CHAPTER 25: CREATING A NATIONAL STRATEGY FOR INCREASING SCIENTIFIC KNOWLEDGE

Ocean managers and policy makers need comprehensive scientific information about the ocean and its environment to make wise decisions. Increased knowledge can support sustainable resource use, economic development, and conservation of the ocean's biological diversity and natural beauty. A national strategy is needed to ensure the highest return on the nation's investment in ocean research, exploration, and marine operations. The strategy should coordinate and prioritize basic and applied research supported by federal agencies, increase partnerships with the academic and private sectors, promote enhanced ocean exploration, and coordinate federal marine operations to reduce redundancies. Significantly increased funding for research in ocean-related natural and social sciences and a renewed commitment to ocean exploration are keys to fostering a new era of ecosystem-based management supported by science.

FORTIFYING THE FOUNDATIONS OF OCEAN UNDERSTANDING

Ocean science and technology are integral parts of the overall U.S. research enterprise and contribute greatly to society. They are essential to understanding the Earth's environment and how it changes over time, managing marine resources wisely, finding beneficial new uses of ocean resources, and protecting national security. In addition, important technological advances have resulted from devices originally developed for ocean research and exploration, such as medical acoustic tools that grew out of sonar technologies.

Components of Ocean Science and Technology

For the purpose of this and the following three chapters of Part VII, ocean science and technology is defined as:

- the exploration of ocean environments, and the conduct of basic and applied research to increase understanding of (1) the biology, chemistry, physics, and geology of the oceans and coasts, (2) oceanic and coastal processes and interactions with terrestrial, hydrologic, and atmospheric systems, and (3) the impacts of oceans and coastal regions on society and of humans on these environments; and
- the development of methodologies and instruments to improve that understanding.

Knowledge about the oceans advanced remarkably during the 20th century due to significant financial investments, a host of multidisciplinary and interdisciplinary studies, new technologies, and an expanding community of dedicated experts. Despite this progress, the ocean remains one of the least explored and understood environments on the planet—a frontier for discoveries that could provide important benefits. A broader understanding of coastal waters and the deep ocean is essential to enable the practice of ecosystem-

based, multi-use, and adaptive management and to conserve biodiversity. Ocean science and technology will play an increasingly central role in the multidisciplinary study and management of the whole-Earth system.

The chapters of Part VII focus on four building blocks of a renewed and restructured U.S. commitment to ocean science and technology:
1) a national strategy for conducting research, exploration, and marine operations at the federal level and in partnership with academia and private organizations (Chapter 25);
2) an integrated ocean observing system to better measure and predict ocean conditions and processes (Chapter 26);
3) the infrastructure and technology development needed to conduct and support ocean science (Chapter 27); and
4) data and information management to handle and manipulate research data and generate useful products for resource managers and the general public (Chapter 28).

Federal Leadership in Ocean Science and Technology

Since the mid-1900s, the U.S. government has assumed a leadership role in ocean science and technology. Today, fifteen federal agencies support or conduct diverse activities in ocean research, assessment, and management. The heads of these agencies direct the National Oceanographic Partnership Program (NOPP), which coordinates national oceanographic research and education. NOPP has provided a useful venue for agencies to support selected ocean science and technology projects, but it has not realized its full potential as an overarching mechanism for coordination among federal agencies or between federal activities and those of state, local, academic, and private entities.

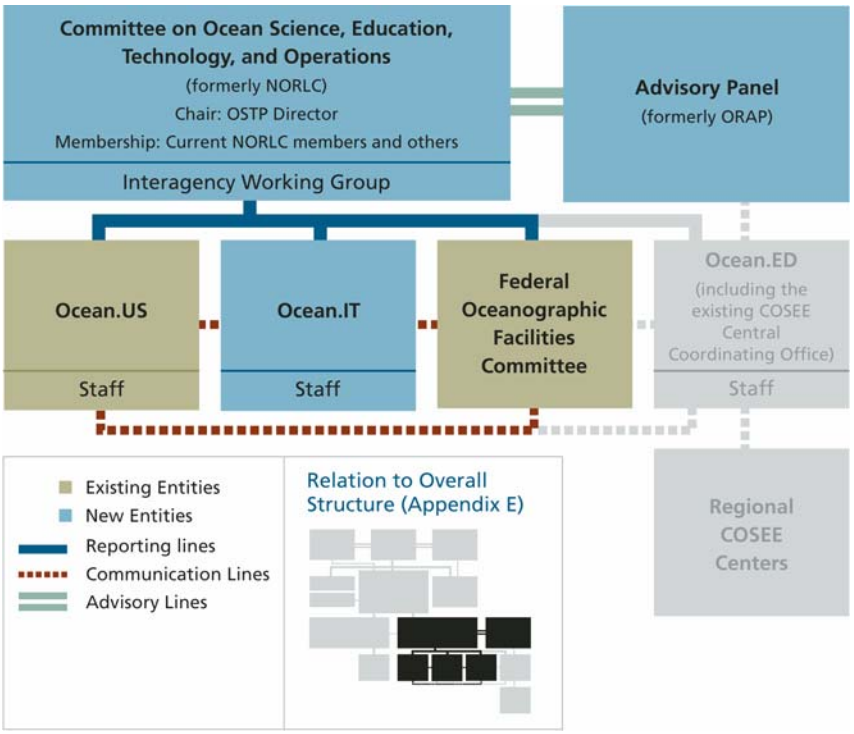
Under the new National Ocean Policy Framework proposed in Chapter 4, the National Ocean Council (NOC) will serve as the federal coordinating body for all ocean-related activities and the NOC's Committee on Ocean Science, Education, Technology, and Operations (COSETO) will assume leadership of NOPP. This new structure will allow for the design and implementation of a national strategy to promote ocean research, education, observation, exploration, and marine operations. NOPP's existing offices and committees will be incorporated within this structure (Figure 25.1). Ocean.US, the lead office for planning the Integrated Ocean Observing System (IOOS), and the Federal Oceanographic Facilities Committee, which provides advice related to oceanographic facilities, will both report to COSETO. An additional planning and coordinating body, Ocean.IT should be added to COSETO to provide stronger integration for information technology activities. (The creation of Ocean.IT is discussed in Chapter 28.)

