Interagency Working Group on Ocean Observations:

Draft Integrated Ocean Observing System Strategic Plan

Purpose

This is a five-year strategic plan developed by the Interagency Working Group on Ocean Observations (IWGOO) that describes the vision and direction of the Integrated Ocean Observing System (IOOS). The plan builds on the IOOS development plan, addendum, and its predecessor documents for the U.S. IOOS and incorporates that work by reference (see Appendix II). Essentially, this plan characterizes the areas of highest priority for the U.S. contribution to the Global Earth Observation System of Systems (GEOSS) over the next five years. Upon adoption of this strategic plan, an implementation plan with roles and responsibilities for these actions will be developed to describe the details of the way forward.

Introduction

Over the past decades, billions of dollars have been invested in observing and predicting global and coastal ocean processes, as well as associated atmospheric processes, to produce the information required for planning, forecasts, warnings, watches, climate assessments, and regulatory policies. These observing and information systems reside in dozens of federal and state agencies, universities, and private industries and are tailored to the individual missions of those who fund them. By continuing on this course of developing isolated, individual systems instead of an integrated system, the nation over the next 20 years could spend billions of additional dollars on ocean observations because of the multiplied costs of development, operations, and maintenance.

About two decades ago, officials and scientists realized that the nation had to integrate the assets of its many ocean and coastal observing systems and focus them on providing solutions to societal needs—solutions that address the missions of several agencies and organizations. Catastrophic weather events, coastal pollution, dead zones, harmful algal blooms, declines in living marine resources, climate change—all these underscore the importance of creating a more integrated approach to providing data and information needed to manage and mitigate the impacts of human activities, natural disasters, and climate change on goods and services provided by the oceans, coasts, and Great Lakes. While the nation has developed some of the most sophisticated and comprehensive Great Lakes, estuarine, and marine monitoring programs in the world, these individual programs are not as robust, effective, or comprehensive as they could be in protecting the societal and economic security of the nation, and therefore in providing the quality of life our citizens expect. In addition, operating separate, largely independent systems is inefficient both logistically and fiscally.

The expectation for integrating ocean observations is that the data, information, products, and services from individual systems have synergistic value beyond their original context. For a

modest investment, existing individual assets and monitoring programs can be connected in a comprehensive ocean-observing framework to realize the full potential of the combined assets, enabling a variety of users to discover, utilize, and exploit existing oceanographic data and information to generate value for our citizens and economy. An integrated system enables not only better decision-making for issues impacting the safety and well-being of citizens (e.g., disaster mitigation and warning, water resource management, and marine transportation), but also supports a value-added market similar to what has emerged from weather and climate services. This integrated system also builds capacity to enable participation without the need to invest a tremendous amount on infrastructure or resources.

Put simply, the existing information provided by the observing systems operated by a range of federal, state, local, academic, and private entities could be much more useful and timely if it were linked, conveyed, and displayed in an integrated, standardized way. Recent major advances in observation, modeling, and information technology now provide the means to help the nation accomplish such an objective.

Benefits of the Integrated Ocean Observing System

IOOS will provide data and information needed to significantly improve the nation's ability to achieve these seven interrelated societal benefits:

1. Improve predictions of climate change and weather and their effects on coastal communities and the nation;
2. Improve the safety and efficiency of maritime operations;
3. Mitigate the effects of natural hazards more effectively;
4. Improve national and homeland security;
5. Reduce public health risks;
6. Protect and restore healthy coastal ecosystems more effectively; and
7. Enable the sustained use of ocean and coastal resources.

These benefits will be accomplished by efficiently linking observations to modeling via data management and communications to provide services, products, and decision-support tools needed to achieve these goals. Some example "outcome/benefit vignettes" for IOOS are highlighted in Figure 1.

Strategically, IOOS cannot address all seven societal benefits simultaneously. IOOS is a complex system of systems that is best implemented in stages. Phased implementation requires the prioritization of existing assets that monitor variables that are essential and common to more than one societal benefit. The highest priority assets measure these core variables, using both in situ and remote sensing platforms, to provide new or existing products that can be improved by integrating data from more than one program, institution, or agency. Four criteria were used to prioritize existing federally operated or funded observing subsystem assets for integration into the initial IOOS:

- Data integration must lead to more accurate and timely assessments of environmental conditions and predictions of changes in conditions that have major socioeconomic consequences.

- Assessment and prediction products must inform decision-makers working in two or more of the seven societal goal areas.
- Data integration resulting in new or improved products and services must be feasible within a short time frame (e.g., 2 years).
- Data streams produced by existing monitoring assets must be sustainable, reliable, and quality-controlled.

Using these criteria, the prioritized assets will address coastal flooding (inundation) aspects of benefits 1 and 3, navigation aspects of benefits 2 and 5, and assessment aspects of benefit 6. The initial phase of IOOS development will focus on integrating data and developing improved products for users of these types of information.

