DISCOVERING EARTH'S FINAL FRONTIER: A U.S. STRATEGY FOR OCEAN EXPLORATION

The Report of the President's Panel for Ocean Exploration

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LETTER OF TRANSMITTAL

Secretary of Commerce, Norman Y. Mineta

October 10, 2000

To the President:

On June 12, 2000, at the Millenium Council presentation "Under the Sea, Beyond the Stars," you ushered in a new era of Ocean Exploration by directing the Secretary of Commerce to convene a panel of America's finest ocean explorers, scientists, and marine educators. You called on the nation's best people to develop a national strategy for ocean exploration.

Your challenge has been met by the Ocean Exploration Panel. Members of the Panel represented the full array of ocean interests, including industry, conservation, educators, academia, and government, who worked together to create this crucial strategy. I am pleased to present their report, "Discovering Earth's Final Frontier: A U.S. Strategy for Ocean Exploration."

Our nation's history, from colonization and westward expansion to the deployment of the Hubble telescope, is testament to the fact that America is a country of explorers. Our pride as a nation is founded upon our yearning to make new discoveries and to seek out new knowledge. Exploration of the oceans responds to a growing national interest in our seas and an acknowledgement of their importance to our environment and quality of life.

We are growing in the awareness that the ocean influences our daily lives in hundreds of ways. From providing fisheries resources or cures for disease, to unlocking the secrets of long-term climate, we are constantly reminded of the ocean's importance in sustaining life. Truly, our economic, environmental, and national security depend on our ability to understand the ocean frontier, as well as balancing the competing interests of conservation and economics.

Within the Department of Commerce, we have had over 30 years experience in managing the conservation, sustainable use, and commercial aspects of our oceans. For this reason, I am proud to offer the National Oceanic and Atmospheric Administration as the lead agency for new national efforts in ocean exploration.

For too long, our natural resource agencies have pursued a course of ocean resource management rather than ocean exploration. We now know the futility of trying to manage systems without complete knowledge of them. This report outlines a coordinated, focused approach that will ensure a better understanding of the oceans for generations to come.

This report envisions a new collaboration among governments, academia, and private industry that reaches out to everyone and marks a turning point for exploration. May it also mark a new era of ocean stewardship.

Norman Y. Mineta
Secretary of Commerce

EXECUTIVE SUMMARY

WITHIN *the past few decades, advances in undersea technology have revolutionized the way we think about the oceans and the life within them.*

New exploration tools can place researchers into the deepest reaches of the oceans, either directly or by telepresence. Hundreds of new marine species and entirely new ecosystems have been discovered. The benefit attributed to these advances has been enormous; for example, a new industry, marine biotechnology, has shown impressive returns. Understanding biodiversity of the oceans is critical to sustaining their immense global economic value. Furthermore, the deep oceans may hold the keys to the origin of life itself. Despite these gains, 95 percent of the oceans remain unknown and unexplored.

On June 12, 2000, President Clinton announced the commencement of a new era of ocean exploration. In an Executive Directive to the Secretary of Commerce, the President requested that the Secretary convene a panel of leading ocean explorers, scientists, and educators to develop a national strategy for exploring the oceans. The Panel has completed its work and presents its recommendations for a national strategy in this report.

The Panel recommends that the U.S. undertake a national program in ocean exploration in which discovery and the spirit of challenge are the cornerstones. Multidisciplinary exploration approaches, covering all three dimensions of space, as well as the fourth dimension of time, should include natural and social sciences as well as the arts. The U.S. Ocean Exploration Program should be global in scope, but concentrated initially in areas under U.S. jurisdiction. Results must be carefully documented and widely disseminated; the program must be innovative and bold.

The President requested objectives and priorities to guide ocean exploration, as well as identification of key sites of scientific, historic, and cultural importance. The Panel identified the following key objectives of an Ocean Exploration Program:

1 |

Mapping the physical, geological, biological, chemical, and archaeological aspects of the ocean, such that the U.S. knowledge base is capable of supporting the large demand for this information from policy makers, regulators, commercial ventures, researchers, and educators;

2 |

Exploring ocean dynamics and interactions at new scales, such that our understanding of the complex interactions in the living ocean supports our need for stewardship of this vital component of the planet's life support system;

3 |

Developing new sensors and systems for ocean exploration, so as to regain U.S. leadership in marine technology; and

4 |

Reaching out in new ways to stakeholders, to improve the literacy of learners of all ages with respect to ocean issues.

The Panel notes that the United States currently does not support a program in ocean exploration, despite our inadequate understanding of the ocean and the living and nonliving resources it contains, and its undeniable importance to the health of the planet and the wealth of our nation. Furthermore, in a number of areas, the U.S. has fallen behind other nations in our capabilities for undertaking ocean exploration. American leadership in ocean exploration can be achieved through the following recommendations.

The U.S. government should establish an Ocean Exploration Program for an initial period of 10 years, with new funding at the level of $75M / year, excluding capitalization costs. The program should include:

— ***Interdisciplinary voyages of discovery within high-priority areas, including the U.S. Exclusive Economic Zone (EEZ) and the continental margin, the Arctic, and poorly known areas of the southern oceans and inland seas. The U.S. inventory of the living and nonliving resources in the ocean should be second to none, particularly within our own EEZ and continental margins.***

— ***Platform, communication, navigation and instrument development efforts, including the capitalization of major new assets for ocean exploration, in order to equip our explorers with the very best in marine research technology.***

— ***Data management and dissemination, so that discoveries can have maximum impact for research, commercial, regulatory, and educational benefit.***

— ***Educational outreach, in both formal and informal settings, to improve the science competency of America's schoolchildren and to realize the full potential of a citizenry aware and informed of ocean issues.***

Partnerships are essential if the full benefits of ocean exploration are to be realized. Mechanisms must be developed for forming appropriate partnerships between federal, state, local, and tribal governments, industry, academic institutions, formal and informal educators, mass media and nongovernmental organizations. These partnerships will greatly expand the opportunities to undertake voyages of discovery, technology development, and educational outreach. The Panel recognizes that the framework for accommodating collaboration in ocean exploration depends upon its broader organizational strategy. Therefore, recommendations concerning partnerships must also consider larger organizational issues.

The President of the United States should instruct the White House Science Advisor and appropriate Cabinet officials to design the management structure for this program. Elements of governance should include:

— ***Designating a lead agency to be in charge of the program and accountable for its success using benchmarks appropriate for ocean exploration, such as the number of new discoveries, dissemination of data, and the impact of educational outreach.***

— ***Using existing interagency mechanisms to ensure federal cooperation among agencies.***

— ***Establishing an Ocean Exploration Forum that would include commercial, academic, private, and nongovernmental organizations, and government stakeholders in ocean exploration, to encourage partnerships and promote communication.***

New technologies will enable the next generation of ocean exploration, but if the U.S. is to be a leader in this area, we must make a commitment to provide the very best technology. Of particular importance are the development of: ***1)*** Underwater navigation and communication technologies; ***2)*** State-of-the-art sensors; and ***3)*** Deployment strategies for multidisciplinary, in-situ and remote-sensing measurements of biological, chemical, physical and geological processes at all levels in the ocean. Therefore, recommendations concerning new technologies must consider:

— ***Undertaking the development of underwater platforms, communication systems, navigation, and a wide range of sensors, including the capitalization of major new assets for ocean exploration.***

The Panel was also charged with recommending mechanisms to ensure that information gathered through ocean exploration is referred to the newly established Marine Protected Areas Center and to appropriate commercial interests for possible research and development. The President can ensure that knowledge gathered during ocean exploration is effectively made available for informed decision-making relative to Marine Protected Areas by:

— ***Assigning leadership in this activity to an appropriate federal agency.***

— ***Establishing a broad-based task force to design and implement an integrated, workable, and comprehensive data management information processing system for information on unique and significant features.***

With respect to assuring that potential opportunities for developing new resources into useful products to benefit mankind are encouraged, the Panel recommends that U.S. laws be re-examined to provide proper incentives for potential commercial users of ocean discoveries. Examples of some areas in which policies could encourage the appropriate use of exploration results include:

— ***Enhancing funding within federal agencies to support early-phase research on discoveries with commercial potential.***

— ***Providing incentives to private industry to encourage the funding of research and development of discoveries with commercial potential.***

— ***Designing mechanisms whereby those who directly profit from the exploitation of marine resources support research on their environmentally sustainable use.***

The Panel advocates a new national Ocean Exploration Program to permit exploratory expeditions for two reasons: ***1)*** The initial phase of oceanographic discovery ended before a significant portion of the oceans was visited in even a cursory sense; and ***2)*** Marvelous new tools now exist that permit exploration in spatial and temporal dimensions that were unachievable 50 years ago. For these reasons, we must go where no one has ever gone before, “see” the oceans through a new set of technological “eyes,” and record these journeys for posterity.

MOTIVATION FOR EXPLORATION

EXPLORATION *is fundamental to the human spirit. Since the dawn of our species we have been explorers, with the motivation for these journeys ranging from survival to spiritual inspiration.*

With the rise of civilization, the search for new wealth and the elevation of national pride drove explorers to risk their lives and benefactors to empty their coffers in the quest for discovery. All of these factors — survival, inspiration, wealth, and national pride — provide the fundamental justification for proposing the most ambitious chapter ever in the history of human discovery of this planet: the exploration of Earth's oceans.

It has been stated many times that we know more about the backside of the Moon than we do about the bottom of our ocean. And that statement just refers to its depth. There exists on our planet, for example, a virtually unstudied ecosystem which rivals all the other known ecosystems on Earth — the mid-water environment in the oceans. This biologically rich and complex domain is known to contain many times the biomass of all the Earth's rainforests and terrestrial biota. Despite this area's size and importance, the biology of the organisms which inhabit the mid-water levels in the oceans, and the complex dynamics between this zone and the upper and lower levels of the ocean, are virtually unknown. We have just begun to learn about the diversity of life in all reaches of the ocean, and the cycling of its critical elements that support life and regulate climate. New physical processes that transport mass and energy await discovery, and most of the record of ancient Earth and human history contained in the cold sediment floor is still unread. To be sure, the United States has a superb record of basic and applied ocean research funded through a variety of federal agencies and private industry in support of U.S. national defense, weather prediction, resource assessments, and the testing of specific scientific hypotheses. What has been lost in this diverse research portfolio, however, is the opportunity to broadly explore on a global basis and across many scientific, cultural, and technological disciplines.

Fifty years ago, during the early days of modern oceanographic research, expeditions were exploratory. Ships were staffed with inter-disciplinary teams of physical and chemical oceanographers, marine biologists, and geologists. The oceanographers made all conceivable measurements, secure in the knowledge that those observations would eventually prove worth-while. Today, expedition personnel tend to be from a narrower range of disciplines, and ship time is allocated for measurements to test the hypothesis and carry out the objectives at hand, with little time left over for unrelated observations.

This Panel advocates a national program to permit exploratory expeditions for two reasons: ***1)*** The initial phase of oceanographic discovery ended before a significant part of the oceans were visited in even a cursory sense; and ***2)*** We now have marvelous new tools now that permit exploration in spatial and temporal dimensions that were unachievable 50 years ago. In other words, we will not only go where no one has ever gone, but we will also "see" the oceans through a new set of technological "eyes" and record these journeys for posterity.

What is Exploration?

For the purposes of this report, exploration is defined as discovery through disciplined diverse observations and the recording of the findings. An explorer is distinguished from a researcher by virtue of the fact that an explorer has not narrowly designed the observing strategy to test a specific hypothesis. A successful explorer leaves a legacy of new knowledge that can be used by

A MYSTERIOUS PLUME

In July 1986, while on a survey of hydrothermal vents on the Juan de Fuca Ridge off the Oregon coast, scientists from NOAA's Pacific Marine Environmental Laboratory began documenting elevated water temperatures at greater heights off the seafloor than ever previously recorded. Most plumes from hydro-thermal vents along the Mid-Ocean Ridge rise only a few hundred meters before reaching temperatures of the surrounding water. However, in this case, the anomalous water was still much higher in temperature than the surrounding water at a height of more than 700 meters above the seafloor and the plume had spread out over an area that measured 20 km in diameter. A plume this size with this temperature was calculated to be the equivalent of approximately an entire year's worth of "normal" hydrothermal out-put from the ridge. However, when the ship returned to the same site a month later, no evidence of this "megaplume" was found. Scientists suspected that the culprit was a deep-sea eruption which is, by nature, a very short-lived oceanographic event. Subsequent studies of the seafloor in the region revealed the presence of very fresh lava and new hydrothermal venting stretching over tens of kilometers along the ridge. The unanticipated discovery of this deep-sea eruption provided a strong rationale for utilizing the Navy's SOSUS system in the area in 1991. The use of this system has led to the detection and intense study of three more seafloor eruptions and several other anomalous earthquake swarms that were essentially inaudible to land-based seismometers along the tectonic plate boundaries of the northeast Pacific basin.

THE ARCTIC OCEAN

The Arctic Ocean is the least explored of the world's oceans. Every voyage through the region, whether by ice-breaking vessel, surface expedition across the ice, or nuclear submarine under the ice, has yielded completely new knowledge and unexpected insights. The role of the Arctic region in global processes is not well understood. More information is needed to understand and predict how freshwater input, variability in sea-ice thickness, and the transport of heat into the Arctic Ocean, affect global climate. Future work in this area will require robust investigative tools and build on entirely new knowledge about the region.

In the summer of 1994, a remarkable expedition to the North Pole was conducted that generated several historic firsts. The expedition included the northernmost rendezvous ever of surface ships from the three largest Arctic nations: Russia, the U.S., and Canada, on August 23. The rendezvous occurred when American and Canadian ships that were the first surface vessels to cross the Arctic Ocean via the North Pole, joined the Russian ship. Significant findings from this expedition were the first observation of direct evidence of overall warming of the entire Atlantic layer, and the discovery of much higher levels of biological activity than previously assumed — from plankton to polar bears. The expedition was truly exploratory in that the findings were not predictable. Its rigorous scientific approaches enabled the new information acquired to advance understanding of the Arctic and paved the way for future scientific exploration and research.

With the Arctic covered by ice much of the year, scientists have never been able to accurately measure the temperature of this vast ocean. A newly emerging technique, using sound sources and arrays of receivers, may finally change that. Initial results have shown that the Arctic Ocean has warmed more dramatically than climatologists had predicted. Clearly, the discoveries in this region demonstrate that the Arctic is ripe for future exploration.

those not yet born to answer questions not yet posed at the time of the exploration. This new knowledge may also have immediate beneficial applications in answering the needs of contemporary ocean scientists, natural resource managers, educators, and industries.

New discoveries come about both in the context of directed, hypothesis-driven research and in the process of pure exploration. Research journals and Nobel prizes give testament to the numerous cases of serendipitous discoveries stumbled upon in the course of directed research undertaken for completely different reasons. Several examples of this sort of fortuitous discovery are described in sidebars contained within this report. The Panel advocates continuing the basic and applied research undertaken by many federal agencies, and in addition, proposes adding a new program in ocean exploration that will expand scientific investigations into new areas. Answering questions and following up on ideas will still be cornerstones of the new program. While hypotheses may be less specific, and their outcome less predictable, than the current norm, the observations will be more broadly based, and the program more interdisciplinary. The potential for payoffs from this endeavor will be enormous.

Characteristics of a U.S. Ocean Exploration Program

The U.S. will greatly benefit from a renewed commitment to exploration. A modern exploration initiative should be designed with the following desirable characteristics in mind.