ESTABLISHING A NATIONAL STRATEGY

The United States does not have a national strategy for ocean and coastal research, exploration, and marine operations that can integrate ongoing efforts, promote synergies among federal, state, and local governments, academia, and the private sector, translate scientific and technological advances into operational applications, and establish national goals and objectives for addressing high-priority issues. Instead, for the most part, each federal ocean agency independently addresses its own specific information needs.

A national strategy can help meet the ocean resource management challenges of the 21st century and ensure that useful products result from federal investments in ocean research. Moving toward ecosystem-based management approaches will require a new generation of scientific understanding. Specifically, more needs to be known about how marine ecosystems function on varying spatial scales, how human activities affect marine ecosystems and how, in turn, these changes affect human health.

Figure 25.1. Proposed Structure for the Coordination of Federal Ocean Research Activities



Shown here are the institutional components that should be established under the National Ocean Council's Committee on Ocean Science, Education, Technology, and Operations (COSETO) recommended in Chapter 4. COSETO's purpose is to improve federal leadership and coordination in ocean science, education, technology, and marine operations. This diagram also illustrates the organizational links between the new Ocean.IT and other existing and planned units under COSETO. Entities shaded in gray are discussed in Chapters 4 and 8.

Ecosystem-based management will also require a deeper understanding of biological, physical, chemical, and socioeconomic processes and interactions. For example, as coastal population growth feeds a demand for new construction, managers will need to know which activities may cause rapid erosion of the beach, increased turbidity that harms a coral reef, or economic disruption. In another example, fishery conservation can be promoted by protecting spawning grounds and other essential habitat; to make this possible, scientists and managers must understand the fundamental biology of the fish species.

Maintaining overall ecosystem health also requires an improved understanding of biological diversity on different levels, including genetic diversity (the variety of genetic traits within a single species), species diversity (the number of species within an ecosystem), and ecosystem diversity (the number of different ecosystems on Earth). The largest threats to maintaining diversity on all three scales are human activities, such as overfishing, pollution, habitat alteration, and introductions of non-native species. The extent of marine biological diversity, like so much about the ocean, remains unknown. But based on the rate at which new species are currently being discovered, continued exploration of the ocean is almost certain to result in the documentation of many additional species that can provide fresh insights into the origin of life and human biology.

A national strategy should promote the scientific and technological advances required to observe, monitor, assess, and predict environmental events and long-term trends. Foremost in this category is climate change. The role of the ocean in climate, although critical, remains poorly understood. The ocean has 1000 times the

heat capacity of the freshwater lakes and rivers, ocean circulation drives the global heat balance, and ocean biochemistry plays a primary role in controlling the global carbon cycle.

The process of climate change should be examined both on geologic time scales, such as the transitions between ice ages, and over shorter periods of time. The buildup of greenhouse gases in the atmosphere will increase the melting of polar ice, introducing large quantities of fresh water into the North Atlantic. Many researchers now believe that could drastically change ocean circulation and weather patterns in the span of a couple of years.[1] In particular, the Gulf Stream could slow or stop, causing colder temperatures along the eastern seaboard of the United States and ramifications around the globe. It is in man's interests to learn more about the processes that lead to abrupt climate changes, as well as their potential ecological, economic, and social impacts.

Even as we try to comprehend the role of the ocean in climate change, we need also to understand the effects of climate change on ocean ecosystems. If temperatures around the globe continue to warm, sea level will continue to rise, putting many coastal residents at greater risk from storm surges and erosion. For individual ecosystems, even small changes in ocean temperature can put the health and lives of sea creatures and humans at risk. Ocean monitoring, through programs like the IOOS, will be essential for detecting and predicting changes more accurately, thereby improving prospects for minimizing harmful effects.

