Drilling Program already well underway, is at a relatively high level of effort. Major gaps include satellite measurements of gravity and magnetic field and Arctic drilling. As critical interagency elements are developed, broad support increases to develop and integrate different techniques.



Coastal Margins and Polar Oceans Processes

This component of the Program addresses physical, chemical, biological, and geological processes along coastal margins and in polar oceans. These areas provide key elements in the transition between processes on land and the global ocean. Infrastructure issues include satellite measurements in coastal oceans, computers, data management, and ships.

Critical Elements and Contributing Agencies

Coastal interactions with global ocean fluxes (NSF, Navy, USGS, NOAA, DOE)
Interactions of land and coastal ocean processes (NSF, NOAA, USGS, DOE)
Arctic air-sea-ice-biology interactions (Navy, NSF, NOAA)
Coastal erosion programs (USGS)
Satellite measurements in polar regions (NASA, NOAA, Navy, NSF)
Ice edge studies (NSF, Navy, NASA)
Coastal transition studies (Navy, USGS, NOAA)
Bilateral and Multi-lateral Programs (DOS, technical agencies)

Gaps

Further efforts needed in:

Coastal part of Global Ocean Flux Study
Global Scale Ocean and Margin Dynamics
Land/Sea Interface studies
Coastal vessels
Arctic System Science studies
Dedicated Ice programs

FY 89 Actions Required

NSF: Maintain Global Geosciences growth, Coastal Ocean Dynamics and Fluxes (including the coastal component of GOFS), Arctic system sciences, Land/Sea Interaction

USGS: Coastal erosion program

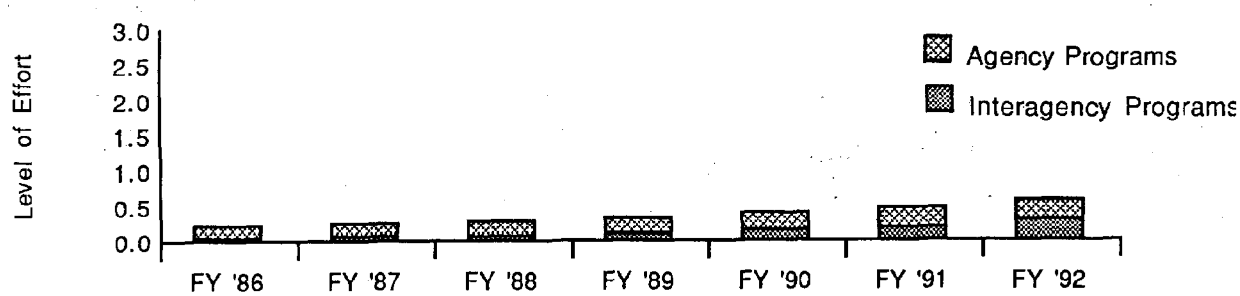
NOAA: Maintain coastal ocean and marine resource research and enhance research on air-sea-ice biologic interactions and estuarine science

DOE: Regional Marine Program, Shelf Edge Exchange Program (SEEP), California Basin (CABS)

Navy: Ship Initiative, Increases in coastal and arctic sciences, Arctic oceanography initiative

Projected Level of Effort

Like the Global Ocean Lithosphere component, this program is largely agency-based at the present time. Beginning in FY 1989, we look to increasing, parallel, support of interagency programs. Projecting the total level of support including logistics is difficult beyond 1992. Although global logistics requirements are less than for other components the diversity of coastal and polar environments can still increase logistics costs.



Technology: Sensors and Sampling

The need for new technology ranging from sensor development to new sampling techniques is evident all across the range of science components above. Specific items of technology are being addressed as part of broader initiatives as noted below.

