Exploration of the Seas

Interim Report

Committee on Exploration of the Seas

Ocean Studies Board

Division on Earth and Life Studies

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This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in their review of this report:

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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by William Fenical, appointed by the Divison on Earth and Life Studies, and Carl Wunsch, appointed by the Report Review Committee, who were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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EXECUTIVE SUMMARY

The ocean is critical to humankind and is increasingly affected by human actions: the ocean influences global climate, is threatened by pollution, overfishing, and habitat degradation. It affects human activity as it influences climate and contains unknown amounts of biological, chemical, and mineral resources, and priceless relics of our maritime past. We have much more to learn about the secrets our ocean holds and how to manage its resources in a sustainable way.

In December 2000, the United States Congress requested that the U.S. National Academies assess the feasibility and value of implementing a major, coordinated, international program of ocean exploration and discovery. The Committee on Exploration of the Seas was appointed, held a series of working meetings and a large international workshop, and is currently drafting a final report. Recognizing the widespread interest in ocean issues, intensified recently by the deliberations of the U.S. Commission on Ocean Policy, the Committee felt it would be helpful to issue this interim report presenting the Committee's broad findings and recommendations. The final report, to be published in Spring 2003, will include more detailed discussion of the justification for an ocean exploration program and recommendations for implementing such a program at the national and international levels.

The Committee recommends that a long-term United States effort in ocean exploration be initiated. An ocean exploration program will provide initial observations and insights that can subsequently be used to develop the testable hypotheses typically associated with scientific research. Ideally, an ocean exploration program should complement ocean research and support a continuum of discovery, research, and new technologies.

The Committee recommends that priority should initially be given to pilot programs for which strong international interest exists, which hold promise of new discoveries or understanding, and which have substantial potential for public outreach and involvement. Initial focus areas could include Marine Biodiversity, The Polar Oceans, Marine Archaeology, Deep Water and Its Role in Climate Change, and Exploring the Ocean Through Time.

To implement the ocean exploration initiative, **the Committee is considering a variety of options, one of which is creating a national program for ocean exploration to be operated by a non-governmental organization**.

The United States will need international partners to achieve a truly global exploration program. To initiate a coordinated international effort, **the Committee recommends the establishment of an International Global Ocean Exploration (IGOE) Committee**, with initial membership drawn from the member countries of the Scientific Committee on Oceanic Research. The IGOE Committee should initially be supported by the national program for ocean exploration, but should evolve over time into an independent, non-governmental organization with financial support from participating nations. The IGOE Committee should develop a broad plan for international collaboration and should catalyze international cooperative efforts. In addition to this international mechanism, cooperative agreements between countries for specific pilot programs should also be pursued.

The Committee recommends that public outreach and education be integral components of the ocean exploration program. Ocean exploration provides rich images and information that easily capture the imagination of people of all ages and are readily translatable into both formal and informal educational settings. As with any large-scale, publicly funded research activity, public education should be an obligation of the exploration program, both for the benefit of the nation's citizens, and for the long-term success of the program.

INTRODUCTION

In December 2000, the United States Congress requested that the U.S. National Academies assess the feasibility and value of implementing a major, coordinated, international program of ocean exploration and discovery. An expert committee was formed and charged to address a specific Statement of Task (Box 1). The Committee on Exploration of the Seas includes members of the academic, legal, commercial, and non-profit sectors, with expertise in earth and oceanographic sciences, marine engineering, underwater archaeology, and national and international law and policy. The Committee held a series of working meetings and a large international workshop for the purpose of information gathering and deliberation and is currently drafting a final report. Recognizing the widespread interest in ocean issues, intensified recently by the deliberations of the U.S. Commission on Ocean Policy, the Committee decided to issue this interim report presenting the Committee's broad findings and recommendations. The final report, to be published in Spring 2003, will include much more detailed analyses of the justification for an ocean exploration program and detailed recommendations for implementing such a program at the national and international levels.

Box 1
Committee on Exploration of the Seas Statement of Task

This study will assess the feasibility and potential value of implementing a major, coordinated, international program of ocean exploration and discovery. The study Committee will survey national and international ocean programs and strategies for cooperation between governments, institutions, and ocean scientists and explorers, identifying strengths, weaknesses, and gaps in these activities. Based primarily on existing documents, the Committee will summarize priority areas for ocean research and exploration and examine existing plans for advancing ocean exploration and knowledge. These findings will then be used to help characterize the technology, human resources, organizational structures, and funding that would be needed to address the identified priorities in the United States and internationally. Finally, the Committee will recommend strategies to facilitate such a program, including information regarding the countries and organizations likely to participate; the institutional arrangements needed (including the possibility of new treaties or laws); the technology and infrastructure needed (including manned and autonomous underwater vehicles [AUVs], ships, observing systems, and data management systems); and an estimate of the potential costs.

COMPARISON OF OCEAN EXPLORATION AND OCEAN RESEARCH

The ocean remains Earth's least explored frontier. A well-planned, international program of ocean exploration, taking advantage of new technologies such as AUVs will allow the discovery of the ocean's living and non-living resources (Figure 1). International agreements (e.g., the United Nations Convention on Law of the Sea, the Convention on Biological Diversity), and both new and existing partnerships (e.g., the Integrated Ocean Drilling Program), are key elements to establishing and supporting such an ambitious program of discovery. In the

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context of this report, ocean exploration is seen as a complement to ocean research. It is distinguished from the traditional view of research in that it may not necessarily test a specific hypothesis, but is driven by a similar search for new knowledge. At a time when the ocean is widely recognized as influencing global climate and containing unknown amounts of biological, chemical, and mineral resources and human artifacts, there is a growing recognition that we have much more to learn about the secrets our ocean holds.

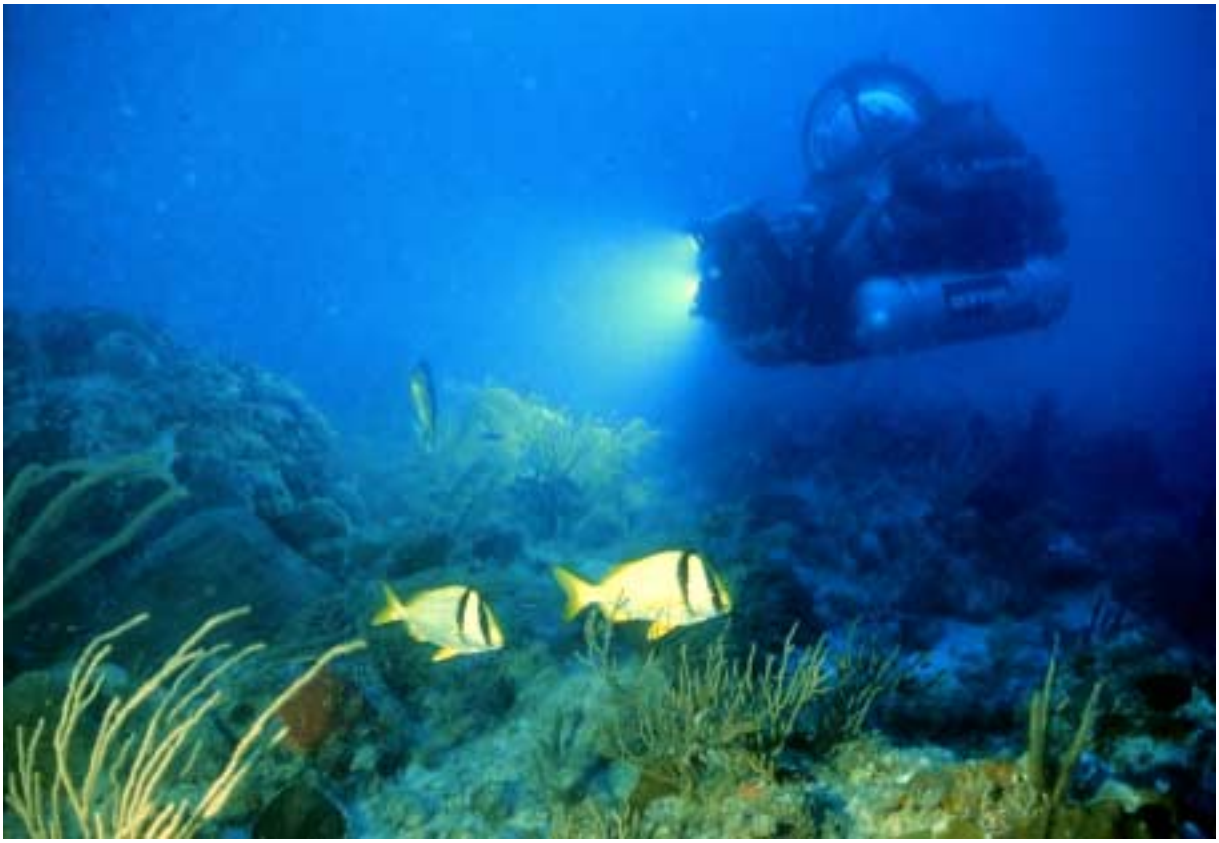

Figure 1. This submersible allows for exploration of natural living and non-living ocean inhabitants (used with permission from Kip Evans, National Geographic Society).

Ocean exploration began in earnest in the 1800s, and was followed by ocean research programs seeking to elaborate on those early discoveries. Our knowledge of the oceans remains limited, and a large-scale exploration program is necessary to continue to broaden ocean research. One short-term commitment, the International Decade of Ocean Exploration (IDOE) in the 1970s, resulted in a re-invigorated oceanographic community. Programs that were included in IDOE greatly improved the systematic quantification of observations. Programs such as Geochemical Ocean Sections, the Joint Global Ocean Flux Study, and World Ocean Circulation Experiment grew from the IDOE initiative. As a result, our understanding of the global climate system, geochemical cycling, and ocean circulation took enormous leaps forward (National Research Council, 2000).

