## CHAPTER 27:

# ENHANCING OCEAN INFRASTRUCTURE AND TECHNOLOGY DEVELOPMENT

*The future success of ocean and coastal research, management, enforcement, and observations in the United States will depend on the availability of modern ships, undersea vehicles, aircraft, satellites, laboratories, and observing systems, as well as the continuous development and integration of new technologies into these facilities. A renewed commitment, a clear national strategy, and significant interagency coordination are needed to plan for the acquisition, maintenance, and operation of such expensive, large-scale assets. In addition, better mechanisms are needed to transition new technologies into operational use and virtual centers for marine technology will help make these technological advances widely available.*

## SUPPORTING OCEAN AND COASTAL ACTIVITIES WITH MODERN TOOLS

A robust infrastructure with cutting-edge technology forms the backbone of modern ocean and coastal science and effective resource management and enforcement. The nation has long relied on technological innovation, including satellites, early-warning systems, broadband telecommunications, and pollution control devices to advance economic prosperity, protect life and property, and conserve natural resources. Ocean research, exploration, assessments, and enforcement activities will continue to rely on modern facilities and new technologies that can operate in the open ocean, along the coasts, in polar regions, on the seafloor, and even in space.

The three major components of the nation's infrastructure for oceans and coasts are:
- *Facilities*—land-based structures (such as laboratories and monitoring stations) as well as remote platforms (such as ships, airplanes, satellites, and submersibles) where research, observations, monitoring, and enforcement activities are conducted;
- *Hardware*—research equipment, instrumentation, sensors, and information technology systems used in the facilities; and
- *Technical Support*—the expert human resources needed to operate and maintain the facilities and hardware and participate in monitoring, research, modeling, resource assessments, education, and enforcement.

This chapter does not attempt to provide a comprehensive review of all marine-related infrastructure and technology needs. Rather, it highlights several key areas where improvements in federal planning, coordination, and investment are sorely needed.

## IMPROVING INFRASTRUCTURE AND TECHNOLOGY

### Gaps in Infrastructure

Periodic surveys have attempted to assess various aspects of academic, private-sector, and federal ocean infrastructure, but many of these attempts have been incomplete, particularly regarding private and academic assets. The last official inventory of marine facilities, undertaken in 1981 by the Congressional Office of Technology Assessment, did not include information related to maritime commerce, marine safety, or education.[1]

As one of its early tasks, the U.S. Commission on Ocean Policy, as required by the Oceans Act of 2000, authorized an extensive assessment of the infrastructure associated with ocean and coastal activities (Appendix 5). This inventory documents the U.S. infrastructure for maritime commerce and transportation; ocean and coastal safety and protection; research, exploration, and monitoring; and marine education and outreach. The number and types of assets included are extensive and cover a wide range of federal, state, academic, institutional, and private-sector entities. Together, they represent a substantial public and private investment that has made possible great strides in modern oceanography, coastal management, and marine commerce over the last fifty years. But the assessment also revealed that significant components of the U.S. ocean infrastructure are aged or obsolete and that, in some cases, current capacity is insufficient to meet the needs of the ocean research, education, enforcement, and operations community.

### Gaps in Technology Development

In both the federal and academic arenas, it is difficult to incorporate rapidly changing technology into ongoing activities. To ensure that the nation's ocean infrastructure is as effective as possible, the science community must learn how to rapidly transition new marine technologies from the research and development stages to sustained applications. In 2003, the National Science Board (NSB), the governing board of the National Science Foundation (NSF), concluded that academic research infrastructure has not kept pace with rapidly changing technology, expanding opportunities, and increasing numbers of users.[2] New technologies should allow researchers, managers, educators, and enforcement personnel to be remotely connected to a sophisticated array of facilities, instruments, and databases; however, these technologies are not readily available today. Better planning and new funding will be needed to bridge this technology gap and revolutionize ocean science and management.

If not remedied, a decline in U.S. leadership in marine technology development will result in increasing reliance on foreign capabilities. In 2001, the U.S. Commission on National Security/21st Century reported that federal investment in non-defense technology development has remained flat since 1989 and that the United States is losing its technological edge in many scientific fields.[3] Japan, the European Community, India, and China are all making great strides in marine technology development and have the potential to outcompete the United States in the near future. Changes in the policies and priorities of foreign nations, and a potential reluctance to freely share technology and environmental information, may leave this nation's ocean research and observation activities behind.

### Maximizing Resources through Collaboration

An overarching message from the Inventory of U.S. Coastal and Ocean Facilities (Appendix 5) is the need for continued partnerships among public and private entities to reduce costs, leverage resources, and encourage information sharing. Many successful collaborations have formed across the nation and around the world in recent decades. Ocean and coastal laboratories are frequently focal points for these efforts, drawing additional resources and new facilities supported by government, private, or academic institutions to advance the capabilities of a region.