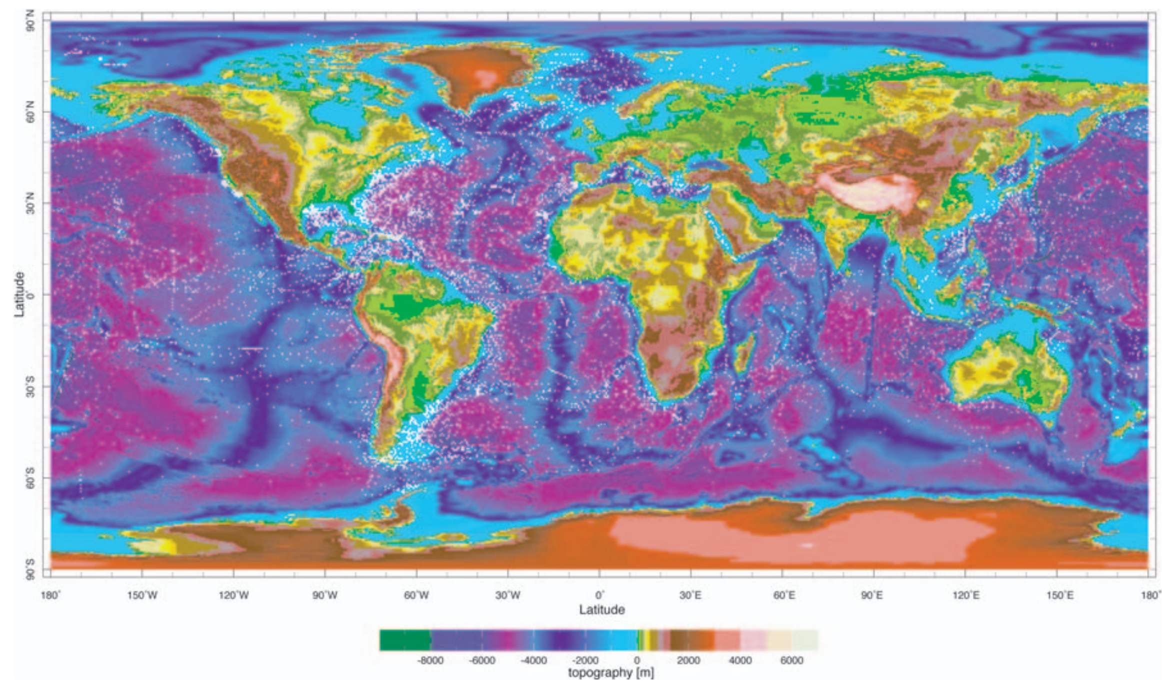
— **DISCOVERY AND THE SPIRIT OF CHALLENGE SHOULD BE CORNERSTONES.** *The tendency in oceanographic research in recent years has been to return again and again to areas visited before as scientific hypotheses become increasingly refined. The emphasis in exploration will be to survey new areas to provide baseline information that may well inspire future hypothesis-driven research.*

— **EACH FACET OF EXPLORATION IS NECESSARILY MULTIDISCIPLINARY** *and should include aspects of the natural sciences, social sciences, and artistic expression. Disciplines that are historically under represented in ocean exploration and can bring to bear new concepts*

LAMONT cores

In the 1950s and 1960s, during the reign of Maurice ("Doc") Ewing at Columbia University's Lamont-Doherty Earth Observatory, Lamont's vessels were under strict orders to stop every day at noon to take a sediment core, no matter where the ship was or what else it was doing. Doc did this purely in the spirit of exploration, understanding that we knew so little about the seafloor and ocean history that a global core database would inevitably be of value. "Value" has turned out to be an understatement. This core database (core locations shown as white dots in figure) has become the foundation of our understanding of climate change mechanisms. A core taken by the vessel *Robert Conrad* in 1967 recorded a particularly complete and high- resolution record of changes in benthic and surface biota over the last 250,000 years.

Nearly a decade later, the pioneering work of John Imbrie, Jim Hays and Nick Shackleton used the cyclic variations found in this core to substantiate the Milankovitch Hypothesis. This hypothesis puts forward the theory that the waxing and waning of ice ages can be attributed in part to variations in orbital parameters that occur at periods of 19, 22, 41, and 100 thousand years. The Lamont core suite also provided the early scientific basis for motivating the Deep Sea Drilling and Ocean Drilling programs. This example of routine data collection that leads to discovery has been repeated frequently over the past 50 years of oceanographic data collection and underscores the importance of the full utilization of existing data sets and serendipitous discoveries in the oceanographic sciences.



and rich experiences should be challenged to participate.

— **THE OCEAN EXPLORATION PROGRAM SHOULD INCLUDE AN EDUCATIONAL COMPONENT** *that encompasses both formal and informal educational institutions as well as the general public. These efforts should incorporate existing programs and organizations that support marine and ocean science education.*

— **THE OCEAN EXPLORATION PROGRAM SHOULD CONSIDER ALL THREE DIMENSIONS OF SPACE, AS WELL AS THE FOURTH DIMENSION OF TIME.** *Exploration must go beyond mapping the seafloor. It cannot ignore the fact that the ocean is forever changing in time, and that human impacts are already substantial. Explorations into all four dimensions will also challenge our knowledge of scales of variability. For example, previously unknown microbial phenomena may yield discoveries as grand as those resulting from basin-scale explorations. Resolving picosecond variability may prove to be as challenging as exploring the changes observed over millennia.*

— **THE OCEAN EXPLORATION PROGRAM SHOULD BE GLOBAL IN SCOPE BUT CONCENTRATED INITIALLY IN REGIONS UNDER U.S. JURISDICTION.** *This focus will provide the best opportunities for immediate benefit to the American people, while controlling the use of national resources and protecting valuable marine life and habitats under U.S. management authority*

— **THE RESULTS OF THE EXPLORATIONS MUST BE CAREFULLY DOCUMENTED** *using the latest in database technology, communications, and recording media. The documentation should take a variety of forms, from the archiving of digital data to the production of multimedia programming and other educational resources and tools for the public.*

— **THE RESULTS MUST BE WIDELY DISSEMINATED,** *through a variety of formats, and particularly the Internet, to reach a large number of potential beneficiaries. Shipboard activities should be available in near real-time to enhance the outreach opportunities provided by a program of this scope and visibility. The results should excite the public imagination as well as challenge and encourage public involvement.*

— **THE OCEAN EXPLORATION PROGRAM NEEDS EXPLORERS, CHAMPIONS, AND ROLE MODELS** *who may not themselves directly benefit from the data being collected. The “human element” is essential to humanize the science and provide role models for future explorers.*

— **THE OCEAN EXPLORATION PROGRAM SHOULD MAKE EVERY ATTEMPT TO WORK WITH INTERNATIONAL PARTNERS** *when appropriate. This is essential for work in waters under the jurisdiction of other nations and will serve to expand the program and leverage its resources in international waters.*

— **THE OCEAN EXPLORATION PROGRAM SHOULD CAPITALIZE ON JOINT OPPORTUNITIES WITH OTHER COMPATIBLE GOVERNMENT MISSIONS AND INDUSTRY** *where appropriate. For example, survey missions of NOAA’s nautical charting program, the U.S. Geological Survey, and the Oceanographer of the*

Navy can substantially contribute to ocean exploration. Joint planning and funding of these missions should be made when mutually beneficial.

— **THE OCEAN EXPLORATION PROGRAM MUST BE SYSTEMATIC IN ITS COLLECTION OF DATA,** *to facilitate the joint interpretation of data collected at different times and in different places. A systematic program will also help to avoid duplication of effort.*

— **THE OCEAN EXPLORATION PROGRAM SHOULD CHALLENGE EXISTING TECHNOLOGY.** *Just as space exploration has become a leading arena for technology development and transfer, ocean exploration must use the latest capabilities and should provide an incentive for creating new tools. Technology partnerships with the petroleum and oil service industries could, for example, tap into their already massive investments in deep-water and ocean technologies. All technologies should be brought to bear — human occupied submersibles: remotely operated vehicles (ROVs); and autonomous underwater vehicles (AUVs); platforms under, on, and above the sea surface; advanced sensor technologies; and information storage and transfer technologies — to meet the challenges of the years to come.*

— **ALL STAKEHOLDERS IN THE OCEAN EXPLORATION PROGRAM MUST BE ENCOURAGED TO ACCEPT RISKS WHERE BENEFITS ARE LARGELY UNKNOWN.** *It is possible that the technology might not work, and that objectives might not be achieved within the specified timeframe. Nevertheless, exploration should be considered a success regardless of what is discovered.*

The Ocean Exploration Program must be innovative and bold. “Business as usual” will not achieve the goals.

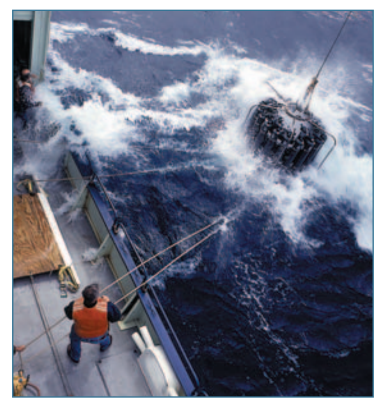
The Fruits of Exploration

Experience has shown that observations from the oceans are eventually put to myriad uses. They result in scientific, cultural, and historic understanding of how our planet functions, who we are, and how we got where we are today. The beauties and mysteries of the oceans inspire artists, authors, and musicians. We cannot protect what we do not know, and thus, without ocean exploration, we are ignorant of what needs to be conserved in a realm that covers most of the surface of the Earth. The ocean provides a bounty of renewable resources, but without knowledge of what’s out there, how abundant it is, and how quickly it is replenished, we cannot plan for its environmentally sustainable use. We also know that the oceans provide a storehouse of non-renewable mineral resources essential for maintaining our quality of life, though much of that wealth remains undiscovered. Every day, governments make decisions on how to best regulate the use of the oceans, yet they lack the basic knowledge to make informed choices. Accurate knowledge of the oceans is essential for environmental, economic, and national security. Designing and building platforms and observing systems for the extremely demanding and unforgiving ocean environment pushes our technology to its limits and leads, more often than not, to commercial spin-offs.

Despite the fact that we can confidently predict that ocean exploration will lead to discoveries that directly benefit the nation, it is impossible to predict when we embark upon the voyage of discovery exactly how that benefit will be manifest. Today, we may discover a new organism with enzymes that render inert a particular environmental carcinogen, or tomorrow, we may learn more about the mechanisms that triggered a catastrophic global warming and led to mass extinctions many millions of years ago. Discovery is the prelude to new paradigms; it jolts us out of the ruts of incremental scientific progress and fuels the great leaps forward.

UNITED STATES DEPARTMENT OF ENERGY EXPLORATION AND PRODUCTION PARTNERSHIP

Nearly one-third of today's U.S. gas supply and one-quarter of the nation's oil come from the ocean coastal zones and continental shelf. Exploring for and producing these resources has steadily moved into ever-deeper waters — from a depth of 300 feet 30 years ago to 6,000 feet today, with future plans to explore new depths below 10,000 feet tomorrow. Thus, there is an ever-increasing demand for advanced technologies that will facilitate the economic, safe, and environmentally benign production of underwater oil and gas resources. To help achieve that goal, DOE through the Exploration and Production Program will partner with industry, academia, national laboratories, and other agencies. For example, DOE is initiating a partnership with industry, for testing of an ocean-floor module for production of oil and gas. If successful, this technology will provide much greater access to underwater oil and gas resources at a lower cost, and it will provide an opportunity to gain knowledge of the sea-floor and its ecosystems. Exploration programs will benefit, particularly those involving methane hydrates—ice-like cages of water molecules containing methane on the ocean floor and below. They have a resource potential estimated to exceed all other oil, gas, and coal resources. The technology will also enhance our understanding of how the oceans affect the Earth's carbon cycle and the causes of global climate change.



OCEAN EXPLORATION
OBJECTIVES AND PRIORITIES

N charting a course of discovery we forsee a captivating set of results and products derived from ocean exploration.

EXPLORATION OBJECTIVES

We are faced with fascinating challenges, founded upon the balance of our current understanding and our expectations for future capabilities. These challenges are, by design, ambitious in nature. Four challenges will constitute the objectives of the Ocean Exploration Program:

— ***Mapping at New Scales Emphasizing Regions not Previously Observed;***

— ***Exploring Ocean Dynamics and Interactions at New Scales;***

— ***Developing New Technologies; and***

— ***Reaching Out in New Ways to Stakeholders.***

Mapping at New Scales Emphasizing Regions not Previously Observed

The most notable product of exploration is the creation of new ways to show others what lies beyond our current understanding. This documentation of discovery is typically articulated in a new or improved map. But current and evolving spatial information systems have redefined the standard notion of a map. The Ocean Exploration Program will recognize these new technologies and produce new generations of maps that include all imagery characterizing ocean geography, physics, chemistry, geology, and biology. These maps will also define sites of archaeological significance and define changes in regions over time. The mapping process should be broadly constituted to include:

— ***Archaeological sites***
We will find and systematically explore dozens of new sites.

— ***Resources, living and non-living***
We will explore what they are, where they are, and how abundant they are, within the U.S. Exclusive Economic Zone (EEZ) and continental margins.

— ***New species***
We will discover thousands of undescribed species.

— ***Ecosystems***
We will find and describe several new communities of organisms displaying novel relationships with their physical, chemical, and geological environments.

DISCOVERIES at our FINGERTIPS

BURIED

A spectacular geological event took place on the Atlantic margin of North America about 35 million years ago. A giant meteorite, 3-5 km wide, struck the seafloor and blasted a crater twice the size of Rhode Island and as deep as the Grand Canyon. The evidence for this Chesapeake Bay impact crater is now buried about 200 km south of Washington, D.C. The story of the discovery of this sixth largest impact crater on Earth 50 years of exploration, observation, changing hypotheses, rapidly improving technologies, and serendipity.

The anomalous ejecta unit associated with the impact was first observed in drill cutting more than 50 years ago. Three decades later, clear evidence for the chaotic nature of the unit came from continuously cored sections (a technological improvement); the unit was attributed to a giant submarine landslide. In the 1980s, the discovery of 35-million-year-old microtektites suggested an extraterrestrial explanation, although the unit was then thought to be deposited by a super tsunami. Technology again improved our understanding when a series of marine seismic imaging systems revealed the enormous buried circular structure. Serendipity came into play because one researcher was either directly or indirectly involved in many of these observations and discoveries and could link the disparate data sets. The discovery of the impact structure and the difficulty identifying it during 50 years of research show the importance of using new technologies and multidisciplinary approaches to explore and reexamine the Earth at different scales. What other exciting discoveries lay buried at our fingertips, awaiting improved technologies and innovative approaches to reveal themselves?

— ***Ocean's interior***

We will explore the temporal and spatial variability of the ocean as well as variations in the interior of the Earth beneath it.

— ***Ocean floor***

We will completely map the ridges, canyons, faults, and other key features of the U.S. EEZ and the continental margins that have economic, hazard assessment, or other scientific or cultural importance.

More than all the world's museums combined, the ocean holds the artifacts that document mankind's historical relationship with the ocean. The Panel recommends that any new program in ocean characterization document and reference historical shipwrecks, submerged villages, and sites of archaeological significance. While the history of ships that sunk while transporting silver and gold is recorded with some accuracy, In the winter of 1871, a fleet of whaling vessels was lost off the northern Alaska coast. The fleet of 32 ships became locked

LOST WHALING FLEET

in heavy ice, where they were crushed and sank. Over 1,200 passengers and crew abandoned ship with no loss of life. The sunken

OFF ALASKA EXPLORED

fleet has been located and preliminary surveys using a remotely operated vehicle (ROV) equipped with stereoscopic cameras with

USING 3-D TECHNOLOGY

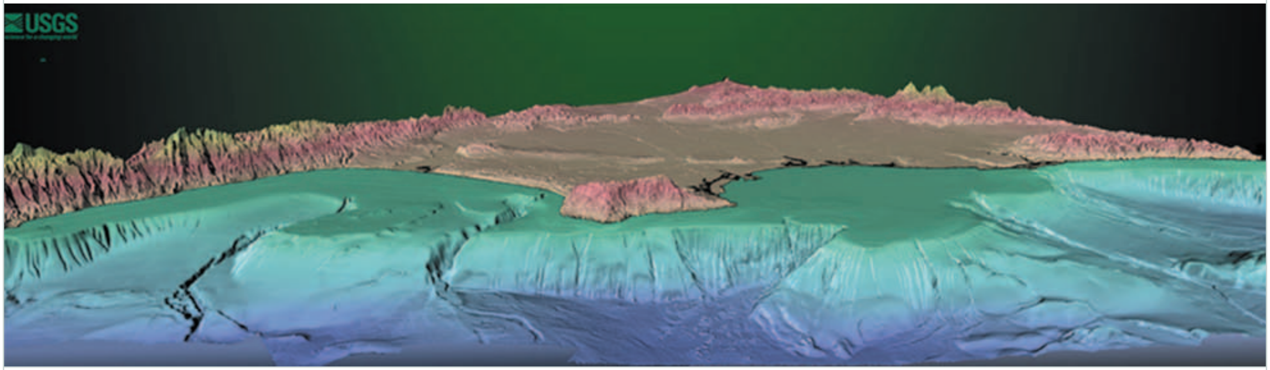
adapted planetary exploration software has been used to document the condition of the whaling vessels.

hundreds of ships that brought slaves to this country also sunk, leaving little or no trace for historians to follow.