Critical Elements and Contributing Agencies

Global Ocean Structure: Large-scale measurement techniques (NSF, Navy, NOAA, NASA, DOE)
Global Climate: Air-Sea Interaction measurement techniques (NOAA, NSF, Navy, DOE, NASA)
Global Ocean Ecosystems: Biological Sampling techniques (Navy, NSF, NOAA, DOE)
Global Ocean Lithosphere: Cores, drilling, seismics, geochemistry (NSF, USGS, DOE)
Coastal Margins and Polar Oceans: Under-ice measurements, near-shore/wave zone techniques, bottom dynamics measurement (Navy, NOAA, NSF, USGS, DOE)

Gaps

Further effort needed in:

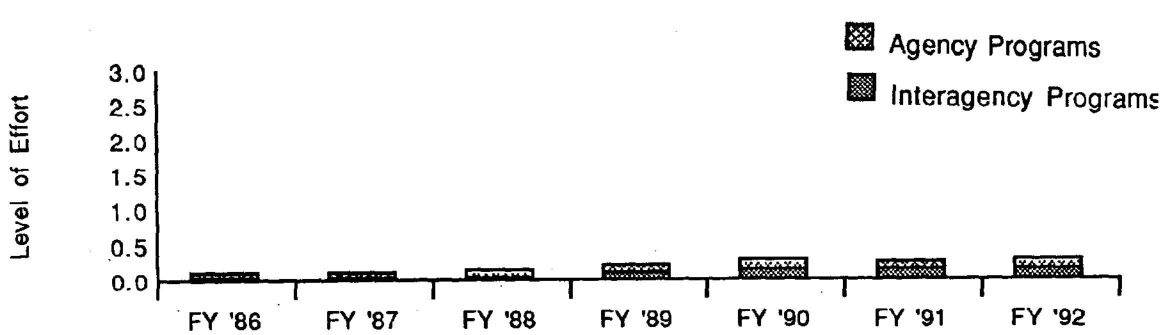
Techniques to measure large-scale phenomena
Air-Sea Interaction packages
Biological sampling techniques
Under-ice and near-shore/wave zone techniques
Long-term, real-time, *in-situ* monitoring techniques

FY 89 Actions Required

NSF: Global Geosciences Instrumentation: large-scale techniques, air-sea interaction, biological sampling
NOAA: New water mass tracer techniques (e.g. freon); large-scale ocean observing techniques; and air-sea interaction technology
USGS: Coastal instrumentation as part of Coastal Erosion program
DOE: New and improved isotopic tracer systems; Biological sampling
Navy: Instumentation/sensor development incentive, improved Arctic sensors, bio optical/acoustical sensors, acoustic tomography

Projected Level of Effort

A steadily growing level of effort in support of global ocean programs is projected. Reflecting the costs of instrument development, the level of effort is an order of magnitude less than those of the field programs.



Facilities and Centers for Global Ocean Science

New facilities and Centers are important for the Global Ocean Science Program. Without a global reach, our shipboard capability cannot produce the scale of measurements we need. Without satellites, we cannot produce the global view essential for the program. Without advanced computing, there will be no way to handle the new data sets and to make the physically correct models essential to understanding interactions and predicting future ocean behavior. Finally, we need major laboratory facilities for measurement and calibration of samples and instruments.

Critical Elements and Contributing Agencies

A Global Fleet: operation, modernization, construction of research ships (NSF, Navy, NOAA, USCG)
Satellites: Research and Operational (NASA, NOAA, Navy)
Computers: Supercomputing capabilities and Links (NSF, NOAA, Navy, DOE)
Major Laboratory Facilities: For example, the Accelerator Mass Spectrometer (AMS) for ^{14}C determinations, Natural Synchotron Light Source (NSF, DOE)

Gaps

Further efforts needed in:

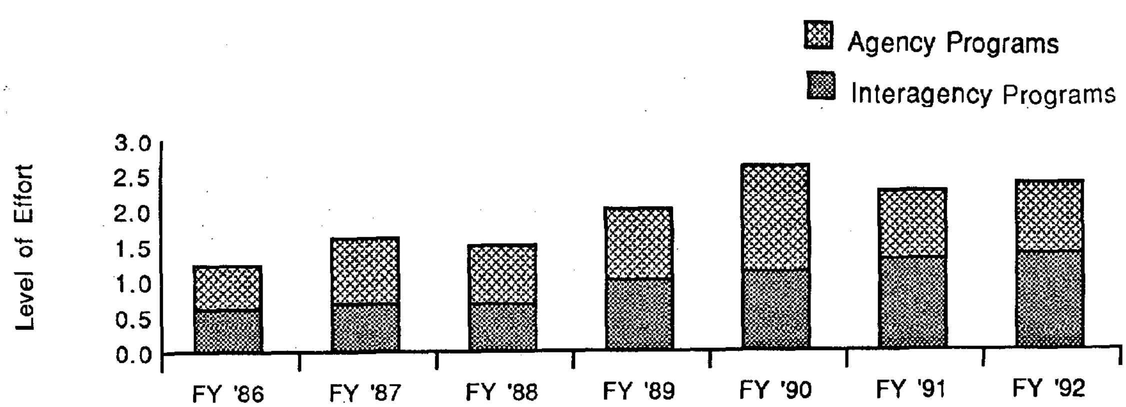
Satellite Ocean Color facility
NROSS capability
New Ship Construction
Supercomputer capabilities and links