Outcome/Benefit Vignettes

- The estimated national benefit across only seven sectors (shipping, recreation, search and rescue, energy, fishing, storm prediction, and health and safety) from a fully functioning national IOOS is between $597 and 684 million per annum. (NOPP–Woods Hole Oceanographic Institute, 2004).
- A fisheries scientist will be able to provide a regional fisheries management council with improved stock assessments that take into account ecological and climate variability, thereby enabling more accurate forecasts of fish recruitment.
- As a hurricane bears down on the coast, coastal managers will be able to instantly access greatly improved forecast information on storm track, intensity, evacuation routes, and destructive potential. They will benefit from the data collected by many agencies, seamlessly merged into tools useful for making the decisions necessary to save life and property.
- A research team will be able to significantly improve the numerical prediction of ocean circulation by being able to access, for the first time, a comprehensive suite of ocean observations. This improved predictive ability would translate quickly into improved long-term weather and climate forecasts.
- Recent lack of protective ice has exposed native Alaskan Eskimo villages to rapid erosion caused by winter storm waves. IOOS data and models will help decision makers better anticipate and respond to these changes in their environment.
- Shallow water wave forecasts (presently unavailable), combined with a local and regional delivery system to provide information to lifeguards and emergency workers, will significantly reduce the number of unsuspecting swimmers who drown every year in dangerous rip currents—currently estimated at 40 to 50.
- Circulation models improved by ocean observations off the coast of New Jersey have helped Coast Guard search and rescue efforts by providing real-time observations and short-term forecasts for the coastal ocean that reduce the search time, resulting in more lives saved, reduced costs, and fewer Coast Guard personnel placed at risk.
- Resource managers and the public will be able to rapidly and easily determine if the beaches and recreational coastal waters are safe to use and swim in, and if the fish caught in the coastal waters and Great Lakes are safe to eat.
- Surface current maps off the coast of California, derived from an array of high frequency radars, are being used to assist in tracking discharge plumes offshore of the beaches.
- Responders to a chemical or oil discharge in the ocean will have access to dispersion forecasts from models improved by input from near real-time ocean observations.

Figure 1. Outcome/Benefit Vignettes.

Definition of the Integrated Ocean Observing System

IOOS is the oceans and coasts component of the U.S. Integrated Earth Observation System (IEOS), and the U.S. contribution to the international Global Ocean Observing System (GOOS), which is the ocean and coastal component of the Global Earth Observation System of Systems (GEOSS). GEOSS is the superset of observing systems, with which IOOS has connection only through IEOS and GOOS.

IOOS will provide timely ocean data and information for people who need it.

IOOS is a partnership and is designed to be a system of systems that routinely and continuously provides quality-controlled data and information on current and future states of the oceans and Great Lakes from the global scale of ocean basins to local scales of coastal ecosystems (Ocean.US, 2006a). It obtains much of its value from four principles:

1. A focus on meeting end user needs with special attention to societal benefits;
2. Recognition that collaborative partnerships will allow several agencies and sectors to achieve an objective that is too large or too broad for any one of them to accomplish alone;
3. A focus on measuring critical ocean variables and the provision of high-quality data in a timely fashion, rather than on specific technologies, so that the system can evolve in approach while being consistent with its goals and objectives; and
4. A structure that is comprehensive yet flexible and agile, derived from a system design that is not based on central control but rather on distributed, coordinated, interacting, and interrelated parts.

These principles are not satisfied easily. Three of them (1, 2, and 4) are somewhat in conflict with traditional federal government organizational and fiscal procedures, and all four require trust and coordination among all sectors—government, private, academic, nongovernmental, and public. An example of an IOOS program that could possibly satisfy the principles described above is the proposed U.S. Surface Current Mapping Program (see Figure 2 for details).

Vision: A dynamic and well-coordinated IOOS evolves from existing efforts, provides users with timely high-quality multisectoral and multidisciplinary information and forecasts about the ocean and coastal environment and living marine resources, and enables responsible bodies to make informed decisions that affect the lives and livelihoods of U.S. citizens and visitors. IOOS includes observations, modeling, data management and communications, and applications that are implemented at the national, regional, state, and local levels.

To achieve this vision, this plan sets out the goals, objectives, and actions for continued progress in three critical strategic areas—organization and governance, IOOS system design, and capitalizing on expertise, capabilities, and interests through distributed implementation functions.

Example IOOS Program: Surface Current Mapping

Our nation is surrounded by an Exclusive Economic Zone (EEZ) that is nominally 200 nautical miles wide and comprises an area greater than that of the United States land mass itself. In this EEZ, thousands of commercial ships, recreational boaters, and government activities are functioning daily. These activities support a large part of our gross national product and our national and homeland security, and contribute to our quality of life.

