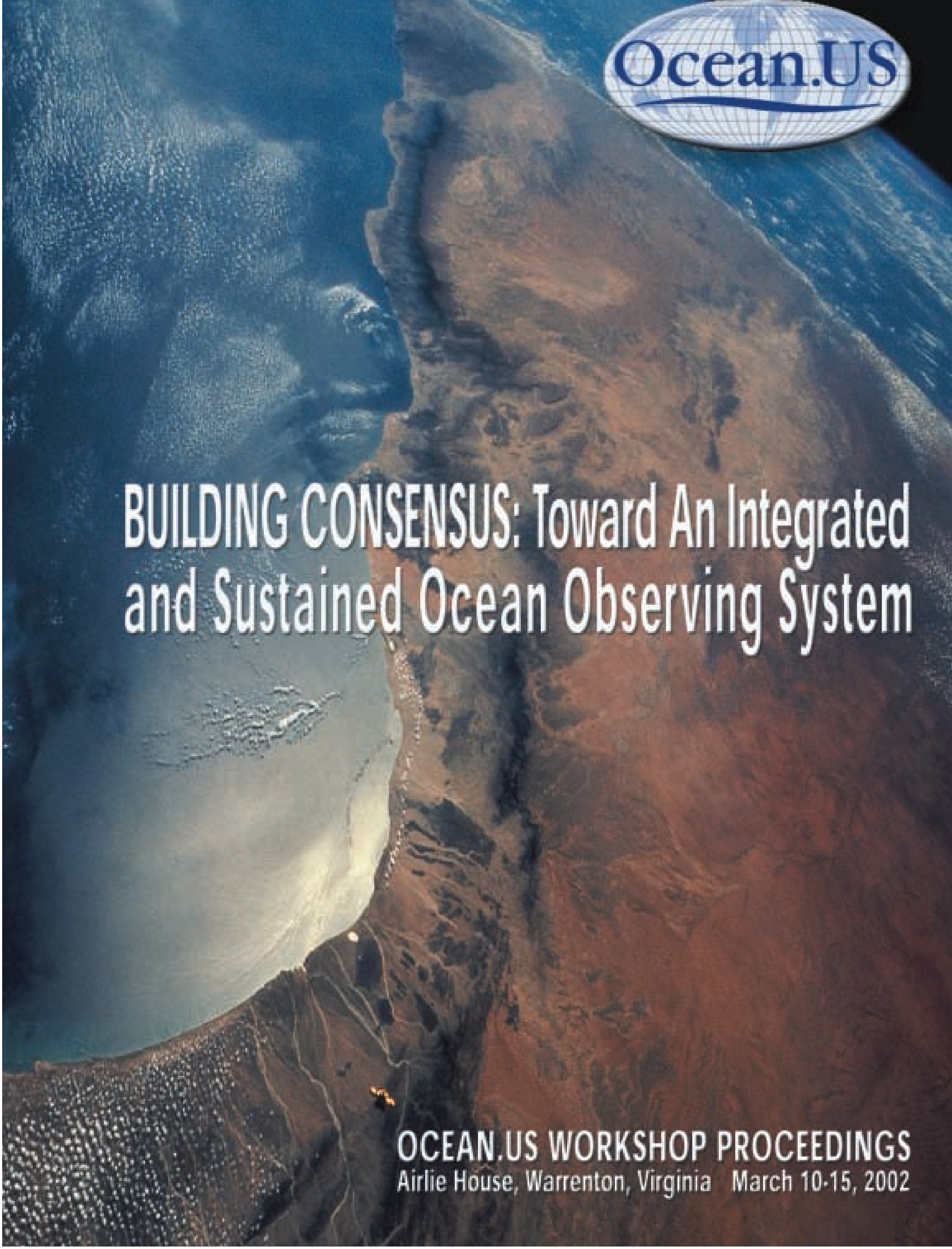

Ocean.US

BUILDING CONSENSUS: Toward An Integrated and Sustained Ocean Observing System

OCEAN.US WORKSHOP PROCEEDINGS

Airlie House, Warrenton, Virginia March 10-15, 2002

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BUILDING CONSENSUS: TOWARD AN INTEGRATED AND SUSTAINED OCEAN OBSERVING SYSTEM

Ocean.US Workshop Proceedings

Airlie House, Warrenton, Virginia
March 10-15, 2002

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BACKGROUND

The goal of the Ocean.US workshop was to provide information and guidance for the formulation of a phased implementation plan for a sustained and integrated ocean observing system (IOOS) for the U.S. The system is intended to provide the data information required to achieve seven major goals:

- Improve predictions of climate change and its effects on coastal populations
- Mitigate more effectively the effects of natural hazards
- Improve the safety and efficiency of marine operations
- Improve national security
- Reduce public health risks
- More effectively protect and restore healthy coastal marine ecosystems
- Sustain living marine resources

An integrated observing system consists of three closely linked subsystems: (1) the measurement (monitoring) subsystem, (2) the data management and communications subsystem, and (3) the data analysis-modeling subsystem. This workshop focused on measurements and data management.

The first workshop task was to come to a consensus on the subgoals and provisional products for each goal above. The resulting lists were used to formulate a comprehensive list of potential variables and observational techniques to be considered for the national backbone of the observing system. Variables were then ranked based on the number of subgoals to which they are relevant. The highest ranked variables are recommended for incorporation into the national backbone of observations. Potential techniques for measuring these variables (platforms, sensors, methods) were then evaluated based on their feasibility and their importance to providing the data required to detect and predict changes in the phenomena of interest identified in the subgoals. This impact-feasibility analysis and the ranking of variables provided the basis for achieving a consensus on high-priority actions needed to develop an IOOS for the Nation.

Through these activities the workshop articulated the community consensus on the core set of ocean variables that are relevant to all of the seven goals and that should, therefore, be incorporated into a federally supported national system of data acquisition, management and analysis. Based on this consensus, various observing technologies were examined to determine the optimum methods for observing the ocean and coastal marine ecosystems in terms of:

1. What is ready to implement now?
2. What elements are ready to transition from research into an operational system?
3. What research and development activities should be given high priority to develop a fully integrated system?

The workshop also addressed the need to identify socio-economic benefits from the observing system. Cost-benefit analyses are needed with initial emphasis on those products that have potentially broad application and a significant return on investment.

The workshop process (consensus building) and its results provided the basis for formulating a design and implementation plan requested by Congress (completed 23 May, 2002, Appendix I) and a detailed, multi-agency phased implementation plan for developing the system over the next 5-10 years (to be completed in CY 2002). This will not be the final plan. It will be periodically reviewed and updated as information needs become more defined and as new technologies and knowledge become available. The actions recommended below are first steps and are intended to significantly improve the ability of government agencies to achieve missions and goals that require ocean observations.

RECOMMENDATIONS

(1) Highest priority was given to the establishment of an integrated subsystem for data management and communications (the DAC) that transcends government agencies, individual research and monitoring programs, and research institutions. Consequently, the establishment of a DAC Steering Committee to develop the preliminary design into a formal DAC implementation plan by the end of CY 2002 was considered an immediate priority.

(2) Based on technical feasibility and importance, the following core variables were given high priority for

incorporation into the national backbone of the IOOS:

- **Physical:** salinity, temperature, bathymetry, sea level, surface waves, vector currents, ice concentration, surface heat flux, bottom characteristics
- **Chemical:** water column contaminants, dissolved inorganic nutrients, dissolved oxygen
- **Biological:** fish species and abundance, zooplankton species and abundance, optical properties, ocean color, phytoplankton species

In addition to those variables required to characterize the marine environment, the following variables are required to quantify the external drivers of change on a national scale:

- **Meteorological:** vector winds, temperature, pressure, precipitation, humidity
- **Terrestrial:** river discharge
- **Human health and use:** seafood contamination, water column concentration of human pathogens.

These variables should be considered high priority for incorporation into programs that are to be linked to form an integrated system of observations.

(3) In parallel with the design and implementation of the DAC, consensus was reached on priority actions required to improve the measurement subsystem. The following recommendations are intended to improve or enhance capabilities for more rapid detection and/or prediction of changes in the time-space distribution of the core variables:

- Enhance existing mooring systems to establish cross-shelf transects based on a network of 500 moorings (nationwide) with automated *in situ* sensors and real-time data telemetry.
- Enhance the existing network of tide gauges in terms of number, the number of geo-referenced gauges, and variables measured.
- Increase the number of ship-days devoted to stock assessments and measurements of key ecosystem variables (ecosystem based fisheries management) from 3,000 to 6,000.
- Invest in aircraft remote sensing to detect changes in distributions and physiological condition of biologically structured habitats (coral reefs, sea grass beds, kelp beds, tidal marshes, etc.), changes in shoreline (coastal erosion), and the distribution and abundance of marine mammals and turtles.
- Enhance satellite capabilities to improve the accuracy and resolution of sea surface height, surface waves and currents, winds over water, sea surface temperature, sea surface salinity, and sea surface chlorophyll-a and other phytoplankton pigments in shallow coastal waters.

(4) Improvements in the initial observing system will require substantial research and development. High priorities include:

- Development of HF radar (coastal currents and wave fields)
- Gliders (water column profiling)
- Enhanced satellite remote sensing including extension of remote sensing capabilities into shallow coastal waters with high resolution of core variables (e.g., surface temperature, salinity, currents, waves, phytoplankton pigments, sea level, health and distribution of coral reefs and sea grass beds)
- Development of operational, coupled physical-ecosystem models
- Development of *in situ* sensors for real-time measurements and telemetry of key biological and chemical variables.

1. THE WORKSHOP AND ITS GOALS

1.1 THE OBSERVING SYSTEM

As articulated in "Towards a U.S. Plan for an Integrated, Sustained Ocean Observing System" (submitted to Congress in 1999 and described on page 9), the purpose of the IOOS is to make more effective use of existing resources, new knowledge, and advances in technology to provide the data and information required to achieve seven major goals:

- Improve predictions of climate change and its effects on coastal populations
- Mitigate more effectively the effects of natural hazards
- Improve the safety and efficiency of marine operations
- Improve national security
- Reduce public health risks
- More effectively protect and restore healthy coastal marine ecosystems
- Sustain living marine resources.

The implementation of the IOOS will require the establishment of two related components, one for the global ocean and one for U.S. coastal waters. The global component is the U.S. contribution to the international Global Ocean Observing System which is part of the Integrated Global Observing Strategy. The coastal component is conceived as a federally supported national backbone of observations and data management that incorporates regional systems, i.e., a National Federation of Regional Observing Systems (Appendix I). The purpose of the national backbone is to develop, maintain, and operate the observing and data management infrastructure that will benefit the nation, regions and states by:

- Providing economies of scale that will improve the cost-effectiveness of regional observing systems by investing in a national system for the measurement and processing of common (core) variables that minimizes redundancy and optimizes data and information exchange
- Establishing national standards and protocols for measurements, data dissemination and management
- Establishing a network of reference stations to provide baseline data required to assess the significance of local variability and sentinel stations to provide early warnings of events and trends and to enable adaptive monitoring for improved detections and predictions
- Linking the large-scale network of observations for the ocean-climate system to local and regional scales of interest in coastal ecosystems
- Providing the means for comparative ecosystem analysis required to understand and predict variability on the local scale of interest
- Facilitating capacity building at the state level to ensure that all states and regions can contribute to and benefit from the IOOS.

The design and implementation of regional observing systems will be guided by state and regional priorities based on socio-economic and ecological considerations unique to each region. Regional ocean observing systems will both contribute to and benefit from the national backbone and will enhance the national backbone based on regional priorities. In most cases, rapid detection and timely prediction of changes in the phenomena of interest in each region will require greater resolution in the measurement of selected core variables and the measurement of additional variables. The design, implementation, operation and development of regional systems will be conducted by regional consortia that include representatives of all primary stakeholders from the region (e.g., private enterprise, state and federal agencies, scientists, educators, and NGOs).

Realization of the IOOS will require unprecedented coordination and collaboration on three related fronts: (1) within and among federal agencies, (2) between federal agencies and regional consortia, and (3) among regional consortia. Achieving this in collaboration with the U.S. GOOS Steering Committee is a major role of Ocean.US.

1.2 DEVELOPING A PHASED IMPLEMENTATION PLAN

This report presents the proceedings of the Ocean.US 2002 Workshop convened by Ocean.US in partnership with the U.S. Global Ocean Observing System (GOOS) Steering Committee. The proceedings, the second of three reports, summarize recommendations for implementing the federal contribution to the development of a sustained **Integrated Ocean Observing System (IOOS)** and the process by which consensus was achieved.

The first report, "An Integrated and Sustained Ocean Observing System For the United States: Design and Implementation" (Appendix I), summarizes

1. The rationale for an Integrated Ocean Observing System
2. The conceptual design of the System
3. Economic benefits of an integrated system
4. Initial steps for implementation
5. The higher priority actions and associated funding levels that should be implemented now

Initial steps and high priorities were based on a consensus that crystallized at the Ocean.US workshop described in this document. This report, which was approved and endorsed by the NORLC on 23 May, 2002, has been transmitted to the Office of Science and Technology Policy (OSTP) and is expected to go forward to Congress before the end of FY 02. The third report, to be completed by the end of calendar year 2002, will describe the first year of a multi-year, phased implementation plan with a timetable and cost estimates for implementing the IOOS. It is intended to be a strategic plan that charts the way forward based on current knowledge and technical capabilities. It will be developed with guidance from the federal agencies of the National Oceanographic Partnership Program (NOPP).

The Ocean.US 2002 Workshop was organized to provide the information and guidance needed to formulate a phased implementation plan for the federal contribution to the observing system. The objectives of the workshop were to achieve a consensus on

1. A prioritized list of **core variables** to be measured as part of the national backbone (the minimum number of variables required to detect or predict changes in a maximum number of phenomena of interest within each of the seven goals. See Appendix I)
2. **Operational techniques** (platforms, sensors, methods) for providing the required data streams
3. Guidelines for the formulation of a **phased implementation** plan based on both feasibility and impact
4. High priority research areas
5. High priority actions that should be initiated now

The consensus developed and the process by which it was reached are described below.

2. WORKSHOP RECOMMENDATIONS

A systematic and open process was used to achieve a national ocean community consensus on the development of a national backbone for an integrated and sustained ocean observing system for the nation. Workshop participants developed a ranked list of variables to be considered for measurement and analysis as part of the backbone, established processes for the development of the data communications and management subsystem and for economic assessments of the efficacy of the observing system, and agreed to high-priority actions that should be taken in the near-term to implement the system. These are summarized below.

2.1 CORE VARIABLES

The problem of detecting and predicting changes in coastal environments has many facets, and the development of a national backbone that will provide comprehensive characterization of all changes on a national scale is neither possible nor desirable. Thus, a major challenge is the specification of key properties and processes (i.e., core variables) that should be measured as part of the national backbone. The goal is not to specify all of the variables that must be measured and processed to detect and predict all changes that are relevant to all regions. The goal is to identify the minimum number of variables (the core variables) that are required to detect and/or predict changes in a maximum number of phenomena of interest to user groups, i.e., to provide data and information required by all regions and relevant to all 7 goals articulated in section 1 and to achieve a maximum number of subgoals within each of these broad goals (Appendices I and V) was guided by the reality that there are a small number of variables that will be required by all regions and that must be measured and processed to achieve the seven goals outlined above. Further, the variables must be suitable for measurement in a national system of sustained, routine, and robustly calibrated observations.

Many types of variables merit consideration for inclusion. Some are clearly relevant and are already measured routinely, others are well recognized as being important for describing or predicting dynamic processes or significant trends, but are not measured systematically in the oceans. Still others are measured more for research than for routine operations. All were considered for inclusion in the national backbone of observations. The inventory of variables considered for this analysis is representative but not exhaustive (Appendix VI). Even so, it greatly exceeds the scope of a national system for sustained observations. Clearly, an important task was to develop a procedure for selecting a small set of core (common) variables from such a long list of measurable properties and processes (Appendices VII and VIII). The procedure had to be guided by the need to detect and predict, in a national and global context, environmental changes and their effects on coastal ecosystems, living marine resources and people. This was achieved, and the top 20 variables that should be considered for measurement as part of the national backbone are as follows:

- **Physical:** salinity, temperature, bathymetry, sea level, surface waves, vector currents, ice concentration, surface heat flux, bottom characteristics
- **Chemical:** water column contaminants, dissolved inorganic nutrients, dissolved oxygen
- **Biological:** fish species and abundance, zooplankton species and abundance, optical properties, ocean color, water column concentration of human pathogens, phytoplankton species

In addition to those variables required to characterize the marine environment, the following variables are required to quantify the external drivers of change on a national scale:

- **Meteorological:** vector winds, temperature, pressure, precipitation, humidity
- **Terrestrial:** river discharge
- **Human Health and Use:** seafood contamination, water column concentration of human pathogens

Finally, many variables are demonstrably important for detecting and predicting changes in coastal marine and estuarine ecosystems, but they are not appropriate for implementation on a national scale, i.e., variables of regional significance that are not national in extent (e.g., coral reefs, kelp beds, sea ice) and variables that should be measured on different time and space scales depending on the region (e.g., upwelling vs river dominated environments, broad vs narrow continental shelves). These variables and time-space scales will be considered by regional observing systems based on priorities established by stakeholders in each region.

2.2 DATA MANAGEMENT AND COMMUNICATIONS

The IOOS interface for most users will be the data management and communications subsystem (DAC). This subsystem will link every part of the observing system from the instruments to the users, and will contribute to defining the quality of the end products. It is a crucial component of the observing system, and its design should ensure that both users and contributors are an effective part of the data management and communications process. A preliminary design plan was developed that includes the following recommendations:

General

- Design and implement an enhanced, distributed data and information management system that links all observational and data management systems across agencies and programs to all data users.
- Improve data management infrastructure.

Specific

- Assess oceanographic middleware protocols for data acquisition and modify as needed to accommodate multi-disciplinary data streams (meteorological, physical, geological, chemical and biological data).
- Use federal standards for semantic metadata descriptions of the data.
- Use http as the network data transport protocol for data discovery.
- Designate the Global Ocean Data Assimilation Experiment (GODAE) as a primary integrator for real-time data assembly.
- Establish a DAC Steering Committee to oversee the formulation of a comprehensive design and implementation plan for the data management subsystem by the end of CY 2002. (The terms of reference for this committee were established at the workshop.)

2.3 ECONOMIC ANALYSIS

The value of improved weather and climate forecasts alone has been shown by numerous cost-benefit studies to substantially exceed the investment required to establish and develop the IOOS. However, additional research is needed to assess specific benefits and to establish procedures for ongoing assessments of system performance in terms of costs and benefits. An *ad hoc* team was created to formulate these procedures. In addition, workshop participants endorsed the following recommendations:

- Initially products that are most likely to have immediate and significant benefits should be selected, prepared, and distributed. These products should have both high impact and high return on investment, and demonstrate the feasibility and potential of an integrated system.

- Products that are in development, have not yet been considered, or have been developed but have uncertain markets should be deferred in the near term.

2.4 Implementation: Near-Term Actions

The workshop concluded with the development of recommendations for near-term (next 1-3 years) actions that should be taken to establish an IOOS that will benefit all participants from federal agencies to regional consortia of stakeholders. These are as follows:

- **Create a National Federation of Regional Ocean Observing Systems.**

1. Define "rules for" and "benefits of" membership in the Federation.
2. Continue economic analyses of costs and benefits of regional observing systems and expand them to include national assessments as the national backbone evolves.
3. With input from regional stakeholders, develop guidelines for governance of the Federation and ongoing evaluations of system performance.
4. Fund regional, end-to-end observing systems to begin building the Federation.
5. Foster linkages with Canada, Mexico, the Caribbean region, and Pacific Islands.

- **Implement the U.S. contribution to the ocean component of the Global Climate Observing System.**

1. Confirm existing commitments and plans.
2. Relate ocean-climate observations in the ocean basins and land-use activities in coastal drainage basins to changes occurring in coastal ecosystems.
3. Incorporate measurements of biological and chemical variables into the global ocean-climate observing system.

- **Design and implement an integrated data management system.**

1. Establish a panel of experts to formulate and promote the implementation of an integrated data management and communications subsystem that (i) is user-driven, (ii) addresses the data management needs of both the national backbone and regional observing systems, and (iii) provides rapid access to multidisciplinary data from many different sources (agencies, programs, remote and *in situ* sensing, etc.).
2. Develop the capacity within Ocean.US to ensure ongoing development of data products in response to user needs and their timely delivery.

- **Establish the initial IOOS by selectively incorporating, enhancing and supplementing existing elements based on user needs.**

1. Support high-resolution mapping of shallow-water bathymetry and the spatial extent of benefit habitats.
2. As a first step, increase by a factor of 5 the number of fixed platforms that are equipped with meteorological and oceanographic sensors.
3. Enhance observations from ships (instrumentation and periodic surveys).
4. Increase the number of sites where water level is measured, add more variables, and increase the number of geo-referenced gauges.
5. Support infrastructure maintenance, e.g., . maintain buoy servicing arrangements.

- **Enhance and supplement education and public outreach programs.**

1. Focus on teachers and the public.
2. Promote the training of the technical workforce that will be required to operate the IOOS.

- **Research and Development: Plan and implement research and pilot projects to develop the following new capabilities:**

1. HF radar for coastal currents and wave fields
2. Gliders for water-column profiling in coastal waters
3. Enhanced remote sensing from satellites (coastal algorithms and higher resolution) and aircraft (coastal erosion, health and distribution of sea grass beds and coral reefs)
4. Coupled physical-ecosystem models that are operational
5. *In situ* sensors for real-time measurements of key biological and chemical variables

3. BACKGROUND

3.1 Recent History of Planning for the Integrated Ocean Observing System

In 1998, Representatives James Saxton and Curt Weldon requested that the National Ocean Research Leadership Council (NORLC) propose "a plan to achieve a truly integrated ocean observing system." In response, a task-force of federal and non-federal experts, chaired by Drs. Worth Nowlin (Texas A&M University) and Thomas Malone (University of Maryland), prepared a report, "Towards a U.S. Plan for an Integrated, Sustained Ocean Observing System." The report, which was submitted to Congress in June, 1999, was the first formal step toward the articulation of a strategic design for an integrated ocean observing system for the U.S. It sets forth the general requirements for (1) a sustained and integrated ocean observing system that will provide the data and information required to improve our ability to detect and predict climate variability, enable safer and more efficient marine operations, improve national security, sustain living marine resources, preserve and restore healthy marine ecosystems, mitigate natural hazards and reduce public health risks; and for (2) the development of the system by selectively linking, enhancing and supplementing existing systems based on the needs of multiple user groups. The report can be found on the web at **http://www.coreocean.org/resources/nopp/towardintegrated.pdf**

This report provided the basis for the next step, the formulation of recommendations for initiating the system by an Oceans Observation Task Team chaired by Dr. Robert Frosch (Harvard University). This report, "An Integrated Ocean Observing System: A Strategy for Implementing the First Steps of a U.S. Plan", called for the creation of an interagency program office (the Ocean.US Office) that would coordinate the design and implementation of the national integrated and sustained ocean observing system (IOOS). This document can be found on the web at **http://www.coreocean.org/Dev2Go.web?id=220672&rnd=28503**

With the approval of the NORLC, Ocean.US. was established in October 2000 by a Memorandum of Agreement (MOA) that has been signed by the leaders of nine federal agencies (Appendix II). Ocean.US immediately began working in partnership with the U.S. GOOS Steering Committee, NOPP agencies and regional stakeholders to address the complex issue of how to develop a regionally relevant national system that builds on existing infrastructure, programs and expertise. The workshop reported on here represents the culmination of the first stage of this process and made possible the development of the implementation plan for Congress.

3.2 Workshop Planning and Organization

Design and implementation of an IOOS for the seven goals (listed on page 3) requires participation and support from a broad spectrum of communities and organizations that do not have a tradition of working together. Accordingly, planning for the workshop began with the formation of a Steering Committee (SC) consisting of members who represent the diverse mix of issues that must be addressed in the design and implementation of the IOOS (Table 1). The SC selected over 100 experts from government agencies (federal and state), private enterprise, academia, non-governmental organizations, and different regions of the coastal U.S. to participate in the workshop (Appendix III). Participants represented the diversity of stakeholders that have interests in or responsibilities for the marine environment from estuaries to the open ocean. Participants not only represented many sectors of U.S. society and geographic regions, they provided the breadth of technical expertise required to develop a plan for a scientifically sound observing system that will serve the needs of many user groups.

The workshop agenda (Appendix IV) was structured by the SC to ensure a systematic and rigorous selection of the variables and techniques that should be incorporated into the initial system. To catalyze this process leaders in the ocean science community were invited by the SC to provide participants with the context for planning and implementing the IOOS. Vice Admiral Paul Gaffney of the U.S. Commission on Ocean Policy kicked off the workshop with a keynote address that highlighted the need for and challenges of establishing an integrated and sustained ocean observing system. On subsequent days Mr. John Rayfield (senior staff member on the House Subcommittee on Fisheries, Wildlife, and Oceans) briefed participants on expectations of Congress for the IOOS; Dr. Rick Spinrad (Technical Director of the Oceanographer of the Navy) described the contributions and expectations of the Navy; Vice Admiral Conrad Lautenbacher (Under Secretary of Commerce for Oceans and Atmosphere and Administrator of NOAA) stressed the importance of achieving the goals of the workshop in a timely fashion; Dr. Larry Clark (National Science Foundation) described the role of current and planned research and its importance to the development of the IOOS; and

TABLE 1. WORKSHOP STEERING COMMITTEE

NAME	AFFILIATION
* Larry Atkinson	Old Dominion University
Jonathan Berkson	U.S. Coast Guard
Bill Birkemeier	U.S. Army Corps of Engineers
Mel Briscoe	Office of Naval Research
Bob Cohen	Weather News, Inc.
Lee Dantzler	NOAA (NESDIS)
Margaret Davidson	NOAA (NOS)
Fred Grassle	Rutgers University
John Haines	U.S. Geological Survey
Ed Harrison	NOAA (OAR, PMEL)
Rick Jahnke	Skidaway Institute of Oceanography
Jim Kendall	Minerals Management Service
Eric Lindstrom	NASA
Mark Luther	University of South Florida
* Tom Malone	University of Maryland Center for Environmental Science
Greg Mandt	NOAA (NWS)
* David Martin	Ocean.US
David Mountain	NOAA (NMFS)
Phil Mundy	Exxon Valdez Oil Spill Trustee Council
* Worth Nowlin	Texas A&M University
Jeff Paduan	Navy (NPS)
Paul Pan	EPA
James Rigney	Navy (NavOceano)
Linda Sheehan	Ocean Conservancy
Mike Szabados	NOAA (NOS)
Steve Weisberg	Southern California Coastal Water Research Project

(* EXECUTIVE COMMITTEE)

Drs. John Delaney(University of Washington), Rick Jahnke (Skidaway Institute of Oceanography), and Bob Weller (Woods Hole Oceanographic Institution) described current and planned research projects that are relevant to the development of the IOOS.

In preparation for the workshop, the SC also selected teams of experts to draft recommended subgoals and provisional products for each of the seven national goals to be addressed by an integrated system (Appendix V). Provisional products were used to develop lists of variables required to produce them and potential techniques for measuring the variables were identified. These "background" papers (Appendix V) summarize the issues associated with each of the seven goals and provided a starting point for the series of workshop phases described below.

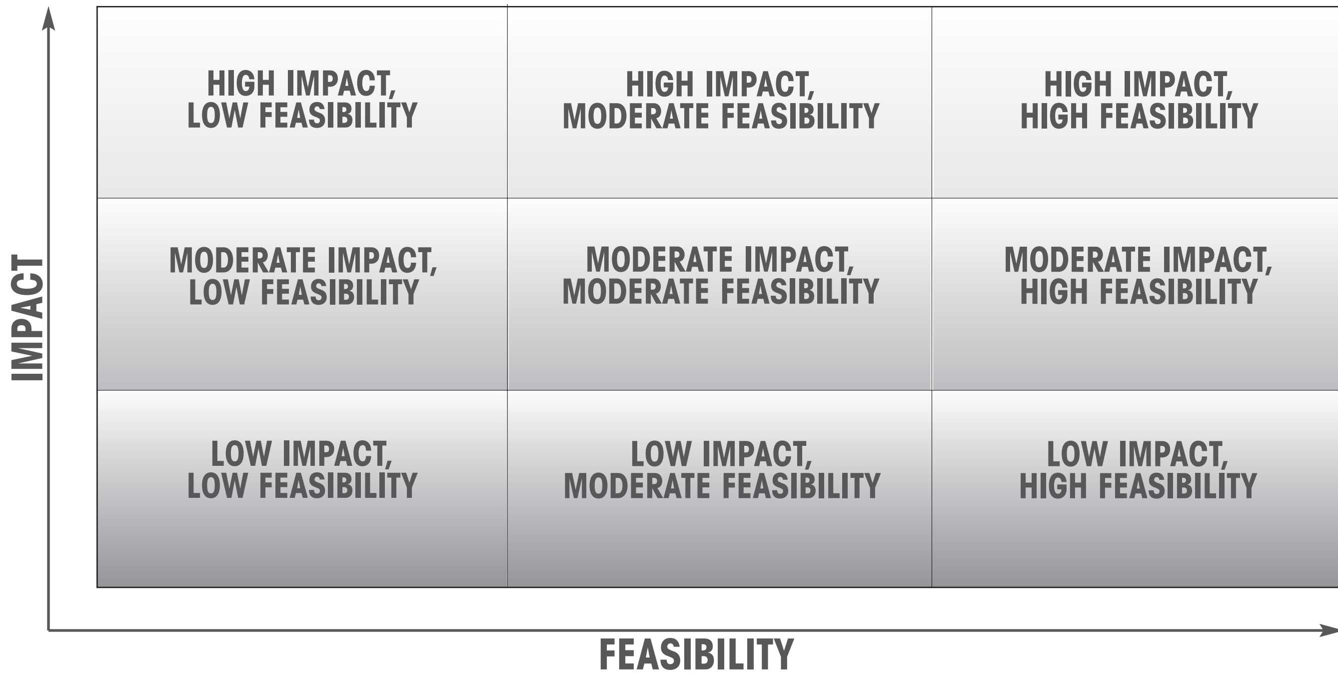
3.2.1 Phase 1: Variables and Techniques

Phase 1 began with a morning plenary session during which the objectives of the workshop and the process by which the objectives would be achieved were described and discussed. That afternoon, seven breakout groups reviewed each background paper (one group for each goal-specific background paper working in parallel) and completed a comprehensive list of variables and techniques to be considered for incorporation into the national backbone of the IOOS. The variables were then ranked based on the number of subgoals to which they are relevant. The groups produced (1) a revised background paper reflecting the group's consensus that included a comprehensive list of variables and techniques and (2) a ranked list of the top ten variables specific to each of the seven goals. All of the variables were then compiled in a matrix and ranked based on the number of subgoals that would require them for detection or prediction of the phenomena of interest (Table 1 in Appendix VII). The rankings were presented and discussed in a plenary session and, once a consensus was reached, used to initiate Phase 2. This procedure was followed for each of the subsequent phases.

