U.S. COMMISSION ON OCEAN POLICY

CHAPTER 27: ENHANCING OCEAN INFRASTRUCTURE AND TECHNOLOGY DEVELOPMENT

The future success of ocean and coastal research in the United States will depend on the availability of modern ships, undersea vehicles, aircraft, laboratories, and observing systems, as well as the continuous development and integration of new technologies into these facilities. Significant interagency coordination, guided by a national strategy, is needed to plan the acquisition and operation of expensive, large-scale assets. A renewed commitment to funding the purchase, maintenance, and operation of these facilities will be essential. Technology development activities would be further aided by creating virtual centers of marine technology with coordinated federal activities to help transition new technologies into operational use.

ADVANCING OCEAN AND COASTAL SCIENCE WITH MODERN TOOLS

A robust infrastructure with cutting-edge technology forms the backbone of modern ocean science. It supports scientific discovery and facilitates application of those discoveries to the management of ocean resources. 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, mapping, and assessment activities will continue to rely on modern facilities and new technologies to acquire data in the open ocean, along the coasts, in challenging polar regions, on the seafloor, and even from space.

The three major components of the nation's scientific infrastructure for oceans and coasts are:

- *Facilities*—land-based laboratories and ocean platforms, including ships, airplanes, satellites, and submersibles, where research and observations 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 as well as participating in data collection, assimilation, analysis, modeling, and dissemination.

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 will be essential to support an enhanced ocean science enterprise.

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 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 science and operational community.

Thirteen federal agencies with activities in ocean and coastal science develop, build, and operate infrastructure components to support their science missions, often in partnership with academic institutions. For very expensive or unique assets, federal organizations can develop shared resources, such as supercomputers and data centers.

The National Science Foundation (NSF) is the lead federal agency for supporting science and engineering infrastructure for academia, and is also the major supporter of basic science. However, NSF's share of support for ocean infrastructure has declined over the recent past as priorities have shifted to other science sectors. NSF funds large research facilities (those costing hundreds of millions of dollars) through its Major Research Equipment and Facilities Construction account. Small infrastructure projects (costing millions of dollars or less) have generally been funded through its 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, but the funding for this program falls far short of the needs and opportunities in the academic community. There is currently no NSF program dedicated to funding mid-size facilities (costing millions to tens of millions of dollars), although the disciplinary research programs would be very hard pressed to support such investments.

In 2003, the National Science Board (NSB), the governing board of the NSF, concluded that academic research infrastructure has not kept pace with rapidly changing technology, expanding opportunities, and increasing numbers of users.[2] New technologies allow researchers to be remotely connected to a sophisticated array of facilities, instruments, and databases; however these technologies are not readily available to the majority of scientists. NSB concluded that additional federal investments would be needed to provide scientists access to the latest and best infrastructure and technologies.

Gaps in Technology Development

In both the federal and academic arenas, it is difficult to incorporate rapidly changing technology into ongoing activities. However, to provide the public with useful information and products, the science community must learn how to rapidly transition marine technologies from the research and development stages to sustained applications. A prime example is the difficulty involved in transitioning the National Aeronautics and Space Administration's (NASA's) research-oriented ocean observing sensors into operational use at the National Oceanic and Atmospheric Administration (NOAA). Better planning and new funding will be needed to bridge this gap, allowing new technologies to revolutionize ocean science and management.

Furthermore, a decline in U.S. leadership in marine technology development will result in increasing reliance on foreign capabilities. Japan, the European Community, India, and China are all making great strides in technology development and have the potential to out compete the United States in the near future. Changes in the policies and priorities of foreign nations, and potential reluctance to freely share technology and environmental information with the United States, may put the nation's ocean research and observation activities at risk.

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]

Maximizing Resources through Collaboration

Ocean science has become a highly interdisciplinary field, requiring close collaborations among natural, physical, and social scientists, engineers, and information technology experts. Because few organizations possess the facilities and expertise to support all major fields of investigation, ocean projects frequently depend on partnerships among federal, state, academic, and private institutions, both U.S.- and foreign-based.

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 science 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, 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.

Consortia and joint programs, with facilities that support several institutions, create marine science 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 scientists is to emphasize partnering among many institutions from all sectors.