An examination of the scientific method can serve to compare ocean exploration and ocean research. The scientific method is the process by which scientists gather data and develop hypotheses to create an accurate representation of how the world works. It attempts to minimize

the influence of bias or prejudice of the experimenter when testing a hypothesis or a theory. The standard application of the scientific method has four steps:

1) observation and description of a phenomenon or phenomena;
2) formulation of a hypothesis to explain the phenomena;
3) use of the hypothesis to predict the existence of other phenomena, or to predict quantitatively the results of new observations; and
4) performance of experimental tests of the predictions by several independent experimenters.

An ocean exploration program should emphasize observation and description of living and non-living resources, rates, and processes (Step 1). Independent verification (Step 4) should not be included in an exploration program, although it is an important role of more traditional ocean research programs. In Steps 2 and 3, ocean exploration and research overlap; such an overlap is highly desirable and demonstrates the value of exploration for fueling the next generation of hypothesis testing. Ocean exploration should be an integral component of a continuum to ocean research and technology development.

The success of U.S. ocean research programs is due in large part to longstanding support from the National Science Foundation (NSF), Office of Naval Research (ONR), National Oceanic and Atmospheric Administration (NOAA), and other government and private sources. Most research grants are funded on a competitive basis, and proposals are evaluated based on a number of factors, including the significance of the hypotheses to be tested and the methods proposed to test the hypotheses. Commonly, ocean research proposals target well-defined, previously studied areas or sites, in an effort to increase our knowledge and understanding of a particular habitat, biological community, or process. Over the long term, this leads to extensive data sets and detailed theories in a certain scientific discipline or geographic region. While the high quality of ocean research in the United States is indisputable, the funding process does not generally encourage exploration. Proposals without sufficient data to develop testable hypotheses, to drive specific investigations, and to predict specific outcomes from the work are not easily funded (National Science Foundation, 2002). A successful ocean exploration program will use a similarly stringent proposal process, within the framework of a large scale, mission-driven program.

A coordinated, high quality, well-managed ocean exploration program would provide a unique framework for discovery of new species, resources, historical artifacts, habitats, and processes. The review process could allow for and encourage multidisciplinary efforts, and seek to capitalize on the synergy of diverse researchers and techniques. It would provide initial observations and insights into the habitats, geological structure, water column processes, air-sea interaction, biological communities, and evidence of past human activities that can then be used to develop testable hypotheses for ocean research.

KEY FEATURES OF AN OCEAN EXPLORATION PROGRAM

Ocean exploration should be global in scope. Vast regions of the ocean remain

unknown with respect to high-resolution bathymetry, biologic and genetic diversity, chemistry, and geophysics. These poorly studied areas extend beyond territorial waters.

Exploration should receive international support. Nearly half of the people on Earth live within 100 km of the ocean (World Resources Institute, 2001) and demands on the ocean for resources and waste disposal are increasing. Exploration in the coastal ocean requires the active participation of the coastal nations that control the exclusive economic zone (EEZ). Moreover, given the considerable economic investment and effort needed for global ocean exploration, the United States alone cannot explore the vast regions of the ocean yet unexplored and beyond the control of any single nation.

Within the United States, existing and new mechanisms for interagency support should be exploited. Exploration requires a breadth of approaches and integration of the interests and missions of several government agencies, academia, and industry. While the variety of involved agencies fosters a robust ocean research program, the lack of coordination among agencies can be problematic. A strong, sustainable, effective ocean exploration program will require several government agencies to invest in the program.

Ocean exploration should consider all three spatial dimensions, as well as the dimension of time. Explorations of time dependent or times series data over time have typically not received sufficient attention in the study of the ocean. Expeditions to new areas for short periods of time are not adequate for understanding processes, changes, small signals in the presence of high noise, or transient events.

Education and outreach should be integral components of the exploration program. The program should engage the public in the excitement of the undertaking and educate ordinary citizens and decision-makers about ocean issues and policy (Figure 2).

Figure 2. Marine Resources Undersea Laboratory is open for education and public visits.

The program should include development of new tools, probes, sensors, and systems for multidisciplinary ocean exploration. New technologies have been key to past advances in ocean science. Examples include the development of a scalar magnetometer leading to the confirmation of plate tectonics or the development of submersibles allowing the discovery of unimagined deep sea communities. Technology development should be an integral part of the program.

The program should standardize sampling, data management, and dissemination to maximize the impact for research, commercial, regulatory, and educational benefits. Freedom of access to data is essential for fostering innovation and conversion of the exploration investment into scientific discoveries, commercial products, and the development of sound ocean policy. Data should be collected following standard sampling procedures, and should be publicly available in real time, insofar as possible. (Commercial investment may require restrictions to protect proprietary data and to foster development of discoveries, but such cases should be regarded as exceptions.)

The program should seek to discover new living and non-living resources in the ocean. Responsible exploitation of the genetic diversity of life in the ocean, of new and existing fisheries, and of the minerals in the ocean floor requires a thorough understanding of these resources and their variability over time.

BENEFITS TO THE UNITED STATES FROM INITIATING AN INTERNATIONAL OCEAN EXPLORATION PROGRAM

No single nation has the financial, intellectual, and technological capacity to undertake a comprehensive ocean exploration program alone. Hence, there is value in undertaking a collaborative, international effort in global ocean exploration.

Nearly 100 representatives from 20 different nations met in Paris in March 2002 (Appendix D) to discuss their respective interests in ocean exploration. As a result, two facts became clear:

1) A number of countries have the funding and ocean-going capabilities to justify partnership in a truly global ocean exploration program.
2) A much larger group of nations have high levels of interest in exploration within their own territorial waters and neighboring ocean basins. A number of these countries are strategically located with respect to the most unexplored areas of the global ocean, such as the Arctic and Southern Oceans.

Based on past experience, an enhanced ocean exploration program will result in discoveries and observations that push the edge of our knowledge forward in great leaps.

- Locating relics of the maritime past can help us piece together portions of our history and improve the understanding of our heritage.
- Creation of detailed maps, both within and outside our EEZ, can aid in creating

inventories of natural resources, improving navigation and commerce, and identifying important habitats.
- The discovery of new resources may boost the U.S. economy.
- New life forms, such as those found within the hydrothermal vents, may provide us with new bioproducts with applications in human health, agriculture, and industry. These discoveries may also help us generate new hypotheses about the beginning of life on Earth, and the potential for life on other planets.

PRIORITY AREAS FOR OCEAN EXPLORATION

Ocean exploration is a vast field and the possibilities of discovery are seemingly endless. However, some key areas for exploration have emerged as particularly valuable. Here we highlight topics that might be suitable as preliminary exploration programs. This list is not intended to be exclusive, nor prioritized, but should provide the reader with an idea of the sorts of programs the Committee feels the international community might be willing and ready to support, with foreseeable outcomes that would serve to enhance greatly our ability to study these facets of the ocean in more detail. Other targeted areas for international cooperation in ocean exploration will undoubtedly emerge as the proposed exploration initiative gets underway. In evaluating the potential of possible topics for exploration, the Committee weighed the following characteristics:

- international interest;
- current state of knowledge;
- characteristics of a habitat, region, or discipline that suggest significant, new discoveries will emerge; and
- possible benefits to humankind.

Some of the promising scientific areas identified as having broad international interest include: marine biodiversity, the polar oceans, marine archaeology, deep water and its role in climate change, and exploring the ocean through time. Studies in these areas will reveal additional insights into living and non-living resources (e.g., fisheries, bioproducts, energy resources, mineral deposits), human history, and the changes in physical, chemical, and biological properties of the ocean and seafloor that affect our environment and climate.

Marine Biodiversity

Only a fraction of the world's marine species have been discovered and even fewer have been scientifically identified and named (Winston, 1992; World Resources Institute, 2001). New species are discovered on virtually every expedition that seeks to uncover them, including corals, fishes, plants, and even microorganisms like *Archaea*, which represent an entirely new domain of life (Norse, 1993). If little is known about the overall biodiversity in the ocean, even less is known about the abundance of organisms, their ecological roles, how food webs are structured, and how vast areas of the ocean are connected through biological interactions. Since we now know that even remote areas of the ocean contain detectable levels of human contaminants (Group of Experts on the Scientific Aspects of Marine Environmental Protection, 2001), we can surmise, but not yet quantify, the extent to which humans directly and indirectly affect marine

ecosystem health and productivity. Ultimately, better understanding of marine systems and our impacts on those systems will enable us to more wisely utilize the vast resources the ocean has to offer, and help us safeguard the wondrous web of life the ocean supports.

