CHAPTER 26:
ACHIEVING A SUSTAINED, INTEGRATED OCEAN OBSERVING SYSTEM

Coastal and ocean observations provide critical information for protecting human lives and property from marine hazards, enhancing national and homeland security, predicting global climate change, improving ocean health, and providing for the protection, sustainable use, and enjoyment of ocean resources. While the technology currently exists to integrate data gathered from a variety of sensors deployed on buoys, gliders, ships, and satellites, the implementation of a sustained national Integrated Ocean Observation System (IOOS) is overdue and should begin immediately. Care should be taken to ensure that user needs are incorporated into planning and that the data collected by the IOOS are turned into information products and forecasts that benefit the nation. In addition, the IOOS should be coordinated with other national and international environmental observing systems to enhance our Earth observing capabilities and enable us to better understand and respond to the interactions among ocean, atmospheric, and terrestrial processes.

MAKING THE CASE FOR AN INTEGRATED OCEAN OBSERVING SYSTEM

About 150 years ago, this nation set out to create a comprehensive weather forecasting and warning network and today most people cannot imagine living without constantly updated weather reports. Virtually every segment of U.S. society depends on the weather observing network. Millions of citizens check reports each day to decide how to dress, whether to plan outdoor activities, and to determine if they need to prepare for severe weather. Commercial interests use daily and seasonal forecasts to plan business activities and to safeguard employees and infrastructure. Government agencies use forecasts to prepare for and respond to severe weather, issue warnings to the general public, and decide whether to activate emergency plans.

Recognizing the enormous national benefits that have accrued from the weather observing network, it is time to invest in a similar observational and forecasting capability for the oceans. This system would gather information on physical, geological, chemical, and biological parameters for the oceans and coasts, conditions that affect—and are affected by—humans and their activities. The United States currently has the scientific and technological capacity to develop a sustained, national Integrated Ocean Observing System (IOOS) that will support and enhance the nation's efforts for:

- improving the health of our coasts and oceans;
- protecting human lives and livelihoods from marine hazards;
- supporting national defense and homeland security efforts;
- understanding human-induced and naturally caused environmental changes and the interactions between them;
- measuring, explaining, and predicting environmental changes;
- providing for the sustainable use, protection, and enjoyment of ocean resources;
- providing a scientific basis for implementation and refinement of ecosystem-based management;

- educating the public about the role and importance of the oceans in daily life;
- tracking and understanding climate change and the ocean's role in it; and
- supplying important information to ocean-related businesses such as marine transportation, aquaculture, fisheries, and offshore energy production.

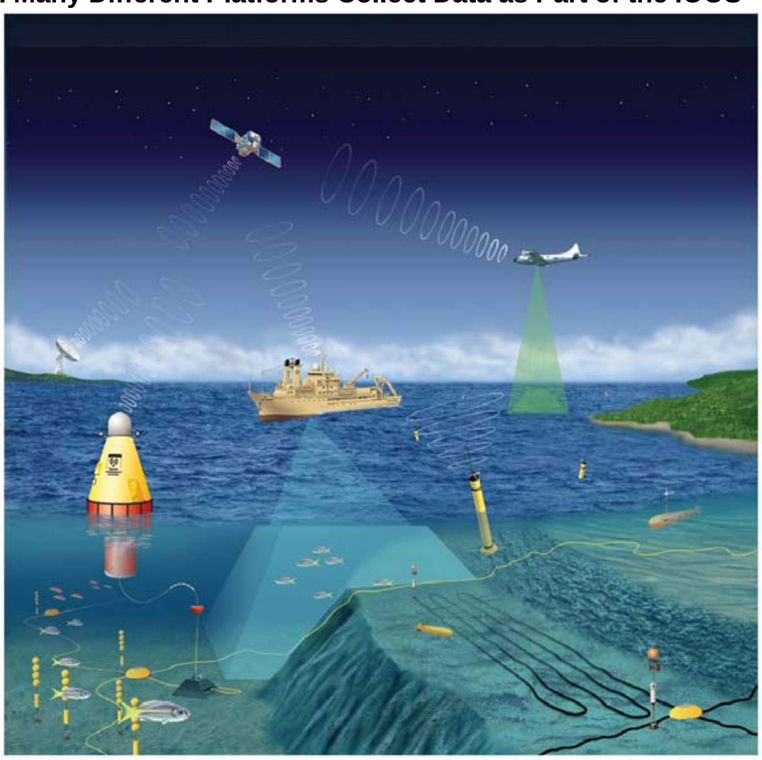
The United States simply cannot provide the economic, environmental, and security benefits listed above, achieve new levels of understanding and predictive capability, or generate the information needed by a wide range of users, without implementing the IOOS.

Components of an Integrated Ocean Observing System

The IOOS, an integrated and sustained ocean and coastal observing and prediction system, is a complex amalgam of many different land-, water-, air- and space-based facilities and technologies (Figure 26.1). Some broad categories of components are:

- *platforms,* such as ships, airplanes, satellites, buoys, and drifters, that are used for mounting or deploying instruments, sensors, and other components;
- *instruments and sensors* that sample, detect, and measure environmental variables;
- *telecommunication systems* that receive and transmit the data collected by the instruments and sensors; and
- *computer systems* that collect, store, assimilate, analyze, and model the environmental data and generate information products.