A further goal for the Ocean Exploration Program should be to largely complete the mapping of the U.S. continental shelf. Maps that interpret

MAPPING

the shape of earth beneath the oceans



Historically, the seafloor and the water column have been mapped by discrete sampling techniques. Trawls, net tows, leadlines, and echosounders have provided a useful, but very sparse, picture of the distribution of marine life, morphology, and relief of seafloor features. Recent advances in sonar technology, which have been led by industry, have revolutionized our view of the water column and the seafloor. Multibeam sonars have the ability to form many (>100) narrow beams across a wide swath, which permits ensonification of large areas while maintaining high lateral (typically better than 2 – 5% of water depth) and vertical (typically better than .05% of water depth) resolution.

These systems can also collect simultaneous sonar backscatter data, resulting in an added layer of structural and textural information that can provide insight into the nature of the seafloor or mid-water properties. The nearly complete coverage provided by these systems results in unprecedented, detailed images of large volumes of the seafloor and the water column. The inherent density of these data sets permits exploration with interactive visualization techniques, allowing marine scientists to be "virtually immersed" in their data. Even more important, when expeditions are broadcast over the Internet, students, educators and the public can share in the excitement of ocean exploration.

the seafloor provide a fundamental framework for research and management of the world ocean and are a prerequisite for identification of regions that warrant protection. They show composition of the seabed, its shape (topography), areas of anthropogenic impact, and areas of historical and cultural interest. They provide information on the transport of sediment and help to define biological habitats. All this information can be used to develop predictive models to guide habitat and resource management, monitoring strategies, and other research / exploration goals. Obviously, all marine life, ecosystems, archaeological sites, and seafloor features cannot be mapped and inventoried immediately. A strategic hierarchical approach to mapping must be considered, perhaps beginning with larger, more obvious species, features and sites on a large geographic scale, and working toward the finer resolution of the identification of biodiversity within the marine system.

Although the production of high-resolution base maps is the first step in a systematic strategy, it is a daunting task, considering how little of the sea-floor has been mapped. For example, less than five percent of the total U.S. EEZ has been mapped in high-resolution. While the United States has always taken great pride in being a world leader in the development of approaches to the under-standing and stewardship of the oceans, we now find that other nations are far ahead of us. England, Canada, and Australia are well along in developing plans for the complete mapping of their EEZs, and New Zealand and Ireland have already begun multi-year, multi-million-dollar programs to be systematically explore their EEZs. It is critical that the United States also begin this important task immediately.

In the summer of 1700, the English merchant ship *Henrietta Marie* sank off the Florida coast shortly after unloading a cargo of enslaved Africans in Jamaica. The ship had been traveling along the infamous triangular route favored by slavers: Great Britain to West Africa to the West Indies and back to England.

the HENRIETTA MARIE slave ship

The *Henrietta Marie* was discovered in 1972 by noted treasure hunter Mel Fisher. She was subsequently researched and excavated by a team of marine archaeologists and members of the National Association of Black Scuba Divers in 1983. The shipwreck and its artifacts have become part of a national traveling exhibit, which is partially devoted to the wreck. The effort to conserve the artifacts recovered from the wreck is highlighted through displays of items in varying stages of the process.

The ship contained no material “treasure” of note. After six archaeological expeditions to the site, divers have recovered only a handful of coins. However, the more than 7,500 items found near the wreck are far more significant than gold or jewels, because artifacts from any aspect of the maritime slave trade are extremely rare. An equally valuable treasure is less tangible: the wealth of information researchers have uncovered about the complex slave trade.

On a mission to study marine life associated with oil seeps on the floor of the Gulf of Mexico, scientists recently discovered a brand-new animal living in the cold, deep depths. The discovery was made because scientists using the Johnson-Sea-Link submersible decided to investigate a curious formation they had glimpsed on an earlier dive. What they found were pink worms (now called "ice worms") that are about 1-2 inches long and apparently sculpt the surface of gas hydrates, which are natural methane water ices that form under conditions

of high pressure and temperature in many areas of the ocean floor. It is not yet known to what extent these worm colonies use the hydrate mounds for protection or nutrition, but they are the only known animal to inhabit this unique habitat. Researchers speculate that these worms may graze on chemosynthetic bacteria that grow on the methane, or may live in symbiosis with them. This discovery exemplifies that we must discard the old view that the deep sea bottom is a biologically impoverished zone.

"ICE WORMS" DISCOVERED IN GULF OF MEXICO

A minimum level of exploration would help identify areas of unique value and global importance. The results of these exploration efforts should be sufficient to guide future exploration and action items for resource managers. Systematic preliminary site surveys should be conducted in advance of more focused expeditions to discover new environments inhabited by presently unknown organisms. Information from satellites should also be used to provide maps of surface water characteristics needed to plan exploration of the EEZ.

While these goals focus on U.S. waters, international efforts should not be ignored. For example, the World Conservation Union objectives for Marine Protected Areas are consistent with the goals identified here, and we should investigate collaborations with other national and international efforts.

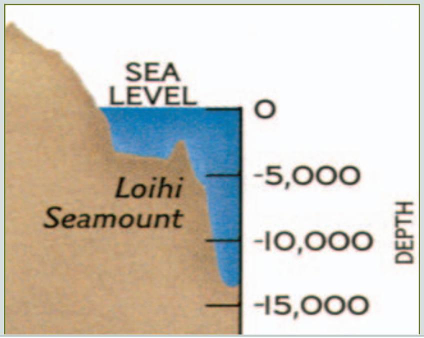
Exploring Ocean Dynamics and Interactions at New Scales

Ocean phenomena, which support complex ecosystems, operate over a broad range of unexplored spatial and temporal scales. Examples of dynamic features to be explored include:

— ***Ocean properties***
We will discover dozens of new oceanographic features changing over spatial scales from 10 to

EXPLORING THE BIRTH OF A NEW HAWAIIAN ISLAND

The recent collapse of the lava dome of the underwater volcano Loihi off Hawaii is giving scientists in a research submersible the opportunity to witness the birth of the next Hawaiian island. Several years after this event, which created an underwater crater more than a half-mile wide and 1,000 feet deep, superheated water and dissolved minerals have



combined to form mats of chemosynthetic life. The bacteria that make up these mats now form the base of elaborate food chains that draw in higher life forms like fish, making the summit of Loihi, some 3,000 feet beneath the surface, a place of rich marine biodiversity.

10,000 km, and temporal scales from picoseconds to millennia. These features include the ocean's interaction with the atmosphere and as a key component of the global hydrological cycle.

— ***Sea surface***
Hyperspectral sensing of the sea surface will reveal unexpected changes in temperature, salinity, photosynthesis, and ocean circulation over a wide range of time scales.

— ***Biological, geological, chemical, and physical interaction***
We will unravel dozens of processes affecting the interactions among species and the cycling of organic materials in the sea and in the coastal zone. We will explore the connection of living and nonliving systems in the largest environment on the planet — the world's ocean.

Until just two decades ago, it was thought that all living things, plants and animals, were supported in a variety of ecosystems that based their supply of energy on photosynthesis, the process by which green plants transform the sun's energy into simple sugars. But in 1977, dives of the deep-sea submersible *Alvin* found marine life thriving in the darkest depths of the ocean on the energy released when chemosynthetic bacteria break down methane and sulfur compounds carried by fluids venting from the seafloor.

In the summer of 2000, biologists discovered yet another mechanism by which marine life can harness energy. As much as 20 percent of the bacterial life in the deep sea might directly convert light to energy for powering cellular processes via a photon pump, thus sidestepping the more complex photosynthesis process entirely. This ability gives these organisms a survival advantage in low-nutrient environments.

These discoveries are rewriting the biology and oceanography textbooks. Science can only speculate what other novel means for powering life might exist in the world's oceans, and how their discovery may revolutionize the understanding of energy transfer in ecosystems.

While the discoveries mentioned above had an immediate impact on our understanding of the ocean, the Ocean Exploration Program must also foster observations over long periods of time to discover new processes and systems in the ocean that are not readily apparent. For example, nearly 15 years ago, scientists began collecting oceanographic and atmospheric data in the Equatorial Pacific. Every year, scientists collected salinity, temperature, wind speed, atmospheric pressure, and sea height data. After many years, Man's ability to intelligently explore the deep sea has been significantly enhanced by the advent of novel, autonomous platforms, remotely operated vehicles (ROVs) that can be submerged for extended periods of time, and satellite communication technology that is used to report data to scientists. Over the past decade, in particular, microelectronic equipment has made it feasible to outfit these platforms with sophisticated sensors that measure a wide variety of chemical, biological, and physical processes over a wide range of time scales. It is now possible, for example, to measure the difference in carbon dioxide concentration in the sea and the air above it over long periods on deep-sea moorings, such as NOAA's TAO-TRITON array in the Equatorial Pacific. Such measurements are required to understand the influence of the ocean on atmospheric carbon dioxide concentrations, the impacts of events such as El Niño, and the feedback processes that act to control the heat balance of the atmosphere.

SENSORS for OBSERVATION of OCEAN BIOGEOCHEMISTRY

In areas closer to land, the extent, frequency, and nature of Harmful Algal Blooms (HABs) have been difficult to document. This is due to the fact that traditional sampling, in order to be effective, had to keep up with the plankton growth rate (the population doubles every 12 hours), and plankton identification was done visually with the aid of a microscope. However, the revolution in biotechnology now makes it possible to conduct rapid, quantitative plankton species identification using only their DNA. A number of HAB species can now be identified automatically from ship-based laboratories. This automation should be adapted for autonomous platforms in the near future to facilitate the remote, quantitative observation of ocean ecosystem structures.

patterns in the data began to emerge and led to our ability to detect the onset of El Niño.

Developing New Technologies

Many of the tools currently used in ocean studies have been borrowed from substantial investments in technology by the Navy and the offshore oil industry. Whereas two decades ago, those tools available to academic researchers were second to none, a number of systems and facilities are aging. Cuts in the budget for Department of Defense development efforts have been felt by the marine technology community that relied on investments in new instruments and platforms by the Office of Naval Research. The deep-sea drilling and multi-channel seismic capabilities in the academic fleet have been eclipsed by new drilling ships and seismic systems routinely deployed in the offshore oil industry and by other countries and foreign investors. Our deep submergence assets are overall older and have shallower depth ratings than those deployed by the Japanese, for example.

What has kept the U.S. marine research program unsurpassed has not been the fact that we equip our investigators with the very best technology, but rather that we have developed the best mechanisms for selecting research programs and for operating our assets for the benefit of those programs. For example, the institutions operating the University Ocean Laboratory System (UNOLS) ships and deep submergence systems have been very responsive to the needs of their user base. Existing systems are constantly being improved, extended, and upgraded. Access to these assets is open to the oceanographic community at large, and program selection is based on some form of merit review. Operations groups in the U.S. pride themselves on the large number of operating days they are able to provide the science community and the low incidence of mechanical failures. Nevertheless, we cannot continue to depend on the ingenuity of our scientists and the dedication of our operations groups to more than compensate for a steady loss in U.S. position relative to other nations with respect to technical capability. By equipping the best researchers and the best marine operators with technology unsurpassed anywhere in the world, the possible benefits from a U.S. program in ocean exploration would be unlimited.

The Ocean Exploration Program can provide the mechanism for reinvesting in American leadership in ocean technology by supporting the following general development efforts:

— ***Remote sensors and in-situ capabilities***
We will invent, build and adapt the wide array of tools necessary for interrogating (measuring, mapping and exploring) the physical, geological, chemical, and biological parameters of the ocean.

— ***Synoptic 4-D capabilities***
We will create new concepts and methods for viewing the whole ocean through time, from anywhere.

LINKING EXPLORERS...

L*ive from Monterey Canyon*, a joint venture between the Monterey Bay Aquarium Research Institute (MBARI) and the Monterey Bay Aquarium (MBA), exposes Aquarium visitors to the wonders of deep sea exploration via telepresence. A microwave connection between MBARI's research ships and the Aquarium's auditorium allows two-way communication between the public and the researchers exploring Monterey Bay. Video images from MBARI's ROVs are projected on to a large screen. The researchers and their conversations are transmitted to the audience via cameras on board the vessel, and they are able to hear and respond to questions from the virtual visitors. The success of the program is largely due to the presence in the auditorium of an interpreter who is able to put the day's activities and unforeseen events into an educational context. The interpreter takes advantage of an electronic podium with an interactive, visual encyclopedia for deep-sea research. The interpreter can move back and forth between the live action and the archived material depending on the circumstances and the questions being asked by the audience.

...WITH THE PUBLIC

The scientific drama surrounding a human voyage beneath the sea first captured the attention and imagination of the nation in the 1960s. The well-documented voyages of Jacques Cousteau captivated American audiences. These images helped demonstrate the vastness of the oceans and the importance of protecting them against pollution and misuse. During the early days of space exploration, underwater vessels and habitats were built to test human endurance in confined spaces, but funding for most programs was sporadic, and research projects were short-lived. While space exploration has evolved and grown with new tools and technologies since the days of Apollo, the U.S. effort in human-occupied underwater technology has evolved little since the 1960s.

Not all technologies require placing scientists in-situ underwater. The continued development of remote and autonomous underwater vehicles will allow scientists to study ocean features without actually visiting them. In fact, programs already exist that allow scientists in California to take measurements and manipulate sensors located underwater in the Atlantic Ocean off the shore of New Jersey. Sensors can be deployed to measure ocean parameters and relay data to shore stations that broadcast information in near real-time over the Internet. These capabilities open access to underwater regions in remarkable ways. With the right assembly of underwater tools, scientists can remotely sense episodic ocean events and deploy the means to study them.

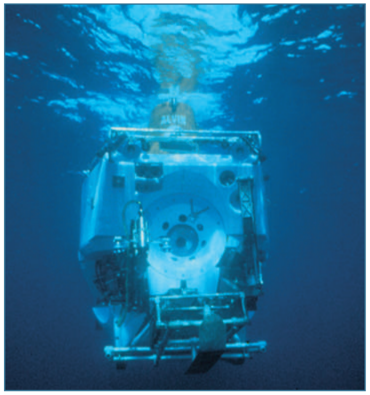
The Ocean Exploration Program will respond to shortcomings in our national underwater infrastructure and capital assets by developing new sensors, vehicles, and capabilities to bring science to the underwater environment.

Reaching Out in New Ways to Stakeholders

The oceans are a common global heritage. The Ocean Exploration Program must build in mechanisms to incorporate the interests and needs of a variety of stakeholders. These stakeholders include state, local and tribal governments, municipal authorities, industries, students, and ocean resource users of all types. Outreach has the potential to transform these stakeholders into concerned and informed constituents of the oceans, who will support the sustained investment that ocean exploration requires. Maintaining open channels of communication with these groups, both for input into the development of exploration plans and output in the form of new information and data products, will strengthen and diversify exploration programs. The program will concentrate on reaching the following stakeholders:

— ***Students***
We will establish the ability to broadcast ocean expeditions to reach every school district in the nation.