FY 89 Actions Required

NSF: Advanced scientific computing capability, AMS, Research vessel modernization
Navy: Research vessel construction and modernization; NROSS approval
NASA: Sea-Wifs Ocean Color satellite instrument for Landsat-6, maintain TOPEX, NSCAT
NOAA: Advanced computing capabilities; research vessel modernization; specialized facilities and research centers (NURP, Sea Grant program)
DOE: Super computer links

Projected Level of Effort

Because of the heavy demand of ocean sciences for facilities, the required support level is high. To meet the needs of developing programs and large field efforts beginning in the early 1990s, this component builds to a steady-state level by 1990. After that funds are needed largely for replacement of existing facilities. Shared use of facilities by the U. S. and other countries will relieve the load on the U.S., hence the slight decrease in 1991 and 1992.



Data Management Systems

New techniques for collecting global data require management systems to make that data available in usable form to researchers and operational users. Both new satellite missions (U.S. and international) and *in-situ* instruments will yield large quantities of global data that must be processed, archived, and accessible. We need to upgrade our national data centers, to provide for joint university and/or industry links with government agencies, and to establish networks that link data centers, research institutions, and supercomputing centers. A new interagency committee on data management chaired by NOAA will provide coordination for data management for earth sciences in general.

Critical Elements and Contributing Agencies

Research satellite data management systems (NASA, NSF)
Operational satellite data management systems (NOAA, Navy)
In-situ data management systems (NOAA, NSF, Navy, DOE)
National Data Centers/Interaction with users (NOAA, NASA,Navy)
Database management system for ocean sciences (Navy, NOAA)

Gaps

Further efforts needed in:

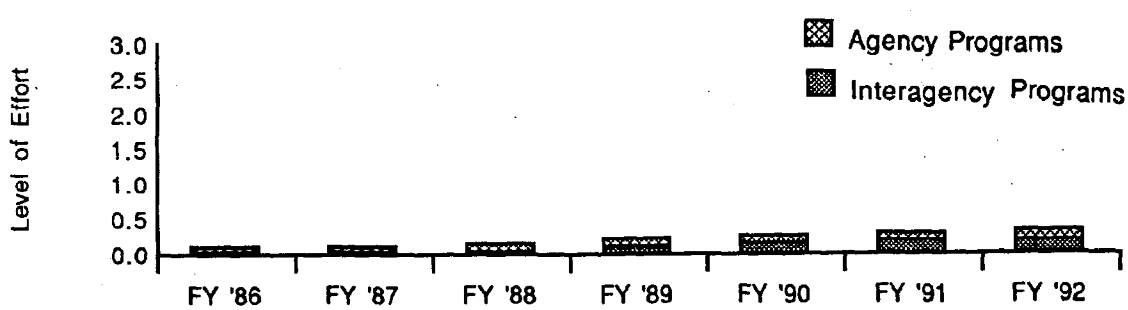
Interagency data programs
Joint Government/University/Industry data arrangements
Network development
Database management systems
International Links

FY 89 Actions Required

NSF: Global Geosciences (data management)
NOAA: Data management for global climate change studies; international data exchange; general improvements to NOAA-wide data management capabilities including systems upgrades and quality control
Navy: Database management system
NASA: Maintain support for data and information systems; international data exchange
USGS: Geonet
DOE: CO_2 data management

Projected Level of Effort

This is an effort that will continually grow and be distributed roughly equally between agency and interagency programs. The level of effort generally reflects the combination of rapidly increasing need with a technology that is becoming more efficient and cost-effective.