A few particularly exciting areas for exploration into marine biodiversity include the following:

- The microbial ocean. Although we know that thousands of organisms may live in a single drop of seawater, the vast majority of these organisms cannot be cultured in the lab. New genetic tools are allowing researchers to unlock the secrets of their identities, taxonomy, spatial diversity, and role in the ecosystem using their genetic code.
- The ocean's extreme environments. The ocean floor harbors some of Earth's most extreme environments, with crushingly high pressures, temperatures from below freezing to almost boiling, and surprising chemical compositions. Up until a quarter of a century ago, the deep sea was viewed as a hostile environment with a limited supply of food descending from surface waters and low biomass. The discovery in 1977 of luxuriant ecosystems associated with deep-sea hydrothermal vents dramatically altered this view. These ecosystems exist in the deep sea and are not dependent on organic matter sinking from the sunlit surface ocean. Rather, the micro-organisms at the base of this ecosystem support it through extracting energy from chemicals in the high-temperature fluids at the vents. Equally sensational discoveries may be waiting in other unusual ocean environments including other planets and moons.
- The subsurface biosphere. In 1991, scientists working on the mid-ocean ridge in the eastern Pacific witnessed a "snow blizzard" of microbes and microbial debris being spewed out of the seafloor (Haymon et al., 1993). The material rose more than 100 feet above the ocean bottom and settled into a thin, white layer on the seafloor. Microbes have also been detected in cores recovered by the Ocean Drilling Program (ODP) down to depths of several hundred meters, and have been demonstrated to play an important role in crustal alteration.
- Coral reefs (Figure 3). Although coral reefs are spectacularly rich in species, complex in their functioning, and high in recreational, fisheries, and socio-economic values, no comprehensive global map of the reefs exists. Coral reef biologists and conservationists often must rely on naval charts and centuries-old ship logs to guess where reefs lie. Corals have been identified in cold water regions, such as the northeast Atlantic, exemplifying how little is known of their distribution, condition, or relative health. Many of the world's coral reefs lie within the territorial waters of nations struggling to maintain environmental quality in the face of economic pressures. An international coral reef exploration program is needed to locate, understand, and protect these fragile ecosystems.

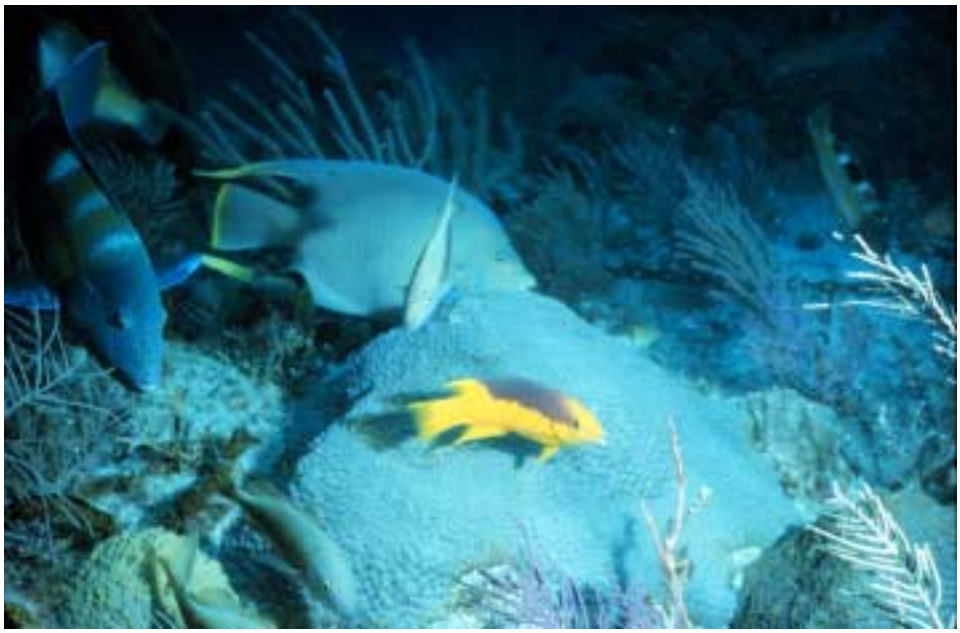

Figure 3. The diversity of fish and other reef organisms rival tropical rainforests.

- Seamounts. These underwater mountains are another rich and functionally important marine ecosystem ripe for discovery. While the major seamounts are known from topographic mapping, many small but ecologically critical seamounts remain unknown. A recent survey of fish aggregation and spawning areas of the western Pacific has revealed an extensive array of seamounts in that portion of the world ocean, providing a good foundation for future efforts to choose sites for marine protected areas that will serve to maintain fisheries production and safeguard biodiversity.
- Continental shelves. The organisms that live within the sediments on continental shelves, especially temperate banks and intertidal areas, include numbers of species rivaling those of insects found in tropical forests. These sediment-dwelling organisms are thought to play an important role in linking the seafloor ecosystem with the water column above, and ultimately in supporting the marine food web. Unfortunately, the seafloor in many of these coastal areas has been degraded or destroyed through uncontrolled trawling, dredging (National Research Council, 2002), and coastal construction. Ocean exploration can take scientists to areas that are still relatively pristine to discover how these systems function and better understand the effects of human intervention.

The Polar Oceans

The Southern Ocean is the least explored of the world's ocean. There are few observations during the austral winter and, even during the austral summer, there are regions beneath the floating ice shelves that remain inaccessible to ships. Highly specialized, but mostly unsampled, biota occupy the extreme habitats under the ice. The Southern Ocean is highly productive biologically, containing large stocks of living resources that require understanding for effective protection and management (Figure 4).

Figure 4. Jellyfish floating under Arctic ice.

The waters under the floating ice are extremely cold and dense, contributing to the formation of the Antarctic Bottom Water with special physical and chemical properties. Deep water formation is one of the most important oceanographic processes on Earth, and a driving mechanism that initiates deep-reaching convection and global-scale thermohaline circulation. The Southern Ocean is one of the regions this process is known to occur. Vast areas of the Southern Ocean seafloor remain unmapped, yet it contains records of the disintegration of the Gondwana supercontinent and the opening of the Drake Passage. Many believe the latter to be one of the key events leading to the present global climate.

Many important aspects of the Southern Ocean have not been properly explored because of the lack of suitable technology. An ocean exploration program could foster the development of a new generation of specialized AUVs and other types of probes that can be lowered through holes drilled through hundreds of meters of ice.

The Arctic Ocean is flanked by broad continental margins likely to contain new living and non-living resources. Because of its ice cover, remoteness, and harsh weather, it has been the target of numerous heroic, and in earlier times often tragic, visits by explorers. This region remains a high priority for exploration because of its influence on the habitability of northern North America and Eurasia.

The tectonic history of the western Arctic Ocean is basically unknown. The ultra-slow spreading of the Arctic midocean ridges gives rise to spectacular topographic relief and a complex crustal architecture. Volcanic activity is markedly reduced, with the result that major portions of the ridge are composed of rocks from the mantle. Virtually nothing is known about this mechanism of building new crust in this extreme environment. The present isolation of the Arctic Ocean and its separation from all other ridge systems also raises fundamental questions about the evolution and ecology of Arctic vent fauna. Hydrographic barriers and geologic features enclosing the Arctic Ocean spreading centers pose a significant barrier to dispersal of vent species. The recent recovery of a few specimens of vent fauna while dredging along the Gakkel Ridge in the Arctic Ocean confirms the existence of vent ecosystems in this region. Indeed, these isolated ecosystems may hold keys to the evolution of life at hydrothermal vents (Figure 5).

Figure 5. Mussels, worms, and a spider crab at a hydrocarbon seep community.

The Arctic sea ice cover existed millions of years ago. Properties of the "warm" Arctic Ocean prior to the sea ice cover are unknown and can only be resolved by applying new technology to sample the history of oceanic sediments beneath the ice. These sediments may illustrate past examples of a scenario that could develop again due to global warming.

Exploration of the polar oceans will be most effectively undertaken through a large, multi-platform ocean exploration program. Expense and logistical support necessitate strong international collaboration, for which there is growing support. Because our current understanding of the polar oceans is fragmented and spatially limited they are a strong candidate for program initiation.

Marine Archaeology

One cannot imagine a history of our globe without watercraft. From the primitive floats or rafts that carried the first people to Australia 50,000 years ago to the giant oil tankers and aircraft carriers of today, boats and ships have allowed the discovery, colonization, supply, and defense of entire continents. The study of the history of ships is therefore important in itself. But just as important, virtually everything ever made by humans, from tiny obsidian blades and bits of jewelry to the huge marble elements of entire temples and churches, has been transported at one time or another over water. Thus, the exploration of shipwrecks of all periods will write definitive histories of weapons, tools and other utensils, glass, ceramics, games, sculpture, weights and measures, metallurgy, and, especially in later times, instruments and machines of all types (Figure 6). Equally important, shipwrecks can teach us about economic history. Marine

archaeology can also uncover inundated coastal habitation sites that teach us about our early ancestors. Exploration of the Earth's blue museum will rewrite whole chapters in history and could reveal the most startling archaeological discoveries of the 21st century.

Figure 6. Carolyn visits a medieval shipwreck whose cargo consisted of millstones (used with permission from Tufan Turanli, Institute of Nautical Archaeology).

Deep Water and Its Role in Climate Change

The ocean and the atmosphere store heat derived from the sun and redistribute that heat from the Equator toward the poles. The ocean's mass may slow the transitions from one climate regime to another, as the slow overturning of the deep-ocean limits heat absorption and release at the ocean surface. On the other hand, there is also evidence that a reduction in surface salinity due to melting polar ice in the North Atlantic Ocean could increase the speed of climatic transitions. Suppression of the flow of cold, salty, dense surface water into the deep ocean (the North Atlantic Deep Water [NADW] formation) could alter the global-scale thermohaline circulation, resulting in less intense surface currents and less poleward transport of heat.

The formation of NADW has other effects on global climate as well because it carries greenhouse gases to the deep ocean, out of contact with the atmosphere for hundreds of years. Finally, extraction of fresh water from the ocean via evaporation, which produces the high salinity of the NADW, provides water for the global hydrological cycle. A better understanding of the global climate system requires a much more sophisticated understanding of the thermohaline circulation, its vulnerability to change, and the processes that govern water mass formation rates (National Research Council, 1994, 2001).