— ***The public***
We will lead the world in developing new technologies



that bring scientists and explorers into formal and informal educational settings, and students, educators, and the general public into the field.

— ***Industrial partners***
Petroleum, fisheries, and biomedical industries will make hundreds of discoveries of new materials, pharmaceuticals, and enzymes using the knowledge gained from ocean exploration.

The measure of success in educational outreach will be found in the numbers of new "students" of all ages interested in ocean science. Internet technology and webcasts bring new capacity to outreach programs. Ocean exploration provides rich content that easily captures the imagination of the concerned public. Outreach cannot be viewed as an afterthought of science, but rather a vital step in the scientific process.

EXPLORATION PRIORITIES

The Panel believes that these objectives can be met by establishing a new Ocean Exploration Program. The Program should be comprised of the following critical components within the organizational structure and governance discussed later in this document:

— ***Voyages of Discovery***

— ***Tools for Probing the Ocean***

— ***Data Management and Dissemination***

— ***Education and Outreach***

— ***Capital Investment***

Voyages of Discovery

The Ocean Exploration Program will require a wide range of field and laboratory equipment distributed throughout the United States as well as marine assets deployed around the world. In order to provide a focus for the program, the Panel proposes that the centerpiece of the Program be a Signature Mission -- a multi-year voyage of discovery. Complementary expeditions to the Signature Mission will use a wide variety of ships, submersible vehicles, and other investigative strategies that help foster exploration and provide the information base to capitalize on exploration opportunities.

All of the exploration missions envisioned in the Ocean Exploration Program will meet the highest scientific standards and will be carried out by highly qualified, multi-disciplinary staff. Achieving the goals will involve individuals from academia, the private sector, and government, and will, at fundamental levels, involve teachers and students so that the fruits of exploration are provided to the broadest audience possible. The goal of the voyages of discovery will be to make the United States second to none in terms of our knowledge of the oceans.

Expeditions that are complementary to the Signature Mission will play an important role in facilitating discoveries in remote areas and in capitalizing on opportunities for multi-faceted investigations. For example, the exploration of the Arctic will require an icebreaker, perhaps a nuclear submarine, active satellite sensors (e.g., radar and laser), or, at a minimum, an ice-hardened ship and AUVs with specialized sensors and capabilities for exploring the harsh Arctic

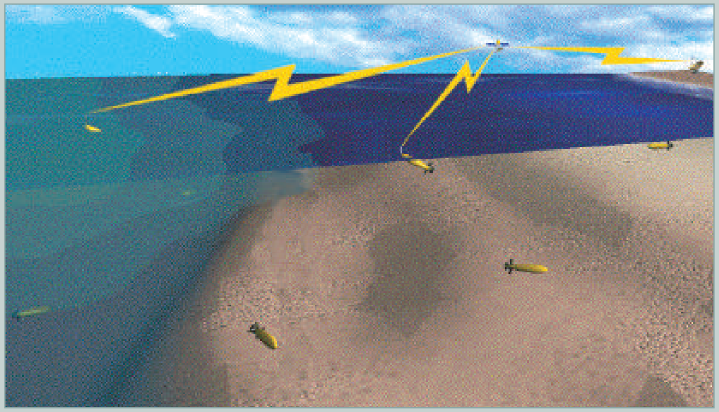
WANTED

OCEAN EXPLORERS

QUALIFICATIONS: CURIOSITY, WEB PROFICIENCY, BASIC SCIENCE LITERACY

HEY KIDS!!! Do you imagine yourself as a modern-day explorer, eager to probe uncharted territory and discover new worlds? Join the Ocean Explorer Corps! Pilot your own inner-spaceship and report new findings!

The combined technologies of the Internet, wireless communications, global positioning systems, miniaturized sensors and intelligent, robotic undersea platforms now make it possible for you to purchase and operate your own customized ocean exploration vehicle. Several models and a variety of sensor payloads are available to observe, listen to or measure the vital signs of the oceans. All are affordable, with a number of subsidized financing options. Interactive wizards will help you configure your ship and identify the part of the global ocean you wish to explore. Initial vectors will be pre-programmed into your vehicle for transit from your homeport, but you can change course at any time after launch, using your web-based controller o investigate new discoveries.



You will be registered as an active member of the fleet, and your vehicle's name and position will appear daily on the global grid of operating explorers. The data you collect will be universally available on-line in near real-time, and will be archived in an easily accessible global database. At any time, you will be able to locate from the global grid other explorers throughout the world operating in your region. You may wish to coordinate with them and organize a cooperative expedition to investigate a particular feature or phenomenon. This can all be accomplished interactively on the Web.

For more information, log on to Ocean Exploration Headquarters today! (www.exploreocean.gov)*

*Note: This is a future scenario and a proposed web site.

Signature Mission

The Panel proposes that a Signature Mission be designed as an important part of the U.S. exploration strategy and as a symbol of U.S. commitment to ocean exploration. Addressing the exploration challenges described in this report, the Signature Mission would explore the global ocean, circumnavigating the globe from pole to pole. It would concentrate on the U.S. EEZ and continental margins, but also take advantage of opportunities for visiting the most unexplored reaches of the global ocean. This mission will actually need to be more than a single shipboard expedition; it will be the first undertaking of its kind. The pole-to-pole routing will require a variety of vessels and platforms over a period of several years. All means of exploration will be folded into the Signature Mission, including satellites, seafloor moorings, specially outfitted ships, and submersible vehicles. Over several years, the Signature Mission would work its way south

from Maine, through the North and South Atlantic to Antarctica, incorporating international cooperation with coastal nations along the route. The Mission would then proceed eastward around Antarctica, adding to the southern ocean information void, with expeditions into the southern Indian Ocean and into the western Pacific before exploring the west coast of North America. The final goal of the Signature Mission will be to explore the Arctic Ocean beneath the polar sea ice cover.

environment. Information from a global acoustic monitoring system, a facility that is considered to be critical to global ocean exploration, might guide the Signature Mission to areas where submarine eruptions, earthquakes, or concentrations of marine mammals are occurring. Seafloor observatories, whether deployed as part of this Program or other initiatives, will explore geological, biological, and chemical processes as they occur. These seafloor observatories will be linked to shore-based laboratories and will employ state-of-the-art sensors and AUVs. Real-time results from seafloor observatories will also be used to help guide the Signature Mission.

Tools for Probing the Ocean

In addition to the voyages of discovery, the Ocean Exploration Program should fund the creation of technology to probe the ocean in new ways. In many areas of ocean technology, the systems available to the U.S. research community are no longer state-of-the-art, and the submersibles available to U.S. academic researchers are limited to depths less than 4,500 meters. Engineering development projects will often best be undertaken via partnerships with groups developing technology for other uses (e.g., national defense and the petroleum industry), but the availability of funds under the Ocean Exploration Program will make the difference as to whether the resulting systems are relevant to, and capable of, ocean exploration. Furthermore, the Panel fully expects that technology developed under this program will lead to spin-off applications elsewhere in ocean research and development (e.g., in-situ sensors for monitoring ocean health).

Data Management and Dissemination

An essential element of this program is data management and dissemination. The database must incorporate a variety of data types, including biological observations. It should be easy to put data into the archive as well as to extract it. A properly designed database should use widely accepted standards, whenever possible, and set new standards when none exist. Flexibility, however, is the key to integrating a broad range of data; rigid conformity to standards can discourage such integrations. The program should incorporate older, historic data sets relevant to exploration into the new database.

A goal for this program should be to develop by 2005, a plan for a Geographic Information System (GIS) for exploration data. Many federal agencies already have made substantial investment in modern data systems (e.g., Navy's Fleet Numerical Data Center, NASA's Earth Observing System Data and Information System [EOS-DIS], NOAA's National Geophysical Data Center). Thus, the first step in building this comprehensive system should be to draw on this collective experience. Furthermore, all federal agencies engaging in activities that lead to the accumulation of oceanographic, biologic, or geological data should commit to placing their data in a compatible system in the public domain. The GIS should include proprietary and classified data, as much as possible. This system must allow for timely access of usable, comprehensive data.

Some mechanism must also be developed to assure timely review of data and responses to recommendations from users. This may include a formal structure, such as a standing committee responsible for biennial or annual review of data within the GIS. To ensure quality data, standards and protocols for data collection, storage, and dissemination must also be developed.

Education and Outreach

The Program should include a coordinated effort to improve and promote ocean science education. Children and adults alike are intrinsically fasci-

Creating an Integrated Sustained Ocean Observing System

OCEAN.US

The impact of our inadequate ocean knowledge has become increasingly apparent. Following calls by Congress to plan for "a truly integrated ocean observing system," the National Ocean Research Leadership Council approved the establishment of the OCEAN.US office in May 2000.

OCEAN.US will integrate existing and planned observational activities and databases into an integrated observing system. This system will be comprised of real-time operational ocean observations, long-term research observations, technology development, and web-based access to models, algorithms, numerical techniques, etc., for improved predictions by the users. All ocean and ocean-related data — chemical, biological, physical — will be formatted, assimilated, and shared through the program using existing resources, such as the U.S. Global Ocean Data Assimilation Experiment (GODAE) server, to provide vital knowledge to many different users.

OCEAN.US

nated by the ocean and its unfamiliar creatures and habitats. This natural curiosity provides an excellent opportunity to increase science literacy, which is an essential ingredient for U.S. competitiveness in the 21st century. Ocean Exploration Program educational materials and resources should be widely available and easily accessed by teachers, students, and the general public. The program should expand efforts to create discovery-driven interactive web sites. Efforts should be made to build upon and expand partnerships and networks with educational groups (e.g., National Marine Educators Association, National Science Teachers Association, and Association of Zoos and Aquaria) and federal agencies that promote and fund education and outreach in ocean science. A high priority should be placed on interactions with informal science education centers (e.g., museums and aquaria) because of their proven ability to reach large numbers of people, including traditionally under represented groups. Additionally, these centers have demonstrated the ability to reach large numbers of teachers through high-quality professional development programs, and could serve as "portals" through which teachers, students, and the public can become involved in the world of the explorers. In this regard, the Panel recommends launching the Ocean Exploration Program with a national competition to name the Signature Mission.

The creation of an Ocean Exploration Program could reverse the current tendency for graduate oceanography programs in the United States to educate increasingly specialized professionals. Several top programs no longer require students to obtain some proficiency across the allied disciplines of marine biology, geology and geophysics, chemistry, archaeology, ocean engineering, and physical oceanography. Because our modern-day explorers will be specifically chosen from the ranks of those conversant across fields, graduate programs will need to adapt if their students are to take advantage of this new opportunity. Overall, the Panel would view this adjustment as beneficial, since many new discoveries await at the interfaces of established disciplines.

Capital Investment

Given the long lead time necessary to develop the capabilities and realize the potential for the Ocean Exploration Program, the Panel recommends funding the Program for an initial period of 10 years. The approximate level of new funding for annual operation of the Program should be on the order of $75 million. The Panel believes that this relatively small investment (less than one-hundredth of one percent of the federal discretionary budget) will serve as a magnet to attract other public and private assets that could amount to several hundred million dollars per year. "Seed" money from the federal government will be a critical catalyst in making this happen.

Some assets and capabilities required by the Ocean Exploration Program already exist and can be provided by academia, industry, and the government. The Program should take advantage of these when beneficial; however, some capital investment will be required. With the personnel effort and ship / vehicle time that will be devoted to the Program, it would be imprudent to use anything but the latest technology in platforms,

DIVE and DISCOVER

BRINGING OCEANOGRAPHIC RESEARCH INTO THE CLASSROOM AND TO THE GENERAL PUBLIC VIA THE INTERNET

Using funds from the National Science Foundation's Awards for Geoscience Education Program, the Woods Hole Oceanographic Institution has developed a web-based education and communications platform for providing near real-time access to ongoing oceanographic research at sea. The Dive and Discover website is targeted at middle school students (Grades 6-8) and the public. It is structured to provide multiple layers and levels of information on the basic scientific concepts at the core of the research being carried out. More important, the site provides daily updates from the research ship, including still and video images from shipboard operations and the bottom of the ocean, graphical representations of a wide variety of oceanographic data, explanations about the technology being used, and general information about life at sea for the scientists, engineers, and shipboard support crews that make oceanographic research and exploration possible.

Dive and Discover also provides sea-going scientists with web-based templates so that they can easily incorporate their scientific and field objectives into an expandable and easy-to-use web structure to broadly communicate their work.

http://www.divediscover.whoi.edu

systems, and sensors. There are a number of good arguments for mounting as many of these systems as possible on a state-of-the-art research ship, as a flagship for the Ocean Exploration Program. Outfitting a flagship will avoid the mobilization costs and compatibility problems when new systems are installed on vessels of opportunity. A properly equipped flagship will also facilitate multidisciplinary data management and educational outreach by centralizing much of the data collection and outreach technologies on a dedicated platform. The flagship could be purchased or leased, depending on platform availability and the final list of expedition requirements. In addition to capitalizing this flagship, the Program will need to acquire other technologies, which may include submersibles, sensors and communications, and information technology.

The approximate costs of capitalizing this program over the 10-year period will be two to three times the annual operating costs. Thus, some of the initial capitalization could conceivably be funded in place of operational costs during the first few years of the Program, while operations are starting up.

Priority Sites

The Panel concluded that the following sites are the highest priority areas for the Program:

— ***U.S. EEZ and continental margins***
Americans are the stewards of these areas, and thus, have a moral obligation to concentrate efforts here.

— ***The Arctic***
This region is largely unexplored, and yet is believed to be the most sensitive to climate change of any place on Earth.

— ***Southern oceans***
This vast region of the planet's ocean is also largely unexplored. Opportunities for fundamental discovery are particularly great.

— ***Inland seas, including the Great Lakes***
Other water bodies (e.g., Mediterranean and Red Sea) are also important targets, assuming international collaboration. These regions contain a significant amount of the world's cultural heritage.

RECOMMENDATIONS

The Ocean Exploration Program will be designed to map and document discoveries in new ways that maximize the use of the best technology available for this purpose, and track changes over time. The initial focus of this mapping effort should be the U.S. Continental Shelf and EEZ. Along with mapping the physical features of the ocean, ocean processes and dynamics should be studied

at new scales to help increase our knowledge of the poorly understood energy transfer systems present in this complex environment. The success of the Ocean Exploration Program will also depend on efforts to recapture the public imagination with regard to exploring the vast ocean, and to promote U.S. leadership in this arena. Broad, sustained popular support for investment in the Ocean Exploration Program will ensure that the best possible tools and resources are made available to those who will work to overcome the obstacles in carrying out such an ambitious program.

The Panel notes that the United States currently does not support a program in ocean exploration, despite our inadequate understanding of the ocean, the living and nonliving resources it contains, and its undeniable importance to the health of the planet and the wealth of our nation. Furthermore, in a number of areas, the United States has fallen behind other nations in its capabilities for undertaking ocean research. American leadership in ocean exploration can be achieved by first addressing the objectives of the Ocean Exploration Program discussed above, and then implementing the Program as follows:

The U.S. government should establish the Ocean Exploration Program for an initial period of 10 years, with new funding at the level of $75M / year, excluding capitalization costs. The Panel envisions that a program funded at that level would include the following critical elements:

— ***Interdisciplinary voyages of discovery in high-priority areas***
This includes the U.S. EEZ and the continental margins, the Arctic, and poorly known areas of the southern oceans and inland seas. U.S. knowledge of the living and nonliving resources in the ocean should be second to none, particularly within its own EEZ and continental margins.

— ***Platform, communication, navigation and instrument development efforts***
This includes the capitalization of major new assets for ocean exploration, in order to regain U.S. leadership in marine research technology.