For example, Narragansett, Rhode Island is home to a strong coalition of diverse research organizations, including the Atlantic Ecology Division of the U.S. Environmental Protection Agency's (EPA's) National Health and Environmental Effects Research Laboratory, the National Oceanic and Atmospheric Administration's (NOAA's) Northeast Fisheries Science Center Narragansett Laboratory, and the University of Rhode Island's Graduate School of Oceanography. Similarly, at the Hollings Marine Laboratory in Charleston, South Carolina, NOAA's National Ocean Service, and the National Institute of Standards and Technology have partnered with the South Carolina Department of Natural Resources, the College of Charleston, and the Medical University of South Carolina to construct and operate a state-of-the-art marine laboratory dedicated solely to collaborative, interdisciplinary research.

The Monterey Bay National Marine Sanctuary and the Monterey Bay Aquarium regularly collaborate with the Monterey Bay Aquarium Research Institute and other research institutions in the area, sharing ships and undersea vehicles, as well as information, to improve management practices and educational outreach. Partnerships of other kinds, such as the Cooperative Enforcement Program between the National Marine Fisheries Service and state agencies, allow these organizations to coordinate missions and responsibilities in order to maximize vessel use.

Consortia and joint programs, with facilities that support several organizations, create marine communities that interact closely, share knowledge, enhance career pathways, and promote collaboration among government, academic, and private sectors. The most cost-effective means of making infrastructure available to the largest number of people is to emphasize such partnerships.

In 1969, the Stratton Commission recognized that the technological and scientific demands of global ocean research would overtax the means of any single nation, stressing the need for international partnerships.[4] Realizing the expense involved in building and maintaining infrastructure and developing new technologies, nations have joined together in extremely successful ways. Current examples of such shared resources include satellite-based sensors, Argo profiling floats that measure meteorological and ocean variables as part of the Global Ocean Observing System, the Global Climate Observing System, and the Integrated Ocean Drilling Program. It is in the interests of the United States to continue to pursue partnerships with foreign nations for high-cost technology development activities with worldwide applications, while ensuring that foreign efforts are complementary to those in the United States, not replacements for them.

## A National Strategy

Despite the growing need to improve ocean science, resource assessments, education, operations, and enforcement, the federal government has yet to develop a long-range strategy to support the necessary infrastructure and technology needed for these purposes. Although federal agencies have made efforts to improve their coordination in some areas through the National Oceanographic Partnership Program and other mechanisms, infrastructure and technology planning is still not conducted in an integrated fashion that reflects regional, national, and international priorities.

Furthermore, while some facilities are operated with joint funding, interagency budgeting for shared facilities has had limited success due to differences in congressional oversight and financial and project approval processes. As a result, facilities are typically constructed or modernized in a piecemeal fashion, often through earmarked congressional funding. A unified national strategy can help achieve and maintain an appropriate mix of federally supported, modern ocean facilities that meet the nation's needs for quality science, resource management, enforcement, education, and assessments. Federal coordination can also accelerate the development of new research-based technologies and their rapid transfer into operational settings.

**Recommendation 27–1. The National Ocean Council (NOC) should develop a national ocean and coastal infrastructure and technology strategy, including detailed plans for funding and implementation, to support science, resource management, assessments, enforcement, and education. The strategy should guide agency plans for facility construction, upgrading, or consolidation and for new technology development.**

*In particular, the national strategy should:*

- *be developed through the NOC's Committee on Ocean Science, Education, Technology, and Operations.*
- *set specific priorities for acquiring and upgrading ocean and coastal infrastructure, including vessels, facilities, instrumentation, and equipment.*
- *build on the existing capabilities of federal, state, academic, and private entities.*
- *identify emerging technologies that should be incorporated into agency operations.*
- *promote international partnerships to deploy and share major oceanographic assets.*

The incorporation of useful new ocean technologies into operational infrastructure requires directed funding and coordination. The U.S. Navy, in particular, devotes significant attention to transferring new technologies into military operations. Domestic management programs can also benefit by having a centralized office responsible for accelerating the transition of technological advances made by federal and academic laboratories into routine, nonmilitary operations. NOAA, by virtue of its mission, is the logical agency to take on this role.

**Recommendation 27–2. The National Oceanic and Atmospheric Administration should establish an Office of Technology Transfer with responsibility for expediting the transition of proven ocean-related technologies into operational applications. This office should work closely with the National Science Foundation, the U.S. Navy, the National Aeronautics and Space Administration, academic institutions, regional organizations, and private industry to achieve its mission.**

## Periodic Reviews and Assessments

In conducting its inventory of U.S. coastal and ocean facilities, the Commission discovered few long-term plans for maintaining, replacing, or modernizing facilities (Appendix 5). As the first such assessment conducted in twenty-two years, the need for periodic future infrastructure assessments became obvious. A meaningful accounting of national assets, facilities, and human resources requires regular updates to ensure that the national strategy is based on an up-to-date understanding of capacity, capabilities, and trends.

Developing a national facilities database based on comprehensive inventories would improve plans for asset replacement or refurbishment. Furthermore, organizing such a database along regional lines would help identify the facility needs of each region and improve the prospects for resource sharing. State, academic, and private-sector capabilities should be included in the inventory to alert scientists to the existence and potential availability of these assets.