Some large initiatives, such as the U.S. Climate Change Science Program and the Census of Marine Life, have been launched in the last couple of years to study large-scale research topics. However, many of the issues most relevant to the needs of coastal managers do not occur on such global scales. Due to the regional nature of many ocean and coastal ecosystem processes, regional-scale research programs are also needed. Currently, insufficient emphasis is placed on this kind of research. The regional ocean information programs discussed in Chapter 5 are designed to close this gap and increase our understanding of ocean and coastal ecosystems by prioritizing, coordinating, and funding research that meets regional and local management needs.

At the state level, the National Oceanic and Atmospheric Administration's (NOAA's) National Sea Grant College Program can make essential contributions to achieving research goals. The state Sea Grant programs have the organization and infrastructure necessary to fund research and conduct educational activities that will expand understanding of ocean ecosystems up and down our coasts. Sea Grant's current strategic plan focuses on promoting ecosystem-based management and on involving constituencies from government, universities, the public and the private sector, all of whom are needed to strengthen the U.S. research enterprise.[2]

It is time for the United States to establish a national strategy for ocean research investments, and oversee implementation and funding of programs throughout the ocean science community. This plan should address issues at the global, regional, state, and local levels. It should emphasize ecosystem-based science to help resolve the current mismatch between the size and complexity of marine ecosystems and the fragmented nature of science and the federal structure. Better coordination and integration will help provide the information needed to sustain resources, protect human lives and property, identify and nurture new beneficial uses, and resolve issues that result from competing activities. A unified national approach to ocean research, exploration, and marine operations, structured around national investment priorities, will also result in wiser and more efficient use of resources.

ADVANCING OCEAN AND COASTAL RESEARCH

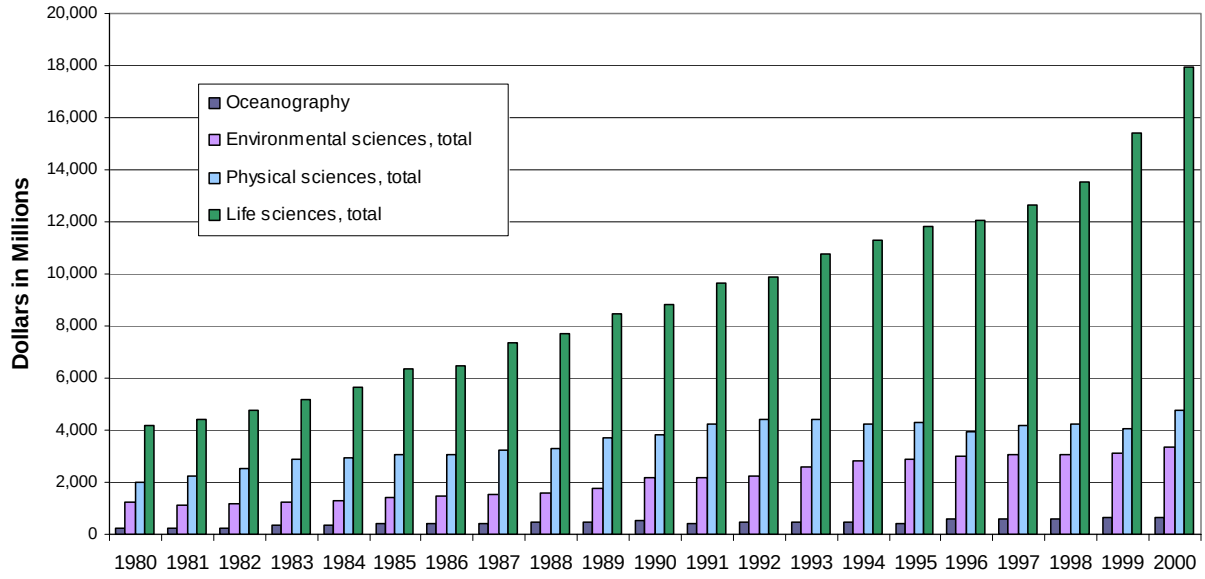
Better coordination of ocean and coastal research is needed at all levels and across all sectors. Increases in funding, changes in grant practices, and the establishment of new partnerships are all essential to maximize the national research enterprise. Advances in social science and economic research are particularly important to generate information needed for the wise management of ocean resources.

Reviving the Federal Investment

The United States has a wealth of ocean research expertise spread across a network of government and industry laboratories and world-class universities, colleges, and marine centers. With strong federal support, these institutions made the United States the world leader in oceanography during the 20th century. However, a leader cannot stand still. Ocean and coastal management issues continue to grow in number and complexity, new fields of study have emerged, new interdisciplinary approaches are being tried, and there is a growing need to understand the ocean on a global and regional scale. All this has created a corresponding demand for high-quality scientific information.

Federal investments during the cold war years of the 1960s and 1970s enabled scientists to help promote our national economy and security through research into the fundamental physical, chemical, biological, and geological properties of the oceans. During that period, ocean research funding constituted 7 percent of the federal research budget. However, the federal investment in ocean research began to stagnate in the early 1980s, while investments in other fields of science continued to grow (Figure 25.2).[3] As a result, ocean research investments comprise a meager 3.5 percent of today's federal portfolio.

Figure 25.2. Ocean Research Neglected as Part of the National Research Budget



Funding for oceanography has remained stagnant for twenty years while other scientific disciplines have experienced steady increases in research funding.