Figure 26.1. Many Different Platforms Collect Data as Part of the IOOS



This picture is an artist's rendering of the various water-, air-, and space-components of ocean observing systems. The data collected by each of these different sensors are transmitted via seafloor fiber optic cables and satellites to a central location on land.
Picture courtesy of the Marine Technology Society, Columbia, MD.

Assessing Existing Observing Systems

The United States has numerous research and operational observing systems that measure and monitor a wide range of terrestrial, atmospheric, and oceanic environmental variables (Appendix 5). For the most part, each system focuses on specific research objectives or limited operational applications. Among these are the U.S. Geological Survey's (USGS's) stream gage monitoring system that helps predict flooding and droughts, the National Weather Service's atmospheric observation system for weather, wind, and storm predictions and warnings, and the USGS/National Aeronautics and Space Administration (NASA) Landsat satellite system that characterizes landscape features and changes for land use planning. The technologies used run the gamut from simple on-the-ground human observations to highly sophisticated instruments, such as radar, radiometers, seismometers, magnetometers, and multispectral scanners.

Coastal and Ocean Observing Systems

Currently, the United States has more than forty coastal ocean observing systems, operated independently or jointly by various federal, state, industry, and academic entities (Appendix 5). The federal government also operates or participates in several large-scale, open-ocean observing systems. Examples include the National Oceanic and Atmospheric Administration's (NOAA's) Tropical Atmosphere Ocean program in the central Pacific Ocean that provides data to monitor and predict El Niño–La Niña conditions and the global-scale Argo float program for monitoring ocean climate.

There are several independent regional ocean and coastal observing systems. For the most part, they were built for different purposes and applications, measure different variables at different spatial and temporal scales, are not intercalibrated, and use different standards and protocols for collecting, archiving, and assimilating data. They also compete with each other for the limited funding available to support such efforts. As a result, despite considerable interest among stakeholders, and existence of required technology and scientific expertise, the United States has progressed very slowly in the design and implementation of a cohesive national ocean observing system.

An integrated ocean and coastal observing system that is regionally, nationally, and internationally coordinated and is relevant at local to global scales can serve a wide array of users, be more cost-effective, and provide greater national benefits relative to the investments made. Although the current regional systems are valuable assets that will be essential to the implementation of the IOOS, they are insufficiently integrated to realize a national vision.

Committing to Creation of the IOOS

The global ocean community has consistently articulated the need for a sustained ocean observing system to address the myriad challenges facing the world's oceans. In 1991, the United Nations Intergovernmental Oceanographic Commission proposed implementation of the Global Ocean Observing System (GOOS), and in 1992 participating nations at the United Nations Conference on Environment and Development (known as the Earth Summit) in Rio de Janeiro agreed to work toward establishment of this global system.

The U.S. National Ocean Research Leadership Council (NORLC), the leadership body for the National Oceanographic Partnership Program, has taken the lead in creating the IOOS, which will serve in part as the U.S. contribution to the GOOS. In response to congressional requests, the NORLC drafted two reports outlining the steps for creating a national system: *Toward a U.S. Plan for an Integrated, Sustained Ocean Observing System (1999)*, and *An Integrated Ocean Observing System: A Strategy for Implementing the First Steps of a U.S. Plan (2000).* The second report provided a blueprint for the system's design and implementation. In October 2000, the NORLC established a federal interagency office called Ocean.US and charged it with coordinating development of the IOOS.

Ocean.US has made significant progress on a strategic plan for design and implementation. The plan is based on two distinct components: open ocean observations conducted in cooperation with the international GOOS and a national network of coastal observations conducted at the regional level. The coastal component will include the U.S. exclusive economic zone, the Great Lakes, and coastal and estuarine areas.

Developers of the IOOS must ensure that the global component is not minimized and that the connectivity with GOOS, including U.S. funding and leadership, remains strong and viable. GOOS data will be essential for assimilating environmental data that spans many spatial scales and for creating forecasts of national and regional impacts that may originate hundreds or thousands of miles away. Strong U.S. involvement in the GOOS will also demonstrate the nation's commitment to working toward an inclusive Earth observing system.

Although many individuals and agencies have spent countless hours creating plans for the IOOS, its successful realization will require high-level visibility and support within the administration, Congress, and the broad stakeholder community.

Recommendation 26–1. The National Ocean Council should make development and implementation of a sustained, national Integrated Ocean Observing System a central focus of its leadership and coordination role.

The support of a broad-based, multi-sector constituency is also critical to the success of the IOOS, particularly in light of the funding levels required to build, operate, and sustain such as system. As a first step, two national pilot projects and one or two international pilot projects should be implemented to link existing systems and produce operational applications relevant to national policy and a broad spectrum of users. The pilot projects will provide important visibility and demonstrate the potential economic and societal benefits of the full system, while advancing research and development of useful technologies and applications.