3.2.2 Phase 2: Prioritize Variables

Four breakout groups were established with members from each of the seven Phase 1 groups and charged with evaluating the list of variables and their rankings based on their expertise and experience. This provided an opportunity to add or remove variables and change rankings based on the expertise and experience of members of the breakout groups. Changes were only made when a group consensus could be reached. The rankings of the four groups were then reconciled by consensus.

FIGURE 1.
Impact-Feasibility Analysis of Techniques



3.2.3 Phase 3: Evaluating Techniques for Incorporation into the IOOS

The final list of ranked variables was divided into two groups: (1) physical variables (including coastal geological processes) and (2) non-physical variables (biological, chemical, ecological, public health). Two working groups were tasked with evaluating the impact and feasibility of potential techniques (from Phase 1) for determining the distribution of each variable in time and space. Beginning with the highest ranked variable, all potential techniques were evaluated in terms of their feasibility and impact (I-F analysis, Figures 1 and 2). Impact is a subjective assessment of the relative value of the technique for making quality measurements of the variable in question at the required time-space scales (temporal resolution, spatial extent and resolution, synopticity). Feasibility is a subjective appraisal of the degree to which observational techniques can be used in a routine, sustained and cost-effective fashion, i.e., the extent to which they are operational. Once the I-F analysis was completed for each variable, techniques were categorized in one of the following four categories:

- Suitable for incorporating into the observing system now (operational)
- Suitable for pre-operational testing
- Ready for evaluating as part of a pilot project
- Requires additional research and development

3.2.4 Phase 4: Recommendations and Guidelines for Phased Implementation of the IOOS

Following presentation and discussion of the results of both breakout groups in plenary session, four breakout groups worked in parallel to formulate scenarios for a 10-year step-wise, phased implementation of the IOOS. The groups were provided with general guidelines but encouraged to use not only the workshop information gathered previously, but also their expertise and expectations in formulating their scenarios.

Scenarios were crafted based on:

1. An analysis of observing system requirements (results of Phases 1 and 2)
2. Existing observing capabilities (results of Phase 3)
3. Gaps between requirements and capabilities
4. Resource implications of addressing these gaps in a phased, prioritized fashion

The groups were also asked to:

1. Confine their scenarios to the global ocean component and the federal backbone for the coastal component
2. Consider federal resources that may or may not

remain within the federal system

3. Assume that techniques that have both high impact and high feasibility are high priority candidates for incorporation in IOOS now, while those that are rated as high impact and low feasibility are high priority candidates for research and development
4. Consider both the extent to which capacity building is needed (personnel technical expertise & training, manufacturing, data and communications, etc.), and the time and effort required (both nationally and regionally) and then develop an investment strategy targeted to those areas able to absorb resources
5. Estimate the time required for high impact-low feasibility techniques to become operational.

3.2.5 Phase 5: Reaching Consensus

The four scenarios and the results of the Data and Communications and Economic Breakout groups (see below) were presented and discussed in plenary session. Recommendations were then prioritized by consensus in plenary and used to (1) establish guidelines for the formulation of a phased implementation plan based on both feasibility and need, (2) specify high priority actions that should be implemented within the next 1-3 years, and (3) recommend high priority research areas.

3.2.6 Data Management and Communications

The development of an integrated data management system that transcends individual government agencies and programs is critical to the successful development of the IOOS. In an effort to address this challenge from the beginning, a breakout group of experts in the field of data management worked in parallel with the five phases described above to define the needs for and the conceptual design of a data management and communications subsystem (DAC) for the IOOS. This group summarized their discussion in a revised DAC background paper (Appendix V) which describes the system vision, components and design, as well as a process to develop a system implementation plan. A second document (Appendix X) was also prepared which describes the process to develop the system implementation plan in greater detail.

The plan, a phased prioritized approach to developing the DAC, will include: cost estimates; mechanisms for allowing continued oversight; processes for evaluating system performance and incorporating user feedback; definition of a path for introduction of new technologies; processes for developing/adopting standards, protocols, and formats, and consensus agreement on a policy statement on data release and distribution; etc. The plan will redress major deficiencies of the present system as well as improve the efficiency and efficacy of system elements that are functioning now. Notable examples of current major challenges include: (1) the separation and relative roles of real time and delayed mode/archive centers for most data types and (2) the lack of capability to handle most types of non-physical data (real time/delayed mode/or archive) needed by the observing system. Among the many additional elements that will be addressed in the plan are, for example, the use of self-describing data syntax, the need for a controlled vocabulary for marine variables, and the need for more consistent data exchange protocols. The plan will be completed in December 2002.

3.2.7 Economic Considerations

A second group of experts in economics also worked in parallel to create (1) a template for economic assessments of IOOS benefits at the user sector level that could be utilized by different regions of the country and (2) a prioritized list of user sectors for which economic assessments should be developed. More specifically, this working group developed a methodology to assemble the following information necessary for more precise estimates of IOOS benefits:

- Data parameters and cost estimates for IOOS itself and for value-added products to be derived from IOOS, including the means of distributing these products to users and how the IOOS data and products differ from what is presently available
- A comprehensive list of industrial, recreational, and public administration activities that use products derived (in part) from ocean observation
- Information about how these activities use ocean observation products (at present and, hypothetically, under IOOS) to make economic decisions
- Information about how these decisions affect the (economic) outcome of their operations

3.3 Workshop Perceptions

The workshop began with a briefing on the goals and format of the workshop, the rationale for an integrated and sustained ocean observing system, and work to date on its design and implementation. Immediately following this, participants were given an opportunity to express what they thought was good about the process and their concerns. These may be summarized as follows:

THE POSITIVES

- The meeting's approach is pragmatic and goals are realistic. The organizers have established a framework for constructive interaction among participants. The approach is integrated for more cost-effective detection and prediction and to leverage funding. Participants are encouraged to think broadly across disciplines and geographically.

- There is recognition that to be successful the system must have clients from government, private enterprise and public sectors.

- The timing is right. The IOOS is a concept whose time has come. There is a clear need for a sustained system of ocean observations, the technology is at hand, and the benefits to society will be substantial.

CONCERNS

- The effort to design and implement the IOOS does not appear to be sufficiently coordinated on regional to national scales. What is the relationship between Ocean.US and the Ocean Commission and are these efforts duplicative?

- Participation and support of the research community is critical. How will this be achieved? How will the broader community be engaged? How can we engage the commercial sector as both users and contributors to the IOOS?

- Who is in charge and how does the proposed system relate to research programs? How will the required support be developed in public, private and government sectors? How will the problem of selectively shifting elements from the research realm to an operational mode be addressed institutionally given that government mechanisms are not in place to do this?

- Open access to data and information may not be realistic given proprietary issues with data that are particularly relevant to industry and national security.

- Build on existing infrastructure and programs. Don't reinvent the wheel.

- Can the cost of such a system be justified in economic and social terms?

- Are current participants the best group to be recommending priorities? There is too much emphasis on physics. User groups other than scientists are not well represented.

Although all of these could not be addressed during the course of the workshop, they did help guide the debate and helped to develop the consensus recommendations described below.

4. RESULTS & RECOMMENDATIONS

4.1 Potential Variables and Techniques (Phase 1)

4.1.1. Detecting and Predicting Climate Variability

Climate has received substantial national and international attention for several years, and many workshops have been convened to effect the planning and implementation of an efficient observing system for the global ocean-climate component. The focus has been on monitoring, describing, and understanding (1) the physical and biogeochemical processes that determine ocean circulation and (2) the effects of the ocean on seasonal to decadal climate changes, as well as to provide the observations needed for climate predictions and related research (see Appendix V). The climate background paper used to initiate Phase 1 draws heavily on the work of two international panels (the Ocean Observing System Development Panel, OOSDP, and the Ocean Observations Panel for Climate, OOPC) and the results of an international conference (The First International Conference for Climate Observations).

Four subgoals were considered:

1. Obtain improved estimates of surface fields and surface fluxes
2. Document variability and change to obtain improved ocean analyses and predictions on seasonal and longer time scales
3. Detect and assess the impact of ocean climate change on the coastal zone
4. Establish and maintain the infrastructure and techniques that will ensure that information is obtained and utilized in an efficient way

The products and associated variables and techniques that were considered by the group are listed in Appendix VI.

The Climate working group encountered several philosophical issues that prompted discussion and evaluation. These included the need to:

1. Coordinate with the coastal module for both boundary conditions and forcings
2. Examine the climate of the ocean as well as the influence of the ocean on climate, including the full water column and its variation with time
3. Examine the non-physical aspects of blue water climate investigations
4. Interface with data management to ensure adequate infrastructure, product development, data maintenance, and quality climate observations
5. Remain an evolving system, and allow for changes over time in the approach, products, and goals of the IOOS

4.1.2 Facilitating Safe and Efficient Marine Operations

This working group examined the role of a national ocean observing system in the U.S. marine transportation system's vision to be the "world's most technologically advanced, safe, efficient, effective, accessible, and environmentally sound system for moving goods and people" (Appendix V). The group noted that the current system needed substantial improvements in the areas of marine transportation, offshore energy, environmental management, and recreation to satisfy the demands of growing international trade, the presence of oil and hazardous cargo in populated areas, and public concerns about maritime accidents. An integrated system of navigation information is required for real-time delivery of data and access to current, historical, and forecasted oceanographic and meteorological conditions.

To that end, users in those sectors most likely to be impacted by marine operations were identified as follows:

1. Commercial and military shipping
2. Commercial fishing
3. Recreational users (boaters, fishermen, surfers),
4. Extraction industries (e.g., oil and gas)
5. Construction
6. Cable laying
7. Community response agencies
8. Insurance and reinsurance industries

In this context, three major subgoals were defined:

1. Maintain navigable waterways.
2. Improve search and rescue and emergency response capabilities.
3. Ensure safe and efficient marine operations and activities.

The associated products, variables, and potential techniques are listed in the Marine Operations background paper (Appendix V), as well as in the subgoal/product and variable association matrix.

4.1.3. Ensuring National Security

National security is generally considered to encompass not only the protection of U.S. citizens and interests, but also the promotion of economic and social interests of the United States. Relative to the national ocean observing system, national security is limited to the military's mission of warfighting, peacekeeping, and humanitarian assistance. The role of oceanography in this context is to provide sufficient knowledge of the ocean to allow for "better decision making and employment of people, platforms, and systems, increasing their effectiveness, and decreasing risks to those resources" (Appendix V). Oceanography is considered to include classic oceanography, meteorology, hydrography, acoustics, precise timing, astrometry, and GIS. The ocean observing requirements for the national security theme have been examined previously in formal Department of Defense processes and in the Chief of Naval Operations-Oceanographer of the Navy R&D strategy. These requirements, along with review of the background paper and the associated discussions at the Ocean.US workshop, led to the following subgoals within the national security theme:

1. Improve the effectiveness of maritime homeland security and war-fighting effectiveness abroad, especially mine warfare, port security, amphibious warfare, special operations and antisubmarine warfare.
2. Improve the safety and efficiency of operations at sea.
3. Establish the capability to detect airborne and waterborne contaminants in ports, harbors, and littoral regions at home and abroad, and the capability to predict the dispersion of those contaminants for planning, mitigation, and remediation.
4. Support environmental stewardship.
5. Improve system performance at sea through more accurate characterization and prediction of the marine boundary layer.

These subgoals are all related to functions of national security including homeland security, seaport security, mine warfare, contaminant dispersal, and environmental sabotage prevention. The working group also provided an extensive list of techniques in a matrix format associated with specific variables (Appendix V).

4.1.4. Managing Living Resources

Managing living resources is a topic that has gained much attention in recent years. In addition to being a theme for national and international ocean observing systems, it has also been addressed by a dedicated panel (Living Marine Resources-LMR) within the GOOS structure. This panel has been joined in its efforts by the Health of the Ocean (HOTO) and the coastal component of GOOS (C-GOOS) panels in generating recommendations for an integrated plan to address this issue. The main objective of these groups is to provide operationally useful information on the state of living marine resources and their ecosystems. Specifically, a three-system approach (inshore, coastal ocean, and open ocean) for observational needs has been recommended. This approach would enable the development and implementation of an ecosystem-based management approach to living marine resources, which was the primary recommendation of the Managing Living Resources working group at the Ocean.US workshop. After examining the background paper, the results of the previous groups' (LMR-GOOS, HOTO, C-GOOS) efforts, and taking into account the need for ecosystem-based management, the working group then developed the following five subgoals:

1. Measure fluctuations in harvested marine species and improve predictions of abundance, distribution, recruitment, and sustainable yield.
2. Measure and detect changes in spatial extent and condition of habitat, production, and biodiversity.
3. Predict effects of fishing and other human activities on habitat and biodiversity.
4. Improve knowledge of spatial distribution of habitat and of living marine resources.
5. Improve measurements of abundance and impacts (environmental and human) on endangered species, marine mammals, and seabirds.

The working group noted, during their evaluation of subgoals, products, variables, and techniques, that a substantial infrastructure currently exists to fulfill many aspects of the subgoals, however, augmentation of these current systems is required (Appendix V).

4.1.5. Preserving and Restoring Healthy Marine Ecosystems

Preserving and restoring healthy marine ecosystems is a topic of intense discussion and evaluation on a national and international scale. *Agenda 21*, a mandate generated at the UN Conference on Environment and Development in 1992, specifically called for a global ocean observing system that will "enable effective management of the marine environment and sustainable utilization of its natural resources" (Appendix V). While significant strides have been made toward implementing the global ocean component of GOOS, the development of a coastal module that would address these broad goals has been limited.

Impediments to the development of this component of the coastal module include:

1. The challenge of designing and implementing a system to detect and predict changes in an area as inconstant as the coastal zone
2. Inefficient data management systems
3. Technological immaturity in the area of detecting and predicting changes within this region
4. Ineffective or absent mechanisms to support the transition of research capabilities to an operational context
5. The challenges of developing partnerships between all stakeholders.

The working group addressed the first three issues in its deliberations. The subgoals addressed were as follows:

1. Establish ecological "climatologies" for key biological and chemical variables.
2. Detect changes in the spatial extent and physiology of biologically structured habitats.
3. Detect changes in species diversity.
4. Detect/predict coastal eutrophication.
5. Detect/predict toxic and noxious algal species.
6. Detect/predict non-native species.
7. Detect/predict diseases in and mass mortalities of fish, marine mammals, and birds.
8. Monitor effects of anthropogenic contaminants on marine organisms.

Detecting and predicting changes in or the occurrence of these factors (Appendix IV) was a major goal for not only the coastal module of GOOS, but the Ocean.US working groups. In their evaluation of the background paper and associated reports, the workshop participants generated a large list of subgoals, products, variables (by far the most numerous of the working groups), and potential techniques. The full list of products, variables and techniques are given in Appendix V.

4.1.6 Mitigating Natural Hazards

During the discussions of the hazard mitigation working group, the participants determined that natural hazards and their impacts extend beyond what is typically considered. Impacts should include risks to ecosystem resources in addition to direct and indirect losses to human health and the economy. Mitigating the effects of natural hazards, including weather events, biological hazards, and anthropogenically-induced hazards (e.g. oil spills), consists of "actions taken to prevent and reduce risks to life, property, and social and economic activities" (Appendix V). While controlling natural hazards is beyond human control, their effects can be mitigated through improved predictions and enhanced technologies beyond current capabilities. Current natural hazard mitigation is impeded by an "under-sampling of the coastal ocean, a lack of an integrated data management system, and the capabilities (or lack thereof) of existing models." The working group discussions of the background paper, associated reports, and the current capabilities for hazard mitigation held to a common theme, specifically, filling gaps in the present system. The specific subgoals generated by the background paper and these discussions were the following:

1 Provide adequate data gathering capabilities at the temporal and spatial scales required to improve the understanding of the physical and biological nature of natural hazards.
2 Improve modeling capabilities and predictions.
3 Provide timely dissemination and convenient online access to real-time hazards observations. and warnings as well as complete metadata and retrospective information on all aspects of natural disaster reduction.
4 Develop new instrumentation to improve the existing systems, i.e., make them workable in wider areas for longer duration, and with higher reliability, safety, and efficiency.

The working group also generated specific products, variables, and potential techniques associated with these subgoals (Appendix V).

4.1.7 Ensuring Public Health

The public health working group examined two primary potential health risks associated with the ocean: (1) swimming safety (to include all water-contact activities), and (2) seafood safety. The presence of pathogens, derived from wastewater discharge and stormwater runoff, was considered the most probable risk for swimming activities. Seafood consumption risk involves three separate areas. The first is poisoning through consumption of filter-feeding shellfish that concentrate natural toxins produced by phytoplankton during harmful algal blooms (HABs). The second is the risk of illness by consuming raw shellfish contaminated with pathogens (human/animal or naturally-derived source). The third is the risk of long-term illness (e.g., cancer) from consuming contaminated finfish. Contaminants include a wide range of compounds such as pesticides, PCBs, and metals. An additional area of concern, confined to the Great Lakes, is risks associated with the drinking water supply. This concern was not specifically addressed in the context of the Ocean.US workshop as the participants determined that the effects were regional, not national in scope, and so did not fit into the workshop criteria of broad national relevance. The working group did examine possible effects of climate change on human health. These effects would consist of indirect impacts such as possible increased rainfall promoting higher runoff and increased contaminant loading to the nearshore zone, and alteration of the distribution, intensity, and frequency of HAB events. The public health working group discussions and evaluation of the background paper reflected a systematic risk assessment approach to public health relative to ocean impacts and influence. This approach has five main features: (1) describe patterns of risk, (2) assess overall risk from present conditions, (3) predict risk from specific sets of conditions likely to occur in the future, (4) measure exposure of human populations to factors related to risk, and (5) calculate risk from measures of exposure and estimates of dose-response relationships.

To satisfy these requirements, the working group developed two main subgoals:

1 Nationally standardized risk measures for swimming
2 Nationally standardized risk measures for seafood consumption

Multiple products, variables, and potential techniques were initially presented in the background paper and then substantially expanded in the ensuing discussions.

4.2 Ranking Variables for the National Backbone (Phase 2)

Breakout groups reviewed the variable lists and each came to a consensus on the variables and their rankings. These results, and details of the procedure used, are given in Appendix VII. Chairs of the breakout groups and the Executive Committee worked together to ensure that the names of variables were consistent (e.g., it was agreed to list variables without specifying spatial criteria such as "surface" or "water column") and to eliminate duplication (e.g., same variable, different name). Even so, as noted in the table legends, some duplication and inconsistency survived in the "final" list of 59, and corrections were made in the preparation of this report resulting in a final list of 55 variables. It should be noted that, despite efforts to ensure consistency and minimize redundancy, some duplication survived the workshop process. Ocean color, surface spectral irradiance, ocean surface chlorophyll-a, and phytoplankton abundance/biomass were ranked 19, 35, 48 and 53, respectively. Surface spectral irradiance was dropped. Bottom charac-

TABLE 2. Rankings of Variables that Measure Attributes of Oceanic and Coastal Marine Systems

FOR THE TOP 20 VARIABLES TWO RANKINGS ARE GIVEN: ORIGINAL RANK (NUMERATOR) AND RANK WITHOUT THE NON-OCEAN VARIABLES.

PHYSICAL	RANK	CHEMICAL	RANK	BIOLOGICAL	RANK
Salinity	1/1	Contaminants: water	9/8	Fish species	11/10
Water temperature	3/2	Dissolved nutrients	10/9	Fish abundance/biomass	12/11
Bathymetry	4/3	Dissolved oxygen	23/18	Zooplankton species	13/12
Sea level	5/4	Contaminants: sediments	28	Optical properties	14/13
Directional wave spectra	6/5	Carbon: total organic	32	Ocean color	19/15
Vector currents	7/6	Suspended sediments	34	Pathogens: water	22/17
Ice concentration	8/7	pCO_2	40	Phytoplankton species	24/19
Surface heat flux	15/14	Carbon: total inorganic	42	Zooplankton abundance	25/20
Bottom characteristics	20/16	Total nitrogen: water	50	Benthic abundance	27
Sea floor seismicity	39			Benthic species	29
Ice thickness	46			Mammals: abundance	37
Sea surface height	51			Mammals: mortality events	38
				Bacterial biomass	47
				Chlorophyll-a	48
				Non-native species	52
				Phytoplankton abundance	53
				Phytoplankton productivity	56
				Wetland: spatial extent	58
				Bioacoustics	59

TABLE 3. Non-Ocean Variables that are Drivers of Changes in Oceanic and Coastal Marine Systems.

METEOROLOGICAL	RANK	TERRESTRIAL	RANK	HUMAN HEALTH & USE	RANK
Wind vector	2	River discharge	16	Sea food contaminants	17
Air temperature	18	Groundwater discharge	41	Pathogens: sea food	30
Atmospheric pressure	21			Fish catch & effort	49
Precipitation (dry and wet)	26			Sea food consumption	54
Humidity	31			Beach usage	57
Aerosol type	43				
Ambient noise	44				
Atmospheric visibility	45				
Cloud cover	55				

FIGURE 2. Categorization of Techniques in Terms of Their Impact and Feasibility

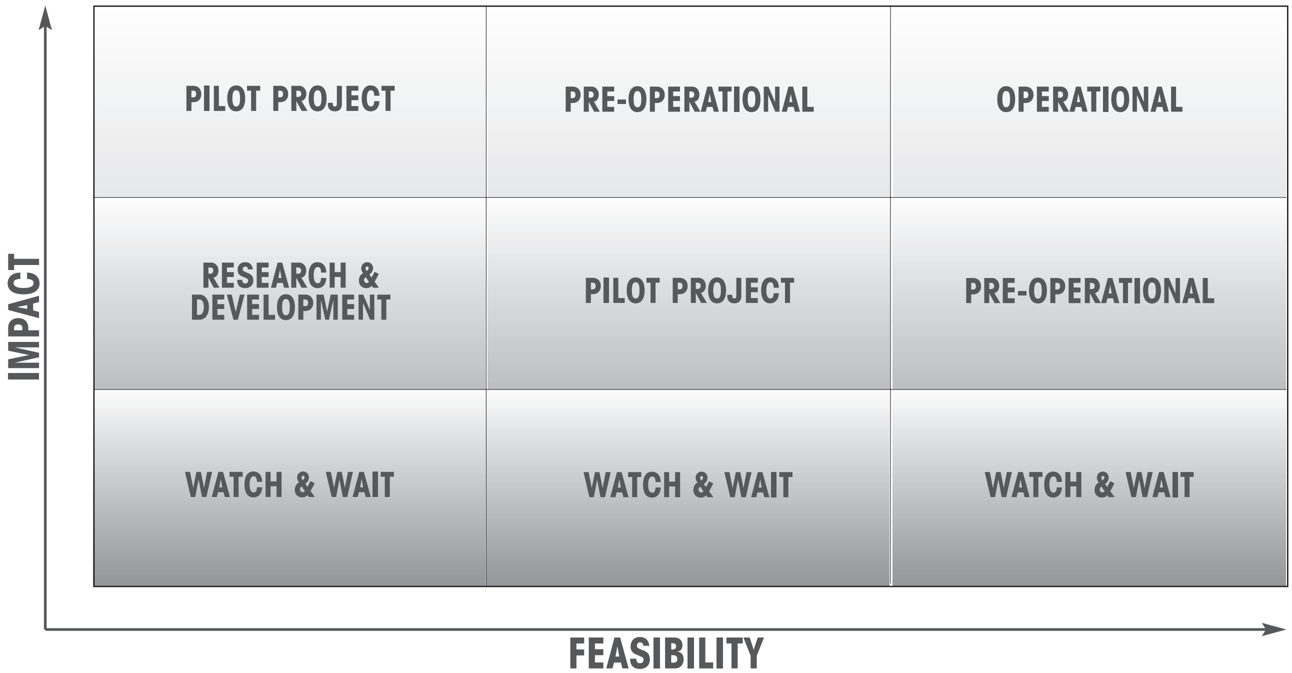


FIGURE 2. **Impact-feasibility analysis (IFA) used to categorize potential techniques as operational (ready to incorporate into the IOOS now), pre-operational (testing required to assess the extent to which the technique can be sustained in a routine and cost-effective fashion), ready for evaluation as part of a pilot project (to gain community consensus on accuracy and precision), high priority for research and development (R&D), or "watch and wait."**

teristics and physical characterization of habitat were ranked 20 and 33, respectively. "Bottom characteristics" was retained as it would include physical characterization of (benthic) habitat.

Variables were categorized in two groups, (1) variables that measure attributes of oceanic and coastal marine systems (Table 2) and (2) non-ocean variables (Table 3). Within category 1 (ocean and coastal systems), the highest ranked variables (ranks 1-8) are physical variables. This was expected given the importance of physical processes to most of the subgoals. The top 20 includes 3 chemical variables (contaminants in the water column, dissolved nutrients, and dissolved oxygen) and 8 biological variables (fish species and abundance, zooplankton species, optical properties, ocean color, pathogens, phytoplankton species, and zooplankton abundance).

4.3 Evaluating Techniques for the National Backbone (Phase 3)

Based on the ranked list of variables, two breakout groups performed Impact-Feasibility Analyses (IFAs) for the physical and non-physical variables, respectively (section 3.2.3). The groups completed IFA worksheets and a short summation for each of the variables evaluated. The techniques identified in the IFA were then categorized based on their operational status (Figure 2).

Results of this analysis for the top 20 ocean-system variables (Table 2) are given in Table 4. Results for all variables are in Appendix VIII. Some techniques fall into more than one category. For example, the use of XBTs for water temperature is currently operational in the open ocean, but is considered pre-operational for use within the coastal zone.

4.4 Guidelines for phased implementation (Phases 4 and 5)

With the completion of the IFAs and the work of the DAC and Economics breakout groups (sections 4.5 and 4.6 below), workshop participants had developed the information required to formulate realistic scenarios for the phased implementation of the IOOS. Four breakout groups, working in parallel, were tasked to do just that. Although asked to develop scenarios for multi-year

TABLE 4. Summary Results of Impact-Feasibility Analysis for the 20 Highest Ranked Variables from Table 2.

VARIABLES	OPERATIONAL	PRE-OPERATIONAL	PILOT PROJECT	RESEARCH & DEVELOP
SALINITY		Profiling floats, CTD, Underway	Moorings, XCTD, Drifters	Remote sensing (aircraft, sa
TEMPERATURE	AVHRR + GOES, XBT, Profiling floats, Surface drifters	High resolution (moorings, XBT), CTD, Underway	Hull mounted, Microwave radiometer, Airborne radiometer	Drifting thermister chain
BATHYMETRY	Multibeam sonar (>12 kHz), Altimetry, Interferometric side scan, Multibeam sonar, SAR	LIDAR, Multispectral, Land-based video, Echo sounder, Airborne video	SAR (high resolution)	
SEA LEVEL	Tide gauges, Precision altimetry	Bottom pressure		Delay-doppler altimetry, Air altimetry, GPS reflectometry
SURFACE WAVES		ADCP, bottom mounted, High resolution pitch-roll buoy, Platform-based 1-D measurements, Altimetry, Moored accelerometers	Moored currents	Platform-based arrays, Botto mounted arrays, HF phased radar
CURRENTS		Hi resolution fixed sensors, Hi resolution surface drifters, Fixed ADCP	HF radar, Fixed ADCP, Floats, Hi resolution surface drifters	
ICE CONCENTRATION	Microwave sensors, SAR	Ocean leaving radiance		
WATER CONTAMINANTS	Mussel watch, Sediment grab samples	Water samples	*In situ* sampling (semi-permeable membranes)	Electrochemical probes, Fluorescence, Gene probes, Phytotoxics
NUTRIENTS		Moorings, Discrete samples, Underway	VOS	UV detection of nitrate, AUVs/Gliders
FISH SPECIES	Stock assessment	Ship-based acoustics		Ship-based optical recorders LIDAR
FISH ABUNDANCE	Stock assessment	Ship-based acoustics		Acoustic lens technology
ZOOPLANKTON SPECIES	Towed nets, CPR		Optical plankton recorders	Biochemical indicators, Gen probes
OPTICAL PROPERTIES		Ocean leaving radiation, AOPs, IOPs	LIDAR	CDOM fluorescence, Fast repetition fluorescence Laser linesheets
HEAT FLUX		Fixed platforms	Hi quality VOS, Hi resolution NWP	
OCEAN COLOR				High spatial resolution rem sensing (300 m resolution)
BOTTOM CHARACTERISTICS	Interferometric side scan, Multichannel seismic, Chirp, Video, Core & grab samples	Multispectral remote, Line-scan laser, Expendable bottom penetrometer, Instrumented bore hole	Seabeam, Hyperspectral remote	
WATER PATHOGENS	Enteric bacteria culture	Runoff		Genetic & immunoassay in tors, Pathogens by culture, Chemical indicators
DISSOLVED OXYGEN		Moorings, Discrete samples, Underway	VOS	AUVs, Gliders, Optical sens
PHYTOPLANKTON SPECIES	HAB counts, State warning systems		*In situ* hyperspectral	*In situ* flow cytometry, Underway imaging, Genetic probes
ZOOPLANKTON BIOMASS	Net tows, CPR-VOS		Optical plankton recorders, Acoustics	

development of the IOOS, the groups were told to focus on activities required for implementation and development now and over the next 1-3 years. The resulting scenarios would be used to guide the drafting of "An Integrated and Sustained Ocean Observing System for the United States: Design and Implementation" (Appendix I) for Congress and the completion of a more detailed, multi-year phased implementation plan.