Source: National Science Foundation. *Federal Funds for Research and Development, Detailed Historical Tables: Fiscal Years 1951–2002*. <http://www.nsf.gov/sbe/srs/nsf03325/> (Accessed January, 2004).

The current annual federal investment of approximately $650 million in marine science is well below the level necessary to address adequately the nation's needs for coastal and ocean information. Unless funding increases sharply, the gap between requirements and resources will continue to grow and the United States will lose its position as the world's leader in ocean research.

Recommendation 25–1. Congress should double the federal ocean and coastal research budget over the next five years, from the 2004 level of approximately $650 million to $1.3 billion per year.

A portion of these new funds should be used to:

- *support regional research, directed by the regional ocean information programs discussed in Chapter 5.*
- *significantly enlarge the National Sea Grant College Program.*
- *support other high priority research areas, as outlined throughout this report.*

Coordination and Prioritization

To ensure that increased investments are used wisely and that important research activities continue, federal agencies will need to create long-term strategic plans and remedy structural problems in their grant mechanisms.

In creating long-term plans, a balance must be reached between funding basic, curiosity-driven research conducted mostly at universities and marine research centers and more applied research conducted largely at government laboratories to support operations, management, and monitoring activities. Over time, changes in national priorities may shift the balance slightly between basic and applied research but the enduring value, and often unexpected outcomes, of basic research should never be underestimated. Basic oceanographic research in the 1940s, 1950s, and 1960s increased our understanding of ocean currents, marine acoustics, seafloor geology, and robotics, and basic research supported by the U.S. Navy has led to many widely-used and versatile new technologies, such as the Global Positioning System. Improved cooperation between federal labs and academic institutions can combine the strengths of both, ensure that quality research is conducted, and achieve a balance between basic and applied science.

Problems in the current system for awarding federal research grants make it difficult to conduct the kind of interdisciplinary, ecosystem-based research required to understand the ocean environment. Short-term research grants of two- to five-years duration are now typical. This type of funding is useful for research on discrete topics of limited scope, and has the advantage of giving agencies the flexibility to adjust quickly to changing priorities. However, it is not adequate to acquire the continuous data sets that will be essential for examining environmental changes over time.

In addition, a variety of mechanisms are used by federal agencies to review proposed ocean research grants. Some of these mechanisms work better than others. Grant review systems that are not open to all applicants or that do not use an objective review process for ranking proposals are unlikely to produce the highest quality research. Systems that favor established researchers to the detriment of young scientists, whether intentionally or not, are also flawed, stifling diversity and limiting the infusion of new ideas. When all research proposals, including those from scientists working at federal labs, are subject to the same rigorous review process, tax dollars are more likely to support the best science. Streamlined grant application and review processes will also help get more good science done in a timely way.

The ocean science community includes many scientists outside academic and federal labs. Although coordination among sectors has steadily improved, the process remains mainly ad hoc, without the backing of a national strategy and leadership. A clearer understanding of the respective strengths and roles of the different sectors could lead to productive new research partnerships, foster intellectual risk-taking, leverage funding, and encourage participation in large multi-sector research efforts valuable to the nation.

There is also a need to gain feedback from managers at state and federal levels and from the private sector that can guide new research directions and technology development. The regional ocean information programs recommended in Chapter 5 will provide an excellent mechanism for gaining input on user needs and regional research priorities.

A mechanism is required to coordinate federally funded ocean research (both basic and applied), support long-term projects, and create partnerships throughout all agencies and sectors. Transparent and

comprehensive research plans would achieve these goals and ensure that research results can be translated into operational products in a timely manner.

Recommendation 25–2. The National Ocean Council should develop a national ocean research strategy that reflects a long-term vision, promotes advances in basic and applied ocean science and technology, and guides relevant agencies in developing ten-year science plans and budgets.

The national strategy should:

- *require agencies to provide multi-year (greater than 5 year) funding opportunities.*
- *reiterate the importance of balancing basic and applied research projects.*
- *promote the transition of basic research results to applied uses.*
- *require a system of independent review for all grant applications, including those from federal labs.*
- *recognize the different ocean science sectors (government, academic, commercial, and non-governmental), clarify their roles, and maximize the use of partnerships.*
- *incorporate the science needs and priorities of local, state, regional, and national managers, working through the regional ocean information programs described in Chapter 5.*

Each agency's first ten-year science plan should include a detailed strategy for how the proposed doubling of federal ocean research investments would be incorporated into new and ongoing activities.

The Need for Social and Economic Research

The ocean and coastal environment is rife with conflicts among competing users and between groups of people applying different sets of values to the same issues. To resolve these conflicts, information is needed not only about the natural environment but also about relevant social, cultural, and economic factors. The funding required to increase knowledge in these areas is modest when compared to the cost of the ships, labs, and instruments used in oceanographic research. Nevertheless, social and economic research related to our coasts and oceans has long been overlooked.

A Neglected Research Area

The National Sea Grant College Program does fund some studies that examine legal, political, economic, anthropological, and other human dimensions of ocean and coastal affairs. However, these projects often receive less than 10 percent of the program's overall research budget. In other research programs, social and economic science garners even less support, creating a situation where basic information is not available to support management and planning.