**Recommendation 27–3. The National Ocean Council should commission an assessment of U.S. ocean and coastal infrastructure and technology every five years. These assessments should account for all federal, state, academic, and private assets and should be used to create and update a national facilities database.**

*The assessment should build on this Commission's efforts (Appendix 5), including information on:*

- *the location, ownership, availability, remaining service life, and replacement cost for a wide range of ocean infrastructure assets.*
- *maintenance and operational costs associated with these assets.*
- *associated human resource needs.*
- *the outcomes of past federal investments in ocean technology and infrastructure, with recommendations for improvements.*

## FUNDING THE MODERNIZATION OF CRITICALLY NEEDED ASSETS

Too often during the past decade, federal and state agencies have had to delay, reduce, or cancel infrastructure upgrades due to budgetary constraints or changing agency priorities. Similar challenges arise within the academic community, which must balance the cost of expensive facilities with other institutional priorities.

Recent fiscal crises have exacerbated the problem at the state and local level, and a significant decline in the both private and state funding at universities has delayed modernization and expansion activities at many institutions. Funds dedicated for operations and maintenance of existing equipment have also declined. As a result, significant parts of the ocean and coastal infrastructure are outmoded, limiting the progress of ocean research and education and hindering the implementation of improved management and enforcement practices.

### Essential Science Infrastructure and Technology Components

The following discussion provides a summary of the condition of several major ocean science infrastructure categories, highlighting those most in need of coordinated planning and increased investment.

#### *Surface Vessels*

Despite the increasing availability of moored instruments, drifters, gliders, and satellites to collect ocean data, the need remains for traditional ships to conduct research, exploration, and education. But insufficient vessel capacity, vessel deterioration, and outdated shipboard equipment and technology hinder the conduct of vessel-based science. In some cases, these conditions also present safety issues and increase costs.

The nation's existing surface vessels for research are spread across federal and state agencies, universities, private research institutions, and private industry. The four largest U.S. government fleets conducting global, coastal, and nearshore research are operated by NOAA, the Navy, EPA, and the U.S. Department of the Interior. The University-National Oceanographic Laboratory System (UNOLS) is an organization of sixty-two academic institutions and national laboratories involved in oceanographic research that coordinates oceanographic ship schedules. There are currently twenty-seven UNOLS research vessels—owned by the Navy, NSF, or individual research institutions—located at twenty operating institutions. Most coastal states also own and operate vessels of various sizes and mission capabilities to satisfy state research needs. A significant and growing number of privately-owned vessels are also being used by federal and state agencies and academic institutions through contract or lease arrangements, particularly for highly specialized work.

The U.S. Coast Guard operates three icebreakers in coordination with UNOLS, which provide polar research capabilities. This fleet was recently updated with a new vessel specifically designed for research, but two of these ships will reach the end of their service life within the next four to seven years. NOAA has enlarged its fleet by refitting surplus Navy vessels and launching a ten-year plan to build four specialized fishery research ships at a price of $52 million per vessel.[5] Two of the ships are under construction, but funding has not been finalized for the remaining two.

While all of the agency research fleets would benefit from upgrades, the UNOLS fleet is in need of immediate attention. Twelve of the seventeen largest UNOLS ships will reach the end of their service life over the next fifteen years, and almost all UNOLS ships require significant enhancements.[6] The National Ocean Partnership Program's Federal Oceanographic Facilities Committee, comprised of representatives from thirteen federal organizations and one representative from UNOLS, was established to oversee oceanographic facility use, upgrades, and investments. The Committee's 2001 plan for recapitalization of the UNOLS academic research fleet is an excellent example of successful interagency planning at the national level.[7] Unfortunately, its plan has not yet been funded or implemented.

Furthermore, as the international Integrated Ocean Drilling Program gets underway, the United States has pledged to provide a modernized non-riser drilling vessel with enhanced coring and drilling capabilities at an estimated cost of $100 million.[8]

Modern research ships are designed as flexible platforms that can accept different instrument systems to suit particular projects. However, the built-in instrumentation (such as sonars, mapping systems, and computer labs) must be considered part of the vessel. These onboard technologies typically require much more frequent maintenance and upgrades than the vessels themselves. Thus, fleet planning strategies need to consider the costs of maintaining existing instrumentation and integrating emerging technologies.

### *Undersea Vehicles*

Scientists working in the deep ocean have made fundamental contributions to understanding ocean and planetary processes and the nature of life itself. Further scientific breakthroughs are likely if more regular access to the ocean depths can be provided. Ninety-seven percent of the ocean floor can be accessed by existing undersea vehicles with depth capabilities of around 20,000 feet. The remaining 3 percent—an additional 16,000 feet of ocean depth—remains largely inaccessible, although it includes most of the deep ocean trenches and comprises an area the size of the continental United States, Alaska, and about half of Mexico combined.

Human-occupied deep submersible vehicles came into operation in the late 1950s, followed by tethered remotely operated vehicles, and later by autonomous underwater vehicles. All three types of vessels are still used, and this variety allows researchers to choose the best tool for their needs, based on factors such as task, complexity, cost, and risks.