Retrospective exploration of deep ocean water temperatures over time may provide new insights to trends in global climate. Surface water temperature can be measured with limited accuracy but high resolution, from space. New systems like the Array for Real-Time Geostrophic Oceanography can measure the temperature of the ocean to depths of 1,000 m with an average of 300 km resolution. Ocean thermometry using acoustic methods can resolve deep

water temperature at basin scales. Our relatively limited knowledge of the deep oceanic realm makes it another strong candidate for an ocean exploration program to aid our understanding of the forces that shaped climate changes in the past and may shape them in the future.

Exploring the Ocean Through Time

Sustained, large-scale, long-term observations are indispensable to all ocean science disciplines and often lead to discoveries of new processes that link the physics, chemistry, biology, and geology of the ocean. The ocean exploration initiative should be a partner in the establishment and use of ocean observing systems, particularly in previously unexplored priority areas. Exploration-oriented ocean observations can provide information useful for basic and applied research and for real-world applications, such as physical transport processes important to global climate. The benefits of ocean exploration observing systems to various economic sectors and to nations worldwide would add substantially to the value of the program.

The opportunity exists for a cooperative effort by all involved countries to work toward the emplacement and operation of multi-national exploration-oriented regional and global observing systems. This goal will require the creation of new partnerships between multinational scientists, federal agencies, industries, and other potential users, including sharing of intellect, experience, data, instruments, facilities, and labor. Ocean observing systems for exploration, shared within a multinational framework, should help provide answers to pressing regional problems in fisheries, pollution, biodiversity, and ocean circulation to worldwide ocean exploration participants.

PROPOSED ORGANIZATION OF AN OCEAN EXPLORATION PROGRAM

The Program in the United States

In proposing a strategy for international ocean exploration, it is prudent to start with a model for a U.S. national program that may encourage the development of similar national programs elsewhere. Once a number of national programs are established, nations can then collaborate in specific areas or along themes of mutual interest.

The Committee recommends the creation of a national program for ocean exploration, which will be the principal implementing entity for carrying out the ocean exploration initiative in the United States. The Committee believes that an organization charged with implementing an effective international ocean exploration program should not be part of a government agency where it may be subject to internal budgetary and mission pressures, lack of transparency in budgeting and expenditures, as well as influences on program review not based on merit. The government would provide funding to the national program, offer assistance with respect to public affairs, platforms, and data management, engage in budgetary oversight, and administer a competitive process for the selection of an external national program for ocean exploration project office. The oceanographic community has had successful experiences contracting with not-for-profit corporations to perform similar functions (e.g., the Joint Oceanographic

Institutions, Inc. which manages ODP). Although an existing institution or for-profit company could also operate the national program office, these arrangements are less likely to achieve broad community support.

The Committee is considering a series of administrative structures for the planning, oversight, and management of an ocean exploration program. Upon completing a review of large-scale ocean research programs, an earlier National Research Council (NRC) committee found:

> there is no one ideal structure that should be used for all programs, and it is important for NSF/OCE [Ocean Sciences Division] and other agencies to maintain flexibility to consider a number of options regarding the design and execution of future programs. Some factors to be considered include the following:
>
> - The structure of the program should be dictated by the complexity and nature of the scientific challenge it addresses.
> - The nature and support of program administration should reflect the size, complexity, and duration of the program.
> - The structure should encourage continuous refinement of the program.
> - All programs should have well-defined milestones, including a clearly defined end. (National Research Council, 1999)

Using these recommendations as a foundation, this Committee is considering the effectiveness of existing research program management structures, and developing a hybrid as an alternative framework. An effective approach may be to combine the benefits of independent operation, federal funding, the use of scientific advisory panels, and federal programmatic support.

NOAA, NSF, ONR, and the National Aeronautics and Space Administration all have a long tradition of supporting discovery and exploration in the ocean sciences and building upon this capability is essential. A more detailed description of the proposed organizational structure will be included in this Committee's final report.

Funding a U.S. Program

An appropriate funding level for ocean exploration will, of course, depend on the breadth of the vision behind this effort. The President's Panel on Ocean Exploration recommended expenditures of $75 million per year for a U.S. program, excluding capitalization costs (National Oceanic and Atmospheric Administration, 2000). In FY2002, NOAA's Office of Ocean Exploration was budgeted at $14 million and this Committee concludes that this level of funding is not adequate to ensure success. While the current NOAA effort has heightened the visibility of ocean exploration, fiscal limitations have posed serious constraints on its ability to carry out a comprehensive program. Critical elements, such as the following, have been compromised due to funding limitations.

- Data management and dissemination are not funded in the present program, limiting access to the data.
- Post-cruise scientific activities have not been funded so far. Potential discoveries may be missed if specialized onshore tests and evaluations cannot be performed.
- Costly, but critical, technology development has not been pursued. For example, new

sensors that allow for investigation of novel sites or measurement of unique biological, geophysical, and chemical properties of the ocean cannot be developed.

- Ship time has generally been leveraged through other programs. This limits the program's ability to select its own priority sites for ocean exploration.
- Project planning has been short term, due to the nature of government budgeting and agency appropriations.
- International cooperative efforts are not well supported.
- Outreach efforts have been made but, due to limited funding, educational collaborations are limited to the time when offshore operations are underway.
- The scientific community has not viewed the program as a significant resource for funds to undertake sustained programs.
- Underwater archaeological work has been limited to excavation of the U.S.S. Monitor, only one of many important sites worldwide.

The Committee is exploring three possible scenarios for funding and equipping the exploration program. These will be fully analyzed and presented in the final report. The scenarios envision an increasing ability to explore a variety of themes, environments, and locations. The committee feels it is critical that any new effort in ocean exploration must not be funded using funds dedicated to support the premier ocean research currently underway in the United States. Such a reallocation of research dollars would undermine the very synergy between exploration and research that is necessary for the long-term success of both programs.

International Structure

To ensure broad effectiveness of an ocean exploration program it is desirable to involve scientists and governments from many nations in a truly global effort. Most nations of the world have an ocean frontier and ocean processes affect all nations; the benefits of an ocean exploration program are truly global. Capabilities for ocean exploration are widely distributed internationally, and no single nation can afford the kind of effort that will be of greatest benefit to all.

International Implementation Strategy

Some nations are already involved in ocean exploration activities and others may form their own national ocean exploration initiatives in the future (Figure 7). As such parallel programs are established, it may be helpful to set up an informal umbrella organization, with the national program for ocean exploration representing the United States, to provide information sharing and coordination between the national programs.

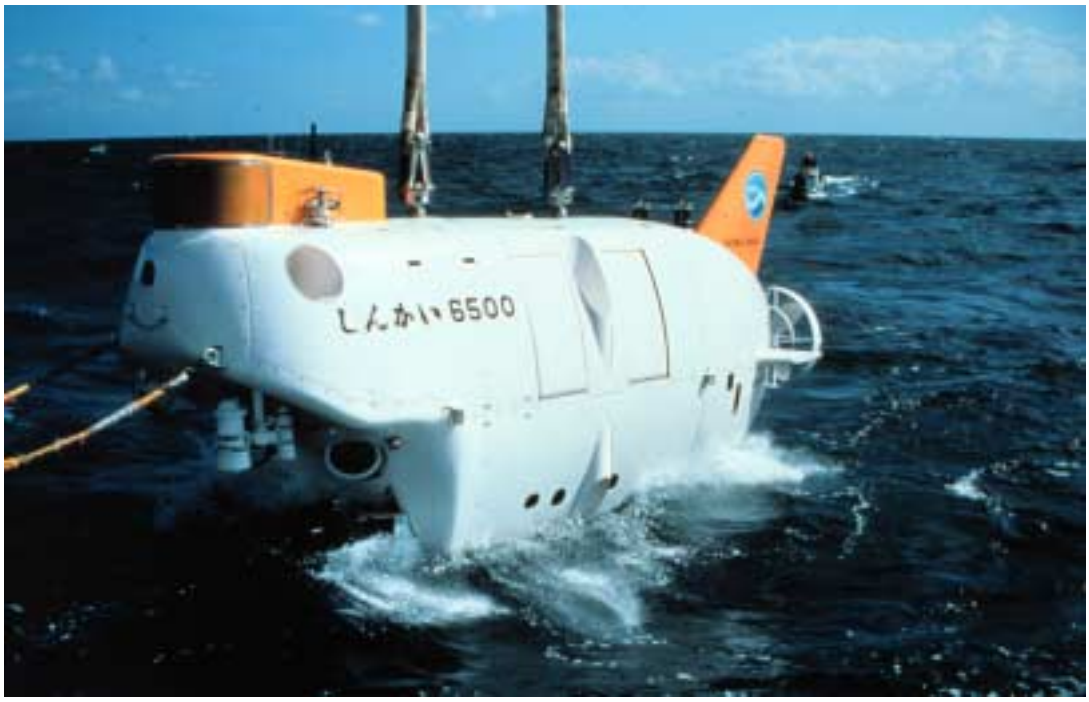

Figure 7. SHINKAI 6500 is rated to 6500 meters, deepest active sub in the world.

There are several strategies for implementation of a coordinated global ocean exploration program. For example, the Committee looked at two possible existing models: ODP and the Inter-RIDGE program. ODP developed a robust international component by establishing a formal structure for centralized funding through a series of bilateral agreements. At present some 22 nations participate effectively in that program. A second possible model is the U.S. RIDGE program along with its counterparts in other nations for interdisciplinary study of mid-ocean ridges. Inter-RIDGE acts as the international umbrella organization to coordinate these national efforts.