The working groups were asked to use their best judgment and the results of the previous phases of the workshop to construct realistic scenarios. During deliberations, the participants considered the requirements of an integrated observing system and both existing and potential observational techniques and capabilities. In the process, they identified shortfalls, introduced maturing technologies, proposed research essential to complete a national system, and identified implementation tasks and timelines. As one might expect, each group developed implementation scenarios at different levels of detail. The specific plans are provided in Appendix IX. Highest priorities identified by each group were as follows:

- **Group 1:** Moored Buoys: National Data Buoy Center (NDBC) array with 500 stations (60 now), existing package –surface met,

TABLE 5. Development of an Operational Observation System

ELEMENTS	OPERATIONAL	PRE-OPERATIONAL	PILOT PROJECT	RESEARCH
MOORINGS	**Network** existing moorings[1] **PORTS** (enhance, supplement)			
AUVs			**Spatial** distributions of physical & optical properties (gliders)	**Bottom** crawlers
SHIPS	**Enhance** existing surveys[2]	**Optimize** VOS system	**Nested** technologies to map benthic habitats (e.g.,multi-beam + video)	**Technologies** for more rapid habitat & stock assessments
SHORE-BASED	**Increase** no. of tide gauges & no. of geo-referenced gauges **Increase** no. of gauged rivers & streams			
REMOTE SENSING SATELLITE AIRCRAFT LAND		Access to SAR for ice	**Hyperspectral** & IR imagery[5] **Photography** **High** frequency radar: regional pilot projects	Delayed Doppler altimeter
SENSORS		Enhance NDBC moorings with physical oceanographic sensors[3]	**Develop** standard sensor package for use on a variety of platforms **Enhance** NDBC moorings with biological & chemical sensors[3]	Develop operational sensors for key biological & chemical properties[4]
DATA	**Assess** performance of Iridium One stop shopping for satellite & *in situ* data	**Develop** Iridium-like global cellular data communications for at sea use		

Phased implementation of an operational system should begin by linking existing operational elements into an integrated system. Pre-operational, pilot, and research projects that are likely to contribute to the development of an operational system should be developed in parallel.

1. NDBC + those that meet standards for greater resolution of met variables over water. Increase number of NDBC buoys to 500 (from current array of 60).

2. This should include multibeam surveys, CalCOFI, and stock assessments. Expand as appropriate to establish repeated (monthly to decadal depending on scales of variability) cross-shelf transects (300 miles spacing) on both coasts and the Gulf of Mexico. Develop event-driven response capability.

3. Water temperature, salinity, currents, directional waves, bio-optical properties, dissolved oxygen, chlorophyll fluorescence, zooplankton (Acoustic Doppler Current Profiler-ADCP), and dissolved inorganic nutrients

4. Including a "fish" sensor package based on ADCP technology.

5. Habitat assessments (areal extent and physiological condition) and monitoring changes in shoreline.

6. Distribution and abundance of marine mammals and turtles.

enhanced package- (several variables listed), cost-$200K initial/$50K per yr to maintain, R&D needed for enhanced buoy, phase over 3-5 yrs

- **Group 2:** Detailed 'System' timelines and associated tasks for three major components: IOOS Management, Data Management, Design and Dissemination, and Monitoring/Measurements
- **Group 3:** 'Process' identified products, defined elements, and made recommendations
- **Group 4:** Plan was developed for such purposes as: weather and marine conditions for recreational users, waves, 3-D coastal circulation model to support regional models, etc.

Although each group approached this challenge differently and focused on different aspects of the IOOS, common themes were apparent and are summarized in Table 5. Note that workshop participants were asked to focus on the *in situ* elements of the observing subsystem. Thus, this analysis does not do justice to the importance of remote sensing to the development of the IOOS.

4.5 Data Management and Communications

4.5.1 The Vision

The Data and Communications (DAC) subsystem will knit together the different components of the national IOOS and function as a unifying component within the international GOOS (Appendix V – the DAC background paper). The vision for the DAC subsystem includes the collection of data, as well as the data and communications components needed to move data among systems and users in a distributed environment. The DAC subsystem will link multidisciplinary observations collected from a broad range of platforms and transmit them (in real-time, near-real-time, and delayed modes) to provide rapid access to diverse data for research and applied purposes.

4.5.2 Subsystem Components

The DAC subsystem will consist of the following key functional elements: data transport, quality control, data assembly, limited product generation, metadata management, data archeology, data archival, data discovery, and administration functions (Appendix V). A design plan is proposed to integrate these components (Figure 3). The basic concept underlying the plan is to implement a "middleware" level of connectivity for the IOOS – a common set of standards and protocols that connects heterogeneous data sources to heterogeneous user communities. The most broadly tested and accepted middleware in oceanography is the OPeNDAP[1] data access protocol, which underlies the National Virtual Ocean Data System (NVODS). The DAC WG members recommend that OPeNDAP be considered as the preferred middleware solution to achieve the goals of the DAC subsystem in a rapid and cost effective manner. Considerable progress in the encoding of ocean biological data has also been demonstrated in the OBIS[2] data system. Modifications to accommodate OBIS standards may be required in OPeNDAP. In addition to a syntactic description of the data, machine-to-machine interoperability within the DAC subsystem also requires a consistent semantic description of the data. The DAC WG members recommend the FGDC[3] standard for this purpose in the IOOS.

4.5.3 Subsystem Design

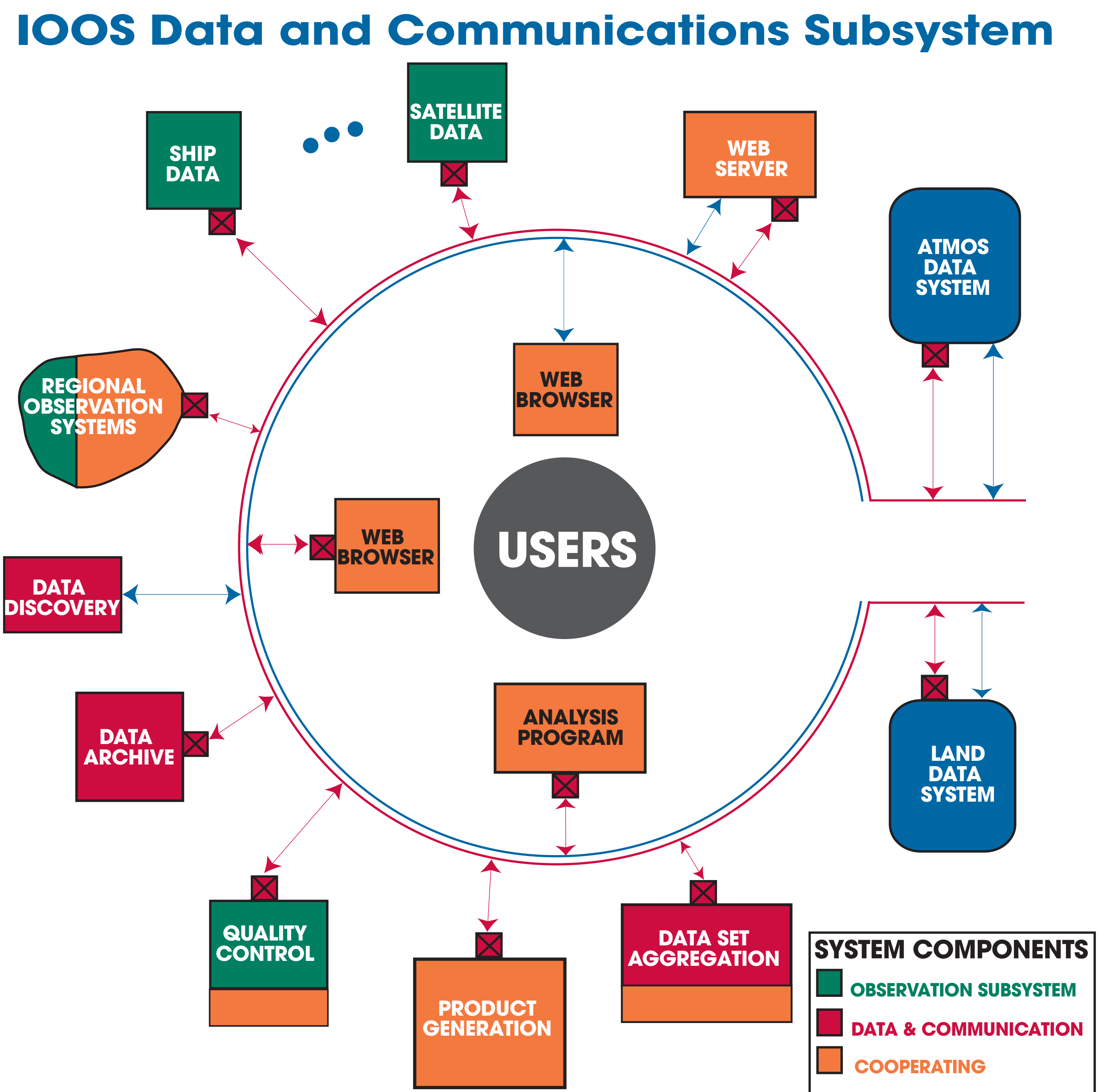
Figure 3 depicts the elements of the national ocean observing system in cyan, elements of the DAC subsystem in red, elements supplied by cooperating IOOS entities in pink, elements of other data systems in blue, and the user community as a white circle at the center of the diagram. The red and blue concentric circles with attached lines leaving the diagram to the right represent the World Wide Web (Web). The blue circle represents transfers on the Web which do not adhere to the DAC middleware standards – the documents, images, user interface forms, etc. that are typical today. The red circle represents data transfers made using the middleware standards adopted by IOOS[4].

The DAC subsystem contains a data discovery element and it is recommended that NOAA's National Coastal Data Development Center be designated as a primary data discovery facility. It is also recommended that HTTP be the network data transport protocol for data discovery search parameters and search results (as indicated by the blue line connecting this element to the network). The DAC subsystem also contains a data assembly (a.k.a. "aggregation") element, and a "deep" archive for the system. As with data discovery, the system design encourages multiple data assembly elements, but the DAC WG members recommend that the GODAE Data Server be designated as a primary center for real-time assembly. Until the data of interest have been moved to the "deep" archive, at least one assembly center or local storage center must maintain the data. Coordination of these activities will be an important administrative function of the DAC subsystem.

Quality control (QC) is shown as a separate function, but in fact it will be performed by several components – at the observing subsystem, at the real-time data assembly centers, at the delayed-mode (climate) data assembly centers, and often again at the product generation sites. The development of metadata (not shown) reflecting these QC operations must occur in lock-step.

A process was initiated at the workshop to transform this preliminary design plan into a formal implementa-

FIGURE 3.
IOOS Data and Communications Subsystem



tion plan for the DAC. It began with the creation of a Data and Communications Steering Committee (DACSC) by Ocean.US (Table 6). The DACSC will be supported by four Expert Teams (Data Transport, Discovery/Metadata, Applications, and Archival), and two Outreach Teams (Data Facilities Management and User Outreach). The Expert Teams will evaluate available technologies and make recommendations in the form of White Papers; the Outreach Teams will assemble Community Issues Lists. Following receipt of the White Papers and Community Issues Lists, the Steering Committee will write the Plan. It will be circulated for review and comment, and presented at a meeting, hosted by Ocean.US, for additional review in a public forum. The final Plan will be submitted to Ocean.US in December, 2002.

4.6 Economic Considerations

The Economics breakout group was charged with developing procedures for determining the economic benefits of the IOOS (Appendix XI). Cost-benefit studies have concluded that the value of improved weather and climate forecasts alone far outweigh the investment required to implement and sustain an IOOS. However, as stressed in the background paper (Appendix V), additional research is required to assess the specific benefits accruing from the data and information that would be provided by the IOOS. To accomplish this task, three questions must be addressed:

- What information will the system provide?
- To what use will that information be put?
- What is the economic value of that information?

The Ocean.US workshop, as whole, was designed to provide the answer to the first question. The second question has been addressed theoretically and speculatively by both producers and users of data, but has not been empirically assessed. Techniques for considering the third question exist, but have not been examined in the context of a national ocean observing system. The task of the Economics working group was to put forth a plan for answering the second and third questions. A second task was to familiarize workshop participants with the economic framework and the analytical approaches that such an analysis will require. To these ends, the group reviewed the full list of subgoals and provisional products and selected 12 products whose costs and benefits could be estimated quantitatively. The group then conducted a simple analysis illustrating how such estimates could be made by listing products, and establishing the degree of benefit and the timing of the information (Table 7). In generating this table and formulating a plan for economic analysis, the working group stressed that in addition to benefits and timing, incremental costs of implementation and operation must be estimated.

The group recommended that the preparation and distribution of products that have significant short-term net benefits should be a high priority. Such products should (1) have a high impact, (2) have a high return on investment, and (3) demonstrate the capabilities and potential of an IOOS. Products that are in development or have not yet been considered, as well as those that have been

TABLE 6. The DAC Steering Committee

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Lowell Bahner	NOAA Chesapeake Bay Office
Landry Bernard	National Data Buoy Center (NOAA)
Peter Cornillon	University of Rhode Island
Fred Grassle	Rutgers University
Chuck Hakkarinen	EPRI
*Steve Hankin	Pacific Marine Environmental Laboratory (NOAA)
David Legler	U.S. Climate Variability and Predictability Office (CLIVAR)
John Lever	Naval Oceanographic Office
Phil Mundy	Exxon Valdez Oil Spill Trustee Council
Worth Nowlin	Texas A&M University
Susan Starke	National Coastal Data Development Center (NOAA)
Steven J. Worley	NCAR/SCD

* CHAIRMAN

TABLE 7. Example of a Cost-benefit Analysis for Ocean Observing Variables

		COSTS INCURRED		EXTENT AND TIMING OF BENEFITS		
		ADD'L OBS	VALUE-ADDED PROCESSING	FREQ	UNIT $	
1.1	SST variability					SHORT & LONG-TERM
2.2	ENSO prediction		X	HIGH	HIGH	SHORT RUN
2.3	Upper ocean variability/ climate predictions	X	X	HIGH	HIGH	
2.6	Global/regional sea level		X	HIGH	HIGH	LONG RUN
5	Detection/prediction of harmful algal species	X	X	HIGH	LOW?	SHORT & LONG-TERM
9	Anthropogenic Contaminants	X	X	LOW	HIGH	MORE COST-EFFECTIVE RESPONSE
1	Ensure safe and efficient marine ops and activities	X	X	HIGH	HIGH	SHORT & LONG-TERM
2	Maintain navigable waterways	X		HIGH	HIGH?	SHORT & LONG-TERM
3	SAR and Emergency Spill Response	X		LOW	HIGH	SHORT RUN
4	Airborne/waterborne contaminant distribution and prediction	X	X	LOW	HIGH	SHORT RUN
2	Modeling capabilities/predictions/ uncertainty	X	X	LOW	HIGH	
1	Nationally standardized risk measures/swimming	X		HIGH	LOW	
2	Nationally standardized risk measures/seafood consumption	X		LOW	LOW?	
1	Measure fluctuations in harvested marine species	X	X	HIGH	HIGH	SHORT & LONG-TERM
5	Improve measurements of abundance and impacts	X	X	HIGH	LOW	SHORT & LONG-TERM

developed but that have uncertain markets, should be deferred in the near term. Early, successful product development and use should demonstrate economic benefits that can be readily understood by the public.

NOTES

1 The Open source Project for a Network Data Access Protocol (OPeNDAP) is a non profit corporation formed to develop and maintain the syntactic data access protocol used in the NOPP funded National Virtual Ocean Data System (NVODS).

2 The Ocean Biogeographic Information System (OBIS) is an on-line, open-access, globally-distributed network of systematic, ecological, and environmental information systems. Collectively, these systems operate as a dynamic, global digital atlas to communicate biological information about the ocean and serve as a platform for further study of biogeographical relationships in the marine environment. (http://marine.rutgers.edu/OBIS/)

3 The Federal Geographic Data Committee (FGDC) is an interagency committee, organized in 1990, that promotes the coordinated use, sharing, and dissemination of geospatial data on a national basis.
(http://www.fgdc.gov/)

4 OPeNDAP modified to accommodate OBIS data objects with the IOOS required semantic metadata in FGDC containers.

APPENDICES

APPENDIX I: AN INTEGRATED OCEAN OBSERVING SYSTEM FOR THE UNITED STATES

There is an immediate need for a sustained and Integrated Ocean Observing System (IOOS) that will make more effective use of existing resources, new knowledge, and advances in technology as the means to develop a unified, comprehensive, cost-effective approach for providing the data and information required to:

- Improve the safety and efficiency of marine operations
- More effectively mitigate the effects of natural hazards
- Improve predictions of climate change and its effects on coastal populations
- Improve national security
- Reduce public health risks
- More effectively protect and restore healthy coastal marine ecosystems
- Enable the sustained use of marine resources

The development of such an integrated system will benefit those sectors of society that use or are influenced by the ocean from private enterprise and government agencies to the science and education communities, NGOs, and the public at large. Recent studies indicate that benefits will substantially exceed the required investment. For example, improved climate forecasts made possible by the El Niño tropical ocean observing system have been estimated to save the agriculture sector $300M/year. The system costs $10M/year to maintain and operate.

Rationale for an Integrated System

The oceans are critically important to our society. They are the birthplace of weather systems and modifiers of weather and climate; they are highways for marine commerce and a buffer for national security; they are a major reservoir of natural resources; havens for recreation; virtual schoolrooms for educators; and natural laboratories for science. Rapid growth in the number of people living in immediate proximity to the ocean is placing conflicting demands on coastal ecosystems that threaten their integrity and capacity to provide goods and services. This demographic trend is also placing an increasingly large segment of our society at risk to natural hazards. Improvements in the quality of life, effective management of the marine environment and sustained utilization of living resources depend on the ability to (1) rapidly detect changes in the status of marine ecosystems and living resources and to (2) provide timely predictions of changes and their consequences for the public good. **We do not have this capability today.**

Historically, the U.S. has responded to these challenges in an uncoordinated, piecemeal, ad hoc fashion. Consequently, when the programs of all government agencies with ocean related missions and goals are considered as a whole, they are not as cost-effective as they could be, and they do not provide data and information on the causes and consequences of human activities and natural variability rapidly enough to serve as a basis for timely and scientifically sound decision making - **the whole is less than the sum of its parts**. This need not be the case. Today, the rates at which data can be acquired, processed and analyzed are approaching the time scales on which our political, social and economic systems function. It is time to close the gap between scientifically sound analyses of changes in the oceans and the decision making process.

Conceptual Design

The IOOS must be operational (in the same sense as the weather forecasting system), and it must evolve as a partnership of government agencies (state and federal), private enterprise, academia and non-governmental organizations. The ocean observing system is envisioned as a network that systematically acquires and disseminates data and information to serve the needs of many user groups (government agencies, industries, scientists, educators, non-governmental organizations, and the public). Achieving this goal depends on the development of a system that efficiently links ocean observations to data management and analysis for timely delivery of environmental data and information. This is the purpose of the IOOS, the implementation and evolution of which will selectively build on, enhance and supplement existing elements based on user group specifications - **the whole will be greater than the sum of its parts.** The IOOS will develop as two interdependent components, a global oceanic component and a national coastal component. The **global component** of the IOOS is part of an international partnership to develop a global system (the Global Ocean Observing System, GOOS) designed to improve weather forecasts and climate predictions. The **coastal component** is a national effort concerned with the effects of the ocean-climate system and human activities on coastal ecosystems, living resources, and the quality of life in the coastal zone. This component is conceived as a federation of regional observing systems nested in a federally supported national backbone of observations, data management, and modeling. Regional observing systems would both contribute to and benefit from the national backbone and would enhance the national backbone based on regional priorities.

Emphasis here is on *in situ* observations. Although critical to the development of a fully integrated observing system, the recommendations here do not specifically address requirements for satellite-based remote sensing. Clearly, implementation of *in situ* elements of the system must be coordinated with and meet the requirements for the remote sensing elements of the system.

Developing the Initial System

The development of the IOOS requires the establishment of (1) a process for selectively incorporating, enhancing and supplementing existing programs; (2) an integrated data management subsystem; (3) procedures for selectively and systematically migrating new knowledge, technologies and models into the operational observing system; and (4) mechanisms for permanent and ongoing evaluations of system performance.

Development of the global component depends on:

- Full implementation of Argo and the global ocean time series observatories
- Successful completion of the Global Ocean Data Assimilation Experiment (GODAE)
- Optimizing the global network of observations
- Enhancing the ocean time series observatories with key biological and chemical sensors

Implementing the coastal component depends on:

- Enhancing existing federal networks for *in situ* measurements from fixed platforms and tide gauges to improve spatial and temporal resolution and to expand the spectrum of measurements to include physical, chemical and biological variables
- Building the National Federation by establishing regional observing systems as "proof of concept" projects with the goal of transitioning successful systems or elements of these systems into an operational mode as part of the IOOS

Existing governance structures were not designed to implement, maintain, and improve a sustained and integrated observing system for coasts and oceans. Three approaches are described in this report that should be considered in the establishment of an effective governance mechanism.

Funding

Current Federal spending on ocean-related research is approximately $600M, while spending for operational oceanography across all federal agencies and other stakeholders is roughly $1B. The additional annual cost of a fully implemented IOOS is estimated to be $500M in constant dollars. A phased, multi-year development of the IOOS is recommended to implement the system effectively and efficiently. To begin this effort, an initial investment of new money is required to (1) accelerate the implementation of the U.S. commitment to the global ocean observing system for climate change ($30M), (2) develop the data communications and management system required for the IOOS ($18M), (3) enhance and expand existing federal programs ($40M), and (4) develop regional observing systems ($50M). The total new investment needed to begin the phased implementation plan is estimated to be $138M.

Full report can be downloaded at http://www.ocean.us.net/

APPENDIX II: MOA CREATING OCEAN US

National Oceanographic Partnership Program

NAVY • NOAA • NSF • NASA • DoE • EPA • USCG • DoI/USGS • DARPA • DoI/MMS • OSTP • OMB

National Oceanographic Partnership Program (NOPP)

MEMORANDUM OF AGREEMENT
For Establishing A
NOPP Interagency Ocean Observation Office

1. **BACKGROUND.** The statutory authority for the National Oceanographic Partnership Program (NOPP), with representatives from twelve (12) Federal agencies, its National Ocean Reserch Leadership Council (NORLC), and the Ocean Research Advisory Panel (ORAP) is contained in 10 USC 7901 et seq. In response to a Congressional request for "a plan to achieve a truly integrated ocean observing system," the report "Toward a U.S. Plan for an Integrated, Sustained Ocean Observing System" was prepared by a joint federal/non-federal Task Team. This led to a set of implementing recommendations in the report "An Integrated Ocean Observing System: A Strategy for Implementing the First Steps of a U.S. Plan" that was delivered in December 1999. On May 22, 2000, based on the ORAP Report implementation recommandations, the NORLC approved the establishment of an office having the charter to develop a national capability for integrating and sustaining ocean observations and predictions. The formation of this OCEAN.US office was jointly announced by the Chief of naval research, the Administrator of NOAA, and the President of the Consortium for Ocean Research and Education on May 25, 2000, at a joint hearing of the House Resources Subcommittee on Fisheries, Conservation, Wildlife, and Oceans and the Armed Services Subcommittee on Military Research and Development to examine the status of implementing the recommendations of the ORAP report.

   This interagency OCEAN.US Office has as its goal over the next decade to integrate existing and planned elements to establish a sustained ocean observing system to meet the common research and operational agency needs in the following areas:
   - Detecting and forecasting oceanic components of climate variability
   - Facilitating safe and efficient marine operations
   - Ensuring national security
   - Managing resources for sustainable use
   - Preserving and restoring healthy marine ecosystems
   - Mitigating natural hazards
   - Ensuring public health

2. **PURPOSE.** This Memorandum of Agreement (MOA) outlines the initial functions and responsibilities agreed to by the participating agencies to establish the interagency ocean observation office/organization known as the OCEAN.US Office. The Office will serve as the national focal point for integrating ocean observing activities.

3. **AUTHORITY.** This interagency OCEAN.US Office is a functioning entity of, and established under the auspices of, the National Oceanographic Partnership Program, as established by the National Oceanographic Partnership Act (10 USC 7901 et seq). OCEAN.US functions or actions will not conflict with mission prerogatives or regulatory responsibilities of the participating agencies.

4. **DEFINITIONS.**

a. **Observation and Prediction System.** The integrated ocean observation system will be a heterogeneous, distributed system of linked elements, with organizational structures and interfaces developed where common good is identified (e.g., a federation) in the manner described by "An Integrated Ocean Observing System: A Strategy for Implementing the First Steps of a U.S. Plan." OCEAN.US will be the focal point for relating U.S. ocean observing system elements to the international Global Ocean Observing System. The primary purpose is to enhance broad user access knowledge, data, tools and products. In appropriate cases, the OCEAN.US Office will establish, fund, and provide for the operation of components of the observing system whose functionality cuts across the roles and interests of the individual participating agencies. Examples might include network links, master databases and indexes, or collaborative tools and services. The system, therefore, will be a virtual system, consisting of the physical links, servers, and other elements that contribute to the mission, regardless of their ownership or operational responsibility. The system will comprise four main activities:

- operational and routine ocean observations ("data access")
- long-term research observations ("observatories")
- technology development to support the OCEAN.US objectives ("tools"), and
- a web-based "commons" for access to models, algorithms, numerical techniques, etc. to foster improved predictions by the users.

The OCEAN.US Office will integrate and coordinate assigned elements within these four areas. Further, the Office will foster and integrate linkages among the many other agency and partner elements in these areas.

b. **Functioning Bodies.** The following bodies are established by this Agreement:

1. **NORLC OCEAN OBSERVATIONS EXECUTIVE COMMITTEE (EXCOM).** The NORLC Ocean Observations EXCOM will be composed of the NOPP Agency heads (or their designees) for the Agencies that are both party to this Agreement and who provide personnel or resources to the OCEAN.US Office. The Chair of the NORLC will designate the Chair of the EXCOM. The Chair of the EXCOM will be from an Agency other than the Chair of the NORLC. With regard to the OCEAN.US Office, the EXCOM will provide policy guidance, ensure sustained Agency support, and approve implementing documents.

2. **OCEAN.US Office.** The OCEAN.US Offcie will initially establish and have cognizance over the ocean observation federation - as defined above - and, as it evolves over time, other appropriate components of a more encompassing ocean observation and pediction federation as defined by the EXCOM. it will initially have a Director and deputy Director appointed by the EXCOM and will include other technical representatives from the EXCOM Agencies and a modest administrative/support staff, as appropriate. Other agencies and partners may be represented at appropriate times through the invitation of the EXCOM or the Office. The Office will function as an official Federal Government office via assignment of its staff from the NOPP Federal Agencies.

3. **Director of the OCEAN.US Office.** The Director of the OCEAN.US Office will be selected by the EXCOM. The selection process will seek to achieve balance across the participating Agencies.

c. **Project Categories.** Elements of the system may be regarded as "NOPP-related." Elements in the first two categories are to eventually become fully integrated elements of the ocean observation and prediction system by the signatories of this Agreement. NOPP-related elements, while not directly integrated, also can provide valuable data, information, tools or products of interest to the user community.

1. **NOPP-funded elements** are a result of a NOPP solicitation and/or selection process, which is to say, approved by the NORLC and in accordance with overall NOPP objectives. these elements must adhere to the integrating conventions established by the OCEAN.US Office and approved by the NORLC/EXCOM. Once accepted as an element in this category, the sponsoring agency must notify the NORLC of its intent to withdraw.

2. **NOPP-coordinated elements** are ongoing and new activities of one or more NOPP agencies and partners which are offered to the NORLC for integration with the observation system. These elements will adhere to the data access and documentation conventions of the Federation established by the OCEAN.US Office and approved by the NORLC EXCOM at the cost of the offering agency. Once accepted as an element in this category, the sponsoring agency must notify the NORLC of its intent to withdraw.

3. **NOPP-related elements** are ongoing and new activities of agencies and/or adjunct partners (including, for instance, international partnering) which are offered to the NORLC for coordination with the integrated observation system activities.

5. **FUNCTIONS & RESPONSIBILITIES.** This undertaking requires active participation of the involved parties. Further, the Office is of substantive interest in its promotion of collaboration between agencies, in providing information useful for assisting agencies in the development of their budget submissions, and ensuring compatibility and interoperability.

The EXCOM Agencies will support the OCEAN.US Office by (1) designating agency representative(s), as needed, and/or (2) providing adequate funding support to the Office. Costs for operating the Office intend to be shared among the Agency participants at levels commensurate with their involvement. each Agency will be responsible for suppoting its staff seconded to the OCEAN.US Office. Transfer of funds or personnel for this effort will be made pursuant to other appropriate authorities, agreements or by amendment to this agreement.

The OCEAN.US Office will:

1 Develop and maintain a document outlining the long-range vision of an integrated ocean observation and prediction federation. This document will serve as the conceptual foundation for the federation and will delineate the desired goal of a fully integrated and sustained ocean observation and prediction capability for the nation.

2 Ensure integration of the elements of the observing system.

3 Serve as the focal point to coordinate OCEAN.US observing system activities with the NOPP Interagency Working Group (IWG), the Ocean Research Advisory Panel (ORAP), and the Federal Oceanographic Facilities Council (FOFC) as well as other federal and non-federal partners, and with the international community.

4 Report regularly to the EXCOM for guidance and the IWG for coordination. Provide an annual assessment of the observing system status, products and planned directions including results of external reviews, as appropriate.

5 Recommend enhancements to existing systems, new projects, need for research and development, and identification of system components suitable to transition from research to operations.

6 Carry out all other tasks as directed by the NORLC.

6 **DATA.** All NOPP agencies and affiliates partners will provide data required to support OCEAN.US operations, research, and education efforts in accordance with applicable laws, regulations, and policies of the participating agencies.

7 **REVIEWS.** An initial external review of the OCEAN.US program will be conducted after an appropriate startup period as determined by the EXCOM. Regular external reviews will take place periodically thereafter.

8 **PERIOD OF AND PARTIES TO THE AGREEMENT.** This MOA, and thus the establishment of the OCEAN.US Office, shall be effective upon signatures from four NORLC Agencies and is subject to availability of funds. It may be modified by mutual agreement of all the parties, usually by the addition of an Appendix or Annex. Signatory parties may terminate their participation with six (6) months formal notice to all other parties via the NORLC. All NOPP agencies are eligible to participate as active parties to this agreement by affixing a signature of the Agency to this MOA. Other governmental organizations and entities may be recognized as adjunct partners to this agreement by consideration and approval of the National Oceanographic Research Leadership Council (NORLC) upon receipt of a signed statement agreeing to the principles of the MOA, as appropriate to that partner.