Today French, Russian, and Japanese human-occupied submersibles regularly work at depths of 20,000 feet or more. The last such vehicle owned by the United States was the *Sea Cliff*, which was retired in 1998 and not replaced. U.S. capability today is limited to the *Alvin*, built in 1964, which can only descend to 15,000 feet and stay submerged for relatively short periods. The University of Hawaii operates two submersibles that have the next deepest capabilities in the United States. The Pisces IV and Pisces V can dive to about 6,500 feet, with missions lasting seven to ten hours. For missions of long duration, the United States relies on the Navy's NR-1 nuclear research submarine, which can stay submerged for thirty days but has a maximum depth of only 3,000 feet. The NR-1 was constructed in 1969, and its service life will end in 2012.

The United States has a well-developed remotely operated vehicle (ROV) industry, and ROVs are readily available for academic and industrial purposes. The last twenty-five years have witnessed extraordinary advances in the field of subsea robotics, developed mainly for the oil and gas industry, and there is a wide array of ROVs available with working depths of 9,800 feet. Current U.S. ROV capabilities are led by *Jason II*, with a maximum operating depth of 21,325 feet, but it is the only vehicle in the federal fleet capable of reaching this depth. Federal funding has expedited the development of ROVs that can dive to 23,000 feet and deeper, but a concerted effort will be needed to make deep-water capabilities more economical and accessible.

Submersibles in the federal research fleet, including *Alvin* and *Jason II*, are currently housed at the National Deep Submergence Facility at the Woods Hole Oceanographic Institution. The facility is funded through a partnership among NSF, the Office of Naval Research (ONR), and NOAA. In addition, the NOAA-funded Undersea Research Program provides scientists with tools and expertise needed to work in the undersea environment. The vehicles owned and operated by the Undersea Research Program are divided into six regional centers that choose research missions based on a peer review process.

The U.S. autonomous underwater vehicle (AUV) industry has just begun to emerge from the research, development, and prototype phase. Over the past decade, close to 60 development programs have been initiated throughout the world, producing approximately 175 prototypes. About twenty of these programs remain active, with at least eight in the United States. While the primary financial drivers of AUV development in the United States have been the U.S. military and the oil industry, significant programs are in place at a few academic institutions and private institutes.

Nevertheless, a 2003 report by the National Research Council found that the scientific demand for deep-diving vehicles is not being met.[9] The report supports a mix of vehicles to support current and future research needs. Recommendations include: setting aside funds at the National Deep Submergence Facility to gain access to vehicles outside the federal fleet for specific missions; acquiring a second ROV to join *Jason II* by 2005, at a cost of approximately $5 million; and initiating an engineering study to evaluate various options for replacing *Alvin*, with a goal of providing submergence capability up to 21,000 feet, at a cost of approximately $20 million. The report noted that, over time and with additional funding, new platforms with greater capabilities could be profitably added to the fleet.

### *Dedicated Ocean Exploration Platforms*

The success of a robust national ocean exploration program (described in Chapter 25) will depend on the availability of sufficient vessel support, particularly ships and submersibles. Given that the existing suite of platforms requires upgrading just to meet current demands, implementation of a robust, national ocean exploration program will require additional support facilities. These assets should provide dedicated support for exploration missions and the flexibility to investigate many ocean areas and environments.

In 2003, the National Research Council recommended U.S. participation in an international exploration effort and discussed the benefits of providing a $70 million modern flagship and several modernized underwater vehicles and platforms.[10] Such assets should be included in the national strategy for ocean infrastructure and technology.

### *Airborne Ocean Science Platforms*

Piloted and autonomous aircraft are an integral part of modern ocean science. They are needed for precise airborne observation and measurements of the ocean, air-sea interface, and atmosphere. Many multidisciplinary, ocean-atmosphere field projects require a mix of observational platforms, particularly aircraft teamed with ships and satellites. Research aircraft are also instrumental in developing new satellite and airborne sensors.

The future of airborne ocean science and monitoring rests on the increased availability of autonomous or remotely-piloted aircraft. These research platforms, which are being developed now, possess a greater range, duration, and ceiling than conventional aircraft, and present less risk when operating in hazardous environments. The research community has suggested the need for a worldwide fleet of autonomous aircraft for ocean and atmospheric observation by 2005. The National Aeronautic and Space Administration (NASA), ONR, and NSF currently have active autonomous airborne ocean research programs, and are working to develop additional resources.

The national airborne fleet is operated by a partnership of federal agencies and academia. Private aircraft are also used for specialty and operational projects such as aerial mapping, marine mammal surveys, and supply missions. The Interagency Coordinating Committee for Airborne Geoscience Research and Applications, which is composed of federal agencies and academic institutions that operate research aircraft programs, works to improve cooperation, foster awareness, and facilitate communication among its members, and serves as a resource to senior managers. In an effort to coordinate ocean research aircraft, UNOLS recently established the Scientific Committee for Oceanographic Aircraft Research. This committee coordinates the operators and agencies whose aircraft have been chosen by UNOLS to be a part of the National Oceanographic Aircraft Facility.

The demand for these assets is increasing, particularly as collaborative ocean-atmosphere projects become more common. Demand currently exceeds availability. Inadequate funding for research flight time is exacerbating the problem. Furthermore, as with surface vessels, emerging technologies and updated safety and personnel requirements will require significant funding that must be included in planning.