The most fundamental oceanic information to enable effective and safe operations in the EEZ is water temperature and the measurement of ocean currents and waves, analogous to our terrestrial weather forecasts of temperature and winds. The provision of surface current fields in near-real time is also important for ship routing, search and rescue, public safety, and forecasting the impacts of oil spills, harmful algal blooms, waterborne pathogens, and pollutants on human health and well-being, marine ecosystems, and living resources. Ocean current mapping also supports numerous basic and applied research activities in our coastal zones. Although sea surface temperatures are often available from satellites and give desirable wide-area coverage, the current best-practice technology for surface currents and waves is a combination of

- moored and drifting buoys;
- surface-mapping Doppler backscatter radars from fixed platforms (often called High Frequency Surface Radars);
- predictive ocean-current numerical models driven by winds and tides; and
- large-scale occasional coverage by selected satellites.

A national program to provide near-real time maps and short-term predictions of surface currents and waves in the U.S. EEZ by leveraging the specialized knowledge and skills of research institutes and more than six federal agencies illustrates the return on investment of an IOOS:

- Although the data and forecasts are useful in various research activities, the major value is from enhanced search and rescue, more efficient marine transportation, monitoring of traffic in our coastal waters, improved fishing charts, and safer recreational boating.
- Several research institutes and U.S. agencies have portions of the knowledge, tools, and expertise to execute an observing and predicting network for surface currents, namely NOAA, Navy, U.S. Coast Guard (USCG), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), and Federal Communications Commission (FCC). Pilot projects are underway to understand the requirements to transfer the technology to an operational system. The federal user base includes some of these agencies plus Department of Transportation (DOT), Department of Homeland Security (DHS), Maritime Administration (MARAD), Department of the Interior, and others. None of the entities has all of the pieces.
- With a focus on the need for surface currents (an oceanic variable) rather than (for example) high-frequency (HF) Radar (a particular technology), infuse new technologies and methodologies without disruption of information to customers and decision-makers.
- The system design is robust, distributed, coordinated, interacting, and interrelated to optimize the strengths and requirements of partners. To illustrate: USCG can provide shore sites for HF radars; academia or regional groups can run observing systems under contract; NOAA can archive and disseminate data; Navy and DHS can extract ship-monitoring information; and a central Surface Current Program Office can coordinate and monitor the efforts in a cooperative manner with all stakeholders.
- Federal and state agencies, regional associations, and others can access timely, accurate, and reliable data to build and provide improved and new products and services that help better meet national, regional, and local needs.

Figure 2. Example IOOS Program: Surface Current Mapping.

Organization and Governance

Goal 1*: The national IOOS is a unified system that provides seamless delivery of ocean and coastal information and predictions; and includes federal, nonfederal, national, and regional components for implementation.*

Goal 2: *IOOS links to other environmental observing systems into the broader Integrated Earth Observation System (IEOS), the Global Ocean Observing System (GOOS), and thereby the Global Earth Observation System of Systems (GEOSS).*

IOOS System Design

Goal 3: *The U.S. has an IOOS that provides valuable data to improve predictive and decision-making capabilities for the seven societal benefits, with an initial focus on coastal inundation, navigation, public health, and ecosystem assessment.*

Goal 4: *IOOS provides a process for the development and delivery of applications and decision-support tools for advancing critical national and regional priority issues.*

Distributed Implementation Functions

Goal 5: *IOOS will continuously evolve through research and the incorporation of advances in technology and understanding into the operational capability.*

Goal 6: *IOOS is integrated with the ocean science education objectives of informal, formal, and work force and postsecondary communities.*

Goal 7: *The nation's IOOS community will collaboratively advance IOOS and realize benefits from effective coordination of investments made by all members of the public, private, and academic sectors.*

Figure 3. Strategic Plan Goals for IOOS.

Organization and Governance

To benefit from the expertise and assets of all the ocean agencies, regional systems, research institutions, and the private sector, and to allow tailored focus on regional needs, IOOS is structured as a distributed program. The federal challenge is that most of the IOOS societal benefits overlap several federal agency missions, and while the Ocean Research Priorities Plan (ORPP) is a new effort to assist with developing the ocean research priorities of the federal agencies, the organization and governance must allow for and promote coordination, collaboration, and joint efforts. Involvement of the private sector and academia, particularly at the regional level, heightens the need for coordinated organization and management of the U.S. IOOS enterprise.

The U.S. Ocean Action Plan (2004), in response to strong recommendations of the U.S. Commission on Ocean Policy (2004) and building on and complementing the work of past and current interagency efforts to build IOOS, establishes a comprehensive mechanism in the executive branch for coordinating ocean policy at the federal level. Together with the National Oceanographic Partnership Program (10 U.S.C. 7981-7983) there is a combined executive-legislative set of mechanisms to provide the essential organizational structures. This structure includes interagency coordination of IOOS issues at all levels of the federal government.