10/12/00
Robert B. Pirie, Jr. — Date
Under Secretary of the Navy
Acting

10/17/00
Dr. D. James Baker — Date
Under Secretary of Commerce
for Oceans and Atmosphere

10/24/00
Dr. Rita Colwell — Date
Director, National Science Foundation

29 January 2001
Dr. Ghassem Asrar — Date
Associate Administrator for Earth Science,
National Aeronautics and
Space Administration

10/25/00.
Mr. Walt Rosenbusch — Date
Director
Minerals Management Service
Department of the Interior

2/1/01
Dr. Charles G. Groat — Date
Director
U.S. Geological Survey
Department of Interior

3/19/01
Dr. Ari Patrinos — Date
Associate Director for Biological
and Environmental Research
Office of Science
Department of Energy

06/28/01
Terry M. Cross — Date
Rear Admiral, U.S. Coast Guard
Assistant Commandant for Operations

11/19/01
Hans A. Van Winkle — Date
Major General, U.S. Army
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APPENDIX IV: WORKSHOP AGENDA

SUNDAY, 10 MARCH	**1300 - 1700**	● Registration
	1700 - 1800	● Reception
	1800 - 1930	**DINNER** (Speaker: Vice Admiral Paul Gaffney)
MONDAY, 11 MARCH	**0830 - 1230**	● Introduction
	0830 - 0915	● Plenary: Overview of Background and Purpose (Martin, Nowlin)
	0915 - 0930	● Plenary: What is Congress Looking For? (John Rayfield)
	0930 - 0945	● Plenary: Process and Ground Rules (McCaffery)
	0945 - 1030	● Break Out Meetings (7): Clarification of purpose and workshop deliverables
	1030	**BREAK**
	1100 - 1200	● Plenary: Feedback
	1200 - 1300	**LUNCH**
	1300 - 1330	● Plenary: Review agenda, process, charge to Working Groups, Logistics (Malone and Atkinson)
	1330 - 1730	● **BREAKOUT SESSION I: 7 THEME-BASED WORKING GROUPS SPECIFY VARIABLES AND TECHNIQUES**
	1330 - 1345	● Summary of Charge (Chair)
	1345 - 1415	● Review and Discuss Background Paper
	1415 - 1730	● Specify Variables and Potential Techniques
	1730	**SOCIAL**
	1830	**DINNER**
	2000	● Ex Com Meeting with Chairs (progress, problems)
TUESDAY, 12 MARCH	**0830 - 1200**	● **Complete Phase 1 and Begin Phase 2**
	0830 - 1030	● Plenary: Reports from WG Chairs and General Discussion
	1030	**BREAK**
	1100 - 1200	● **Phase 2: Prioritorize Variables** Plenary Review charge to WGs for Phase 2 Processes for Ranking Variables and for Assessing Techniques
	1200 - 1300	**LUNCH**
	1300 - 1730	● **Breakout Session II: Discipline-Based Working Groups**
	1730	**SOCIAL**
	1830	**DINNER**
	2000	● Ex Com Meeting with Chairs
WEDNESDAY, 13 MARCH	**0830 - 1730**	● **Phase 3: Parallel Working Sessions** Discipline-Based Working Groups: Categorize Techniques for Measuring or Estimating the Common Variables DIMS Working Group Socio-Economic Benefits Working Group
	1200 - 1330	**LUNCH** (Speaker: Lautenbacher)
	1330 - 1730	● Resume Working Sessions (Break 1500)
	1730	**SOCIAL**
	1830	**DINNER**
	2000	● Ex Com Meeting with Chairs (progress, problems)
THURSDAY, 14 MARCH	**0830 - 1200**	● **Complete Phase 3 and Begin Phase 4**
	0830 - 1000	● Plenary: Final Reports of WG Chairs, Discussion and Conclusions
	1000 - 1030	**BREAK**
	1030 - 1200	● **Phase 4**
	1030 - 1200	● Plenary: Review Charge to Working Groups
	1200 - 1330	**LUNCH** - Ex Com Meet with Chairs of WGs
	1330 - 1730	● **Breakout Session III** Time Line for developing and incorporating operational elements Cost Estimates Research Priorities
	1730	**SOCIAL**
	1830	**DINNER**
FRIDAY, 15 MARCH	**0830 - 1000**	● Plenary: Final Reports and Discussion (Working Group Chairs)
	1000	**BREAK**
	1030 - 1130	● Plenary: Vision Reports
	1130 - 1145	● Political Realities (McCaffery)
	1145 - 1230	● Plenary: Phase 5 and Beyond, Closure (Martin, Nowlin)
	1230	**LUNCH**

APPENDIX V: BACKGROUND PAPERS

1. DETECTING AND PREDICTING CLIMATE VARIABILITY: A THEME FOR THE U.S. INTEGRATED OCEAN OBSERVING SYSTEM

Prepared By Worth D. Nowlin, Jr. with collaborators Melbourne Briscoe, Ed Harrison, Mike Johnson, and Robert Weller

FOREWORD

This background document was prepared for the Ocean.US Workshop, "An integrated and sustained ocean observing system," held 11-14 March 2002 in Airlie, VA, and it was revised at that workshop. The workshop focused on designing the U.S. contribution to a sustained, integrated ocean observing system and was organized around seven topical themes, plus data and information management and economic benefits.

Section 1 describes the theme, detecting and predicting climate variability, and work done nationally and internationally over the past decade to design an ocean observing system to meet the requirements of this theme on a global basis.

Section 2 describes for this theme the subgoals, expected products, and variables which must be measured to attain those products. Then, in Section 3 the recommended observing system to achieve these subgoals and products is described.

Section 4 gives a brief description of the intergovernmental mechanism now in place to implement and coordinate the observing system described in Section 3. Finally, in Section 5 some suggestions given to this theme at the Ocean.US Workshop are presented.

1. THE THEME—DETECTING AND PREDICTING CLIMATE VARIABILITY

The Earth's climate system consists of five major components: the global atmosphere, the world ocean, the cryosphere, the land surface, and the biosphere, including human influence. All subsystems are coupled, with the complete system exhibiting variations from fractions of seconds to millions of years. The ocean shows variations on all of these time scales. The best understood are those of the diurnal and seasonal cycles, where the response of the system is strong. Interannual variations of the atmosphere-ocean system are beginning to be understood and experimental predictions have shown some skill. Variations with decadal time scales are just beginning to be documented, but it is here that the ocean is most important in influencing long-term changes in the Earth's climate system.

It is useful at the outset to describe what we mean by "climate". For the purposes of this document the climate is a set of low frequency averages of variables of interest, with their associated variances. All available information suggests that there has been considerable climate variability over recorded history. This variability may be contained primarily in the variances if the averaging period is long, or in the evolution of both the means and the variances if the averaging is done over a decade or two. A major aspect of the ocean observing system for climate will be to enable the first reliable climatologies (means and variances) of the subsurface ocean to be prepared. This "baseline" climatology is essential for future work on climate change related to the ocean.

We have only a partial understanding of the role of the ocean in the coupled climate system of the Earth. In spite of their widely different time scales, mesoscale ocean eddies, the global effects of an El Niño, deep water formation, and greenhouse gas warming are all manifestations of the complex interactions between the atmosphere, land, ocean, and human systems. For the most part they can only be poorly modeled and hence poorly predicted. Although our understanding of ocean climate is increasing through research programs such as those of the World Climate Research Programme (WCRP), many aspects require systematic long-term global observations for significant improvements.

"Detecting and Predicting Climate Variability" is one theme of the Global Ocean Observing System (GOOS) and of the U.S. Integrated Ocean Observing System (IOOS), which is a contribution to GOOS. By this theme we mean that part of the observing system designed and implemented to monitor, describe, and understand the physical and biogeochemical processes that determine ocean circulation and the effects of the ocean on seasonal to decadal climate changes and to provide the observations needed for climate predictions and related research. The total system is meant to be sustained and integrated and to be based on the needs of users.

Design of this theme of the GOOS began even before the formal establishment of GOOS. In 1990, the Ocean Observing System Development Panel (OOSDP) was appointed jointly by the Joint Scientific Committee, Sponsored by the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU), and the Committee for Climatic Change and the Ocean, sponsored by the Intergovernmental Oceanographic Commission (IOC) and the Scientific Committee on Oceanic Research (of ICSU). That panel produced in 1995 a scientific design for this theme that had been reviewed by numerous representatives of the sponsoring organizations. That design (OOSDP, 1995; Smith et al., 1995; Nowlin et al., 1996) was accepted by both GOOS and the Global Climate Observing System (GCOS) as the basis for the common portion of those two observing systems.

The OOSDP was succeeded in 1996 by the Ocean Observations Panel for Climate (OOPC), which has since reported to both GOOS and GCOS. Refinement of the design has been continuous under the OOPC, and great strides toward implementation have been made.

In October 1999, the First International Conference for Climate Observations was held in San Raphael, France. Organized jointly by the OOPC and CLIVAR, this conference brought together for the first time over 300 representatives of academia, operational agencies and the private sector from some 20 nations to discuss the climate theme (OceanObs, 1999a, 1999b). Papers presented at the conference have been organized into a reviewed book, Observing the Ocean in the 21st Century, which was published in late 2001. It was agreed that long-term measurements needed for climate-related research should be included with operational needs as part of this module of the observing system. And, in turn, it was agreed that such observations, even those made by researchers, would be made available for other observing system purposes in real time. A review of many of the issues and agreements may be found in Nowlin (1999), Nowlin et al. (2001a), and Nowlin et al. (2001b). A more complete summary may be viewed at *http://www.bom.gov.au/OceanObs99/Papers/Statement.pdf*

In 1999, an Action Plan was developed to bring together previous planning and to provide an embryonic mechanism for coordinating the *in situ* and satellite-based observations needed for this theme (IOC/WMO, 1999). That action plan explicitly stated implementation requirements, recognized strengths and weaknesses of existing bodies and mechanisms, assigned to bodies/mechanisms specific actions, specified implementation gaps and how to address them, specified how future needs might be addressed, and suggested a workable operational coordination and integration mechanism. Following from the Action Plan and the Interim Implementation Advisory Group that prepared it, the decision was made by the WMO and the IOC to establish a Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), replacing the former Technical Commission for Marine Meteorology and the Integrated Global Ocean Services System. Thus for the first time coordination of and commitments for operational oceanography come under the aegis of an intergovernmental organization. JCOMM met for the first time in June 2001 (*http://www.wmo.ch/web/aom/marprog/index.html*). The adequacy of this part of the observing system for climate now is regularly reported to the Conference of Parties for the UNFCCC, e.g. GCOS (1998). (COP/UNFCCC report of COP-7 can be found at *http://www.unfccc.int/resource/docs/2001/sbsta/misc09.pdf* ; General GCOS web page with link to UNFCCC can be found at *http://www.wmo.ch/web/gcos/gcoshome.html*).

This document is based on the aforementioned reports and subsequent work in planning for this theme of the GOOS, including conclusions of the Climate Theme Working Group at the Ocean.US Workshop.

2. SUBGOALS AND PRODUCTS

There are four major subgoals to the theme of Detecting and Predicting Climate Variability listed below with the key products needed to meet each. These subgoals follow the recommendations of the OOSDP (1995) and also reflect discussion at the Ocean.US Workshop at Airlie, VA in March, 2002. Those discussions reviewed the recommendations from the OOSDP, expanded them, and clarified the link between the observing system for climate and the coastal observing system. These are described below, giving for each the key products needed to meet the subgoals.

CLIMATE CHANGE SUBGOAL 1:

Obtain improved estimates of surface fields and surface fluxes. Almost all the information needed to determine the ocean's circulation and properties is originally communicated through the air-sea interface, so the estimation of ocean surface fields and air-sea fluxes is a fundamental requirement of the ocean observing system. Sea ice is included because measures of its extent, concentration, and thickness are intimately related to the fluxes of heat and water to and from the ocean. The necessary products are:

- **Product CC-1.1:** Estimates of the global sea surface temperature (SST) field and its variability on monthly, seasonal, interannual, and longer time scales. Where it can be determined with sufficient accuracy, sea surface salinity and its variability should be measured.

- **Product CC-1.2:** Estimates of global distributions of the surface flux of momentum (wind stress) on monthly, seasonal, interannual, and decadal time scales.

- **Product CC-1.3:** Estimates of global distributions of surface fluxes of heat and fresh water on monthly, seasonal, interannual, and decadal time scales. Additional constraints on these estimates will be provided by products obtained in response to subgoal 2 dealing with upper ocean budgets.

- **Product CC-1.4:** Descriptions of the global distribution of sources and sinks for atmospheric carbon dioxide and the carbon exchanges within the interior ocean. Initially, monthly climatologies of the exchanges are required to resolve longer term changes in the presence of strong variability on interannual and shorter time scales.

- **Product CC-1.5:** Descriptions of the extent, concentration, volume, and motion of sea ice on monthly and longer time scales.

Variables required for Climate Change Subgoal 1 include:

- SST
- Surface Wind Stress
- Surface Gravity Waves
- SSS
- Surface Air Temperature
- Flux Estimates from analyses of atmospheric observations by NWP models
- Surface Weather Measurements to verify and improve NWP models and to calibrate satellite measurements, including SST, surface air temperature, sea level atmospheric pressure, precipitation, solar and longwave radiation, relative humidity, precipitation, and wind velocity time series at selected sites.
- River Discharge Rates
- Heat and Freshwater Transports on transocean sections and in selected straits
- Upper Ocean Temperature and Salinity
- Partial Pressure of Carbon Dioxide, Chlorophyll, Beam C, DIC, DOC, and selected samples of 13C/12C ratio in surface waters
- Sea Surface Color, Chlorophyll and other phytoplankton products from the water column
- Sea Ice Concentration, Thickness, Velocity, and Age

CLIMATE CHANGE SUBGOAL 2:
Document variability and change and obtain improved ocean analyses and predictions on seasonal and longer time scales. The upper ocean is a buffer to the exchange of heat and other properties between the atmosphere and the interior of the ocean and thus provides the first level of "memory" for the ocean-atmosphere system. The upper ocean is characterized by prominent seasonal to interannual signals suggesting that observation of the upper ocean will be important for prediction and regular monitoring of climate variability over these time scales. The interior ocean is characterized by its capacity to sequester heat, fresh water, and chemicals from the surface layers and delay exchange for long periods (from decades to perhaps 1000s of years). Deep ocean observations are essential to reach this subgoal. The focus here is on monitoring, understanding, and validation of model simulations. Key products are:

- **Product CC-2.1:** Global analyses of upper ocean temperature and salinity distributions at monthly intervals. These will allow monitoring, understanding, and analyzing of monthly to interannual upper ocean temperature and salinity variations.

- **Product CC-2.2:** ENSO prediction. Upper ocean data in the tropical Pacific will be used for the initialization and verification of models for ENSO prediction.

- **Product CC-2.3:** Global descriptions of upper ocean variability and climate predictions on seasonal to interannual time scales. Upper ocean data outside the tropical Pacific will be used for understanding and description of ocean variability and for the initialization and development of present and future models aimed at climate prediction on seasonal to interannual time scales. Of particular interest are the decadal modes of variability.

- **Product CC-2.4:** Oceanic inventories of heat, fresh water, and carbon on large space and long time scales. Here the focus is on observations to allow estimation of the changes in these inventories on decadal time scales.

- **Product CC-2.5:** Estimates of the state of the ocean circulation and transports of heat, fresh water, and carbon on long time scales. The focus is on estimating changes in interior ocean transports on decadal time scales. This will be accomplished through the collection of data and their assimilation in ocean circulation models.

- **Product CC-2.6:** Estimates of global and regional sea level. These are needed to monitor the long-term change in sea level due to climate change, in particular that arising from greenhouse gas warming.

Variables required for Climate Change Subgoal 2 include:

- SST, Surface Wind Stress, and Air-Sea Heat Flux (products from Subgoal 1)
- Upper Ocean Temperature and Salinity, including Mixed Layer Depth
- Sea Surface Salinity and/or Air-Sea Freshwater Flux (particularly in regions where salinity is known to be critical)
- Global Sea Level by altimetry and *in situ* observations (including sea level pressure)
- Surface Currents and selected subsurface currents in the tropical oceans
- Subsurface Profiles of Temperature, Salinity, DIC, and DOC
- Over the water column time series of T, S, and carbon related variables at select sites
- Transocean Sections measuring T, S, ^{14}C, and selected tracers
- Repeat Hydrographic Sections in critical regions for water mass formation
- Sea Surface Elevation from precision altimeter, including Marine Geoid mission
- Suite of geocentrically located tide gauges
- Freshwater Discharge from land
- Upper Ocean Heat and Freshwater Content (product 2.1)
- Surface Wind Stress and SST (from Subgoal 1)
- Sea Ice Concentration, Thickness, and Drift (from Subgoal 1)

Improved products could be obtained by:

- Measurement of Inter-Basin Exchanges
- Boundary Current Monitoring
- Sea Ice Thickness
- Sea Surface Fluxes of Freshwater, Heat, and Carbon (from Subgoal 1)
- Sea Surface Salinity and pCO_2 (from Subgoal 1)

CLIMATE CHANGE SUBGOAL 3:
Detect and assess the impact of ocean climate change on the coastal zone.

- **Product CC-3.1:** Ocean state estimates tailored to provide offshore boundary conditions for high(er) resolution coastal models.
- **Product CC-3.2:** Benchmark statistics for higher resolution local observing systems (sparse, high quality time series observations).
- **Product CC-3.3:** Routine analyses of regional sea level change.

Variables required for Climate Change Subgoal 3 include:

- Currents, U(z)
- Density Profiles T(z), S(z)
- Bathymetry
- Nutrients
- O_2
- Air/Sea Exchanges
- $C0_2$ flux
- Density Profiles
- Currents, including Tidal Currents
- GPS receivers at tide gauges
- Air Pressure

CLIMATE CHANGE SUBGOAL 4:
Establish and maintain infrastructure and techniques to ensure that information is obtained and utilized in an efficient way.

This will require the following actions and resulting products:

- **Action CC-4.1:** Providing improved global climatologies (means and variances) of key ocean variables such as temperature, salinity, velocity, and carbon, especially for the purpose of validating probabilistic climate modeling and simulations at decadal and longer time scales.
- **Action CC-4.2:** Providing the system management and communication facilities necessary for routine monitoring, analysis, and prediction of the ocean from monthly to long time scales.
- **Action CC-4.3:** Developing the facilities for processing assembled data sets and providing timely analyses, model interpretations, and model forecasts.
- **Action CC-4.4:** Providing the system with sufficient bandwidth.
- **Product CC-4.1:** Climate quality data. The data system needs to ensure that a) the data are collected and b) they are properly maintained so that the observational data, products, and analyses are of sufficient quality for detecting climate changes, validating climate models and climate forecasting.
- **Product CC-4.2:** Available long records. Climate variability requires long time series of the parameter of interest. In the early years of

IOOS this can only be achieved with the historical record. This requires access to existing historical data, long-term maintenance of these data, and recovery of data that have been collected but are not available digital form or not accessible directly.

- **Product CC-4.3:** The model and data assimilation systems and data delivery systems necessary to synthesize observations into products and analyses for the purpose of climate monitoring and prediction, e.g. ocean model/analysis systems, hardware-computers, and data delivery/product delivery infrastructure.

The effectiveness of the observing system in meeting Subgoal 4 through these needed actions will have direct consequences on its ability to meet Subgoals 1-3. A more effective methodology for interpolating, extrapolating, and drawing inferences from a measurement system will usually imply a reduced reliance on any one particular observation. Ultimately this synthesis will be performed by ocean general circulation model data assimilation systems that will combine all information from the surface, upper ocean, and deep ocean to produce a multivariate description of the global ocean circulation. This system does not yet exist, so we now rely on a variety of simpler tools.

3. RECOMMENDED OBSERVING SYSTEM

The Ocean Obs99 Conference Statement is found at *http://www.bom.gov.au/OceanObs99/Papers/Statement.pdf*. This statement contains the most current intergovernmental description of the observing system recommended to meet the subgoals of the Climate Theme of GOOS. This section gives a brief summary of those recommendations (found in Section 5 of the Conference Statement). **Note** that the Conference Statement does not contain subgoal 3 recommended in this document or its related products.

3.1 - PRIMARY CONTRIBUTIONS

These measurements include sea surface temperature, wave height, surface topography, winds, and salinity, as well as upper ocean color, sea ice properties, and the gravity field. In all cases space-based observations are valid when used in conjunction with complementary *in situ* data

3.1.1 - Sea Surface Temperature

The present operational SST measurement network is sustained through complementary satellite (AVHRR) and *in situ* (surface buoys and the Voluntary Observing Ship (VOS) Program) measurement systems delivering products of modest accuracy (around 0.5ºC) at intermediate resolution (order of 100 km at weekly time scales). Focus should be on continuing the network and improving the quality and accuracy of the long-term record. The scientific and technical issues associated with the treatment of skin and bulk measurements of SST must be addressed. Continuity of the higher accuracy ATSR-class satellite measurements must be addressed and further research is needed on the assimilation and use of geostationary satellite data and microwave measurements for improved temporal resolution and more complete spatial coverage. The major issue is to pursue the development of integrated products based on data from different platforms in order to realize sea surface temperature estimates to better than 0.4°C on fine (order 20 km) global grids.

3.1.2 - Surface Wind Vectors

Surface wind sampling capabilities have been vastly improved with the launch of various scatterometers and the utilization of surface wind speeds provided by passive microwave measurements. The use of dedicated surface moorings (e.g. TAO/TRITON) has also had a significant impact. To support requirements for wind data will require two scatterometers for sustained global daily coverage at around 25-km resolution, together with maintenance of support for *in situ* observations (particularly in the tropics) and continued use of passive microwave measurements. This strategy assumes continued support for analysis via numerical weather prediction and re-analysis systems. The needed coverage is not yet assured for the coming ten years. The impact and utility of enhanced spatial and temporal resolution, including the diurnal cycle, should be carefully evaluated in the next decade using the periods when multiple sensors will be available and through further analysis and sensitivity studies of atmospheric data assimilation systems for global and regional numerical weather prediction.

3.1.3 - The ENSO Observing System

The El Niño/Southern Oscillation (ENSO) Observing System was set up after TOGA to help understand, monitor, and predict ENSO variations and consists of a network of VOS lines (for both surface and subsurface parameters), drifting and moored data buoys (such as TAO and TRITON and those of the DBCP), and island and coastal sea level stations. SST, surface wind and surface topography measurements from satellites provide important complementary data sets. The utility of this network remains one of the most prominent and tangible examples of practical benefits accruing from the ocean observing system and real-time, free distribution of data. The pervasive influence of ENSO on timescales ranging from the intra-seasonal to those of climate change mean the ENSO network also has utility far broader than ENSO prediction. Maintenance of the ENSO observing network in the Pacific is accorded high priority. We anticipate that the detailed configuration will change as observational methods evolve and both knowledge and models improve. A recent review recommended no major changes, though the demand for expansion beyond the tropical Pacific is likely to influence future configurations.

3.1.4 - Argo

Recent advances in technology have made possible a major increment in *in situ* observing capabilities with the potential to close many of the wide gaps in our routine upper ocean measurement network. Such data on temperature and salinity are important for seasonal to interannual and longer time scales climate applications as well as ocean prediction. Complementary ocean topography data are critical. *Argo*, an initiative to populate the global ocean with profiling floats, is an appropriate and effective strategy for large-scale sampling of temperature and salinity in the upper 2000 m of the ocean. The expectation is that *Argo* will become a fully sustained contribution by 2005. The proposed sampling (order 300 km and every 10 days) is appropriate given the limited knowledge of global temperature and salinity variability.

3.1.5 - Ocean Surface Topography and Sea Level

The availability of precise measurements of ocean surface topography from space has had a dramatic effect on our understanding of ocean dynamics and contributed to an enhanced capacity to predict ocean and climate variations and monitor climate change. The remote sensing requirements can be met through a combination of continuing integrated missions of high-precision and low-precision but high-resolution altimetry. These data must be supplemented by a global network of *in situ* measurements for independently monitoring long-term change, changes in the ocean circulation, and to calibrate the satellites. To produce accurate global determinations of sea level change, around thirty geocentrically positioned sites are required. Critical complementary data include *Argo* (for baroclinic structure and thermal expansion) and gravity missions for determination of the geoid (see Section 3.2). Altimetric data also have utility for wave forecasting, surface wind estimation and other geophysical applications.

3.1.6 - The Surface Marine Network

Surface marine data have important roles in addition to those covered above, including the determination of global air-sea fluxes, sea state prediction, inputs for weather prediction, the determination of surface salinity and surface current fields, and as inputs for ocean prediction. The VOS and data buoy programs should have increasing emphasis on quality and a broader suite of measurements to better determine surface fluxes. The surface drifter program is of particular importance for remote locations and as a direct measure of surface currents. Details of enhancements are covered in the next sub-section. For wind waves, good estimates of surface wind velocity remain critical. Significant wave height estimates from altimetry are increasingly being used to initialize models. Data from wave-rider buoys remain important for model validation.

3.1.7 - The Ship-of-Opportunity Network

The advent of Argo and precision altimetry has changed the context within which the Ship of Opportunity Program (SOOP) operates. It has been recognized that there should be a change in emphasis from broad-scale, areal sampling to line mode sampling (high-resolution and frequently repeated lines) progressively over the next five years. This approach will promote synergy with *Argo*, the surface reference network, altimetry, and moored arrays. There is special utility of such sampling in boundary regions and it has a unique role in heat and freshwater transport calculations.

3.1.8 - Sea Ice Concentration, Extent and Motion

Some sea ice measurements of concentration and extent are sustained now through passive microwave observations, as well as combined *in situ*, aircraft, and satellite analyses. These are expected to continue through the next decade. In addition, buoys are used to monitor ice motion, notably as part of the International Arctic Buoy Programme. There is the need for a sustained effort to monitor sea ice concentration, extent, and motion. Enhancements are needed for estimates related to surface fluxes and sea ice thickness.

3.2 - ADDITIONAL CONTRIBUTIONS AND ENHANCEMENTS

In this subsection we briefly describe additional contributions and recommended enhancements that, for various reasons, could not yet be included in the primary network. These reasons include the lack of clearly identified funding mechanisms, the need for further planning and/or design studies, or the need for further research or testing.

No relative priority is attached to these potential enhancements other than to emphasize that all contributions have high priority for at least one of the rationale discussed in Section 2. Also, the order of presentation here is not significant. Global enhancements are discussed prior to regional and/or specific enhancements.

3.2.1 - Global Enhancements

In this subsection we discuss those contributions that might be characterized as global network enhancements. In relation to the scientific rationale, the enhancements are primarily aimed at problems that are global. Remote sensing has obvious advantages as a global approach and experimental missions are driven by both technological challenge and societal need. For the most part, experimental missions over the next 5-10 years have already been decided. In this subsection we restrict the discussion to those developments that, in the view of the OceanObs 99 Conference, represented high priority enhancements to the primary net works described in Section 3.1.

Hydrography and Carbon Inventories

There is a strong conviction that the approach to climate change and longer time-scale problems would be fatally flawed in the absence of a systematic network of deep measurements, in particular repeated hydrographic sections. This view has been manifested in many international negotiations and agreements. Monitoring the earth-system carbon cycle now is an issue of high political and societal interest. However, the view of some is that we are not yet ready for a sustained field program.

The relative importance of carbon inventories has been raised because climate change assessments require knowledge of the anthropogenic carbon (and related trace gas) inventories in the ocean and how they are changing. The inventories completed in 1997 as part of WOCE demonstrated flaws in our global carbon models. The models have been adjusted. However, neither the models nor the global measurements of air-sea gas fluxes are yet reliable approaches to estimating future inventories and changes in storage. At least for the near-term, it will be necessary to make measurements of anthropogenic carbon and other tracers to provide new inventories. Such surveys will extend over the full depth but may be more closely spaced in regions near carbon injection, and more widely spaced and limited in depth in areas where tracers have not yet penetrated into the deep waters. Moreover, the frequency of such surveys will be less as one moves away from the injection region where changes are most rapid. The OceanObs99 Conference concluded the over-riding consideration for deep ocean measurements should be the need to measure and monitor carbon inventories.

Fixed-point Time Series

The above strategy might be termed a “deep line mode”. A complementary strategy of a selected number of deep-ocean, fixed-point time series stations is needed. The multi-disciplinary advantages of time-series stations are well accepted. A plan is being developed for a staged deployment over the next five years and demonstration of the capability to operate as a sustained, real-time network.

Surface Reference Data Sets

In the climate community, the concept of reference sites and/or reference data sets receives considerable attention. This is principally because of the interest in climate change and a sustainable marine environment, but also because defined data sets can be used to calibrate and tune models. High quality is the over-riding characteristic, with continuous records, preferably of some length, being important additional features. Such reference data sets are in demand for testing weather prediction, re-analysis, and coupled climate models. The sustained observing system should include a network of selected surface reference flux sites and a complementary selected network of climate quality VOS lines.

Upper Ocean Current Network

There is the continuing need for direct and indirect estimates of components of the ocean circulation, particularly for non-climate applications such as ocean forecasts, and endorsed efforts to provided synthesized products. A wide variety of instruments measure different components of the upper ocean circulation globally, including surface topography from altimeters, improved reference levels from satellite gravity measurements, surface drift inferred from wind measurements, surface currents from drifters, and subsurface currents from Argo floats. Plans are under development to synthesize these observations into regional estimates of the circulation near the surface and at depth.

Precision Gravity Field or Geoid
Needed are improved estimates of the static (geoid) and time-dependent gravity field for oceanography and in particular for estimates of the ocean circulation (with altimetry). Several missions are planned, with varying degrees of accuracy and spatial resolution. Complementary surface and subsurface measurements of ocean currents are needed.

Salinity
An inability to provide synoptic measurements of global salinity variations represents a significant gap in our primary capabilities. Recommended are experimental development and demonstration of space technologies that can provide long-term surface salinity data. The utility of such methods will need to be considered in conjunction with the enhanced capacity to measure salinity directly from Argo and other platforms and the availability of reliable surface precipitation estimates.