In 2003, NOAA drafted a ten-year plan for airborne platforms that provides an extensive analysis of agency requirements. The plan included an examination of historical flight requests, allocations, and budgets, and delineated future requirements, contracts for service, and a recapitalization schedule and cost.[11]

### *The Ocean Observatories Initiative*

Investigation of the oceans as a dynamic system requires sustained observational capabilities in remote locations not routinely accessible by ships. NSF's Ocean Observatories Initiative (OOI) will develop and construct the initial infrastructure for an integrated research observatory network, providing the research and education communities with a new mode of access to the oceans. The scientific problems driving creation of the OOI are broad in scope and encompass nearly every area of ocean science. Once established, the observatories constructed as part of this initiative will provide earth and ocean scientists with unique opportunities to study multiple, interrelated processes over timescales ranging from seconds to decades, to conduct comparative studies of regional processes and spatial characteristics, and to map whole-earth and basin scale structures.

Funding support for the OOI is scheduled to come from NSF's Major Research Equipment and Facilities Construction account. The OOI is listed as a priority new start for fiscal year 2006, although funding has not yet been appropriated by Congress.

While the OOI is an essential component of the federal research infrastructure, care should be taken to ensure that it is developed in close coordination with its operational counterpart, the Integrated Ocean Observing System (IOOS). The outcomes of research and technology development in the OOI will be indispensable for development and continual enhancement of the IOOS. Likewise, the operational measurements and products of the IOOS will provide OOI researchers with essential ocean background information for experimental planning and execution purposes. Thus, it is imperative that the OOI Project

Office, Ocean.US, NSF, and NOAA, work closely together to ensure mutually beneficial interactions and coordination between these two efforts.

### *Laboratories and Instrumentation*

Maintaining academic laboratory space and instrumentation over the past decade has been challenging due to increased construction of facilities to meet rising student and faculty needs and increased upkeep needs for aging facilities. This problem is aggravated by the prohibition against academic institutions setting aside adequate federal funds for ongoing maintenance and replacement. A recent RAND study estimated that the true cost of providing facilities and administration to support research projects is about 31 percent of the grant amount.[12] However, federal regulations limit the share that can be covered with federal funds to between 24 and 28 percent, leaving the difference to be covered by the institutions.

In 2002, the Consortium for Oceanographic Research and Education surveyed eighty-six non-UNOLS academic ocean programs to examine facility age and replacement plans (Appendix 4). Relatively few institutions had replacement plans for their facilities, and a number of institutions noted that lack of available funds was the primary factor preventing planning and upgrades. Yet increases in both laboratory space and instrumentation capacity will be essential for the continued conduct of cutting-edge ocean research.

Many federal research facilities are also deteriorating due to growing budget pressures and new mandates related to safety, homeland security, and environmental health compliance. NOAA characterizes its need for improvements to equipment and labs as a major impediment to future science capabilities. Other agencies like EPA, U.S. Geological Survey (USGS), and the U.S. Army Corps of Engineers (USACE) also fund and operate laboratories throughout the United States, conducting much needed ocean and coastal research and monitoring. All of these laboratories contribute to our national research goals and need to be maintained in order to support new, cutting-edge science for years to come.

### *Advanced Telecommunications Technology and Broadband Capabilities*

The satellite communications infrastructure provides affordable, global broadband coverage to support ocean observations and exploration. However, current coverage does not provide links to important polar regions or portions of the Southern Ocean. Advanced communication capabilities are also required for scientists to remotely operate ocean exploration vehicles, similar to the highly successful use of space probes. These telecommunication technologies also provide excellent educational opportunities for the general public, allowing them to participate in virtual voyages to deep and inaccessible parts of the ocean. Telepresence—the transmission of real-time, high-quality video, audio, and other digital data from undersea exploration sites over the Internet—will demand modern broadband data transfer capabilities.

A variety of other research activities require upgrades in the current data transmission infrastructure, such as the fiber optics needed for cabled sensor systems. Active partnerships between ocean scientists and the private telecommunications industry will be crucial to ensure that the United States has the capability to transmit and assimilate the data streams of the future.

### *A Federal Commitment to Scientific Infrastructure*

Coordinated federal support for ocean science infrastructure in all the areas discussed above is urgently needed to build or upgrade critical facilities and acquire related instrumentation and equipment. Improved coordination of similar equipment purchases, where feasible, can achieve significant economies of scale.

NSF has traditionally been the lead federal agency for supporting academic infrastructure. NSF can propose funding for large research facilities (those costing hundreds of millions of dollars) through its Major Research Equipment and Facilities Construction account, while small infrastructure projects (costing millions of dollars or less) have generally been funded through the regular disciplinary science programs. In 1997, NSF launched the Major Research Instrumentation program to provide additional support for instrumentation ranging in cost from $100,000 to $2 million, although funding for this program falls far short of the needs. There is currently no NSF program dedicated to funding mid-size facilities (costing millions to tens of millions of dollars).