Summary of Specific FY 1989 Required Actions

In summary, we list the FY 1989 required actions that are identified as crucial by the Global Ocean Science Program.

NSF: Maintain Global Geosciences Growth
Advanced Scientific Computing
Ship Modernization
Ocean Instrumentation
Land/Sea Interaction
Coastal Ocean Dynamics and Fluxes
Artic Systems Science

NOAA: Large-scale ocean observing system, including global sea level
Global climate prediction including TOGA, ocean circulation trace gas and historical proxy studies, satellite applications; climate modelling, diagnostics and data management
Global marine ecosystems and fisheries-oceanography studies
Advanced computing capabilities
Research vessel modernization
Data management upgrades, including data management capabilities for global climate studies

NASA: Sea-Wifs Color Scanner for Landsat-6, Maintain TOPEX, NSCAT

Navy: NROSS approval
Ship Initiative
Ocean Instrumentation
Computers/Modelling
Database Management System

USGS: Geonet data system
Coastal Erosion Initiative
Multi-channel seismic studies of the continental margin

DOE: Expansion of CO2/Biology/Ocean Interactions Program
Development of Isotopic Tracer System
Shelf Edge Exchange Program Expansion
Supercomputer Network
Biologic Sampling Instrumentation

DOS: Strengthen and develop new bilateral and multilateral programs (in cooperation with the technical agencies)

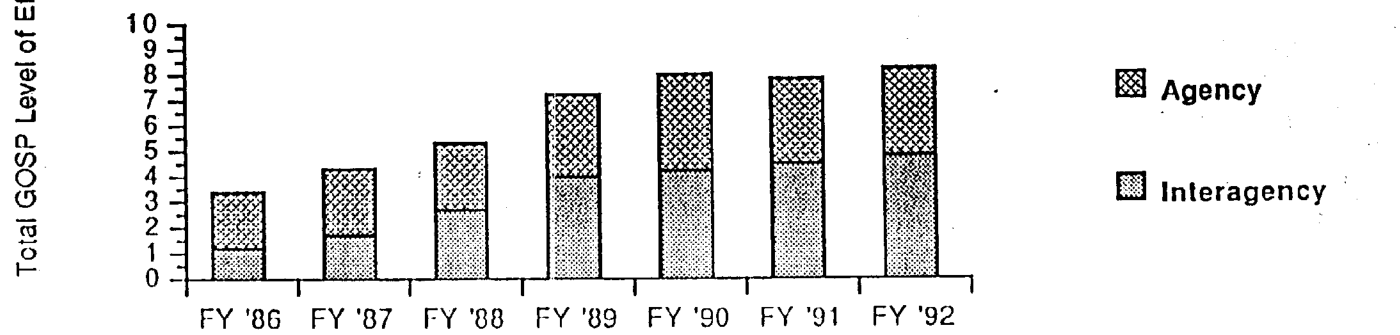
Level of Effort Summaries

Science and Infrastructure

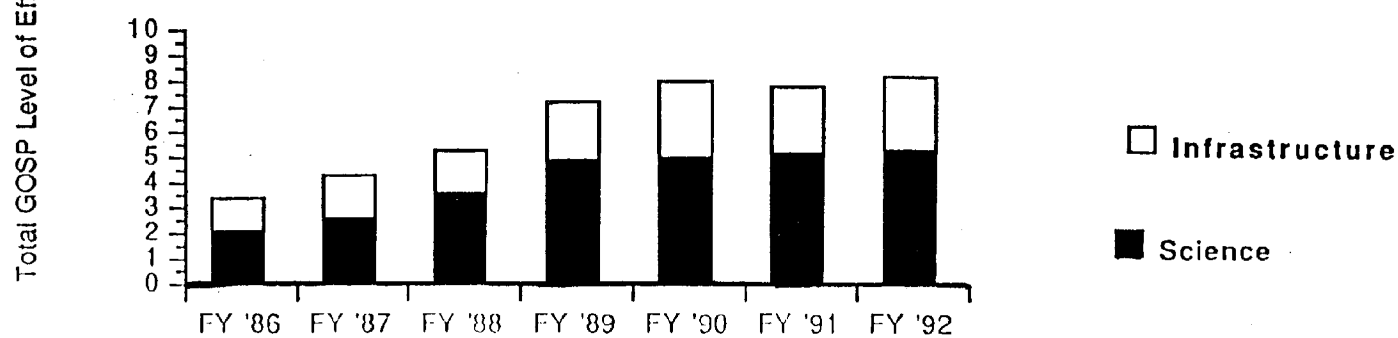
The following table illustrates the estimated level of effort for the science components and infrastructure components and the relative agency and interagency contributions. In the case of science, there is a rapid growth (by roughly a factor of 2) to FY 1989, and then a relatively level activity. This reflects a build-up of field programs that will culminate in the early 1990s simultaneously with the flight of satellite missions planned for that period. The infrastructure programs show a similar structure, with some decrease after FY 1990 reflecting the fact that much of the necessary infrastructure will be in place by then.