Creating a Governance Structure for the IOOS

National Planning

A strong national governance structure is required to establish policy and provide oversight for all components of the IOOS and to ensure strong integration among the regional, national, and global levels. Interagency coordination and consensus through the National Ocean Council and Ocean.US will be essential. While regional systems will retain a level of autonomy, achievement of the IOOS with nationwide benefits will require the regional systems to follow some national guidelines and standards. (Chapter 5 includes additional discussion of regional observing systems and their place within broader regional ocean information programs.) Regional observing systems can and should pursue needs outside the scope of the national system so long as these activities do not conflict with the smooth operation of the IOOS.

NOAA's role as the nation's civilian oceanic and atmospheric agency, and its mission to describe and predict changes in the Earth's environment and to conserve and manage the nation's coastal and marine resources, make it the logical federal agency to implement and operate the national IOOS.

Recommendation 26–2. Ocean.US, with National Ocean Council (NOC) oversight, should be responsible for planning the national Integrated Ocean Observing System (IOOS). The National Oceanic and Atmospheric Administration should be the lead federal agency for implementing and operating the IOOS, with extensive interagency coordination and subject to NOC approval.

Ocean.US

A memorandum of agreement (MOA) among ten federal agencies created Ocean.US as an interagency ocean observation office, supported by annual contributions from the signatories. The fundamental problem with the current arrangement is that Ocean.US has a number of responsibilities without any real authority or control over budgets. Its ephemeral existence under the MOA, its dependence on personnel detailed from the member agencies, and its lack of a dedicated budget severely detract from its stature within the ocean community and its ability to carry out its responsibilities.

Signatories to the Ocean.US Memorandum of Agreement	
U.S. Navy	Minerals Management Service
National Oceanic and Atmospheric Administration	U.S. Department of Energy
National Science Foundation	U.S. Coast Guard
National Aeronautics and Space Administration	U.S. Army Corps of Engineers
U.S. Geological Survey	U.S. Environmental Protection Agency

A more formal establishment of the Ocean.US office is needed for it to advise the National Ocean Council and achieve its coordination and planning mandates. The office requires consistent funding and dedicated full-time staff with the expertise and skills needed to ensure professional credibility. In addition, outside experts on rotational appointments could help Ocean.US meet its responsibilities.

Recommendation 26–3. Congress should amend the National Oceanographic Partnership Act to formally establish Ocean.US, with a budget appropriate to carry out its mission. Ocean.US should report to the National Ocean Council's (NOC's) Committee on Ocean Science, Education, Technology, and Operations (COSETO).

Congress should:

- *make the Ocean.US budget a line item within the National Oceanic and Atmospheric Administration's budget, to be spent subject to NOC approval.*
- *give Ocean.US authority to bring in outside experts on rotational appointments when needed.*

Regional Structure

Ocean.US envisions the creation of a nationwide network of regional ocean observing systems that will form the backbone of coastal observations for the IOOS. Although Ocean.US proposes creation of regional associations for coastal observing, coordinated through a national federation, [1,2] this concept is unnecessarily narrow. To fully address the needs of coastal managers, ocean observations need to be integrated into other information gathering activities such as regionally-focused research, outreach and education, and regional ecosystem assessments. Thus, as recommended in Chapter 5, the regional ocean information programs should be in charge of the development and implementation of regional ocean observing systems, along with their broader responsibilities. Regular meetings among all the regional ocean information programs and Ocean.US will be important for providing regional and local input into the development of the national IOOS.

REACHING OUT TO THE USER COMMUNITY

To fulfill its mission, the IOOS must meet the needs of a broad suite of users, including the general public. However, at this early stage many people do not even know what the national IOOS is, nor do they grasp the potential utility and value of the information it will generate. This has slowed progress in its implementation.

Some important stakeholders outside of the federal agency and ocean research communities have not been sufficiently integrated into the initial planning process. Some of those who were consulted believe they were brought into the process after important design and other decisions had already been made. While Congress and the administration have both expressed support for the concept of a national integrated ocean observing system, there has been insufficient constituent demand to compel appropriation of significant public funds. Clearer communication about the benefits of the IOOS and broader participation in planning activities are necessary to help create a groundswell of support.

To get the most out of the IOOS, resource managers at federal, state, regional, territorial, tribal, and local levels will need to supply input about their information needs and operational requirements and provide guidance on what output would be most useful. Other users, including educators, ocean and coastal industries, fishermen, and coastal citizens, must also have a visible avenue for providing input. Ocean.US and the regional ocean information programs will need to devote significant time and thought to proactively approaching users and promoting public awareness of the enormous potential of the IOOS.

One obvious application of the observing system will be to monitor potential terrorist threats to the United States, including the possible use of commercial and recreational vessels to introduce nuclear, chemical, or biological weapons through the nation's ports to attack large metropolitan areas or critical marine infrastructure. Thus, it is important that homeland security personnel be actively engaged in defining their needs as part of the IOOS design process.