**Recommendation 27–4. Congress should create a mechanism to ensure a dedicated funding stream for critical ocean science infrastructure and technology needs. Spending priorities should be based on the National Ocean Council's ocean and coastal infrastructure and technology strategy.**

*High-priority areas for funding include the following:*

- *the renewal of the University-National Oceanographic Laboratory System fleet and other essential air fleets and deep-submergence vehicles.*
- *the completion of the third and fourth dedicated fishery research vessels.*
- *the acquisition of vessels and infrastructure needed for an expanded national ocean exploration program.*
- *the Integrated Ocean Drilling Program non-riser drilling vessel.*
- *the refurbishment or replacement of two U.S. Coast Guard polar ice breakers.*
- *the ongoing modernization of existing assets, including telecommunications assets, laboratories, and other facilities.*

## Other Essential Infrastructure and Technology Components

Ocean-related agencies maintain the infrastructure needed to carry out their responsibilities in resource management, navigation and safety, enforcement, and environmental protection and response. While the Coast Guard and NOAA generally lead these efforts, other federal agencies such as USACE, Navy, USGS, and EPA also possess assets for specific purposes. With so many government agencies involved and such a wide range of activities included, cooperation among these agencies in planning and deploying these assets is critical. For example, while the Coast Guard is the lead agency for responding to environmental incidents, it receives support for these activities from the Navy, Minerals Management Service (MMS), and EPA, and indirect help with scientific information, surveying, and modeling from NOAA and other parties. Establishing collaborative efforts among agencies, and acquiring infrastructure assets that can respond to multiple mission mandates, will enhance overall federal capabilities.

The following discussion provides an overview of the range of assets the United States requires in order to manage resources, protect human lives, enforce ocean and coastal laws, and predict ocean conditions.

### *Vessels and Aircraft*

A robust federal fleet of vessels and aircraft is required to conduct monitoring, mapping, enforcement, response, and safety activities in both coastal waters and the open ocean. While some activities, such as monitoring and mapping, can be conducted by private companies under contract, the nation will always need to maintain a federal fleet that can quickly and effectively respond to environmental disasters, conduct assessments on a routine basis, and enforce applicable laws. Regular upgrades to these vessels and aircraft are needed to incorporate cutting-edge technologies, increase fleet capacity, and address both national and international safety requirements.

After the Navy, the Coast Guard has the largest fleet of any agency and performs the largest range of activities on the water. It conducts search and rescue missions, prevents and responds to oil spills and other environmental threats, enforces fishery laws and other measures designed to ensure the sustainability of living marine resources, facilitates maritime commerce, and provides for maritime safety, security, and national defense. The Coast Guard's role in enforcement will remain an essential element in the effective management of offshore activities. In addition to their obvious roles, enforcement personnel can provide invaluable feedback on the real-world impacts of management regimes and can suggest potential improvements to enhance their effectiveness. Enforcement activities also provide excellent opportunities to inform and educate the public about resource management requirements.

In order to accomplish its duties, the Coast Guard fleet includes 223 cutters (vessels over 65 feet), 211 aircraft, and 1400 boats (vessels under 65 feet). Unfortunately, the Coast Guard air and surface fleet is aging and falling behind technologically—over half of these assets will reach the end of their service life in the next four years. The consequences of allowing these resources to decline have become even more severe as a result of the Coast Guard's dramatically increased maritime security responsibilities. Accelerated recapitalization of the Coast Guard fleet is critically important because of the wide-ranging roles the Coast Guard plays in furthering U.S. ocean interests.

NOAA operates fourteen vessels for environmental monitoring and fishery and oceanographic research, and maintains a fleet of four additional vessels dedicated to conducting hydrographic surveys. Two of these vessels are stationed in the Pacific and two in the Atlantic. A reconditioned NOAA hydrographic vessel is expected to enter service in the Pacific in late 2004. NOAA also maintains a smaller hydrographic boat in the Chesapeake Bay. NOAA's own hydrographic survey capability is roughly matched by contracts it maintains with private sector vessels; both capabilities will become increasingly important as the nation strives to address the survey backlog discussed in Chapter 25.

Most ocean agencies undertake both biological and physical monitoring activities that require significant ship time. USGS has some vessels that collect samples for sediment and water quality monitoring, and others, including a number in the Great Lakes, that conduct fish stock assessments and determine the effectiveness of stocking programs. EPA also has several ships that monitor potential environmental threats and support coastal marine protection programs. The EPA ships collect environmental information from harbors, ports, and offshore waters in the ocean, as well as the Great Lakes. NOAA conducts extensive fish stock surveys throughout U.S. waters, using both its own ships and contract vessels.

In addition to ship-based monitoring programs, much of the coastal and open ocean monitoring supported by the federal government is conducted using buoys and *in situ* sensors. In addition to the buoys themselves (discussed below), both NOAA and the Coast Guard maintain the ships needed to deploy and care for buoys in the open ocean. The development of the Integrated Ocean Observing System (IOOS), discussed in detail in Chapter 26, will intensify the demand for ship support to install and maintain ocean buoys. This capability is not available in the federal fleet today, nor is it foreseen in the near future.