To initiate a coordinated international effort in ocean exploration, the Committee recommends the establishment of an International Global Ocean Exploration (IGOE) Committee, with initial membership drawn from the member countries of the Scientific Committee on Oceanic Research (SCOR). The IGOE Committee should initially be supported by the national program, but should evolve over time into an independent, non-governmental organization with financial support from participating nations. Appropriate ties to SCOR, the Intergovernmental Oceanographic Commission (IOC), Partnership for Observation of the Global Oceans (POGO), and other international ocean organizations should be established to combine the best features of non-governmental and intergovernmental organizations. Membership should be adjusted as new international participants emerge.

The IGOE Committee could play several useful roles:

1) advancing the establishment of an international ocean exploration program;
2) developing a broad plan for international collaboration in ocean exploration;
3) initiating multilateral cooperative efforts in areas of mutual interest by establishing subcommittees to develop specific coordinated exploration plans;
4) providing input to the national program's Scientific Advisory Committee and other

national ocean exploration committees, as appropriate;
5) facilitating information exchange and capacity building among participating nations; and
6) working with participating nations to coordinate access to exploration platforms, tools, and technologies.

The Committee has chosen not to be overly prescriptive in recommending a structure for the international effort. A variety of different, viable institutional arrangements may arise, based on geography, the ships and other equipment required, and the traditions of the communities involved. It is likely that not all countries will participate in IGOE. However, as subcommittees are set up to develop detailed plans for specific exploration targets, representatives from any interested nation should be able to participate and serve on the subcommittees.

In addition to the above, the Committee recommends that individual cooperative agreements for identified pilot programs be pursued, a strategy that was very successful for ODP. Cooperative agreements allow progress on mutual goals without the need for priority setting among many nations. They result in less overhead for program management and eliminate the need to pool funds internationally or develop new treaties. Individual cooperative agreements may serve as the foundation for a more extensive program.

Ocean Exploration within the United Nations System

To call attention to the importance of ocean exploration internationally, the Committee recommends that an additional ocean resolution be introduced at the next annual United Nations General Assembly, stressing the importance of global cooperation in ocean exploration (Box 2).

Box 2
Proposed United Nations General Assembly Ocean Resolution

Whereas basic knowledge about Earth's ocean is in the overall interest of humankind;
Recognizing there are large areas of the ocean in which we lack such basic knowledge; and
Convinced that cooperation in ocean exploration (seeking basic knowledge about the ocean and ocean processes) holds promise to enhance understanding of our planet.

The General Assembly:
Urges nations to seek to enhance basic understanding about the ocean through programs and activities of ocean exploration, and to cooperate together to that end;
Calls upon IOC to consider establishing a voluntary information sharing program for the cooperative sharing of information about ocean exploration, including planned programs and proposals, institutional and national interests, scientific and technical expertise, capacity building capabilities, available oceanographic ships, and other national or institutional resources available for such exploration; and
Nothing in this resolution is intended to affect the legal regime for the ocean as set out in the United Nations Convention on the Law of the Sea.

Voluntary Information Sharing

It is useful to encourage broad information sharing about ocean exploration initiatives, whether undertaken by the United States or by other nations. Such information sharing could include information about ongoing exploration programs, potentially available resources (including ships and scientists), proposals for exploration, and other pertinent information. The Committee recommends that IOC assist in communicating to participating governments the importance of cooperative ocean exploration efforts. The Committee also recommends that IOC consider convening an annual conference on ocean exploration, seeking advice from SCOR, POGO, and other interested entities as appropriate. Indeed, one option would be for IOC to co-sponsor the recommended annual Ocean Exploration Conference with SCOR. The International Global Ocean Exploration Workshop held at IOC headquarters in May 2002 demonstrated great international interest, as well as capabilities, in ocean exploration. This interest was very broad and included both developed and developing countries.

OCEAN EXPLORATION AS A TOOL FOR PUBLIC EDUCATION

Ocean exploration provides rich images that capture the imagination of people of all ages (Figure 8). Interdisciplinary voyages of discovery present natural examples of science that are both engaging and relevant to our lives. It is only through collaborations between explorers and educators that the full educational potential of ocean exploration can be realized. These collaborations cannot be an after-thought, but must be fully integrated throughout the entire process of ocean exploration.

Figure 8. Educational exhibits allow for the public to experience ocean life (used with permission from Kip Evans, National Geographic Society).

Ocean exploration should provide a venue through which learning about our planet can become a lifelong endeavor. The challenge in achieving this is threefold:

1) to bring new discoveries to the public in ways that infuse exploration into their daily lives and capture the inherent human interest in the ocean;
2) to involve the global community in exploration of our final frontier; and
3) to develop and foster collaborations among scientists and educators in ocean exploration.

To develop and foster collaborations among explorers and educators in ocean exploration, it is critical that educators be an integral part of the planning and conduct of exploration activities, whether ship- or shore-based. Development of these partnerships should be a crucial responsibility of each nation's ocean exploration program, and could be accomplished through national scientific and educational professional organizations. Examples in the United States include the National Science Teachers Association, the National Marine Educators Association, the American Geophysical Union, the Centers for Ocean Science Education Excellence, and others.

CONCLUSION

The global ocean is teeming with undiscovered species and resources in vast under-explored areas. Yet even as our dependence on healthy, functioning marine ecosystems grows, our knowledge about the ocean and its role in keeping Earth's systems in balance remains constrained. Given the importance of the global ocean in guaranteeing food security, providing resources, enabling worldwide commerce, and reminding us of our history, it is shocking that we still know so little about the ocean and the life it supports.

While steady progress in understanding of the ocean has been made possible by traditional hypothesis-driven research, a new program of exploration will permit us to make quantum leaps in new discoveries. A well-organized, adequately funded program in ocean exploration will allow us to plumb the depths of Earth's last frontier and provide the foundation for better understanding, and better stewardship, of Earth's ocean.

REFERENCES

Group of Experts on the Scientific Aspects of Marine Environmental Protection. 2001. *A Sea of Troubles*. Reports and Studies GESAMP No. 70. 35pp.

Haymon, R.M., D.J. Fornari, K.L Von Damm, M.D. Lilley, M.R. Perfit, J.M. Edmond, W.C. Shanks III, R.A. Lutz, J.M. Grebmeier, S. Carbotte, D. Wright, E. McLaughlin, M. Smith, N. Beedle, and E. Olson. 1993. Volcanic eruption of the mid-ocean ridge along the East Pacific Rise crest at 9°45-52'N: Direct submersible observations of seafloor phenomena associated with an eruption event in April 1991. *Earth Planetary Science Letters* 119:85-101.

National Oceanic and Atmospheric Administration. 2000. *Discovering Earth's Final Frontier: A U.S. Strategy for Ocean Exploration*. U.S. Department of Commerce. Silver Spring, Maryland.

National Research Council. 1994. *The Ocean's Role in Global Change*. National Academy Press, Washington, D.C.

National Research Council. 1999. *Global Ocean Science: Toward an Integrated Approach*. National Academy Press, Washington, D.C.

National Research Council. 2001. *Abrupt Climate Change: Inevitable Surprises*. National Academy Press, Washington, D.C.

National Research Council. 2002. *Effects of Trawling and Dredging on Seafloor Habitat.* National Academy Press, Washington, D.C.

National Science Foundation. 2002. NSF proposal processing and review. In *Grant Proposal Guide, October 2002*, [Online]. Available: http://www.nsf.gov/pubs/2003/nsf032/032_3.htm#fn34 [2002, September 19].

Norse, E. 1993. *Global Marine Biological Diversity*. Island Press, Washington, D.C.

Winston, J. 1992. Systematics and marine conservation. In *Systematics, Ecology and the Biodiversity Crisis*, Eldredge, N. (Ed.). Columbia University Press, NY.

World Resources Institute. 2001. *Pilot Analysis of Global Ecosystems: Coastal Ecosystems*. Washington, D.C.

APPENDIX A

COMMITTEE AND STAFF BIOGRAPHIES

Committee

John Orcutt (Chair) is a Professor of geophysics and Deputy Director at Scripps Institution of Oceanography and Interim Dean of Marine Sciences at University of California, San Diego. Dr. Orcutt earned his undergraduate degree in mathematics and physics at the U.S. Naval Academy, a M.Sc. in physical chemistry as a Fulbright Scholar at the University of Liverpool, and a Ph.D. in geophysics from the University of California, San Diego-Scripps Institution of Oceanography. His research focuses on the internal structure of ocean spreading centers, the use of information technology in integrating real-time data from a wide variety of sensors using wireless networks, and ocean seismo-acoustics including rough seafloor scattering and the use of small arrays. Dr. Orcutt is the President-Elect of the American Geophysical Union and is a Secretary of the Navy/Chief of Naval Operations Oceanography Chair. He is a member of the American Philosophical Society and served briefly as Interim President of the Ocean Drilling Program in 2000. Dr. Orcutt is a former member of the Ocean Studies Board and has served on numerous NRC committees.