— ***Data management and dissemination***
This ensures that discoveries can have maximum impacts in the research, commercial, regulatory, and educational realms.

— ***Education and outreach***
This will take place in both formal and informal settings to improve the scientific literacy of America's schoolchildren and to realize the full potential of a citizenry aware of and informed about ocean issues.

OCEAN EXPLORATION PARTNERSHIPS

OVER *the course of history, humankind has explored the oceans in search of natural resources, knowledge to support transportation and military ventures, and to learn more about the things that were in the vast unknown.*

More recently, exploration has laid the foundation for understanding the critical role that the oceans play in sustaining the biosphere. People's seemingly endless thirst for knowledge about the oceans' enormity, extremes in conditions, beauty, complexity, and association with human history can now be quenched with modern communications. While there have been, and still are, many reasons for ocean exploration, it is safe to say that ocean exploration is almost always accompanied by unanticipated discoveries, including knowledge that is invaluable for other purposes. Yet, ironically, most exploration to date has been relatively narrow in its purpose, and knowledge that does not serve the purpose of specific expeditions has not been shared.

Partnerships among all ocean exploration interests are needed if the full benefits of ocean exploration are to be realized. Partners should come from:

— ***Industries*** *seeking knowledge to support commercial activities such as fishing, energy and mineral extraction, pharmaceuticals, and other, as yet unknown, potentials.*

— ***Government agencies (both state and federal)*** *seeking knowledge about how the oceans function and to support their missions of national security, transportation, and the conservation and management of natural resources.*

— ***Academic institutions*** *concerned with ocean research.*

— ***Formal and informal educators*** *at all academic levels.*

— ***Mass media and media companies*** *seeking ways to inform and entertain the public.*

— ***Non governmental organizations*** *groups with a wide array of ocean interests, such as conservation, protection, education, entertainment, and research.*

Ocean exploration partners can play many different roles. Some of the partners will be the primary explorers. They will collect data from above, on and beneath the ocean's surface. Others will use the information collected by ocean exploration (e.g., for the design of future research, commercial enterprises, education, and conservation advocacy). It is also critical for users to be included in ocean exploration partnerships so that their interests are served. It must be recognized, however, that ocean exploration is not intended to be so tightly coupled with any particular user group's needs that the exploration endeavor loses the excitement of unanticipated discovery.

It is also important to recognize the vitality that a diversity of ideas will provide in the development of partnerships in ocean exploration. Some fear that ocean exploration will lead to ocean exploitation that is undesirable from their perspective. Others envision exploitation as the desired outcome. It is not necessary that all partners in ocean exploration share the same vision of the oceans for the future; however, ocean exploration should be neutral with respect to diverse views about how the oceans are used and conserved. If ocean exploration is successful in producing new information that excites and informs the public and officials with responsibility for the oceans, then the activity will likely lead to sound public policy choices that seek to balance diverse interests.

Ocean exploration requires both domestic and international partnerships. Most of the oceans are beyond the jurisdiction of any nation. Yet, the United States has a unique responsibility for the exploration of a larger ocean area (two million square kilometers) than any other nation.

After discovering the wreck of the *RMS Titanic* in 1985, Dr. Robert D. Ballard received thousands of letters from students around the world wanting to go with him on his next expedition.

The JASON Foundation for Education

an educational partnership

In order to bring the thrill of discovery to millions of students worldwide, Dr. Ballard founded the JASON Project, a year-round scientific expedition designed to excite and engage students in science and technology and to motivate and provide professional development for teachers. The JASON Project has been a leader in distance learning programs, and continues to expand its reach by adding more components each year. Funded by a combination of private industry and government, the program is now in its 12th year.

More information on the JASON Project is available at: **http://www.jason.org/**

Census of Marine Life: a Grand Challenge

The Census of Marine Life has been conceived as a bold program of discovery designed to capture the imagination of the American people. The challenge is to respond to important and fascinating questions about the amount, type and global distribution of marine life. These questions apply to past as well as current conditions, in order to prepare for anticipated future conditions. The planning for, and design of, the Census was a grassroots effort that involved the talents of many scientists from around the world, primarily supported by nongovernmental funds. The program they suggested includes the development of an Ocean Biogeographical Information System (OBIS), a research program to understand the history of marine animal populations and a plan for regional censuses to be taken to test technology and strategies. The Census program is now under way. This program will help fill in the gaps that currently exist in the area of marine biodiversity in order to help conserve endangered or overfished species. Without in-depth knowledge, species will be lost without people ever having known they existed. The sense of urgency surrounding this project is heightened by the expansion of fisheries into depths of a thousand meters or more in order to catch new species of fish. Many of these species are part of fragile ecosystems vulnerable to overfishing. Until the Census of Marine Life is complete, it will be extremely difficult to implement responsible management programs to address this situation.

More information on the Census of Marine Life can be found at **http://www.coml.org**

Characteristics of Ocean Exploration Partnerships

Ocean exploration is a broad endeavor, encompassing both vast geographic expanses and a wide range of disciplines (e.g., biology, geology, physical and chemical processes, archaeology). Many different technologies are used for ocean exploration. Thus, partnerships that are flexible in nature will best serve the goals of exploration. Nevertheless, some characteristics of these partnerships should be universal. They include:

— ***Partnership in planning***
An exploration partnership includes a shared plan with consensus building and maintenance. The plan should identify goals, strategies, responsibilities and access to information. All of the partners should stand behind the entire plan, rather than solely advocating their own self-interests.

— ***Multiple use of exploration platforms and sharing of other assets***
The assets needed for exploration include ships, submersibles, observatories, airplanes, satellites, and databases. Many types of sensors and collection devices are used, and often, they can collect multiple types of information on the same mission. A successful partnership for ocean exploration will take advantage of the opportunity to gain as much knowledge as possible from its assets.

— ***Interdisciplinary partnerships***
It will be common for partners in ocean exploration to have multiple interests. As noted above, the assets for ocean exploration may be capable of collecting multiple types of information. Thus, ocean exploration partnerships should be interdisciplinary.

— ***Information sharing***
Information derived from ocean exploration will be accessible in the public domain so that it can achieve its full value, including the intangible value of informing the public.

— ***Partnerships in education***
Partnerships with this group are essential. One mechanism to enhance this partnership would be the creation of an Ocean Corps of students of all ages who dedicate time and energy to specific expeditions. Members of the Ocean Corps would assist in ocean exploration and communicate their experiences to the education community. They will also communicate — often in real-time — to others through the Web and other media. This would provide a unique foundation for school-to-career and public service learning opportunities.

Arrangements for Partnerships

Many existing organizations are capable of planning and / or managing ocean exploration. These include domestic and international, and governmental and nongovernmental organizations. Whenever practicable, existing organizations should be used to avoid creating unnecessary bureaucracy and expenses. In some cases, new arrangements may be necessary to oversee a partnership for exploration, but these should have a finite life span to match the duration of the mission(s) undertaken by the partnership.

While existing organizations will play a critical role in the Program, a Forum must be established to bring together all stakeholders to exchange views, promote communication and networking, and continually inform the participants. Such a Forum will be well suited to identify stakeholders' opportunities and interests as a precursor to forming partnerships.

Vision for Coordinated Federal Ocean Exploration Program

In creating the framework for governing new activities in ocean exploration, the Panel advocates the following steps be taken.

— ***The President should instruct the White House Science Advisor and appropriate Cabinet officials to ensure the successful initiation and implementation of a national Ocean Exploration Program. The Panel also recommends instituting a follow-on group to maintain momentum and provide more detailed planning.***

The European Institute for Underwater Archaeology (IEASM) is a privately funded, multilevel partnership for international underwater archaeology, carried out in collaboration with national governments, museums, and navies of the host countries. Products of the partnership include traveling and permanent museum exhibitions, extensive publications of archaeological reports, popularized high-quality publications for public consumption, film documentaries, educational CDs for students and extensive websites published during field projects. IEASM currently has projects in:

EUROPEAN INSTITUTE FOR

UNDERWATER ARCHAEOLOGY

EGYPT Projects include Alexandria, the Bay of Abou Kir, Napoleon's fleet, and ongoing magnetometer and side-scan surveys.

PHILIPPINES Projects include the San Diego, five Chinese shipwrecks ranging from the 12th to the 16th centuries, and two 18th century East India Company shipwrecks.

CUBA Project consists of extensive surveying and searching for a 16th century shipwreck.

http://www.franckgoddio.org

ACADEMIA and NOAA

The National Undersea Research Program (NURP) is one example of a NOAA program that works directly with academia to carry out its research and exploration. With a mission of providing the expertise and technologies to place scientists underwater, either in person or remotely this program works through a network of regional centers operated by universities or private foundations. Each Center carries out a competitive, peer-reviewed science program supporting the undersea research needs of NOAA and the nation. You can find NURP's web site at:

http://www.nurp.noaa.gov

NOPP: the National Oceanographic Partnership Program

NOPP was established in 1997 by the National Oceanographic Partnership Act to integrate national efforts in ocean science and technology, including both research and education. NOPP's goal is to promote broad national needs by enabling coordinated national investments in ocean research and education. NOPP shares resources, data, intellect and experience between its partners in government, academia, industry, and other members of the ocean sciences community. Leadership is provided by the National Ocean Research Advisory Panel, which includes representatives from the National Academies of Science and Engineering, the Institute of Medicine, ocean industries, state governments and academia. The Partnership was formed by Congress to provide a mechanism for effective coordination of complex studies of the ocean and long-term monitoring between government agencies and the other partners.

For more information, log on to the NOPP web site at:

http://core.cast.msstate.edu/NOPPpg1.html

PARTNERSHIPS

— ***Institutional arrangements should clearly identify and rely on existing interagency mechanisms to ensure federal cooperation, coordination, and efficient use of resources and effectiveness.***

— ***A single lead agency should be designated as in charge and accountable for the program and its budget. Leadership should be assigned to the agency most likely to champion a broad spirit of exploration and least likely to divert ocean exploration toward narrower, mission-oriented activities.***

— ***New support resources and staffing should be allocated to implement and sustain the program.***

— ***The federal Ocean Exploration Program must identify and promote processes to establish effective partnerships and the involvement of stakeholders in all phases of program development and implementation.***

— ***Accountability should be articulated in advance through benchmarks and performance measures to evaluate outcomes. The benchmarks should be appropriate for ocean exploration, and measure the degree to which the Program is following the desired characteristics and meeting the challenges described in the first chapter of this report. The lead agency should, every three years, report on progress toward meeting performance goals, and review funding needs to the President and Congress.***

— ***Program participants should agree on criteria for the selection of projects to assure high scientific quality and visionary oversight.***

— ***The Program should include a global perspective promoting international partnerships.***

— ***The Program should be recognized as requiring implementation over an extended period of time (e.g., several decades).***

— ***The Program should be implemented in a manner that allows public involvement and oversight.***

IRISH SEABED SURVEY REVEALS RICHES

A seven-year project to map the seabed off Ireland's coastline is under way and already delivering results. Ireland's seabed survey has mapped nearly 18 percent of the territory and researchers say they hope to have the first definitive results by next summer. Potential gas reserves associated with carbonate mounds have been identified in preliminary findings, which were released at a Geological Survey of Ireland (GSI) seminar in Dublin last month. According to a spokesman, two ships have been dedicated to the seven-year survey by the agency, the 79.25-meter *R/V Bligh*, a former British navy ship, and the 68-meter *R/V Siren*. Both are owned and run by Global Ocean Technologies Ltd. (Gotech), which was contracted by the GSI as manager of the initiative. The Waterford-based company, which has been involved in seabed projects around the world, believes that this is the most ambitious survey of its type. Ireland has one of the largest offshore exclusive economic zones in Europe, some 850,000 square kilometers. Presenting an overview of progress to date, Gotech's Noel Hanley and the GSI team of Deepak Inamdar, Helen Gwinnutt, Mick Geoghegan, and Garrett Duffy reported that 72,563 square kilometers had been mapped. The main focus initially has been on Zone 3, the more distant and deeper part of the seabed. The multibeam sonar employed, Kongsberg Simrad's EM120, proved to be very successful, according to Hanley. "Its area of coverage is five times as wide as the water depth. It can penetrate the sediment and is fitted with a yaw correction to stabilize images in bad weather", he noted. The high-resolution data collected include an image of the wreck of the *Lusitania*. The wreck has been lying in 100 meters of water 18 kilometers south of the Old Head of Kinsale since its sinking by a first World War torpedo in 1915 with the loss of 1,200 lives. A hydrographic survey ship using echosounders in 1937 first located the wreck. The *Bligh* and *Siren* are also using sub-bottom profiling to detect rocks, gas, and other minerals. They are also fitted with magnetometers and gravity meters. Some 15 major canyons on the side of the Rockall trough were identified in earlier work, and the GSI's reconnaissance survey of the Irish continental shelf and shelf edge in 1996 is regarded as essential groundwork for this initiative.

RECOMMENDATIONS

The President of the United States should instruct the White House Science Advisor and appropriate Cabinet officials to design the management structure for this program. Elements of governance should include:

— ***Designating a lead agency to be in charge of the Program and accountable for its success using benchmarks appropriate for ocean exploration, such as the number of new discoveries, dissemination of data, and the impact of educational outreach.***

— ***Using existing interagency mechanisms to ensure federal cooperation among agencies.***

— ***Establishing an Ocean Exploration Forum to encourage partnerships and promote communication among commercial, academic, private, non governmental organizations and government stakeholders.***

TECHNOLOGY REQUIRED FOR OCEAN EXPLORATION

BECAUSE *the ocean contains the most hostile, dynamic, and complex environments on Earth, the technologies used to unlock its secrets must be innovative, robust, and capable of a broad range of measurements, over time spans from seconds to years.*

These instruments will often be required to operate in chemically caustic and high-pressure conditions, and to transmit the collected data back to shore-based laboratories for further analysis and real-time interaction with seafloor or oceanographic experiments. Such will be the demanding nature of ocean exploration in the coming century and beyond. The past 40 years of outer space exploration has prepared us for what will be the ultimate technological challenge facing the human species — the exploration of the Earth's oceans.

The past half-century of oceanographic research has demonstrated that the oceans and seafloor hold the keys to understanding many of the processes responsible for shaping our planet. The Earth's ocean floor contains the most accurate and complete record of geologic and tectonic history for the past 200 million years. For the past 30 years, the exploration and study of seafloor terrain, and the unraveling of plate boundary processes within the paradigm of seafloor spreading have revolutionized earth and ocean sciences. This new view of how the Earth works has provided a quantitative context for mineral exploration, land utilization and earthquake hazard assessment, as well as conceptual models that scientists use to understand the structure and morphology of other planets in our solar system. Much of this new knowledge stems from studying the seafloor — its morphology, geophysical structure and characteristics, and the chemical composition of the rocks of which it is comprised. Similarly, the discovery of deep-sea hydrothermal vents at the mid-ocean ridge, and the chemosynthetic-based animal communities that inhabit the vents have revolutionized biological sciences. This discovery has also provided a quantitative context for understanding global ocean chemical processes, and suggests modern analogs for both the origin of life on Earth and extraterrestrial life. Intimately

FLOATS & GLIDERS

Satellite-based sensors have provided a remarkable view of nearly the entire global ocean surface at a spatial resolution as small as 1 to 10 kilometers. They have revealed a complexity of patterns that most likely extends into the deeper ocean, but that cannot be measured with ship deployed samplers and sensors. Efforts are being made to improve our ability to image the horizontal scales of the ocean below the sea surface. The Argo program is an international effort that seeks to deploy thousands of pop-up floats throughout the world ocean that will record ocean properties from the sea surface to their "parking" depth and transmit the data back to shore via satellite links. An armada of such floats spread over the ocean will monitor the temperature, salinity and oxygen structure of the ocean. Other parameters, e.g., shear, may also be measured. Sensors to directly measure other parameters from the

floats, such as nutrients and tracer elements, need to be perfected. It is anticipated that soon, CO_2 concentrations and the DNA of a number of plankton species will also be able to be determined from autonomous underwater vehicles. A new generation of gliding vehicles is yet to be developed. These instruments could descend and ascend as floats, but more important, they could use the position fixes obtained when they surface to navigate along a prescribed track. Gliders will be able to traverse the ocean along the same track to provide high-resolution, repeat sections across oceanographic fronts and currents.