Recommendation 26–4. Ocean.US should proactively seek input from coastal and ocean communities to build cross-sector support for the national Integrated Ocean Observing System (IOOS) and develop consensus about operational requirements.

Specifically, Ocean.US should seek input from:

- *state, local, territorial, and tribal management agencies, industry, academia, nongovernmental organizations, and the public in the design and implementation of regional ocean observing systems and their integration into the national IOOS.*
- *Homeland security agencies in the design of the national IOOS, including planning for future research and development efforts to improve and enhance the system.*

Assembling the Elements of a Successful IOOS

The success of the IOOS will depend on several design elements: measuring the right set of environmental variables to meet regional, national, and global information requirements; transitioning research accomplishments into operational applications; and developing technologies to improve all aspects of the system, especially the timeliness and accuracy of its predictive models and the usefulness of its information products.

Critical Environmental Variables

To establish a uniform national system, a consistent core of environmental variables must be measured by all of the system's components. This core must strike a balance, remaining manageable and affordable while including enough parameters to address watershed, atmosphere, and ocean interconnections and support resource management, research, and practical use by many stakeholders. Measurements should include natural variables as well as human influences.

Based on an evaluation of more than one hundred possible environmental variables, Ocean.US identified an initial priority set of physical, chemical, and biological parameters for measurement by the IOOS (Table 26.2). It also created a supplemental list of meteorological, terrestrial, and human variables that are related to ocean conditions (Table 26.3).[3]

Table 26.2. Proposed Core Variables for the IOOS
Participants at an Ocean.US workshop recognized the following variables as important measurements to be made by the national IOOS.

Physical	Chemical	Biological
Salinity	Contaminants: Water	Fish Species
Water Temperature	Dissolved Nutrients	Fish Abundance/Biomass
Bathymetry	Dissolved Oxygen	Zooplankton Species
Sea Level	Carbon: Total Organic	Optical Properties
Directional Wave Spectra	Contaminants: Sediments	Ocean Color
Vector Currents	Suspended Sediments	Pathogens: Water
Ice Concentration	pCO_2	Phytoplankton Species
Surface Heat Flux	Carbon: Total Inorganic	Zooplankton Abundance
Bottom Characteristics	Total Nitrogen: Water	Benthic Abundance
Seafloor Seismicity		Benthic Species
Ice Thickness		Mammals: Abundance
Sea-surface Height		Mammals: Mortality Events
		Bacterial Biomass
		Chlorophyll-a
		Non-native Species
		Phytoplankton Abundance
		Phytoplankton Productivity
		Wetlands: Spatial Extent
		Bioacoustics

Source: National Ocean Research Leadership Council. *Building Consensus: Toward an Integrated and Sustained Ocean Observing System*. Proceedings of an Ocean.US workshop. Arlington, VA, March, 2002.

Table 26.3: Proposed Supplemental IOOS Variables
In addition to the ocean specific variables listed above, the participants at the Ocean.US workshop highlighted a number of other variables that affect ocean and coastal environments.

Meteorological	Terrestrial	Human Health & Use
Wind Vector	River Discharge	Seafood Contaminants
Air Temperature	Groundwater Discharge	Pathogens: Seafood
Atmospheric Pressure		Fish Catch and Effort
Precipitation (dry and wet)		Seafood Consumption
Humidity		Beach Usage
Aerosol Type		
Ambient Noise		
Atmospheric Visibility		
Cloud Cover		

Source: National Ocean Research Leadership Council. *Building Consensus: Toward an Integrated and Sustained Ocean Observing System*. Proceedings of an Ocean.US workshop. Arlington, VA, March, 2002.

While these lists provide a starting point for further discussion, many of the items included are actually broad categories rather than specific variables to be measured. The lists do not specify which variables can be measured with current technologies, which particular contaminants and pathogens should be observed, or which sets of observations can be assimilated to predict potentially hazardous environmental conditions, such as harmful algal blooms. Surprisingly, several important variables, such as inputs of air- and river-borne pollutants, are not included at all.

These lists will require further refinement and review by potential users of the system and a mechanism must be established to solicit additional feedback. Regional observation needs, such as fish stock assessments, assessments of sensitive and critical habitats, or monitoring for invasive species, are best understood by those in the regions affected. Therefore, input from local and regional groups, organized through the regional ocean information programs, will be essential for determining which variables should be included as national priorities.

Variables should be prioritized based on their value in resolving specific issues or questions, their application across issues, and the cost of measuring them. Priorities should also be assigned based on the variable's application to global, national, regional, state, and local information needs. Future deliberations will also need to identify variables for which current observation capabilities are sufficient and those that require new technologies.

Recommendation 26–5. Ocean.US, with National Ocean Council oversight, should develop a set of core variables to be collected by all components of the national Integrated Ocean Observing System.