Back in 1969, the Stratton Commission already 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. The United States should 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 observing, forecasting, and management, the federal government has yet to develop a long-range strategy to support the civilian infrastructure and technology needed for both research and operational purposes. Although federal agencies have made efforts to improve their coordination 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.

Although 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 resource management, science, and assessment. Federal coordination could also focus support on developing and transferring technologies that numerous agencies desire for operational activities.

Recommendation 27–1. The National Ocean Council's Committee on Ocean Science, Education, Technology, and Operations should develop a national ocean and coastal infrastructure and technology strategy, including funding and implementation requirements.

The strategy should include:

- *consideration of the existing capabilities of academic, state, and private entities.*
- *identification of emerging technologies that should be incorporated into agency operations.*
- *mechanisms for establishing international partnerships.*
- *guidelines for incorporating the strategy into agency plans for technology development and facilities construction and consolidation.*
- *specific priorities for acquiring and upgrading ocean research infrastructure, including vessels, facilities, instrumentation, and equipment.*

The development of needed ocean technologies—whether identified by the national strategy or through interagency communication—requires directed funding and coordination. Federal agency programs will benefit by having a centralized office responsible for accelerating the transition of technological advances made by federal and academic laboratories into routine operations. NOAA, by virtue of its mission, is the logical agency for this role.

Recommendation 27–2. The National Oceanic and Atmospheric Administration should create, and Congress should fund, an Office of Technology to expedite the transition of experimental technologies into operational applications. This office should work closely with academic institutions, the regional ocean information programs, the National Science Foundation, the U.S. Navy, the National Aeronautics and Space Administration, and other relevant agencies 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 would help plan 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 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 update the assessment of U.S. ocean and coastal infrastructure and technology, including federal, state, academic, and private assets, every five years.

The assessment should include 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, federal and state agencies have had to delay, reduce, or cancel infrastructure upgrades at government facilities during the past decade 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 state fiscal crises have exacerbated the problem at public universities, and a significant decline in the value of many endowment funds during the same period has delayed modernization and expansion activities at many private 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 hindering the prospects for using science to improve management practices.

Essential 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 will remain for traditional ships to conduct research, exploration, operations, and education. But insufficient vessel capacity, vessel deterioration, and outdated shipboard equipment and technology hinder the conduct of vessel-based science and operations. In some cases, these conditions also present safety issues and increase the cost of routine maintenance and operation.

The nation's existing 400-plus surface vessels for research and operations are spread across federal and state agencies, universities, private research institutions, and private industry. The five largest U.S. fleet operators conducting global, coastal, and near shore research and mission operations are NOAA, the U.S. Navy, the U.S. Environmental Protection Agency, the U.S. Geological Survey, and the U.S. Department of the Interior, which together own and operate the forty-one primary vessels of the federal fleet associated with ocean science and operations. In addition, fifty-four academic institutions and five federal agencies (NSF, the Office of Naval Research (ONR), NOAA, USGS, and the U.S. Coast Guard) operate and use the twenty-nine vessels in the University National Oceanographic Laboratory System (UNOLS) fleet. Most coastal states also own and operate vessels of various sizes and mission capabilities to satisfy state needs. A significant and growing number of privately-owned research and operations vessels are also being used by federal and state agencies and academic institutions through contract or lease arrangements, particularly for highly specialized work.

The Navy survey fleet is relatively new and generally maintained at a level adequate to meet defense mission requirements. The Coast Guard operates three icebreakers, which provide polar research capabilities. This fleet was recently updated with a new vessel specifically designed for research. NOAA has enlarged its fleet by refitting surplus Navy vessels and launching a ten-year plan to build four specialized fishery research ships at $52 million per vessel.[5] Two of the ships are under construction, but funding has not been finalized for the remaining two. USGS and EPA need new vessels to satisfy basic mission mandates, but currently have no funding or plans to acquire these resources.

While all of the agency fleets would benefit from upgrades, the UNOLS fleet is *in extremis*. 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 need immediate and significant enhancements.[6]

The development of the Integrated Ocean Observing System (IOOS, discussed in Chapter 26) will intensify the demand for ship support to install and maintain system components. This capacity is not available in the research fleet today, nor is it foreseen in the near future. With the start of the international Integrated Ocean Drilling Program, 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.[7]

Modern research ships are designed as flexible multi-mission platforms that can accept different instrument systems to suit particular projects. However, the instrumentation that is built in (such as sonars, mapping systems, or 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.