& AUVs

Over the past decade, Autonomous Underwater Vehicle (AUV) technology has advanced to the point where a variety of AUVs have begun to make unique oceanographic measurements. The original concept of the AUV called for it to perform surveys similar to those done with human-occupied submersibles or tethered vehicles, though at a lower cost and with less dependence on support vessels. These capabilities have been proven. AUVs have been shown to make many types of measurements better than other existing devices, especially those that require repeated time-series measurements in hostile weather environments. The new generation of AUVs are capable of reliably determining their position, using the computed position to automatically follow preprogrammed

tracks, and following the bottom using measurements from an array of acoustic sensors. With a focused development program, AUVs will soon be capable of deploying a wide range of mapping and sampling systems to any position in the water column. Future programs of synoptic ocean exploration will rely on fleets of AUVs dispersed throughout large areas of the oceans. These AUVs will begin to record data sets rich in both spatial and temporal resolution of complex oceanographic processes. Key technological challenges related to AUV development entail increasing their endurance through innovative power systems, and improving global navigation schemes to permit unattended operation in remote areas over long periods of time.

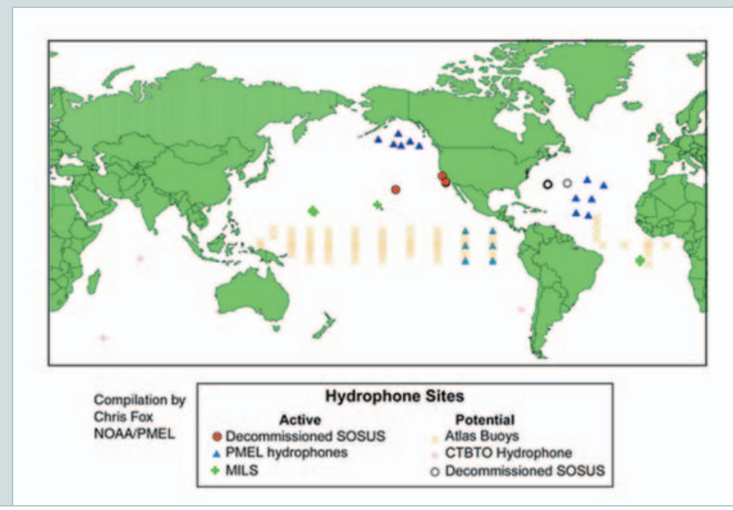
tied to these research themes is the study of physical and chemical oceanography which has resulted in unprecedented perspectives on the processes which drive climate and climate change on our planet. These are but a few of the many examples of how basic oceanographic research has revolutionized our understanding of Earth's history and provided a glimpse at the diversity of scientific frontiers still awaiting exploration.

These breakthroughs resulted from the intensive exploration that typified oceanographic expeditions from the 1950s through the 1970s and focused the development of oceanographic technology and instrumentation that facilitated discoveries on many disciplinary levels. Significant among these enabling technologies were satellite communication, global positioning, microchip technology, the widespread development of computers that could be taken into the field, and increasingly sophisticated geophysical and acoustic modeling and imaging techniques. In addition, traditional 19th and early 20th century methods for imaging the seafloor from the beach to the abyss, and sensing chemical and

EXPLORING the GLOBAL OCEAN

Using passive underwater acoustics to listen to the ocean is an ideal way to monitor oceanographic and tectonic phenomena on a global basis. The presence of an underwater sound channel at ~1000 m in the ocean allows the propagation of low-frequency acoustic energy over ocean-basin scales. Examples of significant discoveries already made using dual-use U.S. real-time hydrophone arrays include the detection of deep-sea volcanic eruptions and the tracing of migratory paths of the blue whale. These listening efforts initially depended on the U.S. Navy Sound Surveillance System (SOSUS). However, other low-cost, portable monitoring systems and devices have been developed and deployed in several ocean areas. Government agency partnerships to promote further development and use of this technology are already in place with NOAA, various Navy commands, academic institutions, and international partners, including the NOPP Ocean Acoustic Observatory Federation. The goal of sensing the "pulse" of the Earth and oceans via a global network of passive acoustic monitors is achievable with appropriate planning and funding, and will result in dramatic new views of the processes and events that shape our planet and its ocean.

USING PASSIVE UNDERWATER ACOUSTICS



biological processes at all levels in the ocean, were supplanted by submersible vehicles of various types, remote-sensing instruments, and sophisticated acoustic systems designed to resolve a wide spatial range of ocean floor and oceanographic features and processes.

Technology will enable the next generation of ocean exploration, but if the United States is to be a leader in this area, we must make a commitment to recapitalize our explorers with the very best technology. New instruments will need to be developed, and existing systems and data will need to be upgraded and fully utilized. In addition, new systems of telecommunication and global positioning infrastructure will be required to collect data from remote parts of the global ocean, especially the polar regions and the southern ocean.

Taking the Cognitive Brain and Spirit into the Ocean

Since ancient times, the human spirit has sought to understand the mysteries of the ocean. For the past 40 years, this need has been met by the ability to take the unique human visual and cognitive abilities into the ocean and down to the seafloor to make observations and facilitate measurements in submersible vehicles. Various types of submersibles were initially developed to support strategic naval operations of several nations. As a result of this effort, in 1963, the deep diving submersible *Alvin* was constructed by the United States. *Alvin* is still is use today as part of the National Deep Submergence Facility (NDSF) funded by the Navy, the NSF, and NOAA, and operated by the Woods Hole Oceanographic Institution (WHOI). It provides routine access to ocean depths as great as 4,500 meters for one pilot and two scientists or engineers at a time. Capable of reaching about 60% of the seafloor, *Alvin* usually dives for 8-9 hours per day and spends about 5 hours a day traversing the seafloor, making observations, sampling, and taking high-resolution still and video photography. Throughout its more than 35-year history, *Alvin* has completed over 3,600 dives (more than any other submersible of its type), and participated in making several key discoveries. These discoveries include mapping the structure of the mid-ocean ridge (MOR), transform faults and submarine canyons, discovering hydrothermal vents, and collecting samples and making time-series measurements of biological communities at the hydrothermal vents. In 1991, scientists in *Alvin* were the first to witness the vast biological repercussions of eruptions at the MOR axis, which provided the first hint that an enormous subsurface biosphere exists in the crust of the Earth on the seafloor.

Despite these significant successes and recent improvements to *Alvin*'s operational systems, deep submergence technology and vehicle system capability in the United States now lag behind Japan and France. These countries have government / industry collaborations, that have been well capitalized for over a decade and that continue to be supported at annual funding levels that vastly exceed U.S. spending on the NDSF and related diving capabilities. The latest French and Japanese submersibles can dive to 6,000 m and 6,500 m, respectively, depths that allow scientists using those vehicles to access more than 98% of the global seafloor. The Japanese deep-diving remotely operated vehicle, *Kaiko*, is capable of reaching virtually all ocean depths. Given these facts, the U.S. needs to rapidly increase the level of its capitalization and construction of new facilities available to ocean explorers.

Enhanced data transmission is needed from all levels in the ocean to the surface and from there to shore-based laboratories. This will require the development of an effective global data communications system and a strategy to bring the fruits of exploration not only to scientists, but also to the public and students at all levels, so that the broadest spectrum of people can benefit from 21st century ocean exploration.

Development of state-of-the-art sensors and deployment strategies will also prove essential for multidisciplinary, in-situ, and remote-sensing measurements of biological, chemical, physical, and geological processes throughout the ocean. This must include real-time remote-sensing of the global ocean via acoustic and seismic monitoring and other means in order to calibrate and study the "pulse" of the Earth and life in the oceans. The construction of new, innovative deep ocean vehicles and ocean-floor observing systems will be needed to facilitate exploration. The types of systems that will be required include human-occupied submersibles, remotely operated vehicles (ROVs), Autonomous Underwater Vehicles (AUVs), mobile observatories for seafloor and oceanographic measurements, and vehicle systems capable of facilitating marine archeological exploration and excavation.

RECOMMENDATIONS

— ***Undertake development of underwater platforms, communication systems, navigation, and a wide range of sensors, including the capitalization of major new assets for ocean exploration, to regain U.S. leadership in marine research technology.***

Measurements of trace chemicals in saltwater and sediments on the seafloor are required to understand a wide range of exchange processes that affect ocean chemistry and biology. One system currently under development by Professor George Luther at the University of Delaware will monitor chemical reactions in environments ranging from microbial mats to sediments to hydrothermal vents. A solid-state, gold-amalgam voltammetric microelectrode is the key component of part of this portable electrochemical system. It can “sniff out” trace chemicals that exist in extreme environments. The new microelectrode can measure dissolved oxygen, sulfide, iodide, Fe(II), Mn(II), and FeS. Each chemical species, if present, produces a current that can be detected in one potential scan. This type of technology represents the vanguard of microsensors that will be capable of detecting and quantifying small changes in chemistry in the myriad of chemical and biological processes occurring in the ocean and on the seafloor.

SOLID STATE VOLTAMMETRY SMELLING UNDERWATER

REALIZING THE POTENTIAL OF OUR DISCOVERIES AND PROTECTING NEW RESOURCES

NCREASED *knowledge and information about marine environments and resources are of great benefit to people the world over.*

Ocean explorers have a moral, if not legal, obligation to share information about important natural and cultural marine resources with all entities having responsibility for governance of the identified areas. Doing so will promote sound resource stewardship for the benefit of current and future generations.

Restoring and Protecting Ocean Resources

There is growing evidence that marine ecosystems have been severely impacted by human activities, most notably the exploitation of living resources. Because of typically strong food-web linkages, the depletion of target species can have ecosystem-level impacts. Marine Protected Areas (MPAs)are widely regarded as one of the more effective means of protecting and restoring these systems to environmentally sustainable levels. MPAs can also serve to protect marine resources for their intrinsic values, and to maintain the numerous life-support systems and ecosystem services that our oceans provide. Increasingly, countries around the world are identifying marine resources and marine areas of particular concern that deserve special protection. American exploration activities can result in discoveries and the collection of information that can be used in decision-making relative to MPAs throughout the world. To achieve this purpose, however, the information must be collected and disseminated to the appropriate decision-making entities in a timely and effective manner.

Although numerous MPAs already exist, nearly all of them are very small and restricted to shallow coastal areas. Thus, a number of fundamental questions remain to be answered relative to establishing and managing an effective system of MPAs: ***1)*** What are the goals and purposes of establishing Marine Protected Areas? ***2)*** How large must they be? ***3)*** How many should there be? ***4)*** Where should they be located? ***5)*** What tools (i.e., the ways and means) are necessary to effectively manage them? Information gathered by exploration can help answer these questions.

It is reasonable to expect that information about significant natural and cultural resources discovered anywhere in the global ocean in the course of exploration supported or sanctioned by the United States will be passed on to the MPA Center called for by the President in Executive Order 13158. This information should also be passed on to the appropriate country or international entity for use in making informed decisions about establishing new or expanding existing MPAs throughout the world.

To ensure that such information is made available to the MPA Center, protocols should be developed and adopted relating to collecting, documenting, storing, accessing and disseminating data. The President should assign leadership to an appropriate federal entity, and create a broad-based task force to implement this portion of the ocean exploration strategy. Representatives should come from affected federal agencies, (e.g., state resource agencies), academia and the non governmental ocean exploration community. While the culture of information sharing among marine scientists is evolving, more should be done to promote accessibility to data, including data that is proprietary and classified. After an integrated, workable and comprehensive information processing system is established, steps must be taken to ensure that the system is implemented, monitored for effectiveness and reliability, and modified, as necessary, based on experience. Implementation should include appropriate institutional arrangements and agreements that are binding and that have leadership support within the respective agencies. In addition, appropriate levels of new funding necessary to sustain the effort should support the information-sharing system.

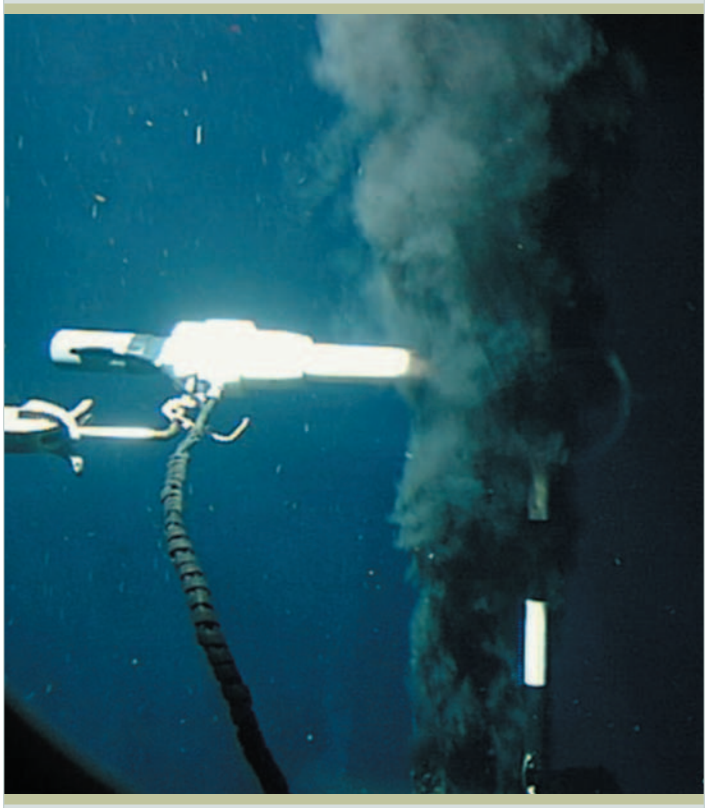
Because Marine Protected Areas often involve prohibitions against the extraction of resources (e.g., fish and minerals) and other uses (e.g., individual watercraft, mineral prospecting), their designations are controversial and often challenged in court. A major exploration initiative focused initially on the U.S. EEZ that is designed to gather information useful to marine resource managers, would be invaluable in carrying out the President’s Executive Order calling for the expansion of a national system of MPAs. To be useful to resource managers, the data collected must be of a type, scale and quality that can be applied to management decision-making in a timely and effective manner, so that it can help promote public support and that can withstand legal scrutiny.

Ocean Resources with Commercial Potential

Mankind has benefited tremendously from the relatively small historic investment in ocean exploration. Multichannel seismic mapping of the ocean sub bottom during the 1970s accelerated deep-water oil and gas exploration. During the past two decades, a renewed interest in marine bioprospecting has led to the discovery of thousands of unique products from marine plants, animals, and microbes, with commercial applications such as pharmaceuticals, nutritional supplements, cosmetics, enzymes, pigments, and fine chemicals. What is remarkable is that the discovery of these thousands of chemicals has come from exploring only a few coastal, and even fewer deep ocean, environments. We have barely begun to tap the potential of the world's oceans to yield useful chemicals. While many fisheries are over exploited, the search continues for environmentally sustainable fisheries to feed our ever-increasing global population. Recent discoveries of gas hydrates, and the unique fauna that live in, on, or because of them, suggest that clean energy for America's future needs may lie within our own unexplored waters. Finally, citizens are eager to share in the exploration of our rich heritage of maritime history, unique archaeological sites, and exotic flora and fauna.

VENTS

The key to understanding the effects of deep ocean volcanism and hydrothermal venting requires voyages of exploration in the time domain. Frequent, in-situ observations, sustained for long periods of time, give scientists information that a snapshot view cannot provide. NOAA's VENTS Program is pursuing this strategy using a wide variety of sensors at seafloor observatories at venting sites. VENTS researchers conduct field operations for at least two months every year at observatories such as the NEw Millenium Observatory (NeMO) at Juan de FucaRidge, using research vessels, submersibles and remotely operated vehicles.