Efforts to integrate elements of federal, regional, academic, and private-sector assets into an effective system that delivers tangible results are critical to the success of IOOS. Although federal funds for IOOS are, or will be, appropriated to many federal agencies, each with its particular mission and priorities, the federal and regional elements of IOOS must work as a seamless unit to develop end products. To accomplish this level of interagency cooperation, the budgets need to be coordinated and activities implemented through existing interagency mechanisms, specifically the Interagency Working Group on Ocean Observations (IWGOO) of the Joint Subcommittee on Ocean Science and Technology (JSOST) (see Figure 4). The organizations or agencies responsible for coordination must have mechanisms for ensuring the transfer of funds between federal and nonfederal partners. The Ocean.US office reports to and serves as the interagency coordinating and planning body of IWGOO.

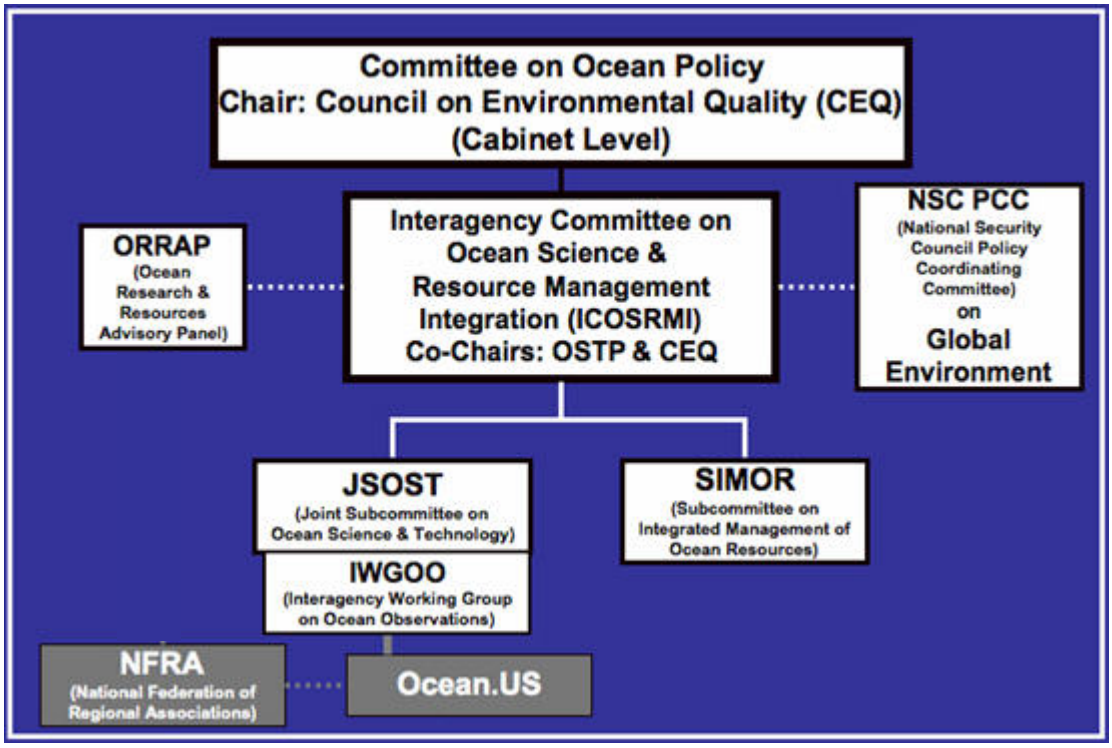

Figure 4. Ocean Governance Structure as described in the U.S. Ocean Action Plan (2004) and the First IOOS Development Plan approved by the ICOSRMI in 2006.

The geographical structure of IOOS includes global, national, and regional scales of observation. Federal agencies are responsible for the global and national scales of observation and analysis. IOOS Regional Associations (RAs) have the primary responsibility for observations within their respective regions that meet the requirements of users to ensure the right products are delivered in a timely way (see Figure 5). This distributed structure with regional building blocks for IOOS recognizes the importance of customizing the provision of data and information collected at all scales to address the diverse, and often unique, needs within each region with sufficient specificity.

Figure 5. Locations of the 11 nascent U.S. IOOS Regional Associations (RAs). See Appendix I for RA acronym definitions.

Goal 1*: The national IOOS is a unified system that provides seamless delivery of ocean and coastal information and predictions and includes federal, nonfederal, national, and regional components for implementation.*

Objective 1.1: Establish national partnership of federal agencies to integrate observing assets of agencies and develop improved capacity to unify IOOS.

Action 1.1.1: Obtain approval of critical agency roles and responsibilities as they relate to IOOS from the Interagency Committee on Ocean Science and Resource Management Integration (ICOSRMI).

Action 1.1.2: Establish a Memorandum of Agreement among the IWGOO agencies that details the specific responsibilities of each participating agency.

Action 1.1.3: Obtain agreement between Ocean.US and the National Federation of Regional Associations (NFRA) on critical roles and responsibilities of the federal and nonfederal regional implementation entities. The Interagency

Committee on Ocean Science and Resource Management (ICOSRMI) is the federal approving authority for this agreement.