Sea-ice Thickness and Extent
An inability to monitor the temporal and spatial variations in ice thickness for the ice-covered ocean constitutes a significant gap for several climate problems, particularly those requiring a determination of the heat and freshwater budget. The Conference welcomed exploratory remote sensing missions aimed at providing useful ice thickness measurements. Radarsat/SAR, SeaWinds/METOP scatterometers, along with EOS, ADEOS and operational passive microwave sensors can provide for long-term observations of ice extent and type. A key issue at present is funding for Radarsat-2.

Ocean Biology
GOOS has endorsed the need for sustained ocean color measurements, and the Ocean Theme Team of the Integrated Global Observing Strategy Partnership (http://ioc.unesco.org/igospartners/) has included those observations in the Theme and noted the additional utility of such data for climate and physical oceanography applications. The issues are to help define and realize the bridging mission(s) for the post-2005 time frame and to refine and coordinate the products that can be derived from such measurements for routine applications. Needed in addition are autonomous measurements of *in situ* ocean biology and optics and of routine measurements of the CO_2 system.

Surface Wind Waves
The Conference noted the utility of the Synthetic Aperture Radar (SAR) and altimeter for wave spectrum and wave height data, respectively, for wave applications. The existing network of wave observations from operational meteorological buoys are valuable fixed point "time series" measurements. Such observations are now routinely assimilated into operational wave forecast models, but only the buoy observations can be considered sustained measurements. The enhancement of buoy observations using oceanographic moorings is an option. Enhanced availability of SAR observations is sought though the considerable cost will be a limiting factor.

3.2.2 - Regional Networks and Other High Priority Enhancements
It is beyond question that focused regional initiatives offer a viable and effective route for building and enhancing the global sustained observing system. Plans for some ocean basins are well developed; those for others are under active development. All are taking somewhat different approaches. Irrespective of the approach, the systems must be integrated so that, to the user, the interfaces between different regional systems and to the global systems will appear seamless, yielding a total system that is more effective than the sum of the parts.

4. A MECHANISM FOR IMPLEMENTATION AND COORDINATION OF THE GLOBAL MODULE
This section is presented to convey to the interested reader the status of intergovernmental focus to coordi-

nate and integrate requirements for the climate variability and predictability from GCOS, GOOS, and the UNFCCC together with requirements for marine weather and services from the WMO and international conventions. This is not necessary reading for participants in the Ocean.US Workshop; that workshop focused principally on what is needed, not on how those needs will be met.

The World Meteorological Organization (WMO) Marine Programme was traditionally the responsibility of the intergovernmental Commission for Marine Meteorology (CMM), with strong links to the Intergovernmental Oceanographic Commission (IOC) and related programs. However, the Thirteenth Congress of WMO (May 1999) and the 20th IOC Assembly (July 1999), following on recommendations of the Executive Councils of both IOC and WMO, and recalling that many areas of close collaboration already existed between WMO and IOC, agreed that a Joint IOC/WMO Technical Commission for Oceanography and Marine Meteorology (JCOMM) should be established with status and responsibilities of a WMO Technical Commission and IOC Committee. JCOMM replaces CMM and the Joint Committee for IGOSS and acts as a reporting and coordinating mechanism for the full range of existing and future WMO operational marine activities. It coordinates and manages the implementation of the operational ocean observing system in support of the Global Ocean Observing system (GOOS) and the Global Climate Observing system (GCOS).

In line with its status as a technical commission of WMO, JCOMM is an intergovernmental body of technical experts in the field of oceanography and marine meteorology, with a mandate to prepare both regulatory (what Member States shall do) and guidance (what Member States should do) material relating to marine observing systems, data management and services. The role of the full commission in session is to act as a final review body for activities, proposals and recommendations prepared for it by its sub-structure of working groups, expert teams and rapporteurs. Based on these, it then prepares recommendations for actions by Member States, for consideration and adoption by the respective governing bodies of WMO and IOC.

The Commission met for the first time 19-29 June 2001 in Akureyri, Iceland. The session was attended by representatives of 42 nations and 10 international organizations, as well as invited experts and staff of the WMO and IOC secretariats. The abridged final report of that meeting with resolutions and recommendations is available as WMO publication 931 or on the WMO website. The organizational structure (see Figure 1) was approved including terms of reference for all elements. Nominees from governments were considered and all key positions were filled. Finally a work program for the Commission, including each of its elements, for the four-year period 2001-2005, was approved. Intersessionally, management of JCOMM falls to the Co-Presidents with the advice of the Management Committee. That committee met for the first time 6-9 February 2002 in Geneva. The four Program Area Coordination Groups will be meeting for the first time before August 2002. Most expert teams already exist and are proceeding with the business of implementation as usual.

At this time JCOMM is concerned only with the physical observations and services needed to support intergovernmental requirements for climate and marine meteorology. However, JCOMM is fully aware of the need to broaden their remit to include non-physical variables as the design for the coastal module of the Global Ocean Observing System is completed and implementation begins to accelerate.

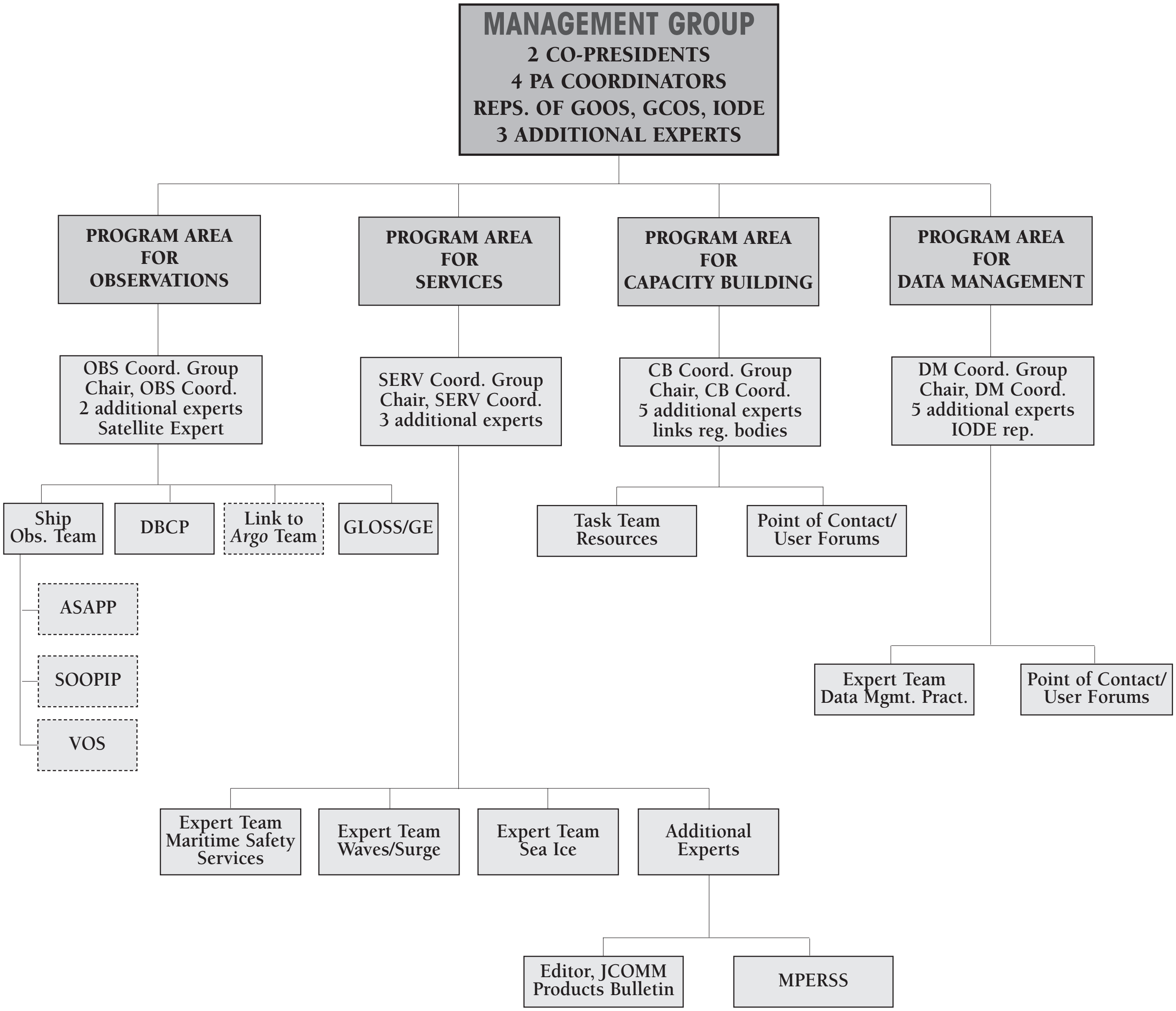
5. SUGGESTIONS FOR CONSIDERATION

The U.S. is a party to the JCOMM and has in effect approved the action plan for the climate module of GOOS and GCOS. That action plan, as described briefly in Section 3, is now being implemented and coordinated under the oversight of JCOMM. U.S. representatives appear on virtually every task team, and the U.S. contributes support to most of those efforts. Of course, it is up to national agencies to provide the support required to carry through the implementation. Moreover, it should be noted that the action plan for the climate module is indeed for a global observing system, and regional enhancements may be needed to monitor, predict, or mitigate effects of climate variability in the coastal zone.

Therefore, it is suggested that strong U.S. support be provided for the global climate module. Moreover, it also is suggested that consideration be given for U.S. support of measurements needed to understand, monitor, and predict the climate of the ocean as well as the ocean's influence on atmospheric climate variability.

The observational network proposed for the climate module is that needed to monitor, understand, and predict climate variability. It is suggested that the U.S. Integrated Ocean Observing System also include those observations in the coastal zone needed to make it possible to predict and perhaps mitigate the effects of ocean and atmospheric climate variability on the coastal zone. Clear examples are (1) effects of currents outside our coastal zone on circulation and distributions of properties within our coastal zone and (2) sea level rise associated with potential continued global warming and high latitude ice melting.

FIGURE 1. **THE ORGANIZATIONAL STRUCTURE FOR THE JOINT WMO-IOC TECHNICAL COMMISSION FOR OCEANOGRAPHY AND MARINE METEOROLOGY. THE STRUCTURE IS DIVIDED INTO FOUR PROGRAM AREAS (PAs), EACH WITH A COORDINATOR AND COORDINATION GROUP. WITHIN EACH PROGRAM AREA THERE ARE VARIOUS TASK TEAMS AND RAPPORTEURS WHO CARRY OUT THE ONGOING ACTIVITIES, ASSISTED BY THE JCOMM SECRETARIAT LOCATED WITHIN THE WMO AND THE IOC.**



It might be noted that much of our climate record today exists because data were needed for shorter time-scale activities, but many were logged and documented. This allowed aggregation as long records. This is an important overlap in the integration of all the observing systems and their elements. Perhaps the list of recommended variables finally recommended by this workshop should be accessed in terms of applicability for other timescales as well as the ones for which they are primarily intended.

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APPENDIX V: BACKGROUND PAPERS

2. FACILITATING SAFE AND EFFICIENT MARINE OPERATIONS: A THEME FOR THE U.S. INTEGRATED SUSTAINED OCEAN OBSERVING SYSTEM

Prepared By Robert Cohen with collaborators Arthur Allen, Jonathan Berkson, James Kendall, and Michael Szabados

1. THE THEME

The health of coastal economies and the nation's success in the emerging global market requires safe and efficient marine operations. More than 98 percent of the U.S. foreign trade by weight moves by sea. Since 1955, maritime trade has doubled and the nation's volume of international trade has nearly quadrupled. By the year 2020, foreign ocean borne trade into the U.S. is expected to at least double again. This growth will increase demands for harbors and shore side facilities and create new pressures to expand development in our nation's sensitive coastal areas. Each year more than 2 billion tons of cargo moves through U.S. ports. The U.S. Marine Transportation System generates more than $200 billion in tax revenues, and contributes more then $743 billion to the nation's Gross Domestic Product. But with increased marine commerce comes increased risks. During the last half century the length, width, and draft of ships have doubled. Every year there are about 3,500 commercial shipping accidents in the U.S. waters, and between 1993 and 1995 the Coast Guard reported 4,078 groundings, 147 collisions, and 12 deaths. One major oil spill can cost billions of dollars, while burdening governments and the private sector with litigation, regulation, cleanup, and remediation expenses.

Petroleum companies drilling in the U.S. who now provide approximately 38 percent of the domestic consumption have for the past decade been reaching into deeper waters to secure oil and natural gas to fuel our nation's growth. In 2000, federal waters in the Gulf of Mexico accounted for 92 percent of the total U.S. reported new oil field discoveries. The total expenditures for offshore exploration and development in 2000 were over $20 billion (Energy Information Administration, 2001). Safe design, construction and efficient operation of these new structures and associated infrastructure requires additional and more detailed knowledge about the meteorological and oceanographic conditions on the surface and throughout the water column.

The existing marine infrastructure, technology, products, and services have not kept pace with the expanding volume of maritime traffic, increase in recreational boating, and development and growth of coastal areas. Improvements are needed throughout the marine transportation, offshore energy, environmental management, and recreational sectors of the maritime community. Improvements in the safety and efficiency of U.S. ports and waterways are necessary for a variety of reasons, including the demands of growing international trade, the trend towards larger ships and faster cargo loading and off-loading operations, the presence of oil and hazardous cargo in congested and heavily populated areas, and public concerns about maritime accidents that can cause environmental damage. Improvements are required that will support the needs of coastal zone planners, regulatory officials, and researchers as they work to ensure the safe, sustainable, and efficient development of our coastal and ocean resources.

The U.S. Integrated Sustained Ocean Observing System theme "Facilitating Safe and Efficient Marine Operations" supports the U.S. Marine Transportation System vision to be the world's most technologically advanced, safe, efficient, effective, accessible, and environmentally responsible system of navigation information to provide real-time delivery and display of current, historical and forecast oceanographic and meteorological conditions from the U.S. waterways, ports and open ocean waters.

2. SUBGOALS AND PRODUCTS

In developing the subgoals and products we have targeted a wide variety of user groups, including commercial and military shipping, commercial fishing, recreational users (boaters, fishing, surfers), the extraction industry, construction, cable laying, community response agencies (federal, state and local), and the insurance industry.

For the purposes of this paper, we define nowcasts as the analysis of current conditions using real time or near real time observations, usually in combination with a "first guess" forecast from a previous model run.

MARINE OPERATIONS SUBGOAL 1:

Maintain navigable waterways. Maintenance of navigable waterways is a requirement of the safe and efficient use of our coastal areas for transportation, offshore industry and recreation.

- **Product MO-1.1:** WATER LEVEL: Real-time, referenced water level in the coastal area, and its variability on 0.1 hour to interannual and longer time scales. Accurate nowcasts and forecasts of water level directly affects safe transportation in the coastal area.
- **Product MO-1.2:** BATHYMETRY: Monitor coastal bathymetry and its variability on monthly, seasonal, interannual and longer time scales. Accurate, up-to-date charts of bathymetry are required to maintain waterways, and as input into ocean current and shallow water wave models.
- **Product MO-1.3:** ESTUARINE/COASTAL CURRENTS: Real-time currents and the variability on 0.1 hourly to interannual and longer time scales.
- **Product MO-1.4:** ICE: Ice in the coastal area and icebergs in the open ocean and the accumulation of ice on vessel superstructures, and the variability on daily, weekly, monthly, seasonal, interannual and longer time scales. Predictions are required for safe and efficient navigation in areas affected by ice and icebergs and where icing on the superstructures of vessels can lead to the catastrophic loss of stability.
- **Product MO-1.5:** NATURAL HAZARDS: Monitor the susceptibility of the coastal area to natural hazards such as extreme weather events, flooding and tsunamis. Timely predictions and analyses are required to provide nowcasts and forecasts, as well as to enable long-term planning and engineering in coastal area.
- **Product MO-1.6:** SURFACE WAVES: Monitor the wave climate to enable assessment of sediment transport.
- **Product MO-1.7:** RIVER FLOW AND SEDIMENT LOAD: River outflow and sediment loading can affect the bathymetry.

The variables required for MarineOperations Subgoal 1 include:

- Dew point
- Humidity
- Pressure
- Air
- Temperature
- Wind
- Bathymetry/Topography
- Ice Concentrations
- Ice Thickness
- Salinity
- Ocean temperature
- Current
- Sea Surface Temperature
- Directional Wave Spectra
- Precipitation Amount
- Precipitation Intensity
- Precipitation Type
- Sea Level
- Current Profile
- Geotechnical Hazard Locations
- Manmade Hazard Locations
- River Discharge
- Sediment Load
- Bottom Type

MARINE OPERATIONS SUBGOAL 2: Improve search and rescue and emergency response capabilities. Short-term trajectories of hours to days are required in conjunction with hazards in the water in order to assess location and survivability. Timeliness of products, as real time, historical and forecast fields are mission critical.

- **Product MO-2.1:** SURFACE AND SUBSURFACE CURRENTS: Real-time products are critical as is access to forecast fields up to 12 hours in the future, and historical fields for the 30 days previous.
- **Product MO-2.2:** SURFACE WINDS: Real-time products are critical, as is access to forecast fields up to 12 hours in the future, and historical fields for the 30 days previous.
- **Product MO-2.3:** SEA SURFACE TEMPERATURE: Real-time for survivability models.
- **Product MO-2.4:** SEA STATE: Directional wave information is required for capsizing/swamping modules and drift trajectories of large vessels.
- **Product MO-2.5:** TOXIC/DANGEROUS MARINE ORGANISMS: Abundance and distribution of organisms which might affect survivability.
- **Product MO-2.6:** METEOROLOGY AFFECTING DETECTION: Weather conditions can affect the ability to locate a target.

The variables required for MarineOperations Subgoal 2 include:

- Aerosol Type
- Average Upper Layer Temperature
- Average Upper Layer Dewpoint
- Boundary Layer Elevation
- Cloud Base Height
- Cloud Density
- Cloud Type
- Dew Point
- Humidity
- Cloud Amounts (low/mid/high)
- Pressure

- Air Temperature
- Wind
- Ice Concentration
- Ice Thickness
- Currents
- Sea Surface Temperature
- Directional Wave Spectra
- Precipitation Amount
- Precipitation Intensity
- Precipitation Type

MARINE OPERATIONS SUBGOAL 3:
Ensure safe and efficient marine operations and activities.

- **Product MO-3.1:** Observations, nowcasts and forecasts of open ocean, coastal and estuarine 4D fields available for real-time operations. Fields include winds, waves, currents, temperature, salinity, visibility, humidity, water levels, and ice.
- **Product MO-3.2:** Geotechnical hazards data on slope instabilities, hydrates, and bottom-type characterization.
- **Product MO-3.3:** Maps of fixed subsurface structures and hazards.
- **Product MO-3.4:** Updated bathymetry.
- **Product MO-3.5:** Monitoring of drifting hazards to navigation.

The variables required for Marine Operations Subgoal 3 include:
- Aerosol type
- Average Upper Layer Temperature
- Average Upper Layer Dewpoint
- Cloud Base Height
- Cloud Density
- Cloud Type
- Dew Point
- Humidity
- Cloud Amounts (low/mid/high)
- Pressure
- Air Temperature
- Wind
- Bathymetry/Topography
- Ice Concentration
- Ice Thickness
- Salinity
- Ocean Temperature
- Currents
- Sea Surface Temperature
- Directional Wave Spectra
- Precipitation Amount
- Precipitation Intensity
- Precipitation Type
- Sea Level
- Current Profile
- Geotechnical Hazard Locations
- Manmade Hazard Locations
- River Discharge
- Sediment Load
- Bottom Type
- Heat Flux Components
- Geolocation Type

3. OBSERVING TECHNOLOGIES

THE AVAILABLE TECHNOLOGIES FOR THE TOP TEN RANKED VARIABLES (BASED ON A RANK OF HOW FREQUENTLY THE INDICATED VARIABLE WAS REQUIRED FOR EACH OF THE THREE SUBGOALS) ARE:

VARIABLE	OBSERVING TECHNOLOGIES
Wind	Scatterometer; aneomometer on buoys, ships, platforms, and coastal stations
Sea Surface Temperature	remote sensing, thermometers on buoys, and ships
Directional wave spectra	accelerometer and pitch/roll buoys, satellites
Surface currents	high frequency radar, ship mounted ADCP's, fixed ADCP's, point moorings
Current profiles	point moorings, ADCPs, drifters
River discharge	water level gauging network (USGS)
Ice coverage/concentration	SAR, ship observations, other satellite instrumentation
Dew point/humidity	hygrometer on buoys, ships and fixed platforms, remotely via satellite
Precipitation intensity/amount	rain gauges on buoys, ships and fixed platforms, remotely via satellite
Air temperature	thermometers on buoys, fixed platforms and coastal stations
Ocean salinity	conductivity from buoys, fixed moving platforms, XBT's
Ocean temperature profile	thermister strings from buoys, fixed/moving platforms, XBT's
Bottom type	bottom grabs, video, multibeam seismic, visual (AUV's, ROV's submersibles)
Marine Organisms	standard biological, chemical and microbial techniques, and visual monitoring

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APPENDIX V: BACKGROUND PAPERS

3. ENSURING NATIONAL SECURITY: A THEME FOR THE U.S. INTEGRATED OCEAN OBSERVING SYSTEM

Prepared By James Rigney and Jeff Paduan

1. THE THEME—NATIONAL SECURITY

National security may be broadly defined to encompass not only the protection of U.S. persons and interests, but also the promotion of the economic and social interests of the U.S. government and its citizens. Using the broader definition, many of the other themes of the U.S. Integrated Ocean Observing System have aspects that can be considered as contributing to national security. Therefore, these broader national security aspects will not be explicitly handled here. Instead, the scope of the National Security theme will be limited to the military's missions of warfighting, peacekeeping and humanitarian assistance. It includes maritime national security interests around the world, in every ocean, as well as maritime homeland security.

As will be detailed in the subgoals and products, the oceans profoundly affect those whose job it is to ensure national security in the maritime environment (for example, the Navy, Marine Corps, and Coast Guard). Knowledge of the ocean makes for better decision making and employment of people, platforms, and systems, increasing their effectiveness, and decreasing risks to those resources. This knowledge is used both operationally in the planning and execution of military missions, and by researchers supporting the development of new national security capabilities. "Operational" refers to those data and products for which availability is assured for timeframes needed to support practical decision making.

The U.S. Navy uses the term "Oceanography" to include classic oceanography (physical, biological, chemical, and geological), meteorology, hydrography, acoustics, precise timing, astrometry, and geographic information and services. The Navy focuses on these disciplines to determine environmental effect on naval operations. Requirements for oceanographic information for national security purposes have been stated and validated through formal Department of Defense processes. In the Chief of Naval Operations-Oceanographer of the Navy R&D Strategy (2001), many of these requirements are translated into various product lines. The subgoals and products below reflect many of these validated requirements and product lines.

It is anticipated that a number of the elements of the IOOS will be useful in addressing a variety of national security issues. For example, a network of coastal radars would not only support the prediction of waterborne contaminant movement, but could also be used for port security and tracking ship traffic. Additionally, a robust U.S. coastal component of IOOS will enable the U.S. Navy to use the U.S. littorals as "surrogates" for denied areas in order to assess its coastal prediction and forecasting capabilities through data deprivation and forecasting experiments and exercises.

2. SUBGOALS AND PRODUCTS

(Note: The term "coastal" below refers to both "denied" areas around the world, and areas accessible to U.S. *in situ* observations, including the U.S. homeland.)

NATIONAL SECURITY SUBGOAL 1:
Improve the effectiveness of maritime homeland security and warfighting effectiveness abroad, especially in the areas of mine warfare, port security, amphibious warfare, special operations and antisubmarine warfare.

- **Product NS-1.1:** Estimates/predictions of near-surface currents on hourly to seasonal (i.e. climatological) time scales.
- **Product NS-1.2:** Estimates/predictions of near-bottom currents on hourly to seasonal time scales.
- **Product NS-1.3:** Estimates/predictions of tidal period, sea level/water level and velocity fluctuations.
- **Product NS-1.4:** Estimates/predictions of near water clarity on hourly to seasonal time scales.
- **Product NS-1.5:** Estimates/predictions of sediment transport on hourly to seasonal time scales.
- **Product NS-1.6:** Estimates/predictions of acoustic performance, especially on the

3. ENSURING NATIONAL SECURITY TECHNIQUES LIST

TECHNIQUES \ VARIABLES	Acoustic travel times	Acoustic Statigraphy	Acoustic Reverberation	Ambient Noise	Air-humidity	Air-temperature	Bathymetry	Bioluminescence	Bottom Characteristics	Bottom Roughness	Contaminant distributi	Flux estimates	Humidity	Ice	
Directed ships		■	■	■	■	■	■	■	■	■	■	■	■	■	■
Volunteer Observation Ships					■	■	■						■		
Drifters				■	■	■		■			■	■	■		
Profiling Floats, e.g. ARGO, Glider															
XBT's/XSV/XCTD															
CTD's/moving vessels profiler															
Side Scan Sonar									■	■					
Multibeam/single beam Sonar							■			■					
Synthetic Aperture Sonar										■					
Scatterometers															
Anemometers															
ADCP's										■					■
Magnetometer															
Gravity meter															
Satellite/Airborne Remote Sensing						■	■	■	■		■	■		■	
Multispectral					■	■	■	■	■		■			■	
Hyperspectral					■	■	■	■	■		■			■	
ATSR												■		■	
AVHRR												■		■	
SOP				■	■	■		■				■	■		
AUV's		■	■				■	■	■	■	■				■
UAV's					■	■	■	■	■		■	■	■	■	
LIDAR (Topo & Bathy)							■	■	■	■		■		■	
Moored Buoys & Platforms				■	■	■		■			■	■	■		■
Satellite Altimetry							■								
HF Radar														■	
Tide gauges															
GPS positioning															
Transmissometer															
Fluorometer											■				
Satellite Imagers											■			■	
NBC detectors											■				
Microwave SST's															
SAR											■			■	
Subbottom Profiler		■							■						
Bioluminescence meter															
Nutrient Analyzer															

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Nutrients	Ocean-3-D-salinity	Ocean-3-D-temperature	Ocean-3-D-velocity	Ocean Color	Ocean directional wave spectra	Ocean surface-wind stress	Optical properties-apparent	Optical properties-inherent	Phytoplankton-abundance	Radiation-long-wave	Radiation-solar	River discharge rates	Sea level datums	Sea Surface Temperature	Sediment-composition	Sediment-thickness	Submerged vegetation	Suspended sediment	Visibility	Wind Velocity	Zooplankton-abundance
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continental shelf on daily to seasonal timescales.

Variables required for National Security Subgoal 1 include:

- 3-D Vector Currents
- 3-D Water Temperature
- 3-D Salinity
- 3-D Suspended Sediment (for density)
- Flux Estimates of Momentum, Heat, Moisture/Freshwater, and Radiation. Usually these are provided by NWP models, need to be verified by observations.
- Wind Vectors
- Water Temperature
- Air Temperature
- Humidity
- Long-Wave Radiation
- Solar Radiation
- Precipitation Amount
- River Discharge
- Bathymetry
- Sea Level/Ocean-Sea Surface Height
- Bottom Characteristics (type, vegetation, sediment composition and thickness, acoustic stratigraphy)
- Ambient Noise
- Nutrients
- Bioluminescence
- Optical Properties
- Ocean Color
- Surface Roughness

National Security Subgoal 2:
Improve safety and efficiency of operations at sea.

- **Product NS-2.1:** Improved wave forecasts at the 3-7 day range, especially for storms and tropical cyclones.

- **Product NS-2.2:** High-resolution (to include variability at scales of meters) shallow-water wave and surf forecasts, especially in denied areas.

- **Product NS-2.3:** Real-time near-surface velocity estimates and forecasts for search and rescue.

- **Product NS-2.4:** Improved navigational products.

Variables required for National Security Subgoal 2 include:

- Directional Wave Spectra
- Bathymetry
- Wind Vectors
- 3-D Vector Currents
- Ice Concentration
- Ice Thickness
- Atmospheric Visibility

National Security Subgoal 3
Establish the capability to detect airborne and waterborne contaminants in ports, harbors, and littoral regions at home and abroad, and to predict the dispersion of those contaminants for planning, mitigation, and remediation.

- **Product NS-3.1:** Background levels of nuclear, biological and chemical (NBC) contaminants.

- **Product NS-3.2:** Analyses and predictions of NBC concentrations on scales from the sub-hourly to weekly.

Variables required for National Security Subgoal 3 include:

- 3-D Vector Currents
- Wind Vectors
- Water Contaminant Observations (both initial conditions and real-time updates)
- Bottom Characteristics (sediments composition)

National Security Subgoal 4:
Support environmental stewardship.

- **Product NS-4.1:** Physiological descriptions of sensitivity to and utilization of acoustic signals by classes of marine mammals.

- **Product NS-4.2:** Real-time and climatological marine mammal/protected species distributions.

- **Product NS-4.3:** Real-time velocity fields in locations of hazardous material spills or potential spills.

Variables required for National Security Subgoal 4 include:

- Marine Mammal Abundance
- All variables listed for Subgoals 1 and 3.

National Security Subgoal 5:
Improve at-sea system performance through more accurate characterizations and prediction of the marine boundary layer.

- **Product NS-5.1:** Improved prediction of electromagnetic/electro-optic propagation through the marine boundary layer in support of strike warfare, antiaircraft warfare, and anti submarine warfare.

- **Product NS-5.2:** Improved prediction of near-surface visibility

Variables required for National Security Subgoal 5 include:

- Water Temperature (especially sea surface temperature)
- Humidity
- Marine Boundary Layer Height
- Directional Wave Spectra (especially wave height)
- Aerosols
- Atmospheric Visibility

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APPENDIX V: BACKGROUND PAPERS

4. MANAGING LIVING RESOURCES: A THEME FOR THE U.S. INTEGRATED OCEAN OBSERVING SYSTEM

Prepared By David G. Mountain in collaboration with Philip Mundy and Thomas Malone

1. THE THEME

Within the structure of the international Global Ocean Observing System (GOOS), issues relating to living marine resources (LMR) were addressed by the LMR-GOOS panel. From 1998-2000 this panel held four meetings [1-4] leading to the development of a Strategic Design Plan [5]. In 2000 the efforts of LMR-GOOS were joined with those of the Health of the Ocean (HOTO) and the Coastal (C-GOOS) GOOS panels in the Coastal Ocean Observations Panel (COOP). A primary task for COOP is to combine the recommendations of the three panels into an integrated plan, which is currently being drafted [6]. In addition two recent National Research Council (NRC) committees addressed the issues of sustaining marine fisheries and of marine protected areas as a tool for sustaining marine ecosystems. The reports of both committees [7-8] made recommendations concerning information needs for fishery and ecosystem management.