To meet specific programmatic requirements of the National Environmental Policy Act (NEPA) and other laws that require impact analyses, individual resource management agencies have had to pull together social science and economic information at various times. For example, NOAA's National Marine Fisheries Service hired anthropologists and economic researchers following enactment of the 1976 Magnuson–Stevens Fishery Conservation and Management Act. The Minerals Management Service instituted a socioeconomic research program in the 1970s to aid in developing five-year leasing plans that would meet NEPA standards. The U.S. Army Corps of Engineers has also funded research into marine cultural heritage to meet its NEPA obligations. And in the 1990s, NOAA's National Ocean Service created the Coastal Services Center to help generate information on coastal demographics. Although wide-ranging, these efforts remain ad hoc, uncoordinated, and related to specific issues that wax and wane in importance over time. Furthermore, the data developed on an agency-by-agency basis are often mutually incompatible and hard to access.

Recently, NOAA has begun to reassess its needs for social and economic information. In 2003, a panel of social scientists established by its Science Advisory Board concluded that NOAA's support for social sciences is not comparable to that of other agencies with similar environmental assessment and stewardship responsibilities and that this shortcoming has hindered the agency's ability to accomplish its mission.[4] NOAA's National Marine Protected Areas Center also issued a report identifying high-priority social science needs to support the planning, management, and evaluation of marine protected areas.[5]

Some existing and emerging ocean and coastal issues that will require better social and economic information include:

- multiple-use controversies in the coastal zone;
- novel offshore uses, such as the proposed introduction of offshore wind farms;
- consensus-based decision making involving stakeholders, watershed councils, public-private partnerships, and numerous nongovernmental organizations;
- changes in coastal communities due to shifts in fisheries policy, growth of the tourism industry, and redevelopment of ports and waterfronts;
- changes in coastal demographics; and
- varying perceptions of coastal environmental values.

Any decision affecting our oceans and coasts should take socioeconomic information into account, harnessing expertise from a wide range of specialties to deal with issues that demand a broad range of knowledge. This will require integrated assessments by teams of natural and social scientists working together with stakeholders and policy makers. Such an approach, which has been employed in the context of climate change, is especially well suited to emerging ocean issues that require a merger of natural and social sciences, technology, and policy.

The Coastal and Ocean Economy

Cost-benefit analyses to support ocean and coastal decisions require enhanced economic data. However, the major federal economic statistical agencies have neither the mandate nor the means to study the ocean and coastal economy.

NOAA undertakes some economic analyses in support of its various missions. For example, its Coastal and Ocean Resource Economics Program has assessed the economic impacts of fishery management plans and marine sanctuaries. NOAA has also worked with other federal agencies to conduct the first major examination of the economics of marine-related recreation.[6] But NOAA's economic analyses tend to be directed at very specific purposes associated with particular programs. NOAA has not supported sustained, consistent, and comprehensive data collection and analyses on the ocean and coastal economies.

To lay the groundwork for a broader program, NOAA and the U.S. Environmental Protection Agency are helping support the National Ocean Economics Project, a multi-year research initiative involving economists from several universities. While this effort is generating valuable information, including much of the economic data used in this report, it remains a research project. To be useful in understanding coastal and ocean economies and assessing the impacts of management policies on individuals, businesses and communities, a long-term, operational program is needed. Coordination between the federal government and other entities will be needed to generate the socioeconomic data required for operational activities (Table 25.3). NOAA, as the federal agency with principal responsibility for the oceans, should take the lead in bringing these parties together to provide the economic data needed for ocean and coastal decision making at the federal, state, regional, and local levels

Table 25.3. Organizations with Important Roles in Collecting and Distributing Socioeconomic Data on the Ocean and Coasts
The organizations listed below will play key roles in creating an operational coastal and ocean economics program to support management activities.

Entity	Role
National Oceanic and Atmospheric Administration	Current economic activities are performed by the National Marine Fisheries Service to help draft and defend Fishery Management Plans and by the Coastal and Ocean Resource Economics (CORE) Program, which conducts individual studies on issues of interest, such as economic valuations of beaches or coral reefs.
Bureau of Labor Statistics	In cooperation with the states, the Bureau collects the largest amount of basic employment and wage data on the U.S. economy. These data will continue to be the fundamental elements used for monitoring the coastal and ocean economies at national, regional, and local levels.
Bureau of the Census	The Census Bureau is the other major collector of primary data on the economy, including the tabulation of population, housing and major economic sectors.
U.S. Department of Agriculture	USDA has responsibility for the Census of Agriculture, which includes data on aquaculture.
Bureau of Economic Analysis	BEA uses inputs from the data-collecting agencies to maintain the most important measure of annual economic activity: the national income and product accounts, whose best-known element is the gross domestic product. Related measures, such as the gross state product, are key to understanding regional economies, as is the measurement of self-employment.
U.S. Environmental Protection Agency	EPA undertakes substantial economic research in the fields of land, water, and air pollution. EPA's economic research focuses particular attention on nonmarket values, and provides an important supplement to the National Oceanic and Atmospheric Administration's work in this area.
National Science Foundation	NSF supports much of the basic research in the sciences, including the social sciences. It has recently undertaken new initiatives to better integrate the natural and social sciences to improve management of the environment and natural resources.
Bureau of Transportation Statistics	BTS collects and analyzes data relative to maritime trade and transportation, such as tonnage of U.S. commerce shipped, and foreign vessel entries and departures at major U.S. ports.
Universities and Other Researchers	As with marine science in general, the majority of research on the coastal and ocean economies is a cooperative arrangement among the federal government and researchers in the nation's universities and private research organizations. The interaction among federal, academic, and private researchers benefits from the strengths of multiple perspectives and organizational missions.