Objective 1.2: Establish effective mechanisms for the budget planning and timely transfer of appropriated resources to IOOS partners.

Action 1.2.1: Establish coordinated approach to the agency budget planning for the budget submission process starting in fiscal year 2009.

Action 1.2.2: Adopt a long-term funding model for sustained operation of the existing federal IOOS assets.

Action 1.2.3: Establish streamlined procedures for the distribution and accounting of funds appropriated to federal partners and distributed to nonfederal partners, including Regional Associations.

Objective 1.3: Ensure the effective implementation of appropriate regional components of IOOS.

Action 1.3.1: Establish a process for regional input into the national dialogue on IOOS planning and implementation through the National Federation of Regional Associations.

Action 1.3.2: Adopt a long-term funding model for IOOS regional partners that provides for sustained operation of the regional IOOS component.

Action 1.3.3: Develop a mechanism by which representatives of federal agencies can participate in the IOOS Regional Associations to ensure effective coordination and collaboration between federal, state, university, and private partners at the regional level.

Action 1.3.4: Implement a review process that ensures that the IOOS Regional Associations are effective partners, contribute to carrying out the IOOS mission at the regional level, and seek feedback and input from all appropriate customers including resource managers.

Action 1.3.5: Coordinate regional IOOS education and outreach efforts using existing ocean education networks (i.e., Centers for Ocean Sciences Education Excellence [COSEE], Sea Grant, National Estuarine Research Reserve System [NERRS], National Marine Sanctuary Program [NMSP]) where possible.

Objective 1.4: Focus national IOOS partners and resources to demonstrate effective development of improved delivery of information and services

Action 1.4.1: The IWGOO/JSOST will utilize existing and new mechanisms to establish the program(s), funding mechanism(s) and process(es) necessary to link federal and nonfederal resources to produce user products. The process will utilize a competitive selection of pilot and demonstration projects.

U.S. IOOS International Collaborations

Our nation's ocean and coastal resources are part of the larger Earth system. Each of the seven societal benefits depends on observing the global ocean, as well as our nation's coastal waters. No single nation can economically and effectively sustain a global ocean observing system on its own. A global observing system by definition crosses international boundaries with the potential for both benefits and responsibilities to be shared by many nations. International coordination will align the development of IOOS to be the U.S. contribution to the Global Ocean Observing System (GOOS); the ocean and coastal component of the U.S. Group on Earth Observations (USGEO)).

Goal 2: *IOOS links with other environmental observing systems into the broader Integrated Earth Observation System (IEOS), the Global Ocean Observing System (GOOS), and thereby into the Global Earth Observation System of Systems (GEOSS).*

Objective 2.1: The IWGOO and JSOST, working with Ocean.US, will coordinate IOOS with current and future terrestrial, aquatic, and atmospheric observing systems to establish and maintain a GEOSS.

Action 2.1.1: The IWGOO will work with the Observations Working Group of the Climate Change Science Program (CCSP) to achieve the CCSP strategic objective: "complete global coverage of the oceans with moored, drifting, and ship-based networks."

Action 2.1.2: The IWGOO will coordinate and contribute to the USGEO Work Plan (CL-06-06): "Global Ocean Observing System – Improve global coverage and data accuracy of the climate-monitoring system and coastal observing systems as well as management and archival of the resulting data."

Objective 2.2: The JSOST will work with international partners to ensure IOOS is compatible with and contributes to the GOOS.

Action 2.2.1: The IWGOO will coordinate through U.S. contributions to the GOOS in cooperation with the Joint World Meteorological Organization (WMO)/Intergovernmental Oceanographic Commission (IOC) Technical Commission for Oceanography and Marine Meteorology (JCOMM)).

IOOS System Design

An integrated system represents an ambitious effort of the national and global ocean community to establish and maintain a robust, adaptive, continuous presence in the ocean and provide critical information and products to users and stakeholders. IOOS intends to be responsive to societal needs, and thus the optimal design of the system is based on the requirements of the user community in fulfilling the IOOS' seven societal benefit areas. To provide this range of data and information, IOOS will cover a diverse suite of spatial (coastal watersheds to polar seas) and temporal (seconds to decades) regimes, and provide data as needed (at real-time and delayed mode) to address a broad spectrum of issues.

Existing data provided by observing systems operated by federal and state agencies, academic institutions, and other local or regional entities will expand the geographic distribution and scope of data types offered through IOOS. The observations will be most useful and timely, and serve the broadest number of users when they are combined and conveyed in an integrated and

standardized manner to ensure maximum interoperability. The need to acquire additional types of data and information products than are currently available calls for development of an IOOS that includes coupled observational and research components. IOOS is designed to remain "state of the art," which enables appropriate and proven advances in science, technology, methods, or best practices be incorporated as appropriate into the operations of the system. It will also incorporate observing, modeling, and application development efforts of the federal, state, and local governments, as well as those efforts of the private sector and academic community. Regional differences in priority issues are taken into account through variation in data collection and model and product development so that the information provided meets local needs from around the nation (for example, red tide information in some regions and ice warnings in others).