Shirley Pomponi (Vice-Chair) is the Vice President and Director of Research at Harbor Branch Oceanographic Institution. Dr. Pomponi earned a Ph.D. in biological oceanography from the University of Miami. Her research focuses on the development of methods for sustainable use of marine resources for drug discovery and development, and in particular, on developing cell lines of bioactive marine invertebrates and determining the role of associated microorganisms in the production of bioactive secondary metabolites. Dr. Pomponi is a member of the Society for In Vitro Biology, the Society for Biomolecular Screening, the American Society for Cell Biology, and the American Geophysical Union. Dr. Pomponi served on the President's Panel on Ocean Exploration and the NRC's Committee on Marine Biotechnology: Development of Marine Natural Products.

Tundi Agardy is the Founder and Executive Director of Sound Seas, which works to promote effective marine conservation by utilizing both science and sociology, and works as the interface between public policy and community-based conservation efforts. Dr. Agardy earned a Ph.D. in biological sciences in 1987 from the University of Rhode Island. She was a Senior Scientist at the World Wildlife Fund and Senior Director of the Global Marine Program for Conservation International. Dr. Agardy has been a member of numerous organizations, such as the International Union for Conservation of Nature and Natural Resources's Commission on National Parks and Protected Areas and Species Survival Commission.

George Bass is a Distinguished Professor Emeritus of Anthropology at Texas A&M University. Dr. Bass earned a Ph.D. in classical archaeology in 1964 from the University of Pennsylvania. His research focuses on classical and nautical archaeology. Dr. Bass has received many honors, including the Archaeological Institute of America's Gold Medal for Distinguished Archaeological Achievement, a National Geographic Society Centennial Award, and the National Medal of Science.

Earl Doyle recently retired from Shell Oil where he worked in the area of ocean engineering and is presently a consultant. Mr. Doyle earned a M.S. in ocean engineering in 1968 from the University of Rhode Island. He is a current member of the Ocean Studies Board.

Terry Garcia is Executive Vice President of the National Geographic Society. Mr. Garcia earned a J.D. in 1980 from George Washington University. He is responsible for the Society's core mission programs and is a member of the Society's Executive Management Council and Committee for Research and Exploration and a trustee of the Society's Education Foundation. Prior to joining the Society in 1999, Mr. Garcia was the Assistant Secretary of Commerce for Oceans and Atmosphere, U.S. Department of Commerce, and Deputy Administrator of the National Oceanic and Atmospheric Administration. In his role he directed and coordinated all domestic and international coastal and ocean programs of the National Oceanic and Atmospheric Administration. From 1994 to 1996, Mr. Garcia was the National Oceanic and Atmospheric Administration's general counsel. Prior to entering government service, Mr. Garcia was a Partner in the law firm of Manatt, Phelps & Phillips in Los Angeles.

Bruce Gilman recently retired from Sonsub Inc. where he worked in the areas of engineering, operations and management of programs, projects and organizations dealing with the offshore and marine environment including manned diving, manned submersibles and unmanned remotely operated vehicles. Mr. Gilman is a graduate of the Polytechnic Institute of Brooklyn, where he earned a degree in aeronautical engineering. Mr. Gilman is a registered Professional Engineer, Marine Technology Society Fellow, member of the American Society of Mechanical Engineers and Society of Petroleum Engineers, serves on the Texas Sea Grant College Program Advisory Committee, and holds several patents relating to the offshore industry.

Susan Humphris is a Senior Scientist in the Department of Geology and Geophysics and Director of the Earth-Ocean Exploration Institute at Woods Hole Oceanographic Institution. Dr. Humphris earned a Ph.D. in chemical oceanography in 1977 from the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution Joint Program. She taught undergraduates and served as Dean at the Sea Education Association for 13 years before returning to Woods Hole Oceanographic Institution. Her research focuses on volcanic and tectonic controls on the distribution and characteristics of hydrothermal activity at mid-ocean ridges, the geochemistry of rock-water interactions, and the role of the associated hydrothermal fluxes in global geochemical mass balances. From 1996 to 1998, Dr. Humphris was Chair of the Science Committee for the International Ocean Drilling Program. She recently served on two NRC committees to review the USGS Coastal and Marine Geology Program and the EarthScope Science Objectives and Implementation Planning.

Isao Koike is the Director of the Ocean Research Institute of the University of Tokyo. Dr. Koike earned a Ph.D. in microbiology in 1975 from the University of Tokyo. His research focuses on marine biogeochemistry, especially dynamics of dissolved and colloidal organic matter in the ocean, microbial nitrogen and carbon transformation, and nutrient dynamics in tropical lagoon. Dr. Koike joined many cruises to the Western Pacific Ocean and the Bering Sea as Principle Investigator, and also performed field surveys in the Pacific Islands and Southeast Asia. He is the Secretary of the Japanese National Scientific Committee for the International

Geosphere-Biosphere Programme and the Treasurer for the Executive Board of the International Council for Science of the International Geosphere-Biosphere Programme.

Richard Lutz is the Director of the Center for Deep-Sea Ecology and Biotechnology at Rutgers University. Dr. Lutz earned a Ph.D. in 1975 from the University of Maine. His research focuses on shellfish ecology and biology of deep sea hydrothermal vents. Dr. Lutz participated in the first biological expedition to the Galapagos Rift vents in 1979. He served on the Steering Committee for the Workshop on the Mid-Oceanic Ridge: A Dynamic Global System.

Marcia McNutt is the President and Chief Executive Officer of the Monterey Bay Aquarium Research Institute, which is privately funded by the David and Lucile Packard Foundation to develop better technology for ocean research and apply it to outstanding problems through teamwork between scientists and engineers. Dr. McNutt earned her Ph.D. in earth sciences in 1978 from Scripps Institution of Oceanography. Her own research focuses on the use of marine geophysical data to study the physical properties of the Earth beneath the ocean. Dr. McNutt has received the Macelwane Award from the American Geophysical Union and fellowship in the American Academy of Arts and Sciences. She is currently the President of the American Geophysical Union and served as Chair of the President's Panel on Ocean Exploration.

John Norton Moore is the Walter L. Brown Professor of Law at the University of Virginia School of Law and Director of the University's Center for Oceans Law and Policy. In addition to his scholarly career, Professor Moore has a distinguished record of public service. Among seven presidential appointments, he served as Chairman of the National Security Council Interagency Task Force on the Law of the Sea, Ambassador and Deputy Special Representative of the President to the Law of the Sea Conference, and as a member of the National Advisory Committee on Oceans and Atmosphere. Professor Moore has served as Chairman of the Marine Education and Policy Division of the Marine Technology Society (MTS) since 1979, was an MTS Fellow in 1983, and received the MTS-sponsored "Compass Distinguished Achievement Award" for 1994. He is also a co-founder of the international Rhodes Academy of Oceans Law and Policy.

Walter Pitman, III is a Special Research Scientist at Lamont-Doherty Earth Observatory at Columbia University. Dr. Pitman earned a Ph.D. from Lamont-Doherty Earth Observatory at Columbia University. His research focuses on past sea-level changes, both short- and long-term, their causes and effects on the sedimentary record, climate change, and human history. He is a member of the National Academy of Sciences.

Jörn Thiede is the Director of the Alfred Wegener Institute for Polar and Marine Research. Dr. Thiede earned a Ph.D. in geology in 1971 from Kiel University. His research focuses on marine sediments and arctic geology. In 1998, Dr. Thiede received the Murchison Medal from the United Kingdom Geological Society and is the current Chairman of the European Polar Board. He served on the NRC Committee on Arctic Solid-Earth Geosciences.

Victor Vicente-Vidal Lorandi is Professor and Head of the Oceanography Studies Group at the Centro de Investigación en Ciencia Aplicada y Tecnología Avanzada of the Instituto Politécnico Nacional. Dr. Vicente-Vidal Lorandi earned a Ph.D. in oceanography in 1978 from the

University of California, San Diego-Scripps Institution of Oceanography. His research focuses on coastal circulation, modeling of coastal discharges, mesoscale circulation phenomena associated with Loop Current ring interactions with topography, and water mass distribution within the Intra-Americas Sea. Dr. Vicente-Vidal Lorandi served on the OSB's Academia Mexicana de Ciencias-National Research Council Joint Working Group on Ocean Sciences.

Staff

Jennifer Merrill earned a Ph.D. in marine and estuarine environmental science from the University of Maryland Center for Environmental Science. Dr. Merrill is a Program Officer for the Ocean Studies Board and staffs a broad range of topical studies. Her research interests include watershed and wetland management, geochemistry, and nutrient cycling in coastal systems.

Morgan Gopnik has been the Director of the Ocean Studies Board since 1996. Ms. Gopnik earned a B.S. in physical geography and environmental studies from McGill University and a M.S. in environmental engineering science from the California Institute of Technology, where she studied turbulent flow in density-stratified fluids. Ms. Gopnik is responsible for all aspects of financial, personnel, and technical management at the Ocean Studies Board.

Jodi Bachim serves as a Senior Project Assistant for the Ocean Studies Board. She received a B.S. in zoology from the University of Wisconsin-Madison in 1998. Since starting with the Ocean Studies Board in May 1999, Ms. Bachim has worked on several studies regarding fisheries, geology, nutrient over-enrichment, and marine mammals.

APPENDIX B

CONGRESSIONAL REQUEST

H. R. 2090

[Report No. 106-810]

To direct the Secretary of Commerce to contract with the National Academy of Sciences to establish the Coordinated Oceanographic Program Advisory Panel to report to the Congress on the feasibility and social value of a coordinated oceanography program.