EXAMPLES OF COMMERCIALLY AVAILABLE MARINE BIOPRODUCTS

PRODUCT	APPLICATION	ORIGINAL SOURCE
Ara-A	antiviral drug	marine sponge (from U.S. coastal waters)
Ara-C	anticancer drug	marine sponge (from U.S. coastal waters)
Okadaic acid	molecular probe for biomedical research	marine microalga
Manoalide	molecular probe for biomedical research	marine sponge
Vent™ DNA polymerase enzyme	polymerase chain reaction	deep sea hydrothermal vent bacterium
Formulaid® (Martek Biosciences)	fatty acids used as additive in infant formula, nutritional supplement	marine microalga
Aequorin Green Fluorescent Protein (GFP)	bioluminescent calcium, indicator reporter gene	bioluminescent jellyfish
Phycoerythin	conjugated antibodies used in ELISAs and flow cytometry	red algae
Resilience® (Estee Lauder)	"marine extract," an ingredient in skin care products	Caribbean gorgonian (sea fan)

Exploring the world's oceans and discovering new resources, both living and non living, will lead scientists to further evaluate the potential of these resources to be developed into useful products to benefit mankind. Ensuring the identification and subsequent research and development of these discoveries is a necessary follow-up to exploration. Thus, important components of a U.S. Ocean Exploration Program will be the support of research by:

— ***Enhancing funding initiatives within federal agencies to support early-phase research on discoveries with commercial potential. Identifying the commercial potential of both living and non living resources will require a multidisciplinary, coordinated, and integrated approach to exploration. Newly discovered plants, animals, microbes, and minerals must be analyzed using state-of-the-art technology to determine their usefulness as pharmaceuticals, nutritional supplements, and fine chemicals for research and industrial applications. Relevant federal agencies must ensure support for early-phase research by establishing new programs specifically targeted for research on discoveries from the Ocean Exploration Program. In addition to the programs that currently exist to support short-term, high-risk research on the living and non living "products" of exploration, federal agencies need to emphasize, prioritize, and fast-track research initiatives on the "products" of the Ocean Exploration Program.***

— ***Providing incentives (such as tax credits, grants, and favorable licensing terms) to private industry to encourage the funding of research and development of discoveries with commercial potential. Private-sector involvement is critical. Although mechanisms exist to support and encourage partnerships between industry, academia, and government (e.g., Small Business Innovation Research [SBIR] and Small Technology Transfer Research [STTR] programs), these programs are not oriented to support the early-phase research that is necessary to identify discoveries with commercial potential. Incentives should be provided to industrial sponsors of high-risk, early-phase, research who are willing to support research directly or through ancillary program support. These incentives should include, but not be limited to, tax credits, grants, and favorable licensing terms. Special attention should be given to incentives for ocean industries to provide platforms for data gathering (e.g., offshore oil/gas platforms, seismic vessels, drill ships) during routine operations and during windows of opportunity for dedicated data gathering during ocean*** *transits (e.g., mobilization and demobilization from remote areas).*

— *Promoting stakeholder support of research on the environmentally sustainable use of marine resources. Finally, and most important, it is recognized that along with identifying marine resources with commercial potential comes the obligation to protect such resources from over exploitation. Developers of products that require the extraction of resources should be strongly encouraged to support research on the potential for biological removal of living resources, including stock assessment, rates of growth and reproduction, and environmental sustainability of the resource and its habitat. The Panel endorses a precautionary approach to minimize the likelihood of detrimental effects. In most cases, taking from wild populations will not be a viable option to supply the development and marketing of marine bioproducts. Therefore, as a follow-up to exploration, both federal agencies and private-sector stakeholders must support research on the environmentally sustainable use of marine resources, including, but not limited to, bulk supply options such as aquaculture, microbial fermentation, chemical synthesis, and transgenic production.*

RECOMMENDATIONS

The President can ensure that the knowledge gained from ocean exploration is effectively made available to ensure informed decision-making relative to Marine Protected Areas by:

— *Assigning leadership in this activity to an appropriate federal agency.*

— *Establishing a broad-based task force to design and implement an integrated, workable, and comprehensive data management, information processing system for all information, including unique and significant features.*

— *Enhancing funding within federal agencies to support early-phase research on discoveries with commercial potential.*

— *Providing incentives to private industry to encourage the funding of research and development of discoveries with commercial potential. U.S. laws should be reexamined to provide proper incentives for potential commercial users of ocean discoveries.*

— *Designing mechanisms whereby those who directly profit from the exploitation of marine resources support research on their environmentally sustainable use.*

OCEAN EXPLORATION DIRECTIVE

The White House
Office of the Press Secretary

June 12, 2000
Memorandum for:
The Secretary of Commerce

Subject:
A New Era of Ocean Exploration

Two years ago, the Vice President and I joined you, other members of my Cabinet, and hundreds of others from across the country at the National Ocean Conference in Monterey. This historic gathering drew together for the first time representatives from government, industry, and the scientific and conservation communities to begin charting a common oceans agenda for the 21st century.

At the Conference, I directed my Cabinet to report back with recommendations for a coordinated, disciplined, long-term federal ocean policy. In its report to me last year, *Turning to the Sea: America's Ocean Future*, the Cabinet outlined an ambitious and detailed strategy to ensure the protection and sustainable use of our ocean resources. I am proud of the actions my Administration is taking to begin implementing this strategy, including the Executive Order I issued last month to strengthen our national network of marine protected areas.

One of the Cabinet's key recommendations was that the Federal Government establish a national strategy to expand exploration of the oceans. Although we have learned more about our oceans in the past 25 years than during any other period in history, over 95 percent of the underwater world is still unknown and unseen. What remains to be explored may hold clues to the origins of life on Earth, cures for human diseases, answers to how to achieve sustainable use of our oceans, links to our maritime history, and information to protect the endangered species of the sea.

Today, I am announcing steps to immediately enhance our ocean exploration efforts and to develop the long-term exploration strategy recommended by you and the rest of the Cabinet. Together, these actions represent the start of a new era of ocean exploration.

First, I am announcing the launch of three new expeditions off the Atlantic, Gulf, and Pacific coasts. As you know, these expeditions, led by the Department of Commerce in collaboration with private partners, will allow the first detailed exploration of the Hudson River Canyon off New York, the Middle

Grounds and Big Bend areas off central Florida, and the Davidson Seamount off central California. Researchers will employ the latest submersible technologies and will share their discoveries with schoolchildren and the public via the Internet and satellite communications.

Second, to ensure that these new expeditions are only the start of a new era of ocean exploration, I am directing you to convene a panel of leading ocean explorers, educators, and scientists and to report back to me within 120 days with recommendations for a National oceans exploration strategy. In implementing this directive, you shall consult with the National Science Foundation, the National Aeronautics and Space Administration, the Department of the Interior, the Environmental Protection Agency, and other agencies, as appropriate. The strategy should consider the full array of benefits that our oceans provide, and should support our efforts to conserve and ensure the sustainable use of valuable ocean resources. Specifically, the strategy should:

1 |

Define objectives and priorities to guide ocean exploration, including the identification of key sites of scientific, historic, and cultural importance;

2 |

Recommend ways of creating new partnerships to draw on the tools and talents of educational, research, private-sector, and government organizations, including opportunities for federal agencies to provide in-kind support for private ocean exploration initiatives;

3 |

Examine the potential for new technologies — including manned and unmanned vehicles and undersea platforms — to observe and explore the oceans from surface to seafloor and recommend ways to explore the oceans remotely using new observatories and sensors and other innovative uses of technology; and

4 |

Recommend mechanisms to ensure that information about newly explored areas warranting additional protection is referred to the newly established Marine Protected Area Center, and that newly discovered organisms or other resources with medicinal or commercial potential are identified for possible research and development.

In the early years of the 19th century, President Thomas Jefferson commissioned Captain Meriwether Lewis to explore the American West. What followed was the most important exploration in this country's history. As America prepares to celebrate the 200th anniversary of the Lewis and Clark Expedition, we have an opportunity to set our sights on a much broader horizon. The time has come to take exploration farther west, and east, and south, to our submerged continents. In so doing, we can challenge and rekindle American's spirit of exploration, open up a whole new underwater world of possibilities, and help preserve our extraordinary marine heritage for future generations.

William J. Clinton

MARINE PROTECTED AREAS

EXECUTIVE ORDER

THE WHITE HOUSE
Office of the Press Secretary

May 26, 2000

EXECUTIVE ORDER:
Marine Protected Areas

By the authority vested in me as President by the Constitution and the laws of the United States of America and in furtherance of the purposes of the National Marine Sanctuaries Act (16 U.S.C. 1431 et seq.), National Wildlife Refuge System Administration Act of 1966 (16 U.S.C. 668dd-ee), National Park Service Organic Act (16 U.S.C. 1 et seq.), National Historic Preservation Act (16 U.S.C. 470 et seq.), Wilderness Act (16 U.S.C. 1131 et seq.), Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1801 et seq.), Coastal Zone Management Act (16 U.S.C. 1451 et seq.), Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.), Marine Mammal Protection Act (16 U.S.C. 1362 et seq.), Clean Water Act of 1977 (33 U.S.C. 1251 et seq.), National Environmental Policy Act, as amended (42 U.S.C. 4321 et seq.), Outer Continental Shelf Lands Act (42 U.S.C. 1331 et seq.), and other pertinent statutes, it is ordered as follows:

Section 1. Purpose. This Executive Order will help protect the significant natural and cultural resources within the marine environment for the benefit of present and future generations by strengthening and expanding the Nation's system of marine protected areas (MPAs). An expanded and strengthened comprehensive system of marine protected areas throughout the marine environment would enhance the conservation of our Nation's natural and cultural marine heritage and the ecologically and economically sustainable use of the marine environment for future generations. To this end, the purpose of this order is to, consistent with domestic and international law (a) strengthen the management, protection, and conservation of existing marine protected areas and establish new or expanded MPAs; (b) develop a scientifically based, comprehensive national system of MPAs representing diverse U.S. marine ecosystems, and the Nation's natural and cultural resources; and (c) avoid causing harm to MPAs through federally conducted, approved, or funded activities.

Section 2. Definitions. For the purposes of this order: (a) "Marine protected area" means any area of the marine environment that has been reserved by Federal, State, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein. (b) "Marine environment" means those areas of coastal and ocean waters, the Great Lakes and their connecting waters, and submerged lands thereunder, over which the United States exercises jurisdiction, consistent with international law. (c) The term "United States" includes the several States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands of the United States, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands.

Section 3. MPA Establishment, Protection, and Management. Each Federal agency whose authorities provide for the establishment or management of MPAs shall take appropriate actions to enhance or expand protection of existing MPAs and establish or recommend, as appropriate, new MPAs. Agencies implementing this section shall consult with the agencies identified in subsection 4(a) of this order, consistent with existing requirements.

Section 4. National System of MPAs. (a) To the extent permitted by law and subject to the availability of appropriations, the Department of Commerce and the Department of the Interior, in consultation with the Department of Defense, the Department of State, the United States Agency for International Development, the Department of Transportation, the Environmental Protection Agency, the National Science Foundation, and other pertinent Federal agencies shall develop a national system of MPAs. They shall coordinate and share information, tools, and strategies, and provide guidance to enable and encourage the use of the following in the exercise of each agency's respective authorities to further enhance and expand protection of existing MPAs and to establish or recommend new MPAs, as appropriate:

(1) science-based identification and prioritization of natural and cultural resources for additional protection;

(2) integrated assessments of ecological linkages among MPAs, including ecological reserves in which consumptive uses of resources are prohibited, to provide synergistic benefits;

(3) a biological assessment of the minimum area where consumptive uses would be prohibited that is necessary to preserve representative habitats in different geographic areas of the marine environment;

(4) an assessment of threats and gaps in levels of protection currently afforded to natural and cultural resources, as appropriate;

(5) practical, science-based criteria and protocols for monitoring and evaluating the effectiveness of MPAs;

(6) identification of emerging threats and user conflicts affecting MPAs and appropriate, practical, and equitable management solutions, including effective enforcement strategies, to eliminate or reduce such threats and conflicts;

(7) assessment of the economic effects of the preferred management solutions; and

(8) identification of opportunities to improve linkages with, and technical assistance to, international marine protected area programs.

(b) In carrying out the requirements of section 4 of this order, the Department of Commerce and the Department of the Interior shall consult with those States that contain portions of the marine environment, the Commonwealth of Puerto Rico, the Virgin Islands of the United States, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands, tribes, Regional Fishery Management Councils, and other entities, as appropriate, to promote coordination of Federal, State, territorial, and tribal actions to establish and manage MPAs.

(c) In carrying out the requirements of this section, the Department of Commerce and the Department of the Interior shall seek the expert advice and recommendations of non-Federal scientists, resource managers, and other interested persons and organizations through a Marine Protected Area Federal Advisory Committee. The Committee shall be established by the Department of Commerce.

(d) The Secretary of Commerce and the Secretary of the Interior shall establish and jointly manage a Web site for information on MPAs and Federal agency reports required by this order. They shall

Section 6. Accountability. Each Federal agency that is required to take actions under this order shall prepare and make public annually a concise description of actions taken by it in the previous year to implement the order, including a description of written comments by any person or organization stating that the agency has not complied with this order and a response to such comments by the agency.

Section 7. International Law. Federal agencies taking actions pursuant to this Executive Order must act in accordance with international law and with Presidential Proclamation 5928 of December 27, 1988, on the Territorial Sea of the United States of America, Presidential Proclamation 5030 of March 10, 1983, on the Exclusive Economic Zone of the United States of America, and Presidential Proclamation 7219 of September 2, 1999, on the Contiguous Zone of the United States.

Section 8. General. (a) Nothing in this order shall be construed as altering existing authorities regarding the establishment of Federal MPAs in areas of the marine environment subject to the jurisdiction and control of States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands of the United States, American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, and Indian tribes. (b) This order does not diminish, affect, or abrogate Indian treaty rights or United States trust responsibilities to Indian tribes. (c) This order does not create any right or benefit, substantive or procedural, enforceable in law or equity by a party against the United States, its agencies, its officers, or any person.

William J. Clinton

REMARKS TO THE OCEAN EXPLORATION PANEL

Secretary of Commerce, Norman Y. Mineta

Ocean Exploration Panel Meeting

August 21, 2000

Good morning fellow explorers! I say fellow explorers because I believe that each and every one of us is an explorer at heart. You just had the good sense to make it your life's work! As space explorers observed over 30 years ago, Earth is a blue planet, an ocean planet. And just as those early explorers set the nation's commitment to space exploration, it is up to us today to build a foundation for a renewed commitment to ocean exploration.

On June 12, President Clinton directed the Secretary of Commerce to put together a panel of America's finest explorers, scientists and educators. He wanted the best people to work on a very, very important task: to develop a national strategy for ocean exploration. I thank each of you for responding to the call. Whenever we explore new frontiers — from the American west to outer space — we reap multiple benefits — to our economy, our technology, our health and our culture. And, as we embark on this new era of ocean exploration, we can envision extraordinary benefits. For example, the economic potential of America's unexplored oceans is vast. Gas hydrates may hold more than 1000 times the fuel in all other estimated oil and gas sources combined. Already one new anti-cancer medicine (called Bryostatin) comes from a marine sponge. This drug is estimated to have an annual market value of over $1.2 billion. And there is more history under the sea than in all the museums of the world. The ocean is home for treasures of antiquity, sunken vessels and the legacy of our maritime past. And we have taken steps to protect this heritage.

The first national marine sanctuary protects the remains of the Civil War ironclad *USS Monitor*. The newest marine sanctuary — the Thunder Bay National Marine Sanctuary — will protect a collection of shipwrecks in Lake Huron. It's been said, rightly, I believe that we only protect that which we understand. By setting out on voyages of exploration and discovery, we build a foundation for conservation.