A major objective of GOOS is to provide operationally useful information on the state of living marine resources and their ecosystems. Such information would include changes in physical conditions and ecosystem components required for now-casting and eventually forecasting of the ecosystem and of its living resources [2]. In general, operational models for LMR management currently do not incorporate environmental variability, essential habitat variability or ecosystem interactions. However, these areas are the focus of major national research programs and the understanding needed to include that variability and those interactions in operational models is increasing. In addition to supporting operational needs, the Integrated Ocean Observing System is intended to provide an informational underpinning for research efforts leading to increased operational capabilities. In the System design, consideration of the informational needs for these emerging capabilities is appropriate.

The LMR-GOOS panel considered a three-system approach for LMR observational needs – inshore, coastal ocean and open ocean. The boundaries separating these systems were nominally at about 3 miles and 200 miles (coincidentally corresponding to the boundaries between state, federal and international jurisdiction). The needs in the coastal and open ocean systems are to be addressed under this national 'backbone' effort, with the expectation that the greater need and greater allocation of resources will be in the coastal system. The needs for the inshore system (particularly for estuarine areas) will be addressed in subsequent regional enhancements to the national system.

2. SUB-GOALS AND PRODUCTS

Following the discussions and recommendations of the LMR-GOOS and the COOP panels and the two NRC committees, five sub-goals are identified for the Managing Living Resources theme. These are described below with key information products needed to meet those goals.

Note: See Addendum below for information about later changes to these initial subgoals.

MARINE RESOURCES SUBGOAL 1:
Obtain improved and more timely predictions of annual fluctuations in spawning stock size, distribution, recruitment and sustainable yield for exploitable fish stocks. Accurate predictions of stock abundance and productivity are the most critical information needs for the management of the living marine resources to insure both the sustainability of the resources and their optimum use.

- **Product MR-1.1:** Estimates of abundance and age structure of exploited stocks

  Variable required:
  - Number and Weight at age for each fish species

  Technologies:
  - Fishing Trawl/Net (various types) Surveys
  - Acoustic Surveys
  - Commercial Landings Data

- **Product MR-1.2:** Estimates of stock parameters (e.g., fecundity, growth rates)

Variables required:
- Maturity at Age
- Size at Age

Technologies: (see above)

- **Product MR-1.3:** Estimates of abundance for key, non-exploited components of the ecosystem

  Variable required:
  - Number and Weight of key non-exploited fish species

  Technologies:
  - Fishing Trawl/Net (various types) Surveys

- **Product MR-1.4:** Estimates of food availability for the early life stages of the fish

  Variable Required:
  - Zooplankton Abundance

  Technologies:
  - Net, Acoustic, and/or Video Sampling

  Variable required:
  - Phytoplankton Abundance and Productivity

  Technologies:
  - Fluorescence Profiles
  - Satellite

- **Product MR-1.5:** Estimates of environmental conditions that influence the survival of the early life stages of the fish and the distribution and migration of the adults

  Variables required:
  - Temperature
  - Salinity
  - Stratification
  - Currents
  - Winds
  - Solar Insolation

  Technologies: (see Detecting and Predicting Climate Variability theme)

- **Product MR-1.6:** Estimates of the condition and extent of essential fish habitat

  Variables and Technologies: see sub-goal 2.2

MARINE RESOURCES SUBGOAL 2:
Detect in a more timely manner changes in the areal extent and condition of essential fish habitat. Availability of appropriate habitat is critical to successful recruitment for fish stocks. Changes in the availability of that essential habitat, due to either natural processes or societal actions, can adversely affect the productivity and sustainability of fish stocks. Timely knowledge of those changes will be important to good management of the resources.

- **Product MR-2.1:** Estimates of the distribution of sediment type

  Variable required:
  - Sediment Grain-Size Distribution

  Technologies:
  - Analysis of Grab Samples
  - Multi-beam Surveys

- **Product MR-2.2:** Estimates of benthic community structure and abundance

  Variable required:
  - Abundance of Dominant Species

  Technologies:
  - Analysis of Grab Samples
  - Multi-beam Surveys
  - Video Surveys

- **Product MR-2.3:** Estimates of environmental conditions that alter benthic habitat

  Variables required:
  - Waves
  - Currents

  Technologies: (see Detecting and Predicting Climate Variability theme)

MARINE RESOURCES SUBGOAL 3:
Obtain improved predictions of when fish stocks are about to be over-fished. A key goal of risk-adverse management for LMRs is to insure that no healthy stock becomes over-fished. Better information on environmental conditions that adversely affect stock reproduction, combined with information on harvesting practices, can insure that management policies do not create situations that put a stock at risk.

- **Products:** The information needs for this subgoal are addressed by the products identified above for subgoal 2.1.

MARINE RESOURCES SUBGOAL 4:
Obtain improved predictions of the effects of fishing on

habitats and biodiversity. Fishing activities can alter benthic habitats by gear impacts and change community species composition by selective harvesting. Knowledge of the environmental and biological conditions that contribute to the recovery from these impacts is important for evaluating the time-scale and the accumulated effect of the harvesting activities.

- **Product MR-4.1:** Estimates of harvesting intensity by area and gear type

  Variables required:
  - Fishing Effort by gear type

  Technologies:
  - From reports by commercial vessels

- **Product MR-4.2:** Estimates of environmental conditions that promote recovery of disrupted benthic habitats

  Variables required:
  - Waves
  - Currents
  - Temperature

  Technologies: (see Detecting and Predicting Climate Variability theme)

  Variable required:
  - Sediment Type

  Technologies:
  - Analysis of Grab Samples
  - Multi-beam Surveys

- **Product MR-4.3:** Estimates of ecosystem community structure

  Variable required:
  - Abundance of Key Benthic Species

  Technologies:
  - Analysis of Grab Samples
  - Multi-beam Surveys
  - Video Surveys

MARINE RESOURCES SUBGOAL 5:
Determine and monitor the effectiveness of Marine Protected Areas. Marine Protected Areas (MPA's) are becoming a common and important tool for promoting the sustainability of marine fisheries and for protecting marine ecosystems. Monitoring conditions within and around an MPA will be needed to determine that the ecosystem objectives for which the MPA was established are being met.

- **Product MR-5.1:** Estimates of the export of adults/juveniles/larvae for selected species from an MPA to the surrounding ecosystem

  Variables required:
  - Abundance of Selected Species by life stage

  Technologies:
  - Net, Acoustic and/or Video Sampling

- **Product MR-5.2:** Estimates of the condition of benthic habitat within and outside an MPA

  Variables required:
  - Abundance of Dominant Benthic Species

  Technologies:
  - Analysis of Grab Samples
  - Multi-beam Surveys
  - Video Surveys

ADDENDUM:

The Managing Marine Resources Working Group met on March 11 to finalize the statement of Subgoals, Products, and required variables based on the background document provided. The group first clarified that its remit focused on Living Marine Resources with guidance provided by the Executive Committee. The group identified an overarching goal for further deliberations during the session: To develop and implement an ecosystem-based management approach for living marine resources. The group then considered the specification of subgoals to fit within this overall framework. Five subgoals were identified; these subgoals represent a consolidation of several of the original subgoals identified above in the working paper and also chose to highlight an additional concern related to monitoring the status of endangered species, marine mammals and seabirds. The subgoals identified by the working group each relate to varying degrees to mandates specified by legal or regulatory requirements and therefore meet immediate needs related to the management of living marine resources. The new subgoals agreed to by the group are:

NEW MARINE RESOURCES SUBGOAL 1:
Measure fluctuations in harvested marine species and improve predictions of abundance, distribution, recruitment and sustainable yield.

NEW MARINE RESOURCES SUBGOAL 2:
Measure and detect changes in spatial extent and condition of habitat, production and biodiversity.

NEW MARINE RESOURCES SUBGOAL 3: Predict effects of fishing and other human activities on habitat and biodiversity.

NEW MARINE RESOURCES SUBGOAL 4: Improve knowledge of spatial distribution of habitat and of living marine resources.

NEW MARINE RESOURCES SUBGOAL 5: Improve measurements of abundance and impacts (environmental, human) on endangered species, marine mammals and seabirds.

Products related to these subgoals, variables required for measurement, and methods of observation were then identified and placed within the matrix format used by all working groups. During the course of the deliberations of the working group, it was noted that a substantial infrastructure now exists to carry out many of the observing system elements for Managing Living Resources. Augmentation of these existing programs, now carried out by the National Marine Fisheries Service, state resource agencies, and other groups will be required to enhance spatial and temporal coverage.

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APPENDIX V: BACKGROUND PAPERS

5. PRESERVING AND RESTORING HEALTHY ECOSYSTEMS: A THEME FOR THE U.S. INTEGRATED SUSTAINED OCEAN OBSERVING SYSTEM

Prepared By Thomas Malone, David Musgrave, Walter Boyton, James Cloern, and Richard Jahnke

FOREWORD

The mandate to establish a Global Ocean Observing System (GOOS) was articulated and ratified as an international consensus in 1992 with the signing of the Framework Convention on Climate Change, the Convention on Biodiversity, and the Program of Action for Sustainable Development (Agenda 21) at the UN Conference on Environment and Development (UNCED) in Rio de Janeiro. In particular, Agenda 21 calls for the establishment of a global ocean observing system that will enable effective management of the marine environment and sustainable utilization of its natural resources. **Achieving this broad and ambitious goal depends on the capability to repeatedly assess and anticipate changes in the status of coastal ecosystems and living resources on national to global scales**.

GOOS is an effort to respond to this mandate by developing a national and international frameworks for coordinating, enhancing and supplementing existing monitoring and research programs to provide the data and information required for more timely detection and prediction of changes in the state of coastal ecosystems and the resources they support. Successful implementation of the observing system will increase the value to society of research and monitoring in marine and estuarine ecosystems, in part by providing the data and information required to routinely assess and predict changes in the status of marine and estuarine ecosystems.

Although "effective management of the marine environment and sustainable utilization of its natural resources" are not restricted to coastal marine and estuarine ecosystems, the effects of climate change and human activities are and will continue to be most pronounced in coastal ecosystems where ecosystem goods and services and people are most concentrated. Thus, the focus of this theme will be on coastal marine and estuarine ecosystems (open waters of the coastal ocean, semi-enclosed bodies of water, and the intertidal).

GOOS is being developed through two related and convergent modules: (1) a global ocean module concerned primarily with the role of the ocean in the earth's climate system and (2) a coastal module concerned primarily (but not exclusively) with changes in coastal environments and their impacts on society and the goods and services provided by coastal marine and estuarine ecosystems. The international effort is lead by a GOOS Steering Committee that oversees the activities of the Ocean Observations Panel for Climate (OOPC) and the Coastal Ocean Observations Panel (COOP). (See the Background Paper: Detecting and Predicting Climate Variability) **Since Rio '92, significant progress has been made in the design and implementation of the basin-scale, ocean-climate module of GOOS. In contrast, although a high national priority, progress in the development of the coastal module has been slow**.

This is primarily a consequence of:

1. The daunting challenge of designing and implementing nationally and internationally accepted systems that will provide the data and information required to detect and predict changes in a wide diversity of phenomena that are occurring in a complex mosaic of coastal ecosystems
2. Inefficient data management systems that do not capture significant amounts of relevant data and do not enable rapid collation of diverse data from disparate sources
3. The primitive state of our capacity to rapidly and routinely detect and predict changes in those phenomena of interest that require measurements of biological and chemical variables
4. The absence of mechanisms (institutional and fiscal) for the selective transition of research activities and products into an operational framework based on user needs
5. The challenges of developing the state, regional and national partnerships needed to fund and implement the coastal module

The design and implementation of coastal GOOS must address these challenges. Here, we are concerned primarily with challenges (1), (2) and (3), however, it is clear that many of the observations needed in the coastal ocean are also required in the deeper ocean since it represents the offshore boundary of the coastal ocean.

For this background paper, section 1 describes the theme and section 2 describes goals and products. Incomplete lists of required variables and potential techniques are also listed, but these must be completed on day one of the workshop (The variables are those that must be measured to achieve the goals and potential techniques are those that could be used to provide the required data, e.g., remote sensing and type of sensor, autonomous *in situ* sensing and type of sensors, *in situ* samples and subsequent measurement and sampling and measurement methods).

1. THE THEME – DETECTING AND PREDICTING ECOLOGICAL VARIABILITY

Protecting and restoring healthy ecosystems is one of seven themes identified as priorities by national and international bodies involved in the design and implementation of GOOS (e.g., NRC, 1994; Nowlin and Malone, 1999; IOC, 2000). Although the concept of ecosystem "health" has been the subject of much controversy, marine and estuarine ecosystems are clearly experiencing changes that affect their capacity to support a broad spectrum of "goods" and "services."[1] The phenomena of interest in the ecosystem health theme are

(1) Habitat modification and loss[2]
(2) Loss of biodiversity[3]
(3) Cultural eutrophication[3]
(4) Harmful algal events[5]
(5) Invasions of non-native species[6]
(6) Diseases in and mass mortalities of marine organisms[7]

Improving our ability to detect and predict changes in or the occurrence of these phenomena is a major goal of the coastal module of GOOS (Nowlin and Malone, 1999; IOC, 1996, 2000; Malone and Cole, 2000). In regard to prediction, the forcings of interest are global warming and sea level rise; extreme weather events; seismic events; basin scale changes (e.g., ENSO, NPDO, NAO); inputs of water, sediments, nutrients, organic matter and chemical contaminants from coastal drainage basins; harvesting living resources; physical restructuring of the environment; and introductions of non-native species. We have only begun to understand the effects of human activities and climate variability on the structure and function of coastal ecosystems and their capacity to support ecosystem goods and services.[9] Resolving and predicting anthropogenic and climate effects requires long-term times series observation of key properties and processes, more efficient and effective data management that enables rapid access to diverse data from disparate sources, more timely delivery and analysis of environmental data, and a more comprehensive understanding of the structure and function of ecosystems and the propagation of variability among them (e.g., the effects of changes occurring in coastal drainage basins, the ocean basins and airsheds on coastal marine and estuarine ecosystems).

2. SUBGOALS AND PRODUCTS

Proposed subgoals corresponding to the phenomena of interest are as follows:

MARINE ECOSYSTEMS SUBGOAL 1:
For each region, establish ecological "climatologies" for sea surface temperature (SST) and sea surface salinity (SSS); surface dissolved inorganic N, P and Si; surface chlorophyll-a concentration and the abundance of harmful algal (HAB) species.

- **Product ME-1.1:** Estimates of the SST field and its variability on monthly, seasonal, interannual and decadal time scales for the coastal ocean within 25 km of the shoreline. (Here and in the following, 25 km is thought to be an arbitrary distance and within any region it likely corresponds to the continental shelf and shelf break.)

- **Product ME-1.2:** Estimates of the SSS field and its variability on monthly, seasonal, interannual and decadal time scales for the coastal ocean within 25 km of the shoreline.

- **Product ME-1.3:** Estimates of surface DIN, P and Si fields and their variability on monthly, seasonal, interannual and decadal time scales for the coastal ocean within 25 km of the shoreline.

- **Product ME-1.4:** Estimates of the chl-a field and its variability on monthly, seasonal, interannual and decadal time scales for the coastal ocean within 25 km of the shoreline.

- **Product ME-1.5:** Estimates of the abundances of HAB species and their variability on monthly, seasonal, interannual and decadal time scales for hot spots (sites where repeated HAB events have occurred).

Variables required for Marine Ecosystems Subgoal 1 include:
- SST
- SSS
- Surface Concentrations of DIN, DIP, and DISi
- Surface Chl-a Concentration
- Cell Densities of HAB Species

Potential Techniques:
- Remote Sensing (SST, chl-a)
- Moored Sensors (SST, SSS, nutrients, chl-a, HAB species)
- *In Situ* Sampling and subsequent measurement (SSS, nutrients, chl-a, HAB species)

MARINE ECOSYSTEMS SUBGOAL 2:
Obtain more timely detection of changes in the areal extent and physiological state of biologically structured habitats (coral reefs, submerged attached vegetation, mangroves, and tidal marshes).

- **Product ME-2.1:** Annual report of areal distribution (GIS) of biologically structured habitats by region and for U.S. coastal waters as a whole (specifically as tidal marsh, mangrove stands, seagrasses, macrobenthic algae, coral reefs, deep-water hard bottom, and shellfish beds as appropriate to the region.

Variables required for Marine Ecosystems Subgoal 2:
- Seagrass Bottom Area Cover
- Minimum and Maximum Seagrass Depth
- Seagrass Canopy Height
- Seagrass Plant Density
- Seagrass Species Composition

Potential Techniques:
- Visual Inspection (scuba)
- Aerial Photography
- Hyperspectral Imagery

MARINE ECOSYSTEMS SUBGOAL 3:
Obtain more timely detection of changes in species diversity of marine and estuarine flora and fauna.

- **Product ME-3.1:** Annually updated inventories of species at reference sites and representative stations for the following groups: macrobenthic animals and plants, microphytoplankton (> 20 µm), macrozooplankton (> 200 µm), fish, mammals and birds.

- **Product ME-3.2:** Annually updated reports of the number of marine and estuarine species legally defined as at-risk that are increasing, decreasing or stable by region and for U.S. coastal waters as a whole.

Variables required for Marine Ecosystems Subgoal 3:
- Species composition and abundance based on monthly (plankton), seasonal (fish, birds and mammals), and annual (sub-tidal and intertidal macrobenthose observations

Potential Techniques:
- Water Samplers, Net Tows, Microscopy, Optical Techniques, Molecular Probes, Photography, Ships, Moorings, AUVs (Plankton)
- Scuba, Dredges, Box Cores, Bottom Photography (Macrobenthos)
- Net Tows, Bottom Trawls, Acoustic Surveys, Fishery Landings (Fishes); Visual Inspection, Aerial Photography (Birds And Mammals), and Acoustic Surveys (Mammals).

MARINE ECOSYSTEMS SUBGOAL 4:
Obtain more timely detection and improved prediction of coastal eutrophication measured in terms of accumulations of organic matter and oxygen depletion of bottom waters on ecosystem and regional scales for coastal marine and estuarine ecosystems.

- **Product ME-4.1:** Improved estimates of episodic and seasonal inputs of freshwater N, P and Si from coastal drainage basins and airsheds into semi-enclosed systems and to the coastal ocean within each region.

- **Product ME-4.2:** Seasonal inventories of total organic C, total organic N and P, and chlorophyll-a content of representative semi-enclosed bodies of water and of the coastal ocean within 25 km of the coast line.

- **Product ME-4.3:** Annual estimates of the volume of water that experiences hypoxia (DO < 2 ppm) for 1 month or more in representative semi-enclosed systems and for the coastal ocean[8] (EEZ) in each region.

- **Product ME-4.4:** Annual predictions of the temporal and areal extent of seasonal bottom water hypoxia for selected semi-enclosed and continental shelf systems based on predictions of monthly river and stream flows and the predicted effectiveness of nutrient control efforts.

Variables required for Marine Ecosystems Subgoal 4 include:
- Atmospheric Deposition
- Surface and Groundwater Discharges and associated inputs of organic C and N and Dissolved Inorganic N, P and Si
- SST
- SSS
- Surface Chlorophyll-A Fields
- Vertical Profiles of Temperature
- Salinity
- TOC
- TN

- Chlorophyll-A
- Dissolved Inorganic N, P, And Si
- Dissolved Oxygen

Potential Techniques:
- Gauged Rivers and Streams
- Aerial and Satellite Remote Sensing (SST, surface chlorophyll)
- Automated *In Situ* Sensing (nutrients, chlorophyll, dissolved oxygen)
- *In Situ* Sampling and Lab-Based Measurements (nutrients, chlorophyll, dissolved oxygen, TOC and TN, organic C and N)

MARINE ECOSYSTEMS SUBGOAL 5:
Obtain more timely detection and improved prediction of the presence, growth, movement, and toxicity of toxic and noxious algal species.

- **Product ME-5.1:** Annual report of the frequency of harmful algal events (blooms of toxic species, HAB induced fish kills and illness in humans) that have high, medium, and low intensity in terms of both spatial and temporal extent for each region and U.S. coastal waters.

- **Product ME-5.2:** For hot spots (areas and seasons that have a history of HAB events), weekly reports on the distribution and abundance of selected HAB species.

- **Product ME-5.3:** For hot spots, weekly forecasts (updated daily) of the formation and trajectory of HABs and where and when the bloom is likely to affect beaches, shellfish beds and aquaculture operations.

Variables required for Marine Ecosystems Subgoal 5 include:
- Inputs of Freshwater Sediments and Nutrients (surface and groundwater discharges, rainfall)
- Surface Currents and Waves
- Incident and Downwelling PAR
- Vertical Profiles of Salinity, Temperature, Dissolved Inorganic Nutrients, Dissolved Organic Carbon and Nitrogen
- Surface and Vertical Distributions (abundance, biomass) of HAB Species and Toxin Concentrations
- Shellfish Bed Closures and Fish Kills caused by HAB species
- Incidence of Human Illness caused by the consumption of seafood contaminated by HAB species or by exposure (skin contact, inhalation) to HAB toxins

Potential Techniques:
- Gauged Rivers and Streams
- Aerial and Satellite Remote Sensing (SST, surface chlorophyll and other phytoplankton pigments)
- Automated *In Situ* Sensing (nutrients, absorption and fluorescence spectra, species specific molecular probes)
- *In Situ* Sampling and Lab-Based Measurements (nutrients, chlorophyll, dissolved oxygen, TOC and TN, organic C and N)
- *In Situ* Sampling and Microscopic Counts

MARINE ECOSYSTEMS SUBGOAL 6:
Obtain more timely detection of non-native species and improved predictions of the probability they will become invasive species.

- **Product ME-6.1:** Annual report on the occurrence of non-native species in semi-enclosed bodies of water for each region where occurrence is measured in terms of both surface area affected and number of species relative to the number of native species.

Variables required for Marine Ecosystems Subgoal 6 include:
- Number and Distribution (abundance) of native and non-native species per unit area

MARINE ECOSYSTEMS SUBGOAL 7:
Obtain more timely detection and improved predictions of diseases in and mass mortalities of fish, marine mammals and birds.

- **Product ME-7.1:** Annual report on the frequency of strandings and mass mortalities of marine organisms for each region and U.S. coastal waters.

- **Product ME-7.2:** For hot spots (areas and seasons with a history of fish lesions), weekly updates on the incidence of skin lesions in fish populations from semi-enclosed bodies of water.

- **Product ME-7.3:** For hot spots, weekly updates on infection rates of Dermo and MSX in oyster populations.

Variables required for Marine Ecosystems Subgoal 7 include:
- Location and number of organisms involved in each mortality and stranding event
- Number of fish species and percent of each population with skin lesions
- Number of oysters infected

Technologies:
- Visual Inspection
- Seines and Net Tows followed by visual inspection
- Microscopic Examination and Molecular Probes of Oyster Samples

MARINE ECOSYSTEMS SUBGOAL 8:
Obtain improved predictions of the effects of habitat modification and loss on species diversity.

- **Product ME-8.1:** Annual report of the species composition and diversity of macrobenthic organisms, macrozooplankton, fishes, mammals and birds in semi-enclosed bodies of water relative to the distribution of biologically structured and abiotic (hard and soft bottom substrates, mud flats) habitats.

- **Product ME-8.2:** Annual report of the distribution and abundance of marine and estuarine species that have been legally identified as at-risk relative to the distribution of biologically structured and abiotic (hard and soft bottom substrates, mud flats) habitats.

Variables required for Marine Ecosystems Subgoal 8 include:
- Species Composition and Abundance based on monthly (plankton), seasonal (fish, birds and mammals), and annual (sub-tidal and intertidal macrobenthos) observations
- Area of Biological Structured and Abiotic Habitats
- Temporal and Spatial Extent of Hypoxia

Technologies:
- Visual Inspection (scuba)
- Aerial and Benthic Photography and Hyperspectral Imagery
- Water Samplers, Net Tows, Microscopy, Optical Techniques, Molecular Probes, Photography, Ships, Moorings, SUVs (Plankton)
- Scuba, Dredges, Box Cores, Bottom Photography (Macrobenthos)
- Net Tows, Bottom Trawls, Acoustic Surveys, Fishery Landings (Fishes); Visual Inspection, Aerial Photography (Birds And Mammals), and Acoustic Surveys (Mammals).

MARINE ECOSYSTEMS SUBGOAL 9:
Monitor anthropogenic contaminants and their effects on the ecosystem.

- **Product ME-9.1:** Annual report of the distribution and levels of anthropogenic contaminants.

- **Product ME-9.1:** For hot spots (areas and seasons that have a history of contaminations), weekly (daily) reports on the distribution and levels of anthropogenic contaminants.

Variables required for Marine Ecosystems Subgoal 9 include:
- Concentrations of Heavy Metals, Endocrine Disrupters, PCBs and Toxins, Marine Debris, Pesticides, Noise, Hydrocarbons, Antibiotics, and Pathogens.

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FOOTNOTES

1 Goods are typically measured in terms of extractable resources (e.g., fish, oil). Services include nutrient cycling, waste treatment, buffering the effects of extreme events, recreation, food production, and aesthetic value.

Reference: Costanza et al., 1997.

2 Habitat modification and loss - Targeted habitats are those of the intertidal (mangrove forests, tidal marshes, mud flats, and beaches) and relatively shallow subtidal zones (kelp forests and other attached macroalgae, seagrass beds, coral and oyster reefs). These habitats are important for recreation and provide food and refugia for a high diversity of organisms, including commercial and recreational fish populations. They play major roles in sustaining living resources, providing habitat for marine organisms, maintaining shoreline stability, mitigating the effect of storm surges and coastal flooding, and controlling the fluxes of nutrients, contaminants and sediments from land to coastal ecosystems. Thus, changes in these habitats have significant effects on marine biodiversity, fisheries, recreation and tourism, the susceptibility of human populations to extreme weather, the capacity of coastal ecosystems to assimilate and recycle nutrients mobilized by human activities, and on the provision of aesthetically pleasing environments. The distribution and areal extent of these habitats are affected by both climatic forcings (e.g., patterns of heat flux and rainfall) and anthropogenic activities (e.g., excess nutrient inputs, overfishing, sediment inputs). Coral reef bleaching and increases in the susceptibility of corals to disease are believed to be related to increases in temperature caused by ENSO events and global warming. Overfishing, nutrient enrichment and coastal erosion are also causes of coral reef loss. Mangrove forests are being cut down for fire wood and to provide space for aquaculture operations (e.g., shrimp farming). Losses of sea grass beds occur as a consequence of nutrient enrichment, coastal erosion and dredging. Tidal marshes are susceptible to sea level rise, subsidence, channelization, invasive species, and land use practices (e.g., coastal development and hardening shorelines, water consumption, dams) that affect their sediment budgets and pore water chemistry.

References: IOC, 2000; Kemp and Boynton, 1997; NRC, 1994; Wilkinson et al., 1999

3 Biodiverstiy - Of the various levels of biological diversity (from molecular to ecosystem levels of organization), the most common indices of biodiversity are based on the number of species and the distribution of abundance among species. Current estimates (which are most likely underestimates) place the number of marine species at about 200,000 with representatives from 32 phyla, 15 of which are found exclusively in the marine realm. This is in marked contrast with the terrestrial environment where there is an estimated 12 million species, over 90% of which are from two phyla: insects and flowering plants.

The rate of species extinction (terrestrial and aquatic) has been estimated to have been about 1 per year prior to the evolution of people compared to the current rate of 100-10,000 species per year. Changes in species diversity are related to large scale changes in the ocean-climate system (e.g., ENSO, NPDO, NAO) and to more local scale changes such as habitat loss or modification (e.g., coral reef bleaching, declines in mangrove forests due to shrimp farming, loss of seagrasses due to nutrient enrichment), oxygen depletion, invasions of non-native species, fishing, mass mortalities of marine organisms, and harmful algal events.

Reference: Norse, 1996.

4 Eutrophication - The structure and function of coastal ecosystems depend on inputs of nutrients (N, P, Si, Fe, etc.) from external sources (ocean basins, coastal drainage basins and the atmsphere). Excess inputs of nutrients (nutrient over-enrichment or nutrient pollution), usually forms of nitrogen, phosphorus, or both, result in a phenomenon called "eutrophication." "Excess" is usually defined in terms of outcomes. These include:

- Accumulations of organic matter (usually in the form of algal biomass but also as organic detritus, dissolved organic matter, or some combination of these)
- Oxygen depletion of bottom waters and benthic habitats (where hypoxia is DO < 2 ppm and anoxia is complete depletion which is often associated with the production of hydrogen sulfide)
- Mass mortalities of marine organisms
- Decreases in water clarity
- Increases in bacterial production
- The loss of sea grass beds and coral reefs
- Harmful algal blooms (HABs)
- The growth of non-native species
- Loss of biodiversity.

Although excess nutrient enrichment may promote losses in biodiversity, mass mortalities, decreases in water clarity, habitat loss, the growth of HABs, and invasions of non-native species in some ecosystems, changes in these phenomena are treated separately below for two reasons: (i) they have significant implications in terms of the stability and resilience of ecosystems, and (ii) they are often a consequence of factors other than over-enrichment.

For the most part, excess inputs of nutrients to semi-enclosed bodies of water and nearshore coastal ecosystems (e.g., in waters less that 50 m deep and within 50 km of the coastline) are related to human activities that mobilize nitrogen and phosphorus and increase their export from coastal drainage basins and airsheds via surface and ground water discharges and atmospheric deposition. For example, over the past 100 years, nitrate concentrations in the world's rivers have increased by as much as 20 fold, largely as a consequence of a rapid increase in the pool of fixed N (due mostly to anthropogenic fixation of N for fertilizers) and to related increases in point (sewage) and diffuse (mobilization of nitrogen by deforestation, fertilizer use, acid rain) inputs. Increases in anthropogenic inputs are reflected in the correlation between riverine N exports to coastal ecosystems and the population density of their watersheds. Evidence is growing that such increases in N loading are responsible for the loss of habitat (seagrasses, coral reefs) and for increases in the occurrence and magnitude of seasonal anoxia. Given the effects of such changes on critical fish habitat and the migrations of anadromous fish, it is likely that these effects are lowering the carrying capacity of ecosystems for exploitable fish and shellfish stocks. The effects of excess nutrient enrichment can also be exacerbated by overfishing, especially when the exploited species are filter feeders such as oysters, clams and mussels.