IN THE HOUSE OF REPRESENTATIVES

June 9, 1999

Mr. GREENWOOD (for himself, Mr. SAXTON, Mr. FARR of California, Mr. GILCHREST, Mr. ROMERO-BARCELO, Mr. SENSENBRENNER, Mr. UNDERWOOD, Mrs. MORELLA, Mrs. CAPPS, Mr. CALVERT, Mr. ENGLISH, Mr. BLUMENAUER, Mr. FOLEY, Mr. EHLERS, Mr. FRANKS of New Jersey, Mr. BILBRAY, and Mr. GUTIERREZ) introduced the following bill; which was referred to the Committee on Resources

September 6, 2000

Reported with an amendment, committed to the Committee of the Whole House on the State of the Union, and ordered to be printed

A BILL

To direct the Secretary of Commerce to contract with the National Academy of Sciences to establish the Coordinated Oceanographic Program Advisory Panel to report to the Congress on the feasibility and social value of a coordinated oceanography program.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the “Exploration of the Seas Act”.

SECTION 2. FINDINGS.

Congress finds the following:

(1) During the past 100 years, scientists working with marine fossils, both underwater and high in the mountains, have traced the origins of life on Earth to the sea, beginning approximately 3 billion years ago. Today, life on our planet remains dependent on the vitality of the sea.

(2) More than two-thirds of the Earth's surface is covered by water, with oceans and inland seas accounting for almost 140 million square miles.

(3) The United Nations forecasts a worldwide population of 8.9 billion by the year 2050, a 50 percent increase from 5.9 billion in 1999. As this trend in population growth continues, increasing demands will be placed on ocean and coastal resources, not only as a result of population growth in coastal regions, but also from the need to harvest increasing amounts of marine life as a source of food to satisfy world protein requirements, and from the mining of energy-producing materials from offshore resource deposits.

4) The ocean remains one of the Earth's last unexplored frontiers. It has stirred our imaginations over the millennia, led to the discovery of new lands, immense mineral deposits, and reservoirs of other resources, and produced startling scientific findings. Recognizing the importance of the marine environment, the need for scientific exploration to expand our knowledge of the world's oceans is crucial if we are to ensure that the marine environment will be managed sustainably.

(5) The seas possess enormous economic and environmental importance. Some ocean resources, such as fisheries and minerals, are well recognized. Oil use has increased dramatically in recent times, and the sea bed holds large deposits of largely undiscovered reserves. Other ocean resources offer promise for the future. In addition to fossil fuels, the ocean floor contains deposits of gravel, sand, manganese crusts and nodules, tin, gold, and diamonds. Marine mineral resources are extensive, yet poorly understood.

6) The oceans also offer rich untapped potential for medications. Marine plants and animals possess inestimable potential in the treatment of human illnesses. Coral reefs, sometimes described as the rain forests of the sea, contain uncommon chemicals that may be used to fight diseases for which scientists have not yet found a cure, such as cancer, acquired immunodeficiency syndrome (AIDS), and diabetes. While the number of new chemical compounds that can be derived from land based plants and microbial fermentation is limited, scientists have only just begun to explore the sea's vast molecular potential.

(7) In spite of the development of new technologies, comparatively little of the ocean has been studied. The leadership role of the United States has been eroded by a gradual decrease in funding support, even while public opinion surveys indicate that

ocean exploration is at least as important as space exploration.

(8) The National Academy of Sciences has the means by which to study and make determinations regarding the adoption and establishment of a coordinated oceanography program for the exploration of the seas, in which the National Oceanic and Atmospheric Administration could participate in a role similar to that of the National Aeronautics and Space Administration with regard to the International Space Station.

SECTION 3. COORDINATED OCEANOGRAPHIC PROGRAM ADVISORY PANEL.

(a) IN GENERAL—Not later than 60 days after the date of enactment of this Act and subject to the availability of appropriations, the Secretary of Commerce shall contract with the National Academy of Sciences to establish the Coordinated Oceanography Program Advisory Panel (in this Act referred to as the "Panel"), comprised of experts in ocean studies, including individuals with academic experience in oceanography, marine biology, marine geology, ichthyology, and ocean related economics.

(b) CHAIRPERSON AND VICE CHAIRPERSON—The Panel shall elect a chairperson and a vice-chairperson.

(c) TERMINATION—The Panel shall cease to exist 30 days after submitting its final report and recommendations pursuant to section 4.

SECTION 4. REPORT AND RECOMMENDATIONS.

(a) IN GENERAL—No later than 18 months after its establishment, the Panel shall report to the Committee on Resources of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate on the feasibility and social value of a coordinated oceanography program. In preparing its report, the Panel shall examine existing oceanographic efforts and the level of coordination or cooperation between and among participating countries and institutions.

(b) INTERNATIONAL WORKSHOP—To assist in making its feasibility determination under subsection (a), the Panel shall convene an international workshop with participation from interested nations and a broad range of persons representing scientists, engineers, policy makers, regulators, industry, and other interested parties.

(c) FINAL REPORT—The Panel shall include in its final report recommendations for a national oceans exploration strategy, which will--

(1) define objectives and priorities, and note important scientific, historic, and cultural sites;

(2) promote collaboration among research organizations;

(3) examine the potential for new ocean exploration technologies;

(4) describe those areas of study in which national or international oceanographic cooperation is currently being undertaken;

(5) identify areas of study in which knowledge of the oceans is inadequate;

(6) ensure coordination with the National Oceanic and Atmospheric Administration's Marine Protected Area Center;

(7) ensure that newly discovered organisms with medicinal or commercial potential are identified for possible research and development; and

(8) identify countries and organizations that would be likely to participate in a coordinated oceanography program.

(d) IMPLEMENTATION—If the Panel determines that a coordinated oceanography program is feasible and has significant value for advancing mankind's knowledge of the ocean, the Panel shall include in its final report recommendations for implementing such program, including recommendations regarding--

(1) the institutional arrangements, treaties, or laws necessary to implement a coordinated oceanography program;

(2) the methods and incentives needed to secure cooperation and commitments from participating nations to ensure that the benefit that each nation that is a party to any international agreement establishing a coordinated oceanography program receives is contingent upon meeting the nation's obligations (financial and otherwise) under such an agreement;

(3) the costs associated with establishing a coordinated oceanography program;

(4) the types of undersea vehicles, ships, observing systems, or other equipment that would be necessary to operate a coordinated oceanography program; and

(5) how utilization of aboriginal observational data and other historical information may be best incorporated into a coordinated oceanography program.

SECTION 5. OBTAINING DATA.

Subject to national security restrictions, the Panel may obtain from any department or agency of the United States information necessary to enable it to carry out this Act. Upon request of the chairperson of the Panel, the head of any department or agency shall furnish that information at no cost to the Panel.

SECTION 6. AUTHORIZATION OF APPROPRIATIONS.

There are authorized to be appropriated for the purposes of carrying out this Act, and to remain available until expended, $1,500,000.

Union Calendar No. 741

106th CONGRESS

2d Session

H. R. 2090

[Report No. 106-810]

A BILL

To direct the Secretary of Commerce to contract with the National Academy of Sciences to establish the Coordinated Oceanographic Program Advisory Panel to report to the Congress on the feasibility and social value of a coordinated oceanography program.

September 6, 2000

Reported with an amendment, committed to the Committee of the Whole House on the State of the Union, and ordered to be printed.

APPENDIX C

COMMITTEE TIMELINE AND FIRST MEETING'S AGENDA

Timeline

2001

November 12-14	Meeting 1—Reagan International Trade Center, Washington, D.C.

2002

February 6-8	Meeting 2—Beckman Center, Irvine, CA (closed in its entirety)
May 13-15	Meeting 3—International Workshop, Intergovernmental Oceanographic Commission, Paris, France (refer to Appendix D)
July 17-19	Meeting 4—J. Erik Jonsson Center, Woods Hole, MA (closed in its entirety)
October 10-11	Meeting 5—American Museum of Natural History, New York, NY (closed in its entirety)

2003

January 21-23	Meeting 6—Beckman Center, Irvine, CA (closed in its entirety)

Agenda

November 12-14, 2001
The International Trade Center
Ronald Reagan Building
Washington, D.C.

Monday, November 12

9:00 a.m. – 5:00 p.m. Closed Session

Tuesday, November 13

8:30 a.m.	Opening remarks—John Orcutt, *Chair*, Shirley Pomponi, *Vice-Chair*, and Jennifer Merrill, *Study Director*
9:00 a.m.	Committee introductions
9:15 a.m.	CAPT Craig McLean, *Director, Oceans Exploration, National Oceanic and Atmospheric Administration*

9:45 a.m. Barbara Moore, *Director, National Undersea Research Program, National Oceanic and Atmospheric Administration*

10:15 a.m. Break

10:30 a.m. James Yoder, *Director, Ocean Sciences Division, National Science Foundation*

11:00 a.m. Melbourne Briscoe*, Director, Processes and Prediction Division, Office of Naval Research*

11:30 a.m. Eric Lindstrom, *Program Manager, Physical Oceanography, National Aeronautics and Space Administration*

12:00 p.m. Adjourn for lunch

1:30 p.m. Reconvene
Margaret Leinen, *Director, Directorate for Geosciences*, *National Science Foundation*

2:00 p.m. Congressman James Greenwood, *U.S. House of Representatives*

2:15 p.m. John Haines, *Program Coordinator, Coastal and Marine Geology, U.S. Geological Survey*

2:45 p.m. Break

3:00 p.m. Chris Fox*, Principal Investigator, Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration*

3:30 p.m. Steve Bohlen, *President, Joint Oceanographic Institution*

3:50 p.m. Edward Urban, *Executive Director, Scientific Committee on Oceanic Research*

4:10 p.m. Carolyn A. Thoroughgood, *Chair, CORE Board of Governors, Consortium for Oceanographic Research and Education*