This set of core variables should:

- *include appropriate biological, chemical, geological, and physical variables.*
- *be agreed on by the regional ocean information programs.*

Space-based Mission Priorities

Space-borne sensors can provide comprehensive, real-time, widespread coverage of ocean conditions and features and will be an integral part of the national IOOS. A growing international constellation of satellites allows extensive observation of ocean-surface conditions as well as the ability to extrapolate measurements from *in situ* sensors. Satellites can also provide baseline measurements at local, regional, national, and global scales that can be used to assess long-term environmental changes and the impacts of catastrophic events.

However, implementing sustained observations from space requires intense planning with long lead times. Given the cost, the time frame for constructing and launching satellites, and the inability to modify satellites once in orbit, five- to ten-year plans are required to ensure that satellite observations will be available on a continuous basis and employ the most useful and modern sensors. NOAA, as the lead federal agency for implementing and operating the IOOS, must ensure that ongoing satellite operations are fully integrated into the national IOOS.

Common needs for space-based observations should be identified and prioritized by a diverse group of users, in a manner similar to that recommended for determining IOOS environmental variables. Coordination with international satellite organizations will also be necessary to integrate the national IOOS with the GOOS and to accelerate development of new satellite-based sensor technologies.

Recommendation 26–6. Ocean.US should recommend priorities and long-term plans for space-based missions as an essential component of the national Integrated Ocean Observing System.

Ocean.US should:

- *work closely with the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, the user community, and the space industry to identify the most important space-based ocean observation needs.*
- *work with the international community on technical requirements for the Global Ocean Observing System in developing a plan for satellite remote sensing.*

Converting Research into Operational Capabilities

Research Observatories

A number of research observatories now in operation were created primarily by academic institutions to develop new observation technologies. Rutgers University's Long-term Ecosystem Observatory and the Monterey Bay Aquarium Research Institute's Ocean Observing System are two examples of programs that have made significant advances in developing observation technologies and the data management systems needed to support them. These observatories provide valuable scientific and engineering information that will be essential in building the IOOS. However, they can not be easily integrated into an operational, national IOOS, which will need to be based on stable, proven technologies and structured to deliver long-term observations.

The national IOOS will also have significant synergies with the NSF Ocean Observatories Initiative, which is being designed to address the ocean research community's needs for long-term, *in situ* measurements of biological, chemical, geological, and physical variables over a variety of scales. The NSF observatories will be used to examine the processes that drive atmospheric, oceanic, and terrestrial systems, and will serve as an incubator for new technologies to monitor these processes. While the IOOS and the NSF observatories have thus far been planned independently, the basic research and technology development from the NSF Observatories and the information generated by the IOOS are in reality interdependent, with each program supplying ingredients essential to the other. Close coordination and cooperation between NOAA and NSF will be necessary to capitalize on these benefits.

To ensure that the best available science and technology are continuously integrated into the national IOOS, mechanisms are needed for transitioning findings from research settings to routine operational applications. A new NOAA Office of Technology, recommended in Chapter 27, would be instrumental in making this transfer proceed smoothly. It would oversee coordination between NOAA, NSF, the U.S. Navy (including the Office of Naval Research, Naval Research Laboratory, Naval Oceanographic Office, Fleet Numerical Meteorology and Oceanography Center, and National Ice Center), NASA, other pertinent federal agencies, academia, and the private sector, all of which are essential in creating the bridge from research to operations.

New Sensor Technology

One area where additional capabilities are critically needed is in sensor technologies. Currently, the ability to continuously observe and measure physical variables (such as water temperature, current speed, and wave height) far surpasses the ability to measure chemical and biological parameters. With a few exceptions, most chemical and biological measurements are still obtained mainly by direct sampling and analysis. This shortcoming seriously hampers real-time observations of a broad range of biological parameters and populations of special interest, such as corals, marine mammals, and fish stocks. To realize the full promise of the IOOS, accelerated research into biological and chemical sensing techniques will be needed, with rapid transitions to operational use. NOAA, NSF, the Navy, and NASA should fund the development, and subsequent integration, of biological and chemical sensors for the IOOS as high priorities. Sensor development is discussed in more detail in Chapter 27.

Recommendation 26–7. The National Oceanic and Atmospheric Administration, the National Science Foundation (NSF), the U.S. Navy, and the National Aeronautics and Space Administration should require investigators who receive federal funding related to ocean research observatories, including the NSF Ocean Observatories Initiative, to develop plans for transferring new technologies to an operational mode in the Integrated Ocean Observing System.

Consolidating Civilian Satellite Observations

Both NOAA and NASA currently operate civilian, space-based, Earth observing programs that measure terrestrial, atmospheric, and oceanic variables (Appendix 5). NOAA's primary mission in this area is to provide sustained, operational observations for monitoring and predicting environmental conditions and long-term changes, with a focus on weather and climate. In contrast, NASA's mission is to advance research efforts and sensor development. A NASA project can last from a few days to a few years, and NASA has repeatedly asserted that it is not in the business of providing data continuity. In many instances, the lifetime of a NASA satellite, and its continued ability to collect and transmit data, outlasts its funding, resulting in premature termination at odds with the pressing demands for data in the operational context.