IOOS is designed as a robust architecture that establishes an integrated infrastructure framework in compliance with Federal Enterprise Architecture and relevant Office of Management and Budget (OMB) Information Technology (IT) requirements. It will be interoperable with other components of GEOSS and with related research efforts such as the National Science Foundation's Ocean Observatories Initiative (OOI). The design will be based on the First IOOS Development Plan and the results of projects such as the National Oceanic and Atmospheric Administration (NOAA)–NAVY IOOS Demonstration completed in 2005. This will allow the diverse set of capabilities and assets of each of its domains (observing, modeling and analysis, and data management) to connect in a nationwide network that operates seamlessly.

Goal 3: *The U.S. has an IOOS that provides valuable data to improve predictive and decision-making capabilities for the seven societal benefits with an initial focus on coastal inundation, navigation, public health, and ecosystem assessment.*

Objective 3.1: Provide integrated data for an initial set of priority core ocean variables that address critical needs within three years and a second set of priority variables within six years.

Action 3.1.1: Ocean.US with federal agencies, through the IWGOO, and the IOOS Regional Associations will identify the primary and secondary sets of variables using the initial focus areas and the first U.S. IOOS Development Plan to guide selection. This will include consultation with appropriate ICOSRMI subcommittees during selection of additional variables for focus.

Action 3.1.2: IWGOO, Ocean.US, and the ocean communities will agree on standards and processes for measurement of high-priority variables to enable integration across federal and regional entities into the seamless national system.

Action 3.1.3: Federal agencies and IOOS Regional Associations will complete compatible and dynamic inventories of existing infrastructure (including in situ sensor systems) and operational models, product systems, and complete system designs, and identify critical gaps in infrastructure (e.g., hardware, software, network capacity, data archives).

Action 3.1.4: NASA and NOAA will develop a plan to evaluate existing satellite coverage and assess any potential gaps in continuous remote sensing coverage of priority variables.

Action 3.1.5: NASA and NOAA will develop a plan to improve remote sensing capabilities to meet observing system requirements for coastal waters as recommended in the Integrated Global Observing Strategy's (IGOS) Coastal Theme report and to provide those variables at scales relevant to coastal waters.

Objective 3.2: Provide an integrated and extensible IOOS system of systems design consistent with GEOSS plans to facilitate use of the IOOS ocean component within the U.S. Integrated Earth Observation System (IEOS) and hence a fully functioning component of the U.S. contribution to GEOSS in the same time frames targeted in Objective 3.1.

Action 3.2.1: Ocean.US with federal agencies, through the IWGOO, and the IOOS Regional Associations will initiate a formal system design process to produce design artifacts for guiding development and implementation of IOOS components. This will include consultation with appropriate ICOSRMI subcommittees and the US IEOS structure in seeking input and review of the evolving design.

Goal 4*: IOOS provides a process for the development and delivery of applications and decision-support tools for advancing critical national and regional priority issues.*

Objective 4.1: Develop and improve national and regional models that produce outputs used to develop products that address the critical regional and national needs in one or more of the IOOS benefit areas.

Action 4.1.1: Use community involvement processes to coordinate national research, observation, and modeling efforts with variables in priority areas.

Action 4.1.2: Develop a research-to-operations transition process to sustain products using the most accurate and timely models available by coordinating with ongoing efforts such as the U.S. Ocean Research Priorities Plan's program.

Objective 4.2: Develop and distribute applications for meeting targeted regional uses developed through a distributed, coordinated, interactive process involving both governmental and nongovernmental organizations.

Action 4.2.1: The IOOS Regional Associations will work with federal agencies to maintain community awareness of existing application development efforts for targeted priorities and ensure effective delivery of applications.

Action 4.2.2: The IOOS Regional Associations will work with federal agencies to identify and fill critical gaps for improved application development to address societal benefits within their regions.

Action 4.2.3: The IOOS Regional Associations and federal agencies will develop pilot applications to demonstrate a capability to meet the needs of users at national to regional scales.

Objective 4.3: Provide users with the information and products needed to address key priorities in planning and decision-making at national to regional scales.

Action 4.3.1: Use successful pilot projects as the foundations to develop more effective programs.

Action 4.3.2: Quantify and communicate the benefit incurred by use of the initial priority IOOS applications.

Distributed Implementation Functions

IOOS is a distributed set of interdependent systems at the national, regional, and state levels that build on and enhance existing efforts in research and education.

Research

Advances in fundamental scientific knowledge of ocean processes are necessary to achieve the goals of IOOS. New technology and scientific knowledge are required to enable IOOS user requirements to be met, to improve IOOS products and their interpretation, to develop new applications to serve existing requirements, and to provide new products for user requirements not currently anticipated. Thus, engaging researchers and research agencies in IOOS is critical to the evolution of the observing system, ultimately leading to broader use of IOOS information, more sophisticated products, and increased user satisfaction (Ocean.US, 2002a, b; Ocean.US, 2006a).