SUMMARY OVERVIEW OF GOSP LEVEL OF EFFORT ANALYSIS

Interagency and Agency-Based



Science and Infrastructure



NOTE: All Data Normalized on a Scale of 0 to 10

The Unfinished Agenda

This plan for the U.S. Global Ocean Science Program is the beginning of a long-term effort. Not all the issues can be addressed immediately. There are unfinished agenda items. Prime among these are international cooperation and site and data access, and recruitment of new scientists into the field.

We have emphasized the global aspect of ocean science and the need to pool resources between the U.S. and other countries. Therefore we must cooperate in international programs with oceanographic communities of other nations; several such international programs have been discussed.

With the expansion of exclusive economic zones to cover much of the global ocean, we need access to foreign waters. In all global programs, there is a need to make measurements in waters that may be claimed by a particular country. The best way to make such arrangements is to involve fully the scientists of the country in the program. We are working hard to do this. For example, in the Ocean Drilling Program which is currently circling the world, scientists from nations near the drilling operations are regularly brought on board for joint projects. Even with these arrangements, however, clearances are often denied. This problem is becoming worse, and we need new ways of addressing it.

We also need to address, at the earliest educational levels, the development of the next cadre of scientists into the field. These programs offer a splendid opportunity for young people to enter the field of science. As was stated at the very beginning of the report, an educated human resource base is an overall rationale and requirement for the U.S. Global Ocean Science Program over the long-term. In order to attract the best students into earth sciences in general and ocean sciences in particular, we need to support the development of exciting new educational programs including field work for students at all levels.

A Final Note

Ocean Science, perhaps more than any other, is global and international in the full sense of the word. Our arena is international, our scientific colleagues are international, and we work with many governments to collect and study the processes that shape our environment. We have learned the ways of many different kinds of organizations, ranging from those under UNESCO to the non-governmental bodies of the International Council of Scientific Unions, and we have worked directly with bilateral arrangements. We are now looking to new programs and new facilities that will allow a new understanding of this global resource. The U.S. Global Ocean Science Program can help put all this together.

Appendix A - Acknowledgements

The Working Group acknowledges helpful imputs and comments from many members of the U.S. oceanographic community. Joint Oceanographic Institutions Incorporated provided staff support for the work of the group and the development and production of the report.

Appendix B

Attendees, Reston Workshop on Ocean Research Priorities

J. Baker, Joint Oceanographic Institutions Incorporated

J. Carey, National Oceanic and Atmospheric Administration

R. Corell, University of New Hampshire

F. Eden, Joint Oceanographic Institutions Incorporated

E. Frieman, Scripps Institution of Oceanography

G. Gross, National Science Foundation

G. Hill, United States Geological Society

M. Katsouros, National Academy of Sciences

J. Kermond, National Association of State Universities and Land Grant Colleges

A. Maxwell, University of Texas at Austin

W. Merrell, National Science Foundation

J. McCarthy, Harvard University

W. McCloskey, Office of Naval Research

T. Offield, United States Geological Survey

J. Orcutt, Scripps Institution of Oceanography

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J. Perry, National Academy of Sciences