Benefits of Consolidation

While NASA-led research missions have greatly advanced our understanding of the oceans, they are developed without regard to ongoing, operational observing needs beyond the planned one- to ten-year life of the individual mission. Thus NASA's efforts have not, and will not, result in the sustained capabilities needed for the national IOOS. NASA also does not have the extensive atmospheric, land, and ocean ground-truthing infrastructure needed to verify remote observations for operational purposes.

The integration of space-based Earth environmental observing into one agency will greatly ease the implementation of a functional national system. Development of a multi-decadal record of observations requires space missions with sufficient overlap to avoid gaps in data collection and allow intercalibration of successive generations of sensors. Lack of such coordination can result in crippling information gaps, such as occurred during an eleven-year hiatus in the collection of ocean color data between the Coastal Zone Color Scanner and SeaWiFS missions. By consolidating Earth, and particularly ocean, observing satellite missions, more seamless, long term planning will be possible, resulting in a smooth concept-to-operations data collection process.

Recommendation 26–8. Congress should transfer National Aeronautics and Space Administration's (NASA's) Earth environmental observing satellites, along with associated resources, to the National Oceanic and Atmospheric Administration (NOAA) to achieve continued operations. NOAA and NASA should work together to ensure the smooth transition of each Earth environmental observing satellite after its launch.

Specifically, NOAA should:

- *work with NASA to define requirements for research-oriented Earth observing missions.*
- *ensure that satellite-derived ocean databases are integrated with traditional ocean and coastal databases.*
- *implement phased satellite missions and equipment replacement to maintain consistent data acquisition, based on Ocean.US plans.*
- *establish a long-term archive that includes historical satellite data to safeguard records, particularly those related to climate trends.*
- *prepare budget submissions that reflect the cost of transitioning satellite research missions into sustained operation.*

Because of its expertise and capabilities, NASA should maintain research, engineering, and development responsibility for Earth observing satellites. However, operational control of these satellites should be turned over to NOAA after the integrity of the satellite is confirmed in orbit (usually within approximately twenty days). This handoff has been demonstrated with the National Polar-orbiting Operational Environmental Satellite System.

Planning for Satellite Consolidation

A number of infrastructure and organizational changes will be needed at NOAA to ensure seamless assimilation of all Earth environmental observing satellites. Enhanced science, technology, and management coordination should occur within NOAA and among NOAA, other agencies, and the private and academic sectors. In addition, NOAA should initiate a review of its past successes and challenges in remote-sensing activities, satellite hardware procurement, satellite data collection and processing, and data distribution and archival strategies and programs. It is essential that NOAA be able to deliver raw data as well as analytical products to the public on an ongoing basis, and archive data in readily accessible formats for future assessments of environmental change.

NOAA's data and information management practices should be flexible, address customer needs, allow for continuous feedback and improvement, and be based on partnerships with industry and academia when appropriate. Further recommendations for improved data management and information product development within NOAA are found in Chapter 28. NOAA will also need to plan for continued calibration of all its observing satellites, using academic and private sector partners to form calibration and validation teams.

Developing Useful End Products Based on IOOS Data

To justify large federal investments in the IOOS, the system must result in tangible benefits for a broad and diverse user community, including the general public, scientists, resource managers, emergency responders, policy makers, private industry, educators, and officials responsible for homeland security. The IOOS cannot be developed as a narrow system useful only for research or federal government applications. The longtime partnership between the National Weather Service (NWS) and the private sector, which results in both general and tailored weather forecast and warning products that are widely acknowledged as valuable, is a good model upon which to build the IOOS.

The National Weather Service: An Investment That Paid Off

Billions of dollars have been invested over the last century to create a robust weather-related observing system. Continued operation of the National Weather Service (NWS) costs every U.S. citizen $4-$5 a year. For this investment, the NWS issues more than 734,000 weather forecasts and 850,000 river and flood forecasts annually, along with 45,000–50,000 potentially life-saving severe weather warnings. These forecasts and warnings have the potential to save millions to billions of dollars. For example, during a typical hurricane season, the savings realized based on timely warnings add up to an estimated $2.5 billion.[4] Geomagnetic storm forecasts are estimated to save the North American electric generating industry upwards of $150 million per year.[5]

NWS and commercial meteorological products have applications ranging from scientific research to human safety, transportation, agriculture, and simple daily forecasts. Similarly, IOOS products should be wide-ranging and based on the needs of regional and local organizations and communities, as well as national needs. The regional ocean information programs described in Chapter 5 will help produce information products of benefit to regional, state, and local managers and organizations. These regional programs will also provide important feedback to national planners about ways to make national IOOS products more useful. In addition, close coordination with Ocean.IT (a new data management office recommended in Chapter 28) will help in developing new forecast models of coastal and open-ocean conditions.