Both hypothesis-driven and mission-driven research is of fundamental importance to the evolution of a fully integrated system that addresses all seven societal benefits. Thus, IOOS is conceived of as consisting of a continuum of research to operational activities that ensures continued improvements in operational capabilities and enhances the research enterprise (Ocean.US, 2006a). For example, the Ocean Observatories Initiative (OOI) of the National Science Foundation (NSF) will support advances in oceanography and make advances in operational capabilities of IOOS. Operational elements of IOOS will be funded for extended periods based on user needs, whereas IOOS research and pilot projects will have specific objectives and will be funded for finite periods. Research and pilot projects that show potential for operational application within IOOS will be recommended for "pre-operational" status and will be endorsed by the organization (or organizations) that will fund and operate them in a "proof of concept" operational mode. As the IOOS operational system evolves, it will stimulate research and help guide the development of new pilot and pre-operational projects. Contributing to the evolution and improvement of IOOS is one way to demonstrate the societal worth of specific research programs.

Goal 5: *IOOS will continuously evolve through research and the incorporation of advances in technology and understanding into the operational capability.*

Objective 5.1: Integrate successful operational and pre-operational programs into IOOS, and continue critical existing operational programs of IOOS.

Action 5.1.1: Identify and sustain present critical operational programs needed to address one or more of the seven IOOS benefits based on consumer demand and societal needs.

Action 5.1.2: Establish a process by which research projects are identified, funded, and transitioned to pre-operational status. Extend selected research projects beyond their intended duration if those projects have an applied use.

Action 5.1.3: Develop platform, hardware, and software standards that are interoperable for research and operational uses.

Action 5.1.4: Develop platform designs and standards that will ensure data are available when needed (e.g., hardened platforms to withstand extreme weather events).

Objective 5.2: Modify and enhance IOOS with new technologies as they are proven.

Action 5.2.1: Identify and develop high-priority sensors and associated algorithms. Initial focus will be on technologies for measuring chemical and biological variables in near real-time to fulfill needs identified by coastal managers, water quality managers, and others (Ocean.US, 2006b).

Action 5.2.2: Use existing programs in NSF, Environmental Protection Agency (EPA), NOAA, and other agencies to focus development of ocean access technologies (e.g., long-term power supplies, transmitting large data volumes, and mobile autonomous platforms) that would enhance the capabilities of the system.

Action 5.2.3: Develop the infrastructure necessary to (a) support the development of new sensors, including biological sensors, (b) field evaluate existing or pre-operational oceanographic sensors, and (c) train observation providers in the proper deployment and use of IOOS sensor systems.

Objective 5.3: Apply the outcomes of basic research as it benefits the operational system.

Action 5.3.1: Establish and conduct a process to identify, rank, and fill significant gaps in observations, including new advances in synoptic coverage (e.g., surface current mapping, and other remote sensing).

Action 5.3.2: Utilize the National Oceanographic Partnership Program (NOPP) to provide multiagency support to science and technology development for IOOS.

Education

IOOS provides an opportunity to change the public perception of our oceans and motivate children and adults to pursue careers allied with the oceans, and thereby to become stewards of the environment (see Ocean.US 2004). A science- and technology-literate society and workforce are essential if IOOS is to significantly address the seven societal benefits. To develop the workforce that will create the breakthroughs needed to tackle these societal issues, it is essential that the public value science and technology and that there be adequate educational and training opportunities. To realize sustained solutions to these societal issues, we need an ocean science and technology enterprise that employs scientists and engineers to transform knowledge and innovations into operational applications. Both the National Oceanographic Partnership Program (NOPP) and the U.S. Ocean Action Plan (2004) have reiterated the importance of science and technology education and the participation of science and technology organizations in these efforts.

Goal 6: *IOOS is integrated with the ocean science education objectives of informal, formal, and workforce and postsecondary communities.*

Objective 6.1: Build and maintain a community of formal and informal educators that use IOOS information to achieve education objectives.

Action 6.1.1: Develop an education strategy and detailed implementation plan to develop learning materials and programs for IOOS.

Action 6.1.2: Initiate and enhance pilot projects that provide access to real-time and continuous ocean observing data in formats that are effective complements to education objectives and teaching standards.

Action 6.1.3: Leverage existing educational efforts occurring at national to regional scales for education and outreach on issues in common among those programs and IOOS.

Action 6.1.4: Build on existing collaborative regional and national ocean education and communication networks (such as COSEE, Sea Grant, NERRS, NMSP) to ensure compatibility with existing efforts.

Objective 6.2: Train the workforce to have the technical and scientific skills necessary (a) to deploy, maintain, and improve ocean observing systems needed to develop and sustain IOOS; and (b) to produce the allied information products, services, and tools.

Action 6.2.1: Conduct a workforce needs analysis for the operational and developmental needs of IOOS to identify needed education and training efforts.