4:30 p.m. General discussion

5:00 p.m. Meeting adjourns for the day

Wednesday, November 14

9:00 a.m. – 5:00 p.m. Closed Session

APPENDIX D

INTERNATIONAL GLOBAL OCEAN EXPLORATION WORKSHOP: AGENDA AND PARTICIPANTS

Agenda

May 13-15, 2002
Intergovernmental Oceanographic Commission
Paris, France

Monday, May 13

9:00 a.m. Welcome: Morgan Gopnik, Director, Ocean Studies Board, U.S. National Academies

9:15 a.m. John Orcutt, Professor, Scripps Institution of Oceanography, California (Chair, NRC Exploration of the Seas Committee)

9:30 a.m. Patricio A. Bernal, Executive Secretary, Intergovernmental Oceanographic Commission; Assistant Director-General, United Nations Educational, Scientific, and Cultural Organization, France

9:45 a.m. U.S. Congressman James C. Greenwood

10:00 a.m. Plenary session
Chair: Shirley Pomponi, Vice President and Director of Research, Harbor Branch Oceanographic Institution, Florida
(Vice-Chair, NRC Exploration of the Seas Committee)

- *Charge to speakers: Why/what is ocean exploration: value of exploration in general, and of a coordinated international exploration program in particular?*

10:10 a.m. Marcia McNutt, Director, Monterey Bay Aquarium Research Institute, California
(Member, NRC Exploration of the Seas Committee)

10:30 a.m. Break

10:50 a.m. Joe Baker, Chief Scientist and Commissioner for the Environment, Department of Primary Industries, Queensland Government, Australia

11:10 a.m. Victor Smetacek, Head, Division on Pelagic Ecosystems, Alfred Wegner Institute, Foundation for Polar and Marine Research, Germany

11:30 a.m. Panel discussion

12:00 p.m. Lunch

2:00 p.m. Existing programs
Chair: Susan Humphris, Senior Scientist, Woods Hole Oceanographic Institution, Massachusetts
(Member, NRC Exploration of the Seas Committee)

- *Charge to speakers: Please detail current or prior oceanographic explorations (including international programs), and their objectives, that have occurred in your nation/organization. What have been the significant discoveries/results?*

2:00 p.m. Keynote: Captain Craig McLean, Director, Office of Ocean Exploration, U.S. National Oceanic and Atmospheric Administration, Maryland
2:20 p.m. John Field, Professor, University of Cape Town, South Africa
2:40 p.m. Jeremy Green, Head, Department of Maritime Archaeology, Western Australia Maritime Museum
3:00 p.m. Shubha Sathyendranath, Executive Director, Partnership for Observation of the Global Oceans, Canada

3:20 p.m. Break

3:40 p.m. Su Jilan, Physical Oceanographer, Second Institute of Oceanography, State Oceanic Administration, China; and Chair, Intergovernmental Oceanographic Commission, France
4:00 p.m. Sunil Murlidhar Shastri, Lecturer, Scarborough Centre for Coastal Studies, University of Hull, United Kingdom
4:20 p.m. Rene Drucker-Colin, President, Mexican Academy of Sciences
4:40 p.m. Rob Murdoch, Director, Research Development, National Institute for Water and Atmospheric Research, New Zealand

5:00 p.m. Panel discussion

6:00 p.m. Reception

Tuesday, May 14, 2002

9:00 a.m. Priority areas for a coordinated international exploration program
Chair: Victor Vicente-Vidal Lorandi, Director, Oceanography Department, Instituto Politecnico Nacional, Mexico
(Member, NRC Exploration of the Seas Committee)

- *Charge to speakers: What distinctive features of ocean exploration would make it a priority area for your country/organization to participate? What*

benefits would your nation/organization foresee in an international ocean exploration program? Based on studies that have been conducted to date by your nation/organization, what would you rate as the top 3-5 exploration goals to be undertaken, with a brief discussion of your reasons for your assessment and priority ranking?

9:00 a.m.	Keynote: Fred Grassle, Chair, Scientific Steering Committee for the Census of Marine Life, Rutgers University, New Jersey
9:20 a.m.	Michael P. Meredith, Senior Scientific Officer, British Antarctic Survey, United Kingdom
9:40 a.m.	Harry Breidahl, Educational Consultant, Nautilus Educational Pty Ltd., Australia
10:00 a.m.	Bryndis Brandsdottir, Research Professor, Science Institute, University of Iceland
10:20 a.m.	Break
10:40 a.m.	James A. Yoder, Director, Ocean Sciences Division, U.S. National Science Foundation, Virginia
11:00 a.m.	Annelies Pierrot-Bults, Science Policy Officer, Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Netherlands
11:20 a.m.	Muthukamatchi Ravindran, Director, National Institute of Ocean Technology, India
11:40 p.m.	Stephen R. Hammond, Chief Scientist, Ocean Exploration Program, U.S. National Oceanic and Atmospheric Administration/Pacific Marine Environmental Laboratory, Oregon
12:00 p.m.	Panel discussion

12:20 p.m. Lunch

2:00 p.m. Technology and infrastructure capabilities and needs
Co-Chairs: Earl Doyle, Shell Oil (retired), Texas
(Member, NRC Exploration of the Seas Committee)

- *Charge to speakers: What assets currently exist, and what technologies/assets are needed to facilitate a coordinated international exploration program?*

2:00 p.m.	Keynote: Alain Morash, TotalFinaElf, France
2:20 p.m.	Suzanne Lacasse, Managing Director, Norwegian Geotechnical Institute
2:40 p.m.	Tamaki Ura, Director, Underwater Technology Research Center, Institute of Industrial Science, University of Tokyo, Japan
3:00 p.m.	Tommy D. Dickey, Professor, University of California, Santa Barbara

3:20 p.m. Break

3:40 p.m. Paul Egerton, Executive Scientific Secretary, European Polar Board, European Science Foundation, France
4:00 p.m. Larry Mayer, Director, Center for Coastal and Ocean Mapping, University of New Hampshire
4:20 p.m. Kiyoshi Suyehiro, Director, Deep Sea Research Department, Japan Marine Science and Technology Center
4:40 p.m. Panel discussion

5:30 p.m. Meeting adjourns for the day

Wednesday, May 15, 2002

9:00 a.m. Strategies for facilitating a coordinated international exploration program
Chair: John Norton Moore, Director, University of Virginia Center for Oceans Law and Policy
(Member, NRC Exploration of the Seas Committee)

- *Charge to speakers: Recommend strategies to facilitate a coordinated international ocean exploration program. What type of organizational structure would be needed to facilitate your nation/organization's participation? Is there a particular program you could suggest for a model to administer a large-scale, international, cooperative ocean exploration program?*

9:00 a.m. Jean-Francois Minster, Chairman of the Board and Executive Director, French Research Institute for Exploitation of the Sea (IFREMER)
9:20 a.m. Mario Caceres, Head, Technical Division, Oceanography Department, Hydrographic and Oceanographic Service of the Chilean Navy
9:40 a.m. Fangli Qiao, First Institute of Oceanography, State Oceanic Administration, China
10:00 a.m. Robert Knox, Research Oceanographer and Associate Director, Ship Operations and Marine Technical Support, Scripps Institution of Oceanography, California

10:20 a.m. Break

10:40 a.m. Montserrat Gorina-Ysern, Adjunct and Assistant Professor, School of International Service, American University, Washington, D.C.
11:00 a.m. Sergey Shapovalov, Head, Center for Coordination of Oceanographic Science, Russian Academy of Sciences

11:20 a.m.	Steven Bohlen, President, Joint Oceanographic Institutions, Washington, D.C.
11:40 a.m.	Nii Odunton, Chief, Office of Resource and Environmental Monitoring, International Seabed Authority, Jamaica
12:00 p.m.	Panel discussion
12:30 p.m.	Closing plenary: Sylvia Earle, President and Chief Executive Officer, Deep Ocean Exploration and Research Inc., California

12:50 p.m. Meeting adjourns

Participants

Constance C. Arvis, *U.S. Department of State*
Jane Breidahl, *Woodleigh School*
Marta Estrada, *Institut de Ciencies del Mar*
Christopher Fox, *National Oceanic and Atmospheric Administration/Pacific Marine Environmental Laboratory*
Sally Goodman, *Nature*
Morgan Gopnik, *The National Academies*
Adolfo Gracia Gasca, *Universidad Nacional Autonoma de Mexico*
Elizabeth Gross, *E&G Associates, LLC*
Nergis Gunsenin, *Istanbul University*
Maria Hood, *Intergovernmental Oceanographic Commission*
Norberto Olmiro Horn Filho, *Santa Catarina Federal University*
Kazuhiro Kitazawa, *Japan Marine Science and Technology Center*
Hermann Kudrass, *Bundesanstalt fur Geowissenschaften und Rohstoffe*
Ulf Lie, *Centre for Studies of Environment and Resources*
David A. Malakoff, *Science Magazine*
Catherine Marzin, *National Oceanic and Atmospheric Administration*
Temel Oguz, *Middle East Technical University*
Ian Poiner, *Commonwealth Scientific and Industrial Research Organization*
Jeremy Potter, *National Oceanic and Atmospheric Administration*
George Satander Sa Freire, *Ceara Federal University*
Anders Stigebrandt, *University of Gothenburg*
Anne Tenney, *National Science Foundation*
Edward Urban, Jr., *Scientific Committee on Oceanic Research*
Marsh Youngbluth, *Harbor Branch Oceanographic Institution*