NOAA–Navy Partnership

Both NOAA and the Navy have the computer infrastructure and human capital needed to produce data and information products at varying spatial and temporal scales, and have experience tailoring products to the requirements of stakeholders in different regions and for different purposes. A joint NOAA–Navy ocean and coastal information management and communications program can help ensure high-quality end products from the national IOOS. Working together, these agencies will be able to produce routine operational ocean condition reports, forecasts, and warning products based on data from the IOOS. The NOAA–Navy program should work closely with nonfederal organizations, such as state and local governments, the regional ocean information programs, educators, nongovernmental organizations, and the private sector, to ensure that IOOS information products are useful to a broad user community. Specific recommendations about a NOAA–Navy ocean and coastal information management and communications program are included in Chapter 28.

Table 26.4. Proposed Annual Costs for Implementation
Assuming startup in fiscal year 2006, this table shows the IOOS cost estimates for each year until 2010. These figures do not include the costs for some essential components, such as satellite observations, which could add another $50-100 million per year.

Fiscal Year	Cost
2006	$138 million (start-up costs)
2007	$260 million
2008	$385 million
2009	$480 million
2010	$500 million (fully operational system)
Total for first five years	$1.7 billion
Out Years	$500 million/yr (to keep system operational, not accounting for inflation)

Data courtesy of Ocean.US., Arlington, VA.

Funding the National IOOS

The existing IOOS implementation plan calls for a distributed funding structure under which funds for implementation and operation of the national IOOS would be appropriated to many individual ocean agencies to support their respective contributions to the system.[6] This approach is not conducive to timely and seamless implementation of the national IOOS. The differences in missions and priorities among the ocean agencies could slow the implementation of key components of the IOOS. Additionally, the federal ocean agencies answer to different congressional committees and subcommittees for authorizations and appropriations, which could result in inconsistent and incomplete funding of the national system. Furthermore, in times of tight budgets, federal agencies may be tempted to tap into their IOOS budgets to support other shortfalls or unfunded initiatives. Only by consolidating the IOOS budget within one agency, with input and agreement on spending from the other agencies, can full implementation be assured.

System Cost Estimates

Ocean.US has provided estimates of the costs of implementing, operating, maintaining, and enhancing a national IOOS. The plan for the system involves a four-year ramp-up of funding, from a $138 million start-up cost in fiscal year 2006 to $500 million annually starting in fiscal year 2010 (Table 26.4). Details of the $138 million start-up cost are provided in Table 26.5.[7] The cumulative cost over the first five years is estimated at $1.7 billion.

Table 26.5: Breakdown of Proposed IOOS Start-up Costs
In fiscal year 2006, the start-up cost of $138 million is based on expenditures for four distinct components.

Activity	Cost to Perform
Accelerate the implementation of the U.S. commitment to the Global Ocean Observing System	$30M
Develop data communications and data management systems for the national IOOS	$18M
Enhance and expand existing federal observing programs	$40M
Develop regional observing systems	$50M
Total	**$138M**

Source: Ocean.US. *An Integrated and Sustained Ocean Observing System (IOOS) for the United States: Design and Implementation*. Arlington, VA, May 2002.

However, these cost estimates are not complete. They do not include all requirements for building, operating, and maintaining the system, such as costs associated with dedicated satellite sensors, space-borne platforms, and data stream collection and assimilation. Considering these additional system elements, rough estimates suggest that total funding for the national IOOS over the first five years may be closer to $2 billion.

Continuous improvements to IOOS observation and prediction capabilities will require sustained investments in technology development. Considering the costs of sensor development, telecommunications, computer systems, and improvements in modeling and prediction capabilities, an additional annual investment of about $100–$150 million will most likely be needed. Thus, the eventual ongoing costs for operating, maintaining, and upgrading the national IOOS could approach $650–$750 million a year.

Given the importance of the IOOS as an element in an integrated Earth observing system, these costs are in line with federal expenditures for other elements, including atmospheric, hydrologic, and pollution-related monitoring. For example, the ongoing cost of operating NWS is a comparable $700 million a year.

To fulfill its potential, the IOOS will require stable funding over the long haul. The lack of long-term funding for existing regional ocean observing systems has contributed to their isolation and piecemeal implementation. Consistent funding will help ensure that the American public receives the greatest return for its investment in the form of useful information, reliable forecasts, and timely warnings.

Recommendation 26–9. Congress should fund the Integrated Ocean Observing System (IOOS) as a line item in the National Oceanic and Atmospheric Administration (NOAA) budget, to be spent subject to National Ocean Council direction and approval. IOOS funds should be appropriated without fiscal year limitation. NOAA should develop a streamlined process for distributing IOOS funds to other federal and nonfederal partners.

An Investment with Big Returns: The Economic Value of Ocean Observations

While it is impossible to predict all the economic benefits that would flow from a national Integrated Ocean Observing System, its potential can be estimated by looking at a few systems currently in operation.