Key functions of an operational program for ocean economic data should include:

- *Data Collection*—Standard measures of employment, income, and output for ocean and coastal economies must be developed. The National Ocean Economics Project provides a foundation for this work, but additional measures are needed to assess: the influence of oceans and coasts on land values; the role of the oceans in the tourism and recreation industries in terms of both market and non-market values; and the economic value of ecosystem services provided by the oceans and coasts.

- *Data Distribution*—Data must be easily accessible to policy makers to assist in management decisions and to scientists to facilitate further research. The availability of modern database and Internet delivery systems has made this function much easier and cheaper than in the past.

- *Data Analysis*—Data only become useful outside the academic realm when they are analyzed and transformed into information products. Data analyses should be tailored to federal, regional, state, and local needs. Socioeconomic trends should be analyzed and linked to environmental trends. Geographic Information Systems will facilitate the integration of socioeconomic and natural resource data.

- *Education and Research*— Additional research should focus on improving measurements of nonmarket values, developing ways to quantify the use of ocean and coastal resources, and standardizing measures such as employment and output. The field of ocean and coastal economics is relatively new and primarily confined to a small group of specialists. To accommodate the growing demand for expertise in this field, expanded training of scientists and policy specialists will be required.

Recommendation 25–3. The National Ocean Council should create a national program for social science and economic research to examine the human dimensions and economic value of the nation's oceans and coasts. All ocean research agencies should include socioeconomic research as part of their efforts.

Implementation of the national program should include:

- *designation of an operational socioeconomic research and assessment function within the National Oceanic and Atmospheric Administration (NOAA).*
- *creation of an interagency group, chaired by NOAA, and including the Bureau of Labor Statistics (BLS), Bureau of the Census, Bureau of Economic Analysis (BEA), U.S. Department of Agriculture, U.S. Environmental Protection Agency, and National Science Foundation.*
- *preparation of biennial reports by BLS and BEA on the employment, wages, and output associated with U.S. coasts and oceans.*
- *preparation of biennial reports by the Bureau of Transportation Statistics on intermodal access to U.S. ports and maritime facilities and assessments of relevant maritime system performance and economic data.*
- *support for periodic reports on such topics as coastal demographics, geographic patterns and trends of ocean and coastal use, economic contributions, attitudes and perceptions, functioning of governance arrangements, and public–private partnerships.*
- *coordination of efforts to take maximum advantage of the expertise resident within government agencies, universities, and the private sector.*
- *creation of formal mechanisms for interacting with the regional ocean information programs so that changes at regional, state, and local levels can be documented and analyzed.*

Funding for these efforts should be at least $8–$10 million a year. While this amount may seem substantial in a time of scarce budgetary resources, it is less than one-tenth the amount the federal government currently spends on economic research related to agriculture, although the ocean economy is 2.5 times larger than agriculture in terms of total production of goods and services (Appendix C).

BUILDING A NATIONAL OCEAN EXPLORATION PROGRAM

Ocean exploration missions conducted during the 19th and 20th centuries were the first attempts to document how deep the oceans are, to chart key bathymetric features, and to identify and study marine life. Previously, the oceans were viewed as mere highways for maritime commerce, void of life below 1,000 feet. But despite the important discoveries made during these missions, we still have only a cursory understanding of the deep ocean.

The Value of Ocean Exploration

About 95 percent of the ocean floor remains unexplored, much of it located in harsh environments such as the polar latitudes and the Southern Ocean. Experience teaches us, however, that these vast and remote regions teem with undiscovered species and resources. On virtually every expedition, oceanographers discover fascinating new creatures. Some, such as the giant squid, have never been seen alive and are known only from dead specimens washed ashore or snagged in fishing gear.

Advances in deep-sea technologies have also made it easier to locate shipwrecks and historical artifacts lost in the ocean depths, such as the stunning discovery of the *RMS Titanic* in 1985. The continued exploration of marine archaeological sites will help us to better understand human history and our global cultural heritage.

In addition, preliminary evidence indicates that immense new energy sources exist in the deep sea. The amount of carbon bound in frozen gas hydrates on the seafloor is conservatively estimated to be twice the total amount of carbon existing in all the other known fossil fuels on Earth.[7]

Ocean exploration also offers an unprecedented opportunity to engage the general public in marine science and conservation. Exploration missions to the depths of the ocean provide images of ancient human artifacts, amazing creatures, and never-before-seen ecosystems. These images fire the imagination of people of all ages and can be used in both formal and informal educational settings. This kind of popular excitement and support can be an enormous asset in sustaining exploration projects over the long term.