Action 6.2.2: Develop and deploy postsecondary curricula aligned with identified workforce needs of the IOOS community.

Action 6.2.3: Engage professional societies to assist in training and developing professional certifications for IOOS-related careers.

Funding

The resources needed to implement IOOS include finances, people, facilities, and knowledge. In many cases these resources can be contributed in kind, but direct contributions will also be needed. The funding strategy includes coordinating the federal agency budget submissions for IOOS activities, according to administration guidance and anticipated congressional approval. Coordinated budgets would include activities that are funded in one agency (where the mission is) but will be performed in another agency (where the expertise is) to gain efficiencies and synergies.

Goal 7: *The nation's IOOS community will collaboratively advance IOOS and realize benefits from effective coordination of investments made by all members of the public, private, and academic sectors.*

Objective 7.1: Establish an environment where current and out-year budget information is shared across agencies for coordinated interagency IOOS planning and programming purposes.

Action 7.1.1: Prepare an annual set of priorities regarding program planning and resource needs, especially funding, for advancing IOOS priorities.

Action 7.1.2: Develop an agreement among participating agencies on the level of budget detail that will be shared (with dependencies/contingencies noted) to enable long-term planning and sustained operation of the system.

Action 7.1.3: Develop a coordinated budget submission across agency lines that advances the overall set of IOOS investment priorities in an integrated fashion.

Objective 7.2: Establish mechanisms, common business best practices, and planning processes for sharing costs and outlining roles and responsibilities among agencies to enhance interagency planning for advancing common IOOS priorities, including joint projects that require shared funding.

Action 7.2.1: Develop a sustained mechanism to transfer funds among agencies that support common IOOS goals and activities.

Action 7.2.2: Adopt a federal management model to deliver financial services that will establish direct lines of accountability.

Action 7.2.3: Employ a federal planning, programming, budgeting, and execution system to enhance IOOS-related agencies' capabilities and guarantee effective delivery of needed products and services.

Action 7.2.4: Evaluate lessons learned from private industry, universities, and national and international agencies that can be adopted by IOOS-contributing agencies to develop more effective IOOS-related services.

Action 7.2.5: Evaluate and assess stakeholder satisfaction and implement a process to incorporate recommendations for program improvement and adaptive management of the IOOS enterprise.

Summary

Realizing the vision of a dynamic and well-coordinated IOOS that provides users with timely information and forecasts about the ocean and coastal environment will require a long-term commitment by federal and state agencies and the support of other members of the coastal and ocean community. Coordination among participants at all levels will be key to building a system off of existing efforts and designing future efforts to fill critical gaps in observations, data management, scientific research, modeling, and application development.

Appendix I:
Acronym List

CCSP – Climate Change Science Program
DHS – Department of Homeland Security
DOE – Department of Energy
DOT – Department of Transportation
EEZ – Exclusive Economic Zone
EPA – Environmental Protection Agency
FCC – Federal Communications Commission
GEO – Group on Earth Observations
GEOSS – Global Earth Observation System of Systems
GOOS – Global Ocean Observing System
HF – High Frequency
ICOSRMI – Interagency Committee on Ocean Science and Resource Management Integration
IEOS – Integrated Earth Observing System
IGOS – Integrated Global Observing Strategy
IOOS – Integrated Ocean Observing System
IWGOO – Interagency Working Group on Ocean Observations
JCOMM – Joint WMO (World Meteorological Organization)–IOC (Intergovernmental Ocean Commission) Technical Commission for Oceanography and Marine Meteorology
JSOST – Joint Subcommittee on Ocean Science and Technology
MARAD – Maritime Administration
MMS – Minerals Management Service
NASA – National Aeronautics and Space Administration
NFRA – National Federation of Regional Associations
NOAA – National Oceanic and Atmospheric Administration
NOPP – National Oceanographic Partnership Program
NSF – National Science Foundation
OAP – Ocean Action Plan
ONR – Office of Naval Research
OOI/ORION – Ocean Observatories Initiative/Ocean Research Interactive Observatory Networks
ORPP – Ocean Research Priorities Plan
RA – Regional Association
USCG – U.S. Coast Guard
USDA – U.S. Department of Agriculture
USGS – U.S. Geological Survey

Regional Associations:
AOOS – Alaska Ocean Observing System
CaRA – Caribbean Regional Association
CeNCOOS – Central and Northern California Ocean Observing System
GCOOS – Gulf of Mexico Coastal Ocean Observing System
GLOS – Great Lakes Observing System
MACOORA – Mid-Atlantic Coastal Ocean Observing Regional Association

NANOOS – Northwest Association of Networked Ocean Observing Systems
NERA – Northeastern Regional Association
PacIOOS – Pacific Islands Integrated Ocean Observing System
SCCOOS – Southern California Coastal Ocean Observing System
SECOORA – Southeast Coastal Ocean Observing Regional Association

Appendix II:
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