Many of the outcomes of excess nutrient enrichment described above are treated as phenomena in their own right (habitat loss and modifiction, water clarity, loss of biodiversity, harmful algal blooms, growth of non-native species, changes in the abundance of exploitable living marine resources). This reflects both their importance and the fact that changes in these phenomena are often due to forcings other than or in addition to nutrient enrichment. Oxygen depletion of bottom waters is nearly always a consequence of excess nutrient enrichment, and there is clear and unequivocal evidence that increases in the frequency and extent (spatial and temporal) of bottom water hypoxia are directly related to human activities that increase inputs from both diffuse and point sources. Thus, the phenomena of eutrophication will be quantified here in terms of seasonal and interannual accumulations of organic matter and the frequency and extent of hypoxia in coastal ecosystems.

References: (1) Howarth et al., 2000; Kemp and Boynton, 1997; Nixon, 1995; Peierls et al., 1991.

5 HABs - There is growing evidence that coastal ecosystems are experiencing an escalating and disturbing trend in the incidence of problems associated with harmful algae, including human illness from contaminated shellfish or fish, the closure of shellfish beds, mass mortality of cultured finfish, and the death of marine mammals and seabirds. Increases in harmful algal events may be associated with the loss of biodiversity in some regions. As a result, government agencies responsible for public health and industries involved in the harvesting and marketing of seafood (wild and farmed) are recognizing the need for more timely detection of HAB events and forecasts of when and where such events are likely to occur. Timely access to such information is required to (1) protect public health; (2) control and mitigate ecological and economic impacts; and (3) disseminate relevant, accurate and useful information in a timely fashion to coastal communities and industries that are impacted or likely to be affected by such events.

Although harmful algal events are often referred to as harmful algal blooms (HABs) or "red tides", it must be recognized that (1) HAB species represent a broad spectrum of taxa (dinoflagellates, diatoms, cyanobacteria, raphidophytes, prymnesiophytes, and pelagophytes) and trophic levels (e.g., autotrophic, heterotrophic, mixotrophic) that are referred to collectively as "algae", and (2) many HAB species cause problems at low cell densities, i.e., a bloom is not necessarily required for a HAB event to occur. There are two general groups of HABs: (1) those that produce toxins that contaminate seafood, kill marine animals or directly cause human pathologies, and (2) those that cause problems by virtue of their high abundance or biomass (oxygen depletion, habitat loss, and starvation, respiratory or reproductive failure in marine animals).

For the purposes of the observing system, a harmful algal event may be one or more of the following: (1) a bloom of a HAB species that is known to produce toxins harmful to marine life or to humans; (2) mass mortalities of marine organisms caused by HAB species; (3) non-lethal manifestations such as lesions, increased parasite load, or decreased reproductive capacity caused by HAB species; or (4) the occurrence of human illness caused by a HAB species. There are approximately 5000 species of microalgae in the world. Of these, about 100 fall into one or more of the above categories. These species produce a spectrum of toxins that typically fall into one of the following categories: paralytic shellfish poisoning, diarrhetic shellfish poisoning, amnesic shellfish poisoning, neurotoxic shellfish poisoning, and Ciguatera fish poisoning. Lesions, respiratory irritation, and memory loss may also occur via contact with water or exposure to aerosolized toxins or irritants.

Reference: http://ioc.unesco.org/hab

6 Invasive species - As the global movement of ships, people and commodities has increased, the number of introductions of non-native species has also increased (global dispersal). The number of successful new invasions (invasive species) appears to have increased dramatically during the 1970's and 1980's, perhaps as a consequence of the combined effects of global dispersal, habitat loss and modification, nutrient enrichment and overfishing in coastal ecosystems. Increases in the occurrence of invasive species may be a factor in the loss of biodiversity in some regions. The list of recent invaders includes several species of benthic algae, SAV, toxic dinoflagellates (e.g., *Alexandrium catenella* in Australia) , bivalves (e.g., the zebra mussel in the Great Lakes and the Chinese clam in San Francisco Bay), polychaetes, ctenophores, copepods, crabs and fish. Such invasions can profoundly alter the population and trophic dynamics of coastal ecosystems. For example, the introduction of the ctenophore *Mnemiopsis leidyi* caused the collapse of the anchovy fishery in the Black Sea by preying on the anchovy's preferred food, copepods; the introduction of the macrobenthic green algae, *Caulerpa taxifolia*, displaced a diverse community of sponges, gorgonians, and other seaweeds over thousands of square meters in the northern Mediterranean; and the introduction of the Chinese clam (*Potamocorbula amurensis*) has severely limited phytoplankton production in San Francisco Bay.

Reference: Carlton, 1996.

7 Diseases and mass mortalities in marine organisms - Fish, shellfish, marine mammals, turtles and sea birds experience mass mortalities and strandings (that typically lead to death) that have been related to disease, parasitism, harmful algal blooms, hypoxia, oil spills, diversions of freshwater, and climate change. The number of such events and assessments of their causes can be considered indicators of the health of marine ecosystems and their capacity to support living resources.

8 U.S. coastal waters include all semi-enclosed bodies of water and the open waters of the coastal ocean out to the boundaries of the Exclusive Economic Zone (EEZ). Regions are based on the boundaries established for the Regional Marine Research Program as follows: Gulf of Maine, Middle Atlantic Bight, South Atlantic Bight, Gulf of Mexico, California Region (southwest), Pacific Northwest, Gulf of Alaska, and Pacific island States (Hawaii, Guam, American Samoa, Northern Marianas Islands).

Reference: NRC, 2000

9 It is important to note that the diversity of issues to be addressed and their complex and interdisciplinary nature underscore the importance of synergy between research programs and the development of the coastal module. Research programs and observing systems are mutually dependent processes that define a continuum of related activities. The observing system will be of limited value if it is not based on sound science and designed to improve through research and development (improved understanding, models, sensor technologies, assimilation techniques). Likewise, research is of limited value if it is not conducted in the context of larger scale observations in both time and space (long term time-series, synoptic observations on large spatial scales). Although both research programs and observing systems may have many elements in common, the development of the observing system is driven by societal needs while research programs are by scientific hypothesis. The purpose of the observing system is to detect and predict patterns of change. In contrast, the purpose of environmental research is to test hypotheses concerning the causes and consequence of environmental changes. Thus, environmental research programs are finite in duration while the observing system must be sustained in perpetuity. These considerations have important implications for the design and implementation the observing system.

APPENDIX V: BACKGROUND PAPERS

6. MITIGATING NATURAL AND ANTHROPOGENIC HAZARDS: A THEME FOR THE U.S. INTEGRATED OCEAN OBSERVING SYSTEM

Prepared By Margaret Davidson and Greg Mandt with collaborators Earle Buckley, Noriko Shoji, Leaonard Pietrafesa and Therese Pierce.

1. THE THEME

Weather events and patterns such as hurricanes, tsunamis, El Niño/La Niña, sea level rise, climate variation phenomena, nor'easters, and west coast winter storms have been reshaping natural coastlines throughout geologic time. High winds, extreme wave action, storm surge, sea and lake ice, and flooding drastically change the shorelines by erosion in some areas, accretion of sediments in others, creation of new inlets or redirection of old inlets. These normal processes can prove deadly and costly in developed coastal areas, becoming in effect coastal hazards and in some cases coastal disasters. In addition, there are biological hazards such as harmful algal blooms and red tides, as well as man-made hazards like oil and chemical spills, water pollution, and habitat degradation due to development. Anthropogenic hazards such as agricultural and urban runoff, unsound coastal development that promotes beach erosion, air quality degradation, and boat groundings also prove to disrupt the coastal health. As we increase our development and populations in coastal areas, natural and man-made hazards will continually challenge attempts to ensure the safety and security of our communities.

Today, more than half the population of the United States lives within coastal regions. As these populations have grown, the nation has experienced increased property losses, dislocation of people, relief costs, interruption and failure of businesses, loss of life, and damages to natural resources as a result of coastal hazards. National Flood Insurance Program Activity data compiled by FEMA also indicate that coastal counties collectively account for over 70% of repetitive losses (Heinz Center, 2000). Coastal hazards can also have significant impacts on commerce and marine transportation through: 1) obstructing major seaports with debris and siltation, 2) severe weather related delays to shipping, and 3) damage to marine transportation infrastructure.

Natural hazards are beyond our ability to control. Mitigating their effects requires developing the predictive understanding, technological capabilities, and societal frameworks necessary for a sustainable society resilient to natural hazards. A predictive capability of environmental change can arm coastal managers with a powerful tool for taking a proactive approach to coastal hazards, mitigating or preventing impacts on life, property and critical habitat before they occur. Numerical, empirical, and statistical modeling, integrative *in situ* and remote observations, and multi-disciplinary knowledge are each important components in the complex process of developing timely and reliable predictions of environmental changes that directly or indirectly affect mitigation of hazards.

The successful implementation of an integrated coastal ocean observing system (ICOOS) and the development of predictive capabilities for the impacts of coastal hazards are not limited by available technologies. Technological advances in new sensors, new platforms, new communications hardware and software provide the ability to maintain long-term, accurate measurements of key physical, chemical, and biological parameters in the coastal ocean (Frosch, 1999). Advances in computer power and information technology make it possible to process immense volumes of data and to create ever more realistic scientific models to forecast and mitigate the impacts of natural hazards. Achieving ICOOS is impeded by:

- Undersampling of the coastal ocean
- The lack of an integrated data management system
- The capabilities (or lack thereof) of existing models

The National Research Council (1998) emphasized the problem of undersampling as the main impediment to improving early warnings of coastal hazards and strongly recommended that the number of stations be significantly expanded. Measurements must be made at higher temporal and spatial resolution than currently collected. Predictive and dynamic models must be developed to provide more reliable means of extrapolating measurements and increasing resolution in areas of special interest but with limited observations. An integrated data management system must be created to allow users to exploit multiple data sets from a variety of sources.

2. SUBGOALS AND PRODUCTS

Among the range of needs for systematic observation of the ocean and coastal environment on all scales, there is a subset of goals and associated products and services for mitigation of natural and man-made hazards that can be most effectively addressed through the development of an Integrated Ocean Observing System (IOOS).

Subgoals or supporting goals are intended to fill gaps in the present systems. This is the common theme in relating each subgoal to the main goal. Filling the gaps includes:

- Getting more/better data to better understand the physics, biology, and chemistry related to or causing the hazard
- Acquiring the data (strategic sampling) that support the forecast system and predictions – these data can be used in models as configuration, constraint, or validation
- Creating/establishing data gathering networks for data that are now missing
- Developing instrumentation that observes the appropriate variables (perhaps never observed before) on new space and time scales

NATURAL HAZARDS SUBGOAL 1:
Provide adequate data gathering capabilities at the temporal and spatial scales required to improve the understanding of the physical and biological nature of natural hazards.

- **Product NH-1.1:** Analyses of climate, weather, and hazard linkages, with special attention to the linkages between weather events and floods and between weather events and storm surges and waves. This will allow for the development of coast-oriented models that can represent the dynamics and interactions associated with the complex air-sea-land boundaries (see Subgoal 2) and better resolve the meteorology at the scales needed to match the transition zones critical to the coast.

- **Product NH-1.2:** Descriptions of the fundamental relationships between ecosystem dynamics and natural hazards, including what ecosystem changes precede and contribute to natural hazards and how these changes, in turn, affect the structure and function of ecosystems and the probability of subsequent events. The focus is on improved understanding of the causal mechanisms and abatement processes that determine the origin, development, and termination of ecological hazards.

- **Product NH-1.3:** Analyses of the interactions between natural hazards, manmade environments and technological systems.

NATURAL HAZARDS SUBGOAL 2:
Improve modeling capabilities and predictions. Models are tools for interpolation, extrapolation, and inference of observing system information. Model validation is essential if the observing system is to evolve and progress. Models must be tested against actual data to ensure that the tools used to process information will continue to improve.

- **Product NH-2.1:** Quantitative prediction of tropical cyclones and extratropical systems with respect to formation, track and intensification, landfall intensity (wind and precipitation), timing and duration, and location.

- **Product NH-2.2:** Improved predictive capabilities with regard to ecosystem response to physical and biological events.

- **Product NH-2.3:** Improved fluid mechanic, air-sea-land interactively coupled models of the coastal zone with bays, estuaries and rivers coupled to the open ocean. These are necessary to make improved storm-surge predictions. The models would also be critical for water quality problems.

- **Product NH-2.4:** Improved wind-wave models, particularly for shallow coastal waters and bays. These are required to forecast breaking wave heights at the coast and in channels. This information is required to make more accurate predictions of overtopping during storms and as input to beach and dune erosion and to structural damage calculations. The inclusion of current effects on waves is also required particularly for wave predictions in channels, near inlets, and on major coastal currents.

- **Product NH-2.5:** Improved flooding and inundation models which couple all the relevant processes including storm surge, surface waves, rainfall, and topography. For both warnings and risk assessments increased accuracy is needed. Improvements to these models should also address degradation of the beach and dune systems, which occurs during major storms and facilitates flooding.

- **Product NH-2.6:** Improved beach and dune erosion models. Progress has been made in developing basic technology to accomplish this but it is rudimentary and requires refinement and validation. Understanding sediment transport patterns along the coast and how beaches build and erode is critical to making better models of beach and dune erosion that can be factored into flood and damage warnings and risk assessments. Historical information on long-term beach erosion trends, how weather events, particularly storms, and how climate, the integral over weather, are linked to long-term sea level rise, and tectonic effects that raise or lower coastal landmasses is required as background to assessment of long-term erosion risk.

NATURAL HAZARDS SUBGOAL 3:
Provide timely dissemination and convenient online access to real-time hazards observations and warnings as well as complete metadata and retrospective information on all aspects of natural disaster reduction.

- **Product NH-3.1:** Conversion of meteorological and oceanographic data into useful decision-making information. The information on risk associated with coastal hazard potential represents spatially complex patterns covering all coastal regions. Observational system databases should be capable of being interfaced with local geographic information systems so that the information is directly transferable to the maps and other relevant databases used for local planning.

- **Product NH-3.2:** Established national and regional databases and information exchanges facilities dedicated to hazard, risk and disaster prevention. These will be linked by agreed communication standards and protocols and supported by adequate mechanisms for the control of scientific quality as well as social and cultural appropriateness.

- **Product NH-3.3:** An established network of extension and education regimes to ensure end users have the knowledge and training to collect, manage, and disseminate data, to produce products and services, and to apply those results to addressing their needs.

- **Product NH-3.4:** An established evaluation and feedback mechanism to routinely assess whether or not the observational systems are operating satisfactorily and meeting user requirements. Lines of communication and dialogue must be established with the principal groups and institutions that use coastal ocean environmental information for decision-making. An iterative process of refinement should narrow requirements to the minimum data flows necessary to support decisions cost effectively.

NATURAL HAZARDS SUBGOAL 4:
Develop new instrumentation to improve the existing systems, i.e., making them workable in wider areas, for longer duration, and with higher reliability, safety, and efficiency. The basic technologies already exist to measure the parameters necessary to accomplish most tasks for forecasts, prediction models, and risk analysis of coastal hazards. Support for new technologies should be based on their ability to meet a need not filled by those systems already existing or under development, as well as continual R&D to improve existing components like better transmission of data, equipment longevity, etc.

- **Product NH-4.1:** Improved marine biological measurements, with new instrumentation that can directly measure or sample the biological properties (i.e. chlorophyll vs. fluorescence) and instrumentation for measuring chemical constituents that affect biological productivity.

- **Product NH-4.2:** Increased efficiency of maintaining observations in the ocean environment. This could be accomplished with new sensor carriers and automated instrument packages and analysis systems for ocean chemistry, e.g., a portable, low cost, low power, and non-fouling *in situ* salinity sensor capable of measuring salinity to 0.1 accuracy on the Practical Salinity Scale and maintain stability for a minimum of 6 months.

- **Product NH-4.3:** Determination of the optimal mix of observations required to cover the complete suite of important weather and climate variables, broadly defined. To maximize the coverage and minimize the costs, the optimal mix of both necessary and sufficient observing systems, must be established. Weather events tend to require high frequency, spatially dense sampling, while climate observations tend to require high precision, lower frequency and spatially dense networks.

3. RELEVANT VARIABLES AND OBSERVING TECHNOLOGIES

The basic data that must be continually measured for improved forecasts, prediction models, and risk analysis include meteorological (winds, temperatures, pressures, humidity, visibility, etc.) physical (waves, water levels, currents, coastal topography and bathymetry, sediment transport), chemical, and biological parameters. Measurements of a core set of these parameters are needed near the coastal interface with sufficient precision and accuracy on spatial and temporal scales commensurate with the variability of the coast. For example, observing and modeling coastal storms and associated surges requires an observing system that has the capability of (1) tracking the size and intensity of storms, both winds and precipitation, in real time; (2) providing data on sea level, waves and currents in real time; and (3) forecasting the areal extent and depth of flooding based on topography, land type and cover, and runoff patterns (C-GOOS, 1998). Other parameters to be considered are shallow-water bathymetry, sediment type and water-column current measurements to model circulation flow in enclosed and semi-enclosed systems.

THE VARIABLES NEEDED TO ATTAIN THESE PRODUCTS AND SERVICES INCLUDE PRINCIPALLY:

VARIABLE	OBSERVING TECHNOLOGIES
Air: winds (including wind stress), pressure, temp, surface waves	Moored systems (includes surface buoys and bottom mounted instrumentation), satellites
Precipitation intensity, type and amount	Satellite and radar estimates, ground observations
Water Level	Fixed platforms, remote
Bathymetry	Ships, aircraft
Ocean surface currents and waves	Moored systems, remote
Ocean surface roughness	Radars, moored systems
Coastal and Estuarine currents	Moored systems, fixed platforms
Sea surface temperature and salinity	Moored systems, AUVs, remote
Sea and lake ice: areal coverage and concentration, extent, thickness, and reflectivity	Satellite, ships, buoys, aircraft
Color (phytoplankton biomass)	Moored systems, AUVs, remote, ships
Nutrients	Moored systems, ships
Suspended solids, turbidity	Moored systems, remote, ships
pCO_2, O_2	Moored systems, ships
Plankton species	Ships

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APPENDIX V: BACKGROUND PAPERS

7. ENSURING PUBLIC HEALTH: A THEME FOR THE U.S. INTEGRATED OCEAN OBSERVING SYSTEM

Prepared By Brock B. Bernstein with collaborator Stephen Weisberg

1. THE THEME

Millions of people use the coastal ocean for water-contact activities such as swimming, surfing, and diving, and for other recreation such as boating, picnicking, and fishing. Such activities add billions of dollars to regional economies and, in some parts of the country, occur year-round. In addition, the public consumes seafood caught commercially, by individual sport fishers, or by individual and small-scale subsistence fishers.

There are two primary concerns the public has expressed with regard to potential health risks associated with these activities. 1) Is it safe to swim (with "swimming" broadly understood to include all water-contact activities) in the ocean?, and 2) Is it safe to eat the seafood?

1.1 Risks from swimming (and other water-contact activities)

Risks from swimming and other water-contact activities stem principally from contamination of nearshore waters by pathogens that derive primarily from two sources: municipal waste water treatment plants and stormwater runoff from the land. There are additional smaller sources such as leaky septic tanks and swimmers at beaches. These pathogens can cause minor illnesses such as sore throats, ear infections, and mild gastroenteritis and, more rarely, serious illnesses including meningitis, encephalitis, and severe gastroenteritis. In general, where wastewater outfalls are located in deep water and/or far offshore, nearshore contamination is less likely. Where deep water is much further offshore, and/or outfalls are nearer shore, contamination from wastewater outfalls is relatively more likely, although a variety of other factors such as current patterns and water column stratification are also important. In contrast, stormwater contamination enters the nearshore zone directly and can be widespread because sources of contamination are numerous, diffuse, and not well regulated. For example, numerous stormdrains flow to the coast in urbanized areas and a recent study showed that shorelines that receive dry weather flows are 10 times more likely to exceed water contact standards than those that are distant from storm drains. In addition, pathogen contamination can derive from both anthropogenic (leaking septic systems, sewage line breaks, illegal connections to stormwater systems, homeless populations, pets) and natural (wildlife, livestock) sources and it can be difficult to distinguish among these. This combination of characteristics makes stormwater contamination much more difficult to understand and control than that from treatment plants.

Despite widespread public concern and growing management attention, there have historically been no nationally, or even regionally, standardized approaches to monitoring and reporting of water quality, exceedances of regulatory standards, or health impacts. For example, only one study has ever estimated the number of beach-mile-days exceeding bacteriological thresholds of concern, and that was a one-time research project. While the U.S. EPA has based national monitoring recommendations on the *Enterococcus* indicator, despite its shortcomings (see below), these have not been widely implemented. Although all states now have at least minimal monitoring programs, only California and (perhaps) Massachusetts have mandated weekly monitoring (at high-use beaches) and there remain wide differences in the spatial coverage and temporal intensity of monitoring. California remains unique in carrying out more intensive (daily or five days per week) shoreline monitoring at the most heavily used beaches. U.S. EPA is currently developing national guidance for beach monitoring and reporting, but these have not yet been completed or implemented.

The only national summary of beach data that is produced routinely has been the National Resources Defense Council's "Testing the Waters," which is simply a compendium of raw beach closure numbers reported by individual states. These numbers can be very deceiving because all beach closures are treated equally, regardless of areal extent, the degree to which indicators exceeded thresholds, or how long the closures lasted. In addition, there is no allowance for large differences in monitoring effort among states, with the result that states such as California, with intensive monitoring, report many more closures than states with minimal monitoring. In addition, U.S. EPA in 1997 began a yearly survey of beach conditions (National Health Protection Survey of Beaches); however, this program has not yet resolved the problems identified above.

There is also widespread dissatisfaction with existing indicators and monitoring methods. The most commonly used indicators of contamination are total coliform bacteria, fecal coliform bacteria, *Escherichia coli*, and *Enterococcus* (both also bacteria). While these indicators are not themselves pathogens, they are abundant in human waste where pathogens such as viruses and parasites also exist. These indicators are used in monitoring programs because they occur in much larger numbers than the actual pathogens themselves and can be measured with much faster and quicker techniques. Despite these conveniences, they are not necessarily tightly correlated to illnesses, although epidemiological studies have shown that *Enterococcus* tends to be better correlated with health impacts than the other bacterial indicators. Thus, currently used indicators are labor intensive, do not measure pathogens directly, do not distinguish among different sources of contamination, and take at least 24 hours to produce results. Newer methods under development utilize modern microbiological techniques that have the potential to overcome these shortcomings. These methods have the ability to identify sources more accurately based on their genetic fingerprints and there are efforts underway to develop reliable methods that would produce results within an hour or two. In addition, some practitioners predict that rapid progress in sensor technology will enable the deployment of automated arrays in the next few years that produce detailed, real-time data on the presence and abundance of specific pathogens.

Additional risks to people frequenting or living near the shoreline may stem from exposure to toxins from harmful algal blooms (HABs), either through ingestion or from breathing in seawater aerosols that contain the toxins. Though this risk is smaller, in terms of overall relative risk, than that from wastewater and stormwater contamination, there are occasional localized events that cause immediate respiratory symptoms in exposed beachgoers. And, though there is a developing national database for reporting HAB events, and a pilot program in the Gulf of Mexico (HABSOS), there is currently no systematic reporting of either HABs or these human health impacts from such events.

Other risks also stem from encounters with dangerous marine organisms such as jellyfish, sharks, and stingrays. There is an existing database that tracks reports of shark attacks worldwide but there is nothing similar for encounters with other dangerous organisms. While encounters with sharks are especially traumatic and sometimes lethal, they are rare. There is no readily available data on the national incidence of jellyfish blooms, although these can keep people out of the water when and where they occur. There is likewise no available data on encounters with other dangerous marine organisms.

A final category of risk related to water-contact activities stems from exposure to hazardous ocean conditions such as riptides and heavy surf. Fatalities from such events are reported by public health agencies and lifeguard agencies maintain records of rescues.

1.2 Risks from consuming seafood

Risks from consuming seafood are of three kinds. The first is poisoning resulting from eating filter-feeding shellfish that concentrate natural toxins that are produced by several species of phytoplankton during harmful algal blooms. While potentially deadly, this risk is quite low, with only a handful of isolated cases being reported in any one year.

The second is the risk of illness from consuming raw shellfish that are contaminated by pathogens from human and/or animal sewage, as well as natural sources (e.g., Vibrios). This problem is most prevalent along the Gulf and Atlantic coasts where shallow, semi-enclosed coastal waters provide adequate habitat. The U.S. EPA maintains a listing (http://map1.epa.gov) of consumption advisories that include shellfish and a similar listing, the Shellfish Information Management System, is maintained by NOAA (http://kingmack.chbr.noaa.gov/web_html/sims/ShellprogInfo.html). In addition, the website of the

Interstate Shellfish Sanitation Commission (http://www.issc.org) contains relevant information. Monitoring is conducted using primarily the same indicators discussed in the preceding section and there are similar problems concerning standardization and reporting. Monitoring and reporting, as for beach contamination, is conducted on a state-by-state basis and, despite some national guidance, advisories may be based on different threshold levels in different states. Because, in many cases, only the presence or absence of an advisory is contained in the national database (rather than the actual contaminant and threshold levels), it is not possible to determine the rate of exceedance of specific contaminant levels. This situation is directly analogous to that for national reporting of beach closures described above. As with monitoring of beach contamination, there is active research into improved methods for identifying specific pathogens and their sources.

The third kind of risk is the risk of long-term illnesses, such as cancer and neurological damage, from consuming contaminated finfish. Many coastal environments are contaminated with toxic substances such as DDT and PCBs, and mercury is widespread in the marine environment. Because they bioaccumulate, these compounds can reach levels that are harmful to humans, especially in larger fish that are at or near the top of the foodchain, or that feed preferentially on bottom organisms in highly contaminated environments. As with shellfish beds, there is national guidance, provided by U.S. EPA, on how to conduct risk assessments and establish consumption advisories, and a national directory of such advisories is maintained at http://map1.epa.gov.

However, individual states are responsible for collecting the monitoring data needed for risk assessments, for conducting the assessments, and for establishing consumption advisories. There is no national system for collecting data on contaminant levels in seafood, although there are some piecemeal efforts currently in place. The Food and Drug Administration has the authority to conduct sampling and measurement of levels of a wide range of contaminants in seafood, to remove contaminated commercial fish from interstate commerce, and to block imports of contaminated fish from abroad. However, these inspections are not conducted systematically and there is no integrated national reporting of findings.

The Food and Drug Administration also has a Pesticide Residue Monitoring Program that does include some commercial seafood products and periodically conducts a Total Diet Study that measures the residues of a wide range of contaminants in commercially available food products. As with the Pesticide Residue Monitoring Program, only a small percentage of food products analyzed are seafood (see http://vm.cfsan.fda.gov/~comm/tds-toc.html for the 1999 study) and seafood products are not linked to specific coastal source areas.

Finally, EPA distributes the National Survey of Mercury Concentrations in Fish (www.epa.gov/ost/fish/mercurydata.html). This survey has been discontinued and, even when active, was plagued by inconsistencies among states in study design, sampling and analysis methods, and reporting.

1.3 Changes to risk due to climate change

There is active concern about the possible effects of climate change on human health. Such change would not affect human health directly but rather through indirect effects on factors such as the distribution of disease vectors or the spread of contaminants. For example, it is possible that increased rainfall would lead to higher runoff and suspended loads and that these in turn could increase the loading of contaminants to the nearshore zone. Similarly, changes in coastal temperature regimes could affect the distribution, intensity, and frequency of HAB events. Monitoring related to the categories of risk discussed above would adequately capture changes over time in risk levels. Associating such changes with climate change would require data from other programs on trends in potential forcing functions (e.g., ocean temperature, rainfall, runoff) that are more directly related to climate change.

1.4 Beneficial uses

In addition to the risks described above, the ocean may play a positive role in human health through the identification and utilization of organisms that produce compounds with beneficial pharmacological properties, that can serve as models for human biomedical research, or that provide useful insights into bioengineered materials. While there is no systematic monitoring of the proportion of medically useful natural products that derive from the ocean, a periodic assessment of such contributions could be a valuable element in establishing the importance of maintaining marine biodiversity.

1.5 The Great Lakes and drinking water
The coastal waters of the Laurentian Great Lakes supply drinking water to over 15 million people. The purity of those waters and the security of supply system infrastructures are major public health and national security concerns. The adverse socioeconomic and public health impacts of failed or inadequate monitoring and security systems are potentially immense. Despite its importance for this region, and the fact that the Great Lakes are often included in the definition of "coastal," this group chose not to include the drinking water issue for two reasons. First, the Great Lakes are not a part of the coastal marine environment focused on by the rest of the workshop. Second, this issue is a regional one and therefore does not fit the organizers' criteria of broad national relevance to the marine coastal zone (because marine waters are not a source of drinking water).

2. SUBGOALS AND PRODUCTS

There are two major subgoals to the theme of Ensuring Public Health. These are described below, giving for each the key products needed to meet the subgoals. The subgoals, products, and associated variables reflect a systematic risk assessment approach to the public health issue. This has the following main features:

- Describing historical patterns of risk
- Assessing overall risk from present conditions
- Predicting risk from specific sets of conditions likely to occur in the future
- Measuring exposure of human populations to factors related to risk
- Calculating risk from measures of exposure and estimates of dose-response relationships.

The variables necessary for carrying out this risk assessment approach are interrelated; that is, the assessments and predictions of risk require the full suite of variables.

The measurement program described below (Section 3) includes all of these elements except for the last; it is assumed that the calculation of dose-response relationships would be a one-time or infrequent activity (e.g., epidemiological study) that would not be a direct part of an ongoing measurement program.

PUBLIC HEALTH SUBGOAL 1:
Obtain nationally standardized measures of the risk of illness or injury from water contact activities in coastal waters (microbiological pathogens, harmful algal bloom toxins, encounters with dangerous marine organisms, and hazardous ocean conditions).

- **Product PH-1.1:** Assessment and prediction of risk from microbial pathogens.