Other routine activities such as marine salvage, dredging, ensuring safe navigation, and monitoring offshore oil and gas activities also require significant support. While most salvage in the United States is conducted by private contractors, both the Coast Guard and the Navy maintain some assets for these activities. In particular, the Navy has four manned rescue and salvage ships and several unmanned underwater vehicles. Like salvage activities, most port and waterway dredging projects are conducted by private companies under contract (over 160 contracts were granted by USACE in fiscal year 2003); however, USACE does keep a small fleet of twelve dredging vessels throughout the country to help maintain navigable waterways. The Coast Guard conducts icebreaking activities to permit vessels to move safely on frequently traveled routes. In particular, the Coast Guard owns and operates thirteen primary icebreaking vessels (some of which are also used for research as discussed above) and conducts numerous ice reconnaissance flights using HC-130 aircraft. As part of its mandate to oversee oil and gas activities in the outer Continental Shelf, MMS must monitor coastal and ocean areas for oil spills. This responsibility is carried out primarily through a fleet of contract helicopters that are used to transport inspectors to over 4,000 offshore oil and gas platforms annually.

### *Land-based facilities*

Federal ocean agencies own hundreds of buildings and structures across the country that house thousands of employees on the front lines of ocean management and protection at the regional, state, and local level.

A small sampling of these facilities includes:

- The Coast Guard's 186 multi-mission stations that operate boats and provide personnel to conduct a variety of operations, including search-and-rescue, law enforcement, and marine environmental protection missions. They also operate twenty-five air stations that provide mission capable aircraft.
- The USGS Coastal and Marine Geology program field centers that collect data and monitor conditions related to geologic processes and hazards, environmental conditions, habitats, and energy and mineral resources.
- EPA's ten regional offices, each of which is responsible for several states and territories. Within some regions there are additional program offices, such as the Chesapeake Bay Program Office which oversees protection and restoration of the Bay.

However, many agencies are experiencing shortfalls in the funds needed to maintain and upgrade these facilities. As an example, in a 2002 performance review, NOAA showed holdings of 800 buildings at 500 installations, representing 6 million square feet of space.[13] Approximately 50 percent of the properties were over 30 years old, and there was a backlog of 316 maintenance and repair projects. Of the estimated $65 million in costs needed to remedy this backlog, $25 million was required just to remedy health and safety problems.

Comprehensive planning, including consolidation or elimination where possible, is needed to ensure that ocean agencies have the facilities required to fulfill their responsibilities for management, monitoring, and enforcement.

### *Monitoring stations and buoy arrays*

*In situ* monitoring stations that collect and transmit continuous data streams, are essential for forecasting marine and weather conditions, predicting marine hazards, and evaluating water quality. In particular, NOAA operates several ocean-observing arrays that collect data on climate, weather, air quality, and ocean variables, including: the Marine Observation Network; the National Water Level Observation Network; the Tropical Atmosphere Ocean (TAO) buoy array; and the Drifting Buoy Program.

Each of these networks can include hundreds of moored or drifting buoys used to collect and transmit data for predicting tsunamis, monitoring El Niño conditions, compiling long-term baseline measurements, and contributing to safe navigation. NOAA also manages the National Ice Center's U.S. Interagency Artic Buoy Program in conjunction with the Coast Guard and the Navy. This program supports the International Arctic Buoy Program, an international collaborative effort that maintains thirty-six operational buoys that monitor air temperature, surface pressure, and ice drift. The Navy also has several buoys and current measurement systems consisting of acoustic profiling instruments which, among other things, are being explored as a method of monitoring marine mammals in cooperation with MMS and the National Marine Fisheries Service.

In addition to ocean monitoring, NOAA, USGS, EPA, and other federal and state agencies oversee a number of coastal and estuarine monitoring programs throughout the nation. For example, USGS operates around 2,900 stations that monitor coastal streams. These monitoring systems are discussed in more detail in Chapter 15.

### *Satellites*

In addition to the satellite operations discussed in Chapter 26 as part of the national IOOS, many environmental management and monitoring programs rely on a constellation of orbiting satellites to collect operational data.

NOAA currently operates two different kinds of satellites in support of its missions. Two Geostationary Operational Environmental Satellites (GOES) collect and transmit data related to many essential weather variables and potential environmental hazards such as hurricanes and flood warnings. In addition, NOAA maintains five Polar-orbiting Environmental Satellites (POES) (some are in orbit as backups if needed) that are able to monitor the entire Earth on a daily basis for a variety of land, ocean, and atmospheric applications. Data support a broad range of environmental monitoring applications, including weather analysis and forecasting, climate research and prediction, global sea surface temperature measurements, atmospheric soundings of temperature and humidity, ocean dynamics research, volcanic eruption monitoring, search and rescue, and many other applications. These satellites send more than 16,000 global measurements daily to NOAA computers, adding valuable information for forecasting models, especially for remote ocean areas where conventional data are lacking.

In 1994, a decision was made to merge the nation's military and civilian operational meteorological satellite systems to lower costs. As a result, NOAA, NASA, and the U.S. Department of Defense designed the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The first NPOESS satellite, which will collect and disseminate data on Earth's weather, atmosphere, oceans, land, and near-space environment, is expected to be launched in 2008.