The National Ocean Partnership Program established the Federal Oceanographic Facilities Committee to oversee oceanographic vessel use, upgrades, and investments. The committee's 2001 plan for recapitalization of the academic research fleet is an excellent example of successful interagency planning at the national level.[8] Unfortunately, the plan has not yet been funded or implemented.

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 three 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 in 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 short periods. 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 sub-sea 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. All submersibles in the federal 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, ONR, and NOAA.

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 sixty development programs have been initiated throughout the world, and approximately 175 prototypes have been developed. 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.

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: (1) setting aside funds at the National Deep Submergence Facility to gain access to vehicles outside the federal fleet for specific missions; (2) acquiring a second ROV to join *Jason II* by 2005, at a cost of approximately $5 million; and (3) 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 in time and with a higher level of funding, additional 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—not to mention the additional needs of the IOOS—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 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 research and operations. 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 national airborne fleet is operated by a partnership of federal agencies and academia. Private aircraft are often used for specialty and operational projects such as aerial mapping, marine mammal surveys, and supply missions.

The future of airborne ocean science and monitoring rests on the increased availability of autonomous or remotely-piloted aircraft. These research platforms are being developed with 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.[11] NASA, ONR, and NSF currently have active autonomous airborne ocean research programs, and are working to develop additional resources.

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 has recently designated certain assets as National Oceanographic Aircraft Facilities.

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.[12]

Laboratories and Instrumentation

Maintaining academic laboratory space and instrumentation over the past decade has been challenging due to increased construction of new 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.[13] 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 lab space and instrumentation capacity will be essential for the continued conduct of cutting-edge ocean research.

Many federal facilities are 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. In a 2002 Performance Review Report, NOAA showed holdings of 800 buildings at 500 installations, representing 6 million square feet of space.[14] 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 address health and safety problems. If the fiscal year 2002 facility funding level of $3.2 million is maintained over the next few years, 60 percent of this backlog will remain in 2010. In its Strategic Plan for 2003-2008, NOAA presented a strategy for improving infrastructure development, construction, consolidation, and maintenance, but additional funding will be needed to implement the plan.[15]

Advanced Telecommunications Technology and Broadband Capabilities

Federal satellite communications infrastructure is needed to provide affordable, global broadband coverage to support ocean observations and exploration. 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. The IOOS will require transmission of large amounts of coastal, oceanic, and atmospheric data in real and near-real time, demanding advanced telecommunications technology and infrastructure. 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.

Environmental Sensors

Development of new environmental sensors—an essential component of the IOOS—will require a substantial federal investment. 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. The 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. Federal support and multisector partnerships will be necessary to turn innovative environmental sensors into operational components of the national IOOS.

A Federal Modernization Fund

Coordinated federal support for ocean research infrastructure could be achieved through the establishment of a modernization fund. Such a fund would be used to build or upgrade critical facilities and acquire related instrumentation and equipment. It would also provide a mechanism to coordinate similar equipment purchases across agencies, where feasible, creating significant economies of scale.

Recommendation 27–4. Congress should establish a modernization fund for critical ocean 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 ocean and air fleets, including the Integrated Ocean Drilling Program ship, 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.*
- *ongoing operations, maintenance, and modernization of existing assets, including laboratory facilities.*

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 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 take advantage of submersibles in one location, ocean observations halfway around the globe, and socioeconomic studies coordinated at another location. Infrastructure components available through the center could be used for small-scale, pilot projects that would normally not have access to such facilities. Investigators could apply for grants to join an ongoing team linked by computers, not geography. The multipurpose focus of each center also lends itself to the development of new approaches to education and public outreach.

The centers will also serve as incubators for infrastructure innovations and new technologies necessary to achieve and sustain national competitiveness in ocean science and engineering research. A strengthened NOAA, as the lead ocean observation, operations, and management agency, is the logical organization to provide funding for these virtual marine technology centers.

Recommendation 27–5. The National Oceanic and Atmospheric Administration should establish, and Congress should fund, national virtual marine technology centers to provide coordinated access, through electronic means, to cutting-edge, large-scale research technologies.

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