  Variables required:
  - Microbiological Indicator and/or Pathogen Levels at beaches around the country
  - Measure of how many people are swimming
  - Reports of swimming warnings and the exceedances these are based on
  - Anecdotal measures of illness rates related to exposure to contaminated waters
  - Nearshore Circulation
  - Discharge to the Coastal Zone

- **Product PH-1.2:** Assessment and prediction of risk from HAB exposure.

  Variables required:
  - Concentration of HAB and HAB products
  - Measure of how many people are exposed
  - Reports of human illness due to HABS
  - Anecdotal measures of illness rates related to exposure to HABs
  - Proxy measures such as fish kills
  - Sea Surface Temperature
  - Nearshore Circulation
  - Chlorophyll

- **Product PH-1.3:** Assessment and prediction of risk from dangerous marine animals.

  Variables required:
  - Distribution and Density of dangerous marine organisms
  - Incidence Rates of deaths and injuries due to contact with dangerous marine organisms

- **Product PH-1.4:** Assessment and prediction of risk from hazardous ocean conditions.

  Variables required:
  - Occurrence of Hazardous Ocean Conditions
  - Incidence Rates of drownings and/or rescues

PUBLIC HEALTH SUBGOAL 2:
Obtain nationally standardized measures of the risk of illness from consuming seafood.

- **Product PH-2.1:** Assessment and prediction of risk from pathogens in seafood.

  Variables required:
  - Microbiological contamination in the water

in shellfish growing areas
- Microbiological Contamination in shellfish tissue
- Shellfish Consumption, including data on key demographic groups and geographic regions
- Number of shellfish beds closed
- Number of reported illnesses

- **Product PH-2.2:** Assessment and prediction of risk from HAB toxins in seafood

  Variables required:
  - HAB contamination in the water in shellfish growing areas
  - HAB Toxins in shellfish tissue
  - Shellfish Consumption, including data on key demographic groups and geographic regions
  - Number of shellfish beds closed
  - Number of reported illnesses

- **Product PH-2.3:** Assessment and prediction of risk from anthropogenic contaminants in seafood.

  Variables required:
  - Chemical Contamination in the water
  - Chemical Contamination in seafood tissue
  - Seafood Consumption, including data on key demographic groups and geographic regions

APPENDIX V: BACKGROUND PAPERS

8. A DATA AND COMMUNICATIONS INFRASTRUCTURE FOR THE U.S. INTEGRATED OCEAN OBSERVING SYSTEM

Prepared by Steve Hankin (WG Chair), Lowell Bahner, Landry Bernard, Phil Bogden, Roz Cohen, Peter Cornillon, Lee Dantzler, Scott Glenn, Fred Grassle, David Legler, Worth Nowlin, Tim Orsi, Ben Sherman, Malcolm Spaulding, Susan Starke

(Note: **This revised background paper incorporates material prepared by participants in the Data and Communications (DAC) Working Group at the Ocean.US Workshop, March 10-15, 2002)**

Abstract: The Integrated Sustained Ocean Observing System (IOOS) is the U.S. contribution to the international Global Ocean Observing System (GOOS), and the U.S. coastal observing module. The Data and Communications subsystem of IOOS will knit together the distributed components of IOOS, and function as a unifying component within the international GOOS framework. The DAC subsystem consists of the following key functional elements: data transport; quality control; data assembly; limited product generation; metadata management; data archeology; data archival; data discovery; and administration functions. A design plan to integrate these elements is proposed, including implementation of a "middleware" level of connectivity – a common set of standards and protocols that connects heterogeneous data sources to diverse user communities. Finally, a process is recommended for developing a phased implementation plan for development of the DAC subsystem.

1. INTRODUCTION

In 1992 an international consensus was reached to develop a Global Ocean Observing System (GOOS), in response to a mandate from the United Nations Conference on Environment and Development. The general mission of GOOS is: i) to "establish a system that provides the information needed by governments, private enterprise, science and the public to deal with marine-related issues and problems and ii) to do this through the development of an integrated global network that systematically acquires and disseminates data and data products in a timely fashion." (UMCES, 1999). The international "GOOS is being developed through two related and convergent modules: i) a global ocean module concerned primarily with the role of the ocean in the earth's climate system and ii) a coastal module concerned primarily (but not exclusively) with changes in coastal environments and their impacts on society and the goods and services provided by coastal marine and estuarine systems." (Malone, 2002). The Integrated Sustained Ocean Observing System (IOOS) is the U.S. coordinated national contribution to GOOS, and the U.S. coastal observing module. The specific goals of IOOS, within this international framework, are:

- Detecting and forecasting oceanic components of climate variability
- Facilitating safe and efficient marine operations
- Ensuring national security
- Managing resources for sustainable use
- Preserving and restoring healthy marine ecosystems
- Mitigating natural hazards
- Ensuring public health

The IOOS is envisioned as a federation of quasi-independent components, within a national integrating framework, consisting of: i) regional observing systems, each tuned to the needs of its region and using the strength of its regional community; and ii) an open ocean/climate component. IOOS will consist of three essential subsystems: i) the observing subsystem (measurement); ii) the communications network and data management subsystem (integration); and iii) the applications, modeling and product services subsystem (prediction) (IOC, 2000). This paper addresses the communications network and data management subsystem of the IOOS (hereafter referred to as Data and Communications, DAC) which will perform the essential integrating functions for the overall system.

The following sections describe the components which constitute the DAC subsystem, a suggested conceptual system design to integrate these elements and their functions, and a process that results in a detailed DAC subsystem implementation plan.

2. THE DATA AND COMMUNICATIONS SUBSYSTEM COMPONENTS

The Data and Communications (DAC) subsystem of the IOOS will both knit together the distributed components of IOOS into a nationwide whole, and function as a unifying component within the international GOOS framework. The vision for the DAC subsystem is not limited to the collection of data; it includes the data and communications components needed to move data among systems and users in a distributed environment. The DAC subsystem will be required to link observations collected from a broad range of platforms: buoys, drifters, autonomous vehicles, ships, aircraft, satellites, and cabled instruments on the sea floor. Observation types include biological and geological specimens and sample data, point measurements, continuous measurements, movies, photographs, and imagery. The many millions of individual measurements anticipated to be obtained daily by the sensor networks will be transmitted (in real-time, near-real-time, and delayed modes) directly to users, as well as to the applications and data-assimilating models that process these measurements into maps, plots, forecasts, and other useful forms of information. While the DAC vision recognizes that data products, rather than raw data, are typically required by users, the development of most data products will be the responsibility of the applications, modeling, and product services subsystem of the IOOS. The responsibilities of the DAC, per se, with respect to product generation are: i) to ensure that the needs of product generators are met for timely delivery of quality-controlled data; ii) to provide accurate and thorough metadata accompanying the data; and iii) to provide a uniform guaranteed minimum level of geo- and time-referenced graphical browse capability for all classes of data. The guarantee of assured data discovery and minimal browsing capability are aspects of descriptive metadata, ensuring that the data are readily intelligible to users.

We envision that the DAC subsystem will consist of the following key elements:

TABLE 1. ESSENTIAL IOOS DATA AND COMMUNICATIONS COMPONENTS

ELEMENT	FUNCTION
Data transport	Collection/transmission of data from sensor subsystems to assembly centers, users, and archive centers in real-tim and delayed mode, for operational, and research and product generation applications.
Quality control	Assurance that data are of known documented quality. QC operations are a partnership among data observa tion/collection components, processors, analysts, other users, and the DAC.
Data assembly	Aggregation and buffering of data streams over useful spans of time and space. Data assembly allows users to mor easily exploit real-time data, especially data from distributed sensor arrays.
Product generation	Products include data products such as assimilation-friendly real-time measurements, model nowcasts and forecasts, GIS layers and climatological reference fields; graphical products such as scientific plots and maps; and text products such as written forecasts and numerical tables. Most product generation is of the Modeling, Data Assimilation subsystem of IOOS.
Metadata management	Establishment of simple, clear guidelines and extensible standards for metadata requirements; ensure that the link ages between data and metadata are maintained with great reliability; provide for communication of metadat between components of the system; provide training and tools to help users conform to them; increase users capacity in metadata generation and management.
Data archeology	Rescue, digitize, and provide access to legacy/historical data sets; retrieve data in danger of loss due to: deterio rating media, out-of-date software, non-digital format, etc. Data archeology activities can be regarded as an addi tional source of data, akin to the measurement subsystems.
Data archival	Provision for the long-term archive and stewardship for IOOS data sets; conform to national archive standards, a well as IOOS standards and user requirements.
Data discovery	Provision of means for determining what data are available within the IOOS based upon user queries. Seamless integration of Data Discovery with data and metadata access functions provided by the Data Transport and Metadata Management components, respectively.
Administrative functions	Provision of oversight mechanisms for IOOS DAC fault detection and correction; security; monitoring and evaluation of system performance; providing for system extensibility; establishing and publicizing policies for data availability; soliciting and responding to user feedback; establishing and maintaining international linkages.

3. THE DATA AND COMMUNICATIONS SUBSYSTEM DESIGN

In the previous section the functional elements of the DAC subsystem are identified. In this section, a design plan is proposed that integrates these components. The basic concept underlying the plan is to implement a "middleware" level of connectivity for the IOOS – a common set of standards and protocols that connects heterogeneous data sources to heterogeneous user communities. Suppliers of data (including instrument subsystems) will be responsible for translating their "native" data and metadata encodings into the middleware standards. Users may optionally choose to translate out of the middleware standards into "legacy" encodings or may work directly with the middleware standards. The uniformity provided by the middleware permits all of the components related to data transport to be interoperable at the machine level, (i.e., data can be moved from one component of the system to another retaining complete syntactic and semantic meaning without human interaction).

Data transport on the World Wide Web (Web) involves protocols at a variety of levels. The foundation of transport on the Internet is TCP/IP, which handles the routing of "packets" of information between source and destination hosts. At the next level up, a variety of protocols are used: FTP, HTTP , SMTP, etc. These protocols are supported on a very wide range of computers and operating systems, and any one of them can be used to move data over the network as part of the IOOS. There is, however, no uniform syntactic and semantic meaning that is guaranteed for data communicated via these transfers and therefore no guarantee of interoperability at the machine level. This is the role of the middleware.

Several (often discipline specific) middleware solutions do exist for the syntactic description of binary data, however none is universally accepted. The most broadly tested and accepted of these in oceanography is OPeNDAP, which underlies the National Virtual Ocean Data System (NVODS). The authors of this report recommend that OPeNDAP be considered as the preferred middleware solution to achieve the goals of the DAC subsystem in a rapid and cost-effective manner. Considerable progress in the encoding of ocean biological data has also been demonstrated in the OBIS[5] data system – an area largely outside the current scope of NVODS. Modifications to accommodate OBIS standards may be required in OPeNDAP.

In addition to a syntactic description of the data, machine-to-machine interoperability within the DAC subsystem also requires a consistent semantic description of the data. The authors of this report recommend the FGDC standard for this purpose in the IOOS. It must be noted, however, that recommending the use of the FGDC standard, alone, does not guarantee that the required interoperability will be achieved. Standards-generating activities are needed to determine which specific FGDC fields must be populated and to define controlled vocabularies for variable names, units, etc. to be entered into these fields.

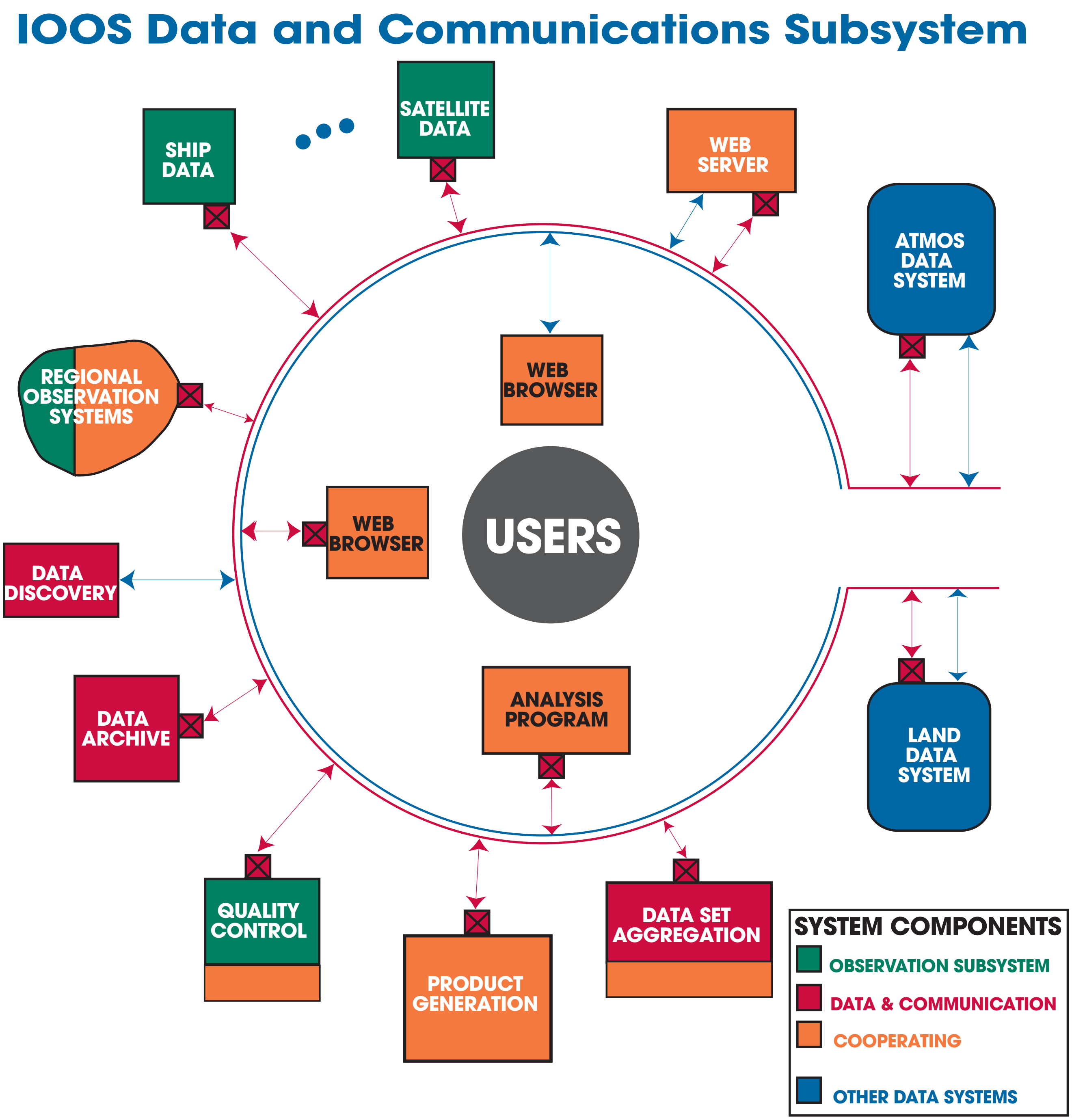
Figure 1 is a pictorial representation of the integrated system. Elements of the National backbone of the IOOS Observing Subsystem are shown in cyan; elements of the National backbone of the IOOS Data and Communications Subsystem are shown in red; elements supplied by cooperating IOOS entities are shown in pink; elements of other data systems are shown in blue; and the user community is depicted by the white circle at the center of the diagram. The red and blue concentric circles with attached lines leaving the diagram to the right represent the Web. The blue circle represents transfers on the Web which do not adhere to the DAC middleware standards – the documents, images, user interface forms, etc. that are typical today. The red circle represents data transfers made using the middleware standards adopted by IOOS .

Several user interfaces are shown between the user circle and the Internet: a Web browser accessing data products (graphics, ASCII tables, etc.) that are generated by a Web server functioning as a gateway from the IOOS; a Web browser running a Java Applet or "plug-in" that can access the middleware data directly; and a desktop application that can access the middleware data directly. The small red squares on the figure represent the computer code that translates from the middleware adopted by IOOS to the "native" or "legacy" encodings expected by the components connected to the system. The Web server which functions as a gateway is worth special note, as this is the means by which many data products will be delivered to users. In this configuration the server requires two (virtual) connections to the Web, one using unrestricted HTTP and the other using the IOOS middleware. The web server requests and receives data from the IOOS system via the middleware standard, converts them to a picture or an ASCII data stream, and returns that product via unrestricted HTTP to the user. Data acquisition and processing elements are shown outside of the concentric circles. The cyan boxes are representative of data sources: satellite data systems, ship-based systems, moorings, buoys, shore-based operations, etc., including non-real time shore-based measurements such as laboratory chemical assays and fish landing counts that provide data. The observing network also includes data collected by participating regional systems. This regional participation is indicated by the cyan portion of the sample system shown. Data enter the IOOS Data and Communications Subsystem from data collection subsystems via a translation process indicated by the small red squares. The translation will often be performed by dedicated servers that translate from the "native" format used within the subsystem to the IOOS middleware standards. The required semantic metadata must also be available via this server for the data to be IOOS-compliant. (Data formats and transfers that occur within the observation subsystem prior to translation lie outside of the DAC subsystem and are under the control of those responsible for that subsystem.)

The IOOS Data and Communications Subsystem contains a data discovery element. The system design encourages multiple data discovery components, but the authors of this report recommend that the NOAA's National Coastal Data Development Center be designated as a primary data discovery facility. The authors also recommend that the network data transport protocol for data discovery search parameters and search results should be HTTP, as indicated by the blue line connecting this element to the network. No translations are necessary in this case.

The IOOS Data and Communications Subsystem also contains a data assembly (a.k.a. "aggregation") element,

FIGURE 1. IOOS DATA AND COMMUNICATIONS SUBSYSTEM



and a "deep" archive for the system. The data assembly components will acquire the data on-the-fly from local storage at the various observational subsystems and facilitate easy access of the aggregated data to the user. The methods of achieving aggregation include the use of relational data bases, of simpler file formats that address specific needs, and of "aggregation servers", which create virtual data sets from multiple (possibly distributed) files or other sources. As with data discovery, the system design encourages multiple data assembly elements, but the authors of this report recommend the GODAE Data Server be designated as a primary center for real-time assembly. Until the data of interest have been moved to the "deep" archive, at least one assembly center or local storage center must maintain the data. Coordination of these activities will be an important administrative function of the DAC subsystem.

Quality control (QC) is shown as a separate function, but in fact it will be performed by several components – at the observing subsystem, at the real-time data assembly centers, at the delayed-mode (climate) data assembly centers, and often again at the product generation sites. The development metadata (not shown) reflecting these QC operations must occur in lock step.

4. THE NEXT STEPS: A PROCESS TO DEVELOP A PHASED IMPLEMENTATION PLAN FOR THE DATA AND COMMUNICATIONS SUBSYSTEM

We recommend that the Process begin with the creation by Ocean.US of a Data Aand Communications Steering Committee (DACSC) that will be supported by four Expert Teams and two Outreach Teams. The Expert Teams will have the task of evaluating available technologies and making recommendations in the form of White Papers. The four Expert Teams will be:

1. Data Transport
2. Data Discovery / Metadata
3. Applications
4. Data Archival

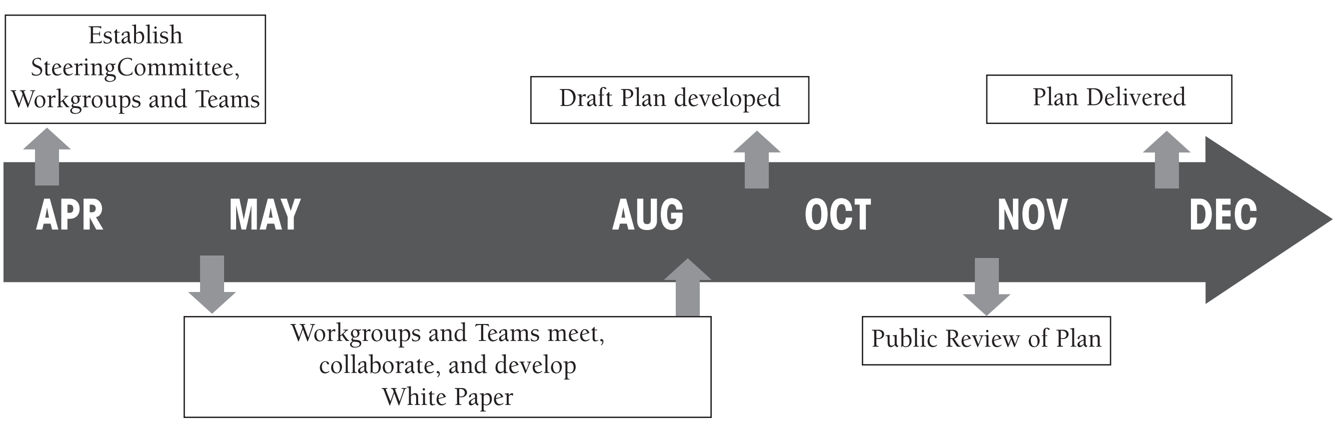
The Outreach Teams will provide guidance and critical feedback from established National and Regional data centers and from stakeholding user groups that have serious interests in ocean data products in the areas of:

1. Data Facilities Management
2. User Outreach

We recommend that the DACSC consist of i) the Chairs from the Outreach Teams; ii) the Chairs of the Expert Teams; and iii) other persons as appointed by Ocean.US. To ensure continuity of the planning process at least two of the DACSC members should be drawn from the Ocean.US Workshop (March 10-15, 2002) DAC Working Group.

Figure 2 outlines the basic timeline and activities that will result in the DAC Implementation Plan. The DACSC, the four Expert Teams and the two Outreach Teams will convene, beginning in April-May, 2002. Based upon the consensus documents developed at the Ocean.US Workshop the DACSC will assign the Expert Teams with areas of responsibility that must be addressed and guidance on specific aspects of the assigned topics. The Expert Teams will meet in person and by conference calls to develop White Papers that thoroughly address their assigned topics by September 1, 2002.

FIGURE 2. TIMELINE FOR PLAN DEVELOPMENT



In parallel with the Expert Teams the Outreach Teams will also meet in person and/or by conference calls. Each Outreach Team has the task of consulting with its respective communities in order to develop Community Issues Lists representing the areas of concern that the Data And Communications Plan should address. Should issues arise in the Outreach Team discussions that might impact the technical conclusions of the Expert Teams, the Outreach Team chairs should promptly bring these issues to the attention of the DACSC (which includes the Expert Team Chairs). The DACSC will meet as required in person or by telephone to resolve these issues. Final versions of the Community Issues Lists should also be delivered to the DACSC by September 1, 2002.

Following receipt of the White Papers and Community Issues Lists the Steering Committee must meet in person and/or by telephone and email to write the Plan by October 1, 2002. The Plan will be circulated for review and comment during October, followed by a meeting to be hosted by Ocean.US in November to review the Plan in a public forum. The DACSC should deliver the Plan in final form to Ocean.US in December, 2002.

As a practical matter there is a need for rapid deployment of the DAC subsystem; the streams of ocean measurements are already in a state of rapid growth both nationally and internationally. To address this time-critical need several pilot projects are recommended to be undertaken in parallel with the planning process. The pilot projects will be conducted on a volunteer basis; other projects may be added as the planning proceeds. The DACSC should monitor the progress of these pilot efforts and provide feedback accordingly to the Expert Teams. The intent is that the pilot projects will provide valuable feedback to the planning process, while also shortening the overall time required to achieve operational status for the DAC subsystem.

A more detailed version of this process, describing the responsibilities of the groups identified, charging them with specific tasks, and providing guidance on their activities, was submitted as a separate Workshop deliverable.

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Note: This revised background paper incorporates material prepared by participants in the Data and Communications (DAC) Working Group at the Ocean.US Workshop, March 10-15, 2002

FOOTNOTES

1 Syntactic Metadata: metadata objects that describe the syntax of a data set - the atomic data types in the data set (binary, ASCII, real, etc), the dimensionality of data arrays (T is a 90 by 180 by 25 by 12 element array), the relationship between variables in the data set (lat is a map vector for the first dimension of T), etc.

2 Semantic Metadata: metadata objects that describe the semantics of the data contained in the data set - the meaning of variables (T represents ocean temperature), the units used to express variables (multiply T by 8 and add 4 to obtain the temperature in degrees Celsius), special value flags (a value of –1 means missing data, 0 land,...), descriptions of the processing or instrumentation used to obtain the data values, etc.

3 When using a web browser one makes use of http.

4 The Open source Project for a Network Data Access Protocol, a non profit corporation formed to develop and maintain the syntactic data access protocol used in the NOPP funded National Virtual Ocean Data System (NVODS).

5 The Ocean Biogeographic Information System (OBIS) is an on-line, open-access, globally-distributed network of systematic, ecological, and environmental information systems. Collectively, these systems operate as a dynamic, global digital atlas to communicate biological information about the ocean and serve as a platform for further study of biogeographical relationships in the marine environment. (http://marine.rutgers.edu/OBIS/)

6 The Federal Geographic Data Committee (FGDC): an interagency committee, organized in 1990, that promotes the coordinated use, sharing, and dissemination of geospatial data on a national basis. (http://www.fgdc.gov/)

7 OPeNDAP modified to accommodate OBIS data objects with the IOOS required semantic metadata in

FGDC containers

8 The “deep” archive refers to the long term commitment to maintain the data and associated metadata.

APPENDIX V: BACKGROUND PAPERS

9. ECONOMICS OF A U.S. INTEGRATED OCEAN OBSERVING SYSTEM

Prepared by Hauke Kite-Powell, Charles Colgan, and Rodney Weiher

1. INTRODUCTION

The United States has long made significant investments in ocean research, monitoring and forecasting. Nonetheless, ocean phenomena remain under-observed compared to observations of atmospheric conditions, and there has been little high-level coordination of ocean data collection. Observations from ships and buoys are sparse compared to onshore environmental monitoring, and satellite data are pervasive but not comprehensive. Large expanses of the oceans remain unobserved, by ship or satellite, for substantial periods of time.

Development of an Integrated Ocean Observing System (IOOS) is a major shift in the approach to ocean observation. By systematically collecting data and integrating hundreds of thousands of measurements from the world's oceans in conjunction with mathematical models, a more sophisticated understanding of ocean-related systems becomes possible. This will improve short-term weather forecasts, seasonal weather forecasts, marine forecasts, environmental assessments, and opportunities for basic research, thereby producing benefits for people and businesses throughout the US economy and internationally.

The evidence from benefit studies to date suggests that, nationally, a major benefit of ocean observations is to improve weather and climate forecasts that are used throughout the economy and produce hundreds of millions of dollars in annual benefits to the United States and to the world economy. Benefits beyond those counted for weather and climate forecasts have been demonstrated at the regional level through preliminary studies in the Gulf of Maine.

Additional research is needed to obtain reasonable estimates of the benefits accruing to a number of sectors from IOOS data and products will differ from those currently available, their incremental costs, how the information is used in decision making, and how that information improves outcomes in economic activities. Ranking IOOS products according to their net benefit is one useful tool to help prioritize investments in improved ocean observing infrastructure.

2. BACKGROUND: RATIONALE FOR FEDERAL SUPPORT OF IOOS

IOOS produces economic value when information derived from IOOS data is made available in a timely manner to those who can use it in economic decisions. This sort of information has some of the characteristics of what economists refer to as a "public good." In particular, once it is produced, information is now almost costless to distribute (e.g., via the Internet), and the total benefit derived from the information is greatest when it is made available to anyone who can make use of it. In some instances – for example, severe marine weather warnings – it is also difficult (or ethically problematic) to exclude potentially affected parties from obtaining the information, whether they have paid for it or not. Finally, some information produced by IOOS may improve long-term public policy decisions that affect everyone in the country (or the world).

These public good characteristics suggest that private investment is likely to produce less information about the oceans than is socially optimal. The direct incentive for any individual or business to invest in generating the information is limited to the value they themselves receive. Many potential beneficiaries may not invest at all, preferring to take advantage of information provided by others. Moreover, the transaction costs involved in negotiating private cooperative agreements to realize the full benefits of IOOS are likely to be formidable. All these problems are largely resolved by public investment in IOOS and wide dissemination of (some) resulting information products.

The public good characteristics of IOOS thus argue for federal support in order to achieve the full benefits of this system. However, the fact that there is a compelling case for public involvement does not mean that any investment should be made. The investment should be made only if the benefits of the system can be reasonably expected to exceed its costs. This can only be determined if a reasonable estimate of costs can be made, and if both the uses of the data, and the value of that use, can be reasonably estimated.

3. BENEFITS AND COSTS

Benefits. Ocean observation has economic benefits because the data are used to derive products, such as forecasts, that are used by decision makers to make choices that affect economic well-being. To estimate the benefits that may accrue from an investment in IOOS, it is necessary to compare the outcome of these decisions under two scenarios: the baseline situation (currently available information and products) and the hypothetical future situation with IOOS data and products. The new information products enabled by IOOS data will alter decisions made in industry, recreation, and public administration, changing the economic outcome from these activities, and thereby affecting economic well-being. The difference in outcome under the two scenarios is the benefit derived from IOOS.

The most accurate measure of this benefit is the marginal increase in consumer and producer surplus. Consumer surplus is the difference between what consumers are willing to pay and what they actually pay. Producer surplus is the difference between the price received for a good or service sold and the costs of producing that good or service. Because this surplus is often difficult to estimate, we also use other measures of benefit, such as the change in value added, or reduction in cost to achieve the same level of output, although these are less precise estimates of true social surplus. Usually, these measures are estimated as annual values at the level of a firm or other economic unit, and then aggregated over geographic regions and industries to estimate total annual benefits.

Costs. Benefits represent only one side of the economics of IOOS. To estimate net benefits, or rates of return, it is necessary to have information on costs as well. There are two categories of costs: the funding for IOOS data collection, processing, and archiving; and the costs of generating the products from IOOS data that decision makers ultimately use. The second component includes activities carried out by both public and private sector organizations. As with benefits, we are interested in the marginal increase in annual costs, or the difference between costs under the current scenario and expected costs under IOOS.

Current federal support for ocean research is about $600 million a year, some portion of which supports activities that may become part of IOOS. Cost estimates for IOOS specifically have been difficult to generate because the system itself is not yet fully defined. Rough estimates of additional costs to implement a coherent US ocean observing system have been on the order of $100 million annually. According to preparatory documents for the 1992 Rio Conference, the project annual operating cost of a fully implemented Global Ocean Observing System, of which IOOS will be a part, was thought to be approximately $2 billion.