Technology is already bringing once inaccessible areas of the ocean within reach of fishermen, miners, and bio-prospectors. In some ways, we are playing catch-up to these advances. But, as we have learned on land, protection must go hand in hand with exploration. Deep ocean exploration presents huge technological challenges. And as we have seen with space exploration, the solutions often have broad benefits.

In turn, we will bring back discoveries of new life forms, geological features and chemical processes. Unraveling their mysteries will spur new developments. In the days of Lewis and Clark, Americans waited months to learn about their discoveries. Today, through Internet and satellite communications, you can take us along. As many of you have shown, students and teachers can share in the excitement of planning and undertaking an expedition.

As President Clinton noted in calling for a new era of ocean exploration, America needs a sustained investment to reap the full benefits for society. Exploration is not partisan, nor is it the exclusive domain of any agency. It requires the full participation of government and the private sector. And, above all, a successful ocean exploration strategy must engage the public. A truly successful report will give us a strategy to make all citizens explorers — and move ocean issues beyond this esteemed panel here today. The effort to reach out and bring the excitement of these endeavors into America's classrooms is one of the best investments we can make. It is often said that children are natural scientists. This great exploration endeavor has the potential to spark and nurture that curiosity through film, television, and the Internet. But let's also remember the adults out there — remember to reach out to the explorer in all of us.

Ask yourself: Where were you when man first walked on the moon? That amazing event remains so vivid in our minds because all Americans, indeed the world, were able to see it live on TV. That day inspired a whole new generation of explorers.

How will Americans be able to join you on your expeditions to new ocean frontiers? Will today's explorations inspire the next generation of ocean scientists — and at home explorers? An ocean exploration strategy that reaches its full potential must tap all the expertise and resources available to us. The exploration of the world's oceans cannot be accomplished by one government agency, nor can it be accomplished by government alone.

I urge you, in your deliberations, to envision a new collaboration among governments, academia, and the private industry that reaches out to everyone. In addition, a successful ocean exploration strategy should explore through time. Voyages to remote places are essential, but so are those that occur through time as well. The establishment of networks, observatories, and data arrays on the seafloor and in the ocean's water column often reveals more to science than a snapshot approach ever will.

Two hundred years after Lewis and Clark forever changed the American landscape, you can chart a new course to explore the American seascape. My hope is that, with public outreach, future generations will view this commission as a turning point for exploration of the oceans. Thank you all for your willingness to be part of this critical task for our future. I eagerly await your report. May it mark a new era of ocean exploration and conservation — a new era of stewardship for the oceans.

Norman Y. Mineta

AGENCY SUMMARIES OF OCEAN EXPLORATION ACTIVITIES

Environmental Protection Agency (EPA)

The EPA's mission is to protect and restore the environmental quality of ocean ecosystems. A priority must be established for the exploration of coastal ecosystems because they are particularly threatened by pollution, coastal development, and overexploitation of resources. These stressors can cause habitat loss, nuisance algal blooms, hypoxia, toxic contamination of marine life, and ecological degradation. Although coastal systems are the most easily accessible to study, our understanding of how they are structured and how they function is still not well established.

To ensure that we manage these systems in a sustainable manner, we must understand them. We should explore coastal ecosystems with new and efficient measurement techniques to establish baselines for status and trends and to allow us to interpret the causes and consequences of change. We must ensure that exploration and discovery of the resources in the oceans do not lead to overexploitation and degradation of these same resources, as they often have in the past.

National Aeronautics and Space Administration (NASA)

NASA is one of the earth science discovery agencies of the federal government. Scientific exploration of the Earth is an essential step in understanding weather, climate and natural hazards. It may also assist in the quest for the origins of life. NASA's mission in the area of ocean exploration is to support the migration of ocean observing techniques from research to operational use, conduct and preserve high-quality, long-term, systematic measurements of the oceans, facilitate data exchange and real-time assimilation within an integrated ocean observing system, and increase public awareness of the critical role the oceans play in our lives on Earth.

To achieve this mission, NASA conducts ocean-observing missions that reveal the new and unforeseen phenomena in Earth's oceans. NASA also develops enabling technology for ocean observing missions throughout the solar system, and contributes to the development of an integrated ocean observing system. NASA also conducts research missions that explore techniques for ocean observation, including new satellite technologies and sensors for ocean remote sensing, in-situ ocean sensors made ready for space environments and vice versa, and creating or refining ocean circulation models.

NASA explores the practical application of its discoveries in ocean science though several partnerships and programs, including the U.S. Global Climate Research Program (USGCRP), National Ocean Partnership Program (NOPP), Integrated Global Observing Strategy (IGOS), and NASA's Seasonal-to-Interannual Prediction Program (NSIPP).

National Science Foundation (NSF)

The National Science Foundation is a primary player in ocean exploration and discovery. NSF supports disciplinary and interdisciplinary research efforts and the means, particularly ships and other equipment, necessary to access the oceans from the surface to deep in the sea floor.

Core programs include investigator-initiated research in biology, chemistry, physical oceanography, and marine geology and geophysics, including research within polar regions. Focused programs include Continental Margins (MARGINS), Life in Extreme Environments (LExEn), Ecology of Harmful Algal Blooms (ECOHAB), Coastal Ocean Processes (CoOP), Environmental Geochemistry and Biogeochemistry (EGB), World Ocean Circulation Experiment (WOCE), U.S. Joint Global Ocean Flux Study (JGOFS), Ridge Interdisciplinary Global Experiments (RIDGE), Global Ocean Ecosystems Dynamics (GLOBEC), Marine Aspects of Earth System History (ESH), Surface Heat Budget of the Arctic Ocean (SHEBA), Science Ice Exercise (SCICEX), and Shelf-basin Interactions in the Arctic (SBIA). Integrating research and education is a high priority for NSF.

NSF provides significant support to facilities and technologies that enable access to various regions of the ocean and ensure effective research and communication capabilities. NSF is the primary supporter of numerous surface vessels, including the academic research fleet (consisting of 28 ships of various sizes), polar vessels, and icebreakers. NSF is also a major supporter of manned submersible activities. Other support includes both the technological development and emplacement of seafloor observatories, remotely operated vehicles, autonomous underwater vehicles, and other instrumentation such as communications technology. Finally, the Ocean Drilling Program, supported by NSF in concert with numerous international partners, enables access to the Earth's undersea crust by drilling into the sea floor to recover rocks and sediment.

United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA)

Exploration is the first step in understanding Earth's environment, undertaking wise stewardship of resources, and understanding ecosystem functioning. NOAA's mission in this area includes finding new resources, bioprospecting materials from exotic species, inspecting new life forms, investigating gas hydrates and associated ecosystems, and exploring mineral-rich geologic deposits. Additionally, NOAA is charged with protecting, developing, and conserving poorly understood resources, including unexplored fisheries, their habitats and ecosystems, deep corals and live bottoms, and our cultural heritage, which encompasses shipwrecks and submerged cultural resources. In addition, NOAA's ocean management programs, such as the National Marine Sanctuary System, seek to fill large gaps in our fundamental understanding of coastal and ocean phenomena through use of exploration technologies and programs. NOAA is also seeking to understand ocean noise, both natural sound levels and human-induced noise, and their effects on marine animals. The organization also works toward developing technologies to support exploration, which will facilitate access to remote, difficult environments, surface to sub-sea floor, and long-term observations and sampling of the biota and environment. NOAA's mission also includes a mandate to conduct education and outreach activities to build an ocean constituency and educate the public on ocean issues. The three most prominent ocean exploration programs currently housed at NOAA are the National Undersea Research Program, the Sustainable Seas Expeditions, and the VENTS Program. NOAA is also hoping to introduce an Ocean Exploration Initiative for FY 2002, which would support discovering new resources, understanding ocean sound, exploring frontier areas, protecting America's maritime heritage, education and outreach activities, as well as data management activities. NOAA strongly supports the concept of a Census of Marine Life, and technology development to improve fish stock assessments.

United States Department of Interior, Minerals Management Service (MMS)

The MMS, a bureau of the U.S. Department of the Interior, is this nation's manager of mineral resources on and under the sea bed of the outer continental shelf (OCS). The bureau has a two-fold mission: ***1)*** Collect, verify and distribute mineral royalties from tribal and federal offshore and onshore lands and ensure a fair return to the American public; and ***2)*** Manage the oil and gas and other mineral resources of the OCS in a safe and environmentally sound manner.

In order to meet its environmental and safety responsibilities, the MMS conducts environmental and engineering research to provide information for management decisions on all phases of mineral resource development activities on the OCS. This research is focused to meet management needs for informed decision making. Environmental research is conducted through the Environmental Studies Program, which has been funded at $19.5 million per year for the past several years. Scientists from academic and research institutions, the private sector, state agencies and other federal agencies conduct virtually all of MMS's research. The MMS has formal research partnerships, called "Coastal Marine Institutes," with Louisiana State University, the University of Alaska at Fairbanks, and the University of California at Santa Barbara.

While MMS research is directed to specific information needs for OCS mineral management purposes, some of that research has been exploratory in nature and has led to major scientific discoveries. Some examples are: discovery of chemosynthetic communities and species in the Gulf of Mexico; initial understanding of noise impacts on marine mammals; better understanding of three-dimensional water circulation on the shelf and slope; and knowledge about the migration patterns of several species of endangered whales via satellite telemetry. Extensive MMS research efforts in the 1970s and 1980s led to the discovery and classification of numerous new species of benthic invertebrates from the OCS.

Beginning in FY 2001, MMS will initiate a marine biotechnology effort. Specifically the bureau, working through its California and Louisiana Coastal Marine Institutes, will conduct research on the taxonomic and genetic biodiversity found on offshore oil and gas platforms, and analyze selected taxa for bioactive compounds that may have pharmaceutical and other commercial applications. Other research initiatives are the intensive investigation of the physical oceanography and benthic ecology of the deep water (water depths greater then 350 meters) Gulf of Mexico, and continued field investigations of the impacts of human-induced noise on marine mammals.

United States Department of Energy (DOE)

Ocean exploration to DOE is the search for energy resources in the ocean's coastal zones and continental shelf. Offshore oil and gas production has been an integral part of domestic and global energy supply for more than 30 years. That contribution has been made possible by a vast investment in the knowledge, technology, and infrastructure needed for production at steadily increasing water depth. With the continuing decline in our domestic onshore oil production and the projected increase in natural gas use, the economic, safe, and environmentally benign production of oil and gas resources in deep- and ultra-deep water will be even more important. To achieve that goal, DOE will partner with other agencies, industry, academia, the national laboratories, and other stakeholders in developing the knowledge and technologies needed. DOE will also be seeking an understanding of the role the oceans play in the Earth's carbon cycle, and how this understanding can contribute to climate change. DOE has also been given the lead responsibility for an interagency program on methane hydrates — ice-like structures containing methane — which are estimated to have a resource potential exceeding that of all other fossil resources. Understanding the nature and behavior of hydrates and their possible impacts on deep-water oil and gas production and climate change, as well as determining whether their contained methane can be economically and safely produced, will be important elements in our understanding of the ocean and its resources.

United States Navy

With the ocean critical to our national security and its primary operating environment, the Navy plays a key role in federal ocean programs. The Office of Naval Research supports ocean exploration as part of its discovery and invention program. The Oceanographer of the Navy is responsible for all operational oceanography in the Navy, including advanced research and development to support it. Ocean exploration is often an outcome and benefit of systematic in-situ and remote data collection activities that the Navy undertakes to map the ocean bottom and diagnose its structure and behavior in support of military operations. Science and exploitation are often built upon such ocean survey results.

Navy niches in such partnership efforts include technology, data management, operational oceanography, cutting-edge science, and the opportunity for pure discovery.

United States Geological Survey (USGS)

Maps, in the broadest sense, are one of the most valuable products of exploration. The mapping of the deep EEZ through the mid-1980s showed that systematic mapping can be carried out on a large scale. The value of a systematic and phased effort was also demonstrated. Detailed seafloor maps invariably expose new features and provide evidence of unknown processes. As map coverage expands, the variety and large-scale structure of the seafloor is revealed. Subsequent developments have enabled high-resolution mapping in shallow waters. Results from the shallow shelf are no less exciting and no less surprising. Mapping is only one facet of exploration, but a critical one that returns a picture of the previously unknown and guides further exploration.

OCEAN EXPLORATION PANEL PROCESS

On June 12, 2000, the President directed the Secretary of Commerce to convene a panel of leading ocean explorers, scientists, and educators to recommend a national ocean exploration strategy. The responsibility for convening the panel of experts within 120 days was delegated to the National Oceanic and Atmospheric Administration (NOAA), within the U.S. Department of Commerce. At the request of the Undersecretary for Oceans and Atmosphere, Dr. D. James Baker, the NOAA Science Advisory Board (SAB) selected the panel of experts, and specifically designated the Chair of the Panel. Technical experts within the federal government were added to the Panel in an advisory capacity.

The Ocean Exploration Panel was designated as a working group of the NOAA SAB, a federal advisory committee. The 23-member Panel met twice. At the first meeting in Washington, D.C., on August 22-23, 2000, they reviewed current ocean exploration activities presented by government agencies, industry, and non-profit organization representatives. Following this meeting, the Panel drafted their report. A notice of the meeting was published in the Federal Register and public input was solicited. The Panel met again on September 14-15, 2000, in Monterey, California, to review progress on the report. The Panel's work on this report was completed through the extensive use of e-mail following the meeting in Monterey. To consult with various federal agencies during this process, an Interagency Task Force was created. NOAA, NASA, DOE, EPA, USGS, MMS, NSF and the Navy were represented on this Task Force. NOAA provided all necessary administrative and logistical support to the Panel to carry out this assignment. Information and points of contact were provided throughout the process on a public website maintained by NOAA.

ACKNOWLEDGEMENTS

Norman Y. Mineta
Secretary of Commerce

The Secretary of Commerce, Norman Y. Mineta, wishes to acknowledge the work of Dr. Marcia McNutt and the Ocean Exploration Panel. The Panel maintained a rigorous schedule to create this report within a mandated 120-day period. Additionally, the hard work of the Science Advisors to the Panel assured that this report will meet the needs of a community of ocean technology and scientific experts.

The Secretary also wishes to thank Marcia Collie, Claire Johnson, Michael Kelly, Christine Maloy, Barbara Moore, and Pam Rubin, the NOAA support team whose hard work and dedication produced this document and organized the working of the Panel.

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Vibrant christmas tree worms. National Oceanic and Atmospheric Administration

Page 28 *(center)*

Vampyroteuthis infernalis, vampire squid. Reisenbichler, Kim/Monterey Bay Aquarium Research Institute ©1996 MBARI

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Polyorchis pencillatus, midwater jelly. Raskoff, Kevin/Monterey Bay Aquarium Research Institute ©1998 MBARI

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The Jason XII Expedition to Hawaii 2001 logo: A Living Laboratory. © The Jason Project

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A diver examining a marine archaeological artifact. Gergk, Christoph © Hilti Foundation/Franck Goddio/Discovery Channel

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Three seagliders aboard the *R/V Miller* in Puget Sound, WA. Seagliders are small remotely controlled autonomous vehicle that repeatedly glide down and up through the ocean as they measure temperature, salinity, current, oxygen, chlorophyll, and other properties. They are designed to dive as deep as 2 km, operate for many months, and travel as far as a quarter of the way around the world. Woods Hole Oceanographic Institution © WHOI

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The Autonomous Benthic Explorer known as ABE. Woods Hole Oceanographic Institution © WHOI

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Compilation of hydrophone sites for passive underwater acoustics. Fox, Chris/National Oceanic and Atmospheric Administration

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Woods Hole Oceanographic Institution © WHOI

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The *Alvin* submersible with microchemical sensor in manipulator at a hydrothermal vent. Woods Hole Oceanographic Institution © WHOI

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A molecular biologist refines probes for detecting toxic algae. Leet, M. Monterey Bay Aquarium Research Institute © 1997 MBARI