For example, the Tropical Global Ocean Atmosphere (TOGA) observing system in the Pacific Ocean provides enhanced El Niño forecasting. The economic benefits of these forecasts to U.S. agriculture have been estimated at $300 million per year.[8] Advanced El Niño forecasts allow fishery managers to adjust harvest levels and hatchery production 12 to 16 months in advance. For one small northwestern Coho salmon fishery, the net benefits of these forecasts have been estimated to exceed $1 million per year.[9] When summed over all economic sectors, the estimated value of improved El Niño forecasts reaches $1 billion a year.[10]

Improved wind and wave models based on ocean observations make weather-based vessel routing possible. Today, at least half of all commercial ocean transits take advantage of this, saving $300 million in transportation costs annually.[11] Search and rescue efforts by the U.S. Coast Guard also benefit from ocean observations. Small improvements in search efficiency can generate life and property savings in excess of $100 million per year.[12] Although more difficult to quantify, marine tourism, recreation, and resource management also benefit greatly from integrated observations and the improved forecasts they allow.

Finally, scientists estimate that reductions in greenhouse gas emissions now, compared to 20 years in the future, could result in world-wide benefits of $80 billion, with the United States' share approaching $20 billion.[13] Such emissions reductions will only be undertaken when policy makers feel fairly certain about their likelihood of success. Improved ocean observations and models will be critical to filling these knowledge gaps to support appropriate action.

STRENGTHENING EARTH OBSERVATIONS THROUGH NATIONAL AND INTERNATIONAL PARTNERSHIPS

Other U.S. Operational Observing Systems

Atmospheric, terrestrial, and oceanic conditions and processes are inextricably intertwined. Progress in managing and protecting global resources will depend on understanding how those systems interact and what their impacts are on all scales, from local to global, over minutes or decades. Understanding such interactions is essential for accurately forecasting global climate change (long-term or abrupt), seasonal to decadal oscillations (like El Niño–La Niña, the North Atlantic Oscillation, or the Pacific Decadal Oscillation), and short and long-term ecosystem responses to environmental change.

The IOOS cannot exist as a stand-alone system, developed without considering associated observations. Rather, it should be integrated with other environmental observing systems to link weather, climate, terrestrial, biological, watershed, and ocean observations into a unified Earth Observing System. Such a system would improve understanding of environmental changes, processes, and interactions, making ecosystem-based management possible.

Integration of the IOOS with NWS's ground-, water-, space-, and atmosphere-based observations, with USGS's stream gage, water quality monitoring, and landscape observations, and with EPA's pollution monitoring, should be essential steps in implementation of the IOOS. The IOOS should also be linked with the broad national water quality monitoring network recommended in Chapter 15. Credible data gathered through other agencies and mechanisms, such as the Coral Reef and Invasive Species task forces, should all be considered in creating a coordinated Earth Observing System.

Recommendation 26–10. The National Ocean Council should oversee coordination of the Integrated Ocean Observing System with other existing and planned terrestrial, watershed, atmospheric, and biological observation and information collection systems, with the ultimate goal of developing a national Earth Observing System.

Enhancing Global Cooperation

The United States should continue to participate in the international Global Ocean Observing System to gain a better understanding of global ocean circulation patterns and biological processes, and answer pressing policy questions about global climate change and resource availability. In July 2003, the Earth Observation Summit was held in Washington, D.C. to focus on building an integrated global observation system over the next ten years. Thirty-four nations, the European Commission, and twenty international organizations joined the United States in adopting a declaration that affirmed the need for timely, high-quality, long-term global Earth observations as a basis for sound decision making. The ad hoc Group on Earth Observations has been formed to implement the declaration, co-chaired by the United States, the European Commission, Japan, and South Africa, and an implementation plan is scheduled to be completed by late 2004.

A recurring limitation of international scientific agreements and programs is the growing divide between scientific capacity and resources in developed and developing nations. Global programs function most effectively when all partners can participate fully. In addition to expanding scientific knowledge and stimulating technological development, capacity-building programs serve U.S. interests by creating goodwill and strengthening ties with other countries. Examples of capacity-building techniques include: providing access to U.S. scientific and technological expertise on a continuing basis; establishing education and training programs; securing funding for travel grants to allow scientists from less developed countries to participate in symposia, conferences, and research cruises; and funding international student fellowships.

High-level U.S. participation in international global observing planning meetings is essential, particularly by top-level NASA and NOAA officials. Furthermore, the United States should be strongly involved in international Earth Observation satellite missions. This includes supporting U.S. scientists to participate in foreign satellite mission planning and execution activities, such as planning for enhanced data management and access protocols.

Compatibility and accessibility of data collected by all participants in the GOOS will be needed to make the whole worth more than the sum of its parts. Although the United States has always supported full and open access to oceanographic data, this policy has met with resistance in some nations, especially where basic data collection and management activities have been outsourced to private companies. The U.S. should encourage foreign entities to engage in a policy of reciprocity, with a commitment to mutual sharing of data.

Recommendation 26–11. The National Ocean Council (NOC) should promote international coordination and capacity building in the field of global ocean observations.

The NOC should:

- *lead the interagency implementation of the 2003 Declaration on Earth Observing.*
- *encourage and support developing nations' participation in the Global Ocean Observing System.*
- *continue to advocate full, open, and meaningful data access policies and contribute technological expertise to ensure such access by all participants.*

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