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S. Wilson, National Aeronautics and Space Administration

Additional Reviewers of Report

D. Boesch, Louisiana Universities Marine Consortium

F. Spiess, Scripps Institution of Oceanography

W. Munk, Scripps Institution of Oceanography

Appendix C

Members U.S. Global Ocean Science Program

Agency	Member
Department of Commerce (NOAA)	Michael Hall, Alan Thomas
Department of Defense (ONR)	Thomas Spence, David Evans
Department of Defense (OCNAV)	Robert Feden
Department of Energy	Helen McCammon
Department of the Interior	David Barna
Department of the Interior (USGS)	Gary Hill
Department of State	William Erb, William Sullivan
Department of Transportation (U.S. Maritime Admin.)	William Creelman
Department of Transportation (Ice Operations Division)	Richard Hayes
Environmental Protection Agency	Peter Jutro
National Aeronautics and Space Administration	Stanley Wilson
National Science Foundation	Grant Gross
Office of Science and Technology Policy	Robert Chapman
Chairman	Robert Corell

Appendix D - Glossary

AMS - Accelerator Mass Spectrometer

ARCSS - Arctic Systems Science

AVHRR - Advanced Very High Resolution Radiometer

CAC - Climate Analysis Center

CAMP - Circum Atlantic Mapping Program

CMAN - Coastal Marine Automated Network

CPMP - Circum Pacific Mapping Program

DARPANet - Defense Advanced Research Project Agency Network

DMSP - Defense Meteorological Satellite Program

EEZ - Exculsive Economic Zone

EROS - Earth Resources Observation Systems

ERS-1 - European Remote Sensing Satellite No. 1

FCCSET - Federal Coordinating Council on Science, Engineering and Technology

FNOC - Fleet Numerical Oceanographic Center

GEDIP - Global Environmental Data Information Program

GEONET - Geological Survey Network

GEOSAT - Navy's Geodetic Satellite Mission

GFDL - Geophysical Fluid Dynamics Laboratory

G & G Archive - Geolgical and Geophysical Archive

GLORIA - Sidescan Sonar System

GLOSS - Global Ocean sea Level System

GOES - Geostationary Operational Environmental Satellite

GOFS - Global Ocean Flux Study

GRM - Geopotential Research Mission

GSGP - Global Sedimentary Geology Program

GSP - Greenland Sea Project

HEBBLE - High Energy Benthic Boundary Layer Experiment

IGBP - International Geosphere-Biosphere Program

IGCP - International Geological Correlation Program

IGOSS - Integrated Global Ocean Services System

ILP - International Lithosphere Program

LIMEX - Laborador Ice Margin Experiment

LOBO - Longterm Ocean bottom Observations

MIZEX - Marginal Ice Zone Experiment

MPBL - Marine Planetary Boundary Layer

NCAR - National Center for Atmospheric Research

NGWLG - Next Generation Water Level Gauge

NMC - National Meteorological Center

NNODDS - Navy/NOAA Ocean Data Distribution System

NODC - National Ocean Data Center

NODS - NASA Ocean Data System

NOMSS - National Oceanic and Meteoric Support System

NSCAT - NASA Scatterometer for flight on NROSS

NROSS - Navy Remote Ocean Sensing Satellite

NURP - National Undersea Research Program

OPC - Ocean Products Center

OTS/IWP - Ocean Turbulence Surface/Internal Wave Processes

PIPOR - Program of International Polar Ocean Research

POES - Polar Operational Environmental Satellite

SCOR - Scientific Committee on Oceanic Research

SEAS - Shipboard Environmental Data Acquisition System

Sea-WiFS - Wide-field sensor (color scanner) flight on Landsat-6

SPAN - Space Physics Analysis Network

STRESS - Shelf Transportation Experiment: Slopes and Shelves

SYNOPS - Synoptic Ocean Prediction

TOGA - Tropical Ocean Global Atmospheric Program

TOPEX - Ocean Topography Experiment

UNIDATA - University Data Network

UNOLS -University National Oceanographic Laboratory System

VENTS - Vents-Ocean Ridge Crest Program

WCRP -World Climate Research Program

WOCE - World Ocean Circulation Experiment

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