Since 1972, NASA and USGS have collaborated to collect important environmental data through the Landsat satellite program, joined in 1994 by NOAA. Landsat's mission is to guarantee repeated observations over the Earth's land mass, coastal boundaries, and coral reefs as needed to monitor long-term changes. The continuity of Landsat satellites (currently Landsat 7 is in operation) ensures the collection of consistently calibrated Earth imagery.

Satellites are also essential for transmitting data from sensors and buoys deployed throughout the world. For example, the data collected by the TAO buoy array located in the tropical Pacific Ocean is transmitted to NOAA via the Argos satellite system. The implementation of the IOOS and Global Observing System will intensify the need to transmit large amounts of coastal, oceanic, and atmospheric data in real and near-real time, increasing the demand for advanced telecommunications technology and infrastructure.

### *Infrastructure Planning to Support Ocean and Coastal Activities*

Most ocean agencies periodically produce infrastructure maintenance and upgrade plans. One important example of such a plan is the Coast Guard's Integrated Deepwater System, a twenty-year program to modernize its fleet through acquisition of new cutters, patrol boats, aircraft, and communications capabilities designed to operate as an integrated system. However, this program was initiated prior to September 11, 2001, before significant new demands were placed on Coast Guard resources. A 2004 study concluded that the Deepwater acquisition program will no longer provide the Coast Guard with the assets and capabilities needed to meet all its responsibilities.[14]

All ocean agencies, both working separately and in coordination through the National Ocean Council, will need to plan for future acquisitions and upgrades of their infrastructure assets related to management, operations, and enforcement missions. Periodic national ocean and coastal infrastructure and technology assessments, as called for in Recommendation 27-3, will aid these agencies in drafting strategic plans that take full advantage of private sector assets and will highlight possible opportunities for interagency coordination.

**Recommendation 27–5. Congress should support the infrastructure and technology requirements related to ocean and coastal management, operations, and enforcement. Priorities should be based on the National Ocean Council's ocean and coastal infrastructure and technology strategy.**

*High-priority areas for funding include the following:*

- *recapitalization of the Coast Guard fleet based on an accelerated modernization plan.*
- *modernization of other federal fleets as needed.*
- *ongoing maintenance and upgrades of land-based operational and enforcement facilities.*
- *maintenance and upgrading of monitoring buoys, gages, and stations.*
- *coordinated satellite observing deployment.*

## CREATING VIRTUAL MARINE TECHNOLOGY CENTERS

Fundamental oceanographic questions require the best scientific and engineering talent working cooperatively to obtain answers. Interdisciplinary oceanographic research programs typically require large numbers of platforms and sensors operating in a coordinated manner. While new technologies are enabling the creation of more powerful sensors, robotic platforms, and ocean observing systems, it would be extremely difficult for any individual research group to acquire all these technologies and master the increasingly complex instrumentation. By sharing expensive technologies, infrastructure, and expertise, more investigators will have greater access to these assets.

Virtual centers will require a smaller federal investment than if numerous institutions all attempt to acquire the same essential instrumentation. By electronically linking existing academic, government, and private-sector capabilities and instrumentation, virtual centers for ocean and coastal technology could maximize the use of the excellent capabilities and facilities already present in the United States. These interdisciplinary virtual centers could simultaneously operate remote submersibles, receive *in situ* ocean measurements taken halfway around the globe, and schedule satellite time to collect additional data from space. Infrastructure components available through the center could be used by small-scale, pilot projects that would not normally have access to such sophisticated facilities. Investigators could apply for grants to join an ongoing team linked by computers, not geography. The multipurpose focus of each center would also lend itself to the development of new approaches to education and public outreach.

Marine technology centers can serve as incubators for innovations and new technologies necessary to achieve and sustain national competitiveness in ocean science and engineering research. In particular, these virtual centers could provide the critical mass of interest to develop much needed new environmental sensors. Sensors for measuring basic oceanographic parameters such as currents, temperature, and salinity are already widely available, but sensors that illuminate the chemistry and biology of the ocean are just emerging. A new generation of sensors will be able to measure such parameters as carbon dioxide, acidity, alkalinity, dissolved oxygen, nitrates, photosynthetically active radiation, spectral radiance and irradiance, back-scattered light, and stimulated fluorescence. Some of the innovative biological technologies currently being investigated include acoustic monitoring and optical scanning systems for identifying and tracking marine life, DNA probes for identifying harmful algal blooms, and nanotechnology sensors for monitoring potentially harmful pathogens. Although prototypes exist, many sensors still need considerable development before they can be expected to operate unattended for long periods of time in the harsh ocean environment.

The virtual marine technology centers, like other successful programs of this kind, should be located at established universities, museums, and science centers in order to take advantage of existing infrastructure and expertise, but should also strive to incorporate outside research groups to ensure an influx of new ideas. A strengthened NOAA, as the lead ocean agency, is the logical organization to coordinate and provide funding for these centers.

**Recommendation 27–6. The National Oceanic and Atmospheric Administration should establish four to six national virtual marine technology centers at existing institutions to provide coordinated access, through electronic means, to cutting-edge, large-scale research technologies.**

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