Given the importance of the ocean in human history and in regulating climate change, guaranteeing food security, providing energy resources, and enabling worldwide commerce, it is astounding that we still know so little about it. This is due primarily to the lack of a long-term, large-scale national commitment to ocean exploration. The ocean and its depths need to be systematically explored to serve the interests of the nation and humankind.

Growing Calls for a National Program

Although our dependence on healthy marine ecosystems continues to grow, ocean exploration remains a relatively minor component of U.S. ocean science and is a missing link in the national strategy to better understand Earth's environment. Comprehending the genetic diversity of ocean life, developing fisheries, discovering energy resources, and mapping the seafloor all require more extensive exploration. U.S. leadership in ocean exploration will increase what we know about all aspects of ocean life and resources and make it possible to reach management decisions based on more complete scientific information.

There have been many calls for a dedicated national ocean exploration program. The Stratton Commission recommended an international program on a global scale.[8] In response, the United States led the International Decade of Ocean Exploration (IDOE) in the 1970s. IDOE programs greatly improved ocean observation systems, and led to such important research programs as Geochemical Ocean Sections, the Joint Global Ocean Flux Study, the Ridge Interdisciplinary Global Experiments, and the World Ocean Circulation Experiment. These initiatives dramatically enhanced our understanding of the global climate system, geochemical cycling, ocean circulation, plate geodynamics, and life in extreme environments.

In 1983, President Reagan directed the U.S. Department of the Interior to take the lead role in exploring the waters of the newly-recognized U.S. exclusive economic zone (EEZ). Three years later, in a report to the President and Congress, the National Advisory Committee on Oceans and Atmosphere (NACOA) detailed

the economic importance of the EEZ and emphasized the need to improve efforts to assess its resources.[9] The NACOA report recognized that federal science programs were making important contributions, but concluded that individual efforts based on separate agency missions were neither comprehensive nor making acceptable progress. In response, the U.S. Geological Survey (USGS) and NOAA were tasked with developing a ten-year exploration plan. Although reconnaissance surveys of much of the EEZ were completed through 1990, more detailed assessments were never pursued. During the late 1990s, efforts to explore the EEZ and beyond lagged due to budgetary constraints.

In 2000, however, the President's Panel on Ocean Exploration called for a robust national ocean exploration program propelled by the spirit of discovery. The panel proposed multidisciplinary expeditions and annual funding of $75 million.[10] These recommendations led to the establishment of the Office of Exploration within NOAA, at a modest funding level of $4 million in fiscal year 2001, and $14 million in each of fiscal years 2002 and 2003. This program is helping NOAA to fulfill its applied science, environmental assessment, and technology development responsibilities, although the program's small budget and agency-specific focus limit its effectiveness.

A 2003 National Research Council report reiterated the need for a comprehensive national ocean exploration program strongly linked to traditional research, with broad international partnerships, and a commitment to educational opportunities.[11] The report offered specific recommendations on exploration priorities, funding needs, management models, and technology and infrastructure requirements.

NOAA and the National Science Foundation (NSF), by virtue of their missions and mandates, are well positioned to lead a global U.S. ocean exploration effort. NOAA currently runs the Office of Ocean Exploration, but NSF's focus on basic research provides an excellent complement to NOAA's more applied mission. Working together, the two agencies have the capacity to systematically explore and conduct research in previously unexamined ocean environments. To succeed, coordination, joint funding, and interactions with academia and industry will be essential.

Recommendation 25–4. Congress should appropriate significant funding for an expanded national ocean exploration program. The National Oceanic and Atmospheric Administration and the National Science Foundation should be designated as the lead agencies, with additional involvement from the U.S. Geological Survey and the U.S. Navy's Office of Naval Research. Public outreach and education should be integral components of the program.

An expanded national ocean exploration program will require a budget of approximately $110 million annually, plus additional funds for required infrastructure (discussed in Chapter 27).

COORDINATING AND CONSOLIDATING MARINE OPERATIONS

The need for routine mapping, monitoring, and assessment of U.S. waters (referred to as marine operations) has grown significantly in the past two decades. Accurate, up-to-date maps and charts of harbors, coastlines, and the open ocean are necessary for many activities, including shipping, military operations, and scientific research. In addition, expanded regulatory regimes rely heavily on routine assessments of living and nonliving marine resources and water quality. However, the ocean environment is changing faster than can be documented by the current number and frequency of surveys.

Modern sensor technologies, which can detect new variables in greater detail in the water column and seafloor, have improved our ability to follow changing ocean and terrestrial dynamics. But as these new technologies are implemented, they need to be calibrated against previous methods, as well as with each other, to provide useful environmental characterizations and ensure the consistency of long-term statistical data sets.

Integrated National Maps and Assessments

At least ten federal agencies, almost all coastal states, and many local agencies, academic institutions, and private companies are involved in mapping, charting, and assessing living and nonliving resources in U.S. waters. However, different organizations use varying methods for collecting and presenting these data, leading to disparate products that contain gaps in the information they present.

Primary Federal Agencies that Conduct Science-based Marine Operations	
U.S. Environmental Protection Agency	U.S. Coast Guard
Minerals Management Service	U.S. Fish and Wildlife Service
National Geospatial-Intelligence Agency	U.S. Geological Survey
National Oceanic and Atmospheric Administration	U.S. Navy
U.S. Army Corps of Engineers	National Science Foundation

Ideally, a variety of information (e.g., bathymetry, topography, bottom type, habitat, salinity, vulnerability) should be integrated into maps using Global Positioning System coordinates and a common geodetic reference frame. In addition, these maps should include living marine resources, energy resources, and environmental data when available, to create complete ocean characterizations necessary for developing and implementing science-based ecosystem-based management approaches. Achieving this integration in the coastal zone is an extremely complex proposition.

By launching the Geospatial One-Stop Portal, the Office of Management and Budget has taken steps to curtail the collection of redundant data, facilitate information sharing, and plan for future integrated mapping and charting. This Web-based server will provide national base maps with administrative and political boundaries that can also incorporate information on agriculture, atmosphere and climate, ecology, economics, conservation, human health, inland water resources, oceans, estuaries, transportation networks, and utilities. In addition, the Federal Geographic Data Committee is developing the National Spatial Data Infrastructure in cooperation with organizations from state, local, and tribal governments, the academic community, and the private sector. This initiative includes policies, standards, and procedures for organizations to cooperatively produce and share geographically-linked data.

The relevant federal agencies must continue to integrate and share data in the quest to create readily accessible maps that track geological, physical, biological, and chemical resources in three dimensions. The fourth dimension—time—should be incorporated wherever possible so changes in ocean resources can be tracked over the short and long terms.

The National Research Council's 2003 study of national needs for coastal mapping and charting includes an examination of the major spatial information requirements of federal agencies and the principal user groups they support, identifies the highest priorities, and evaluates the potential for meeting those needs based on the current level of effort.[12]

Federal Mapping and Charting Activities

Maps of coastal land areas, and charts of nearshore and offshore areas, are essential for safe navigation and for defining boundaries, mitigating hazards, tracking environmental changes, and monitoring uses. Because so many federal agencies have mapping and charting responsibilities (Appendix 5), there are significant overlaps. This situation results in multiple entities within government, industry, and academia undertaking the expensive and time-consuming task of repeating surveys of the same area for different purposes. Furthermore, differences in scale, resolution, projection, and reference frames inhibit the integration of

onshore and offshore data. It is impossible to merge most existing maps and charts to provide a continuous picture of the coastal zone. However, recent advances in the development of satellite positioning systems, mapping sensors, and the manipulation of data have created a new generation of geospatial data products that address some of the key challenges faced by ocean and coastal managers and policymakers.

The U.S. marine transportation system is in particular need of better charts. As this industry prepares for exponential growth over the next twenty years, a backlog of required surveys is developing. Approximately 35,000 square nautical miles of navigationally significant U.S. waters have been designated as critical areas requiring updated information on depth and obstructions.[13] New maps and charts of these waters and ports are essential to minimize shipping accidents and to support the national security missions of the U.S. Navy and U.S. Coast Guard.

Another significant issue is the need to conduct extensive multi-beam sonar mapping of the U.S. continental shelf, where a potential $1.3 trillion in resources (including oil, minerals, and sedentary species) could become available under United Nations Convention on the Law of the Sea (LOS Convention) provisions concerning extensions of the continental shelf. If the United States accedes to the LOS Convention, it would be able to present evidence to the United Nations Commission on the Limits of the Continental Shelf in support of U.S. jurisdictional claims to its continental shelf. The University of New Hampshire's Center for Coastal and Ocean Mapping/Joint Hydrographic Center, in conjunction with NOAA and USGS, has already identified regions in U.S. waters where the continental shelf is likely to extend beyond 200 nautical miles and is developing strategies for surveying these areas.[14] Bathymetric and seismic data will be required to establish and meet a range of other environmental, geologic, engineering, and resource needs.

Consolidation and coordination of the many existing federal mapping activities will increase efficiency and help ensure that all necessary surveys are conducted. NOAA, which has responsibility for collecting hydrographic and bathymetric data and creating navigational charts for safe and efficient maritime commerce, is the logical agency to lead the nation's coastal and ocean mapping and charting activities. Where consolidation is not feasible because of another agency's mission needs, clearer definitions of roles and responsibilities will be helpful. Drawing upon the mapping and charting abilities found in the private sector and academia will also be necessary to achieve the best results at the lowest cost.

Recommendation 25–5. The National Ocean Council (NOC) should coordinate federal resource assessment, mapping, and charting activities with the goal of creating standardized, easily accessible national maps that incorporate living and nonliving marine resource data along with bathymetry, topography, and other natural features.

In addition, the NOC should:

- *review and make recommendations on consolidation of appropriate federal, nonmilitary ocean mapping and charting activities within a strengthened National Oceanic and Atmospheric Administration.*
- *ensure that federal mapping and charting activities take full advantage of resources available in the academic and private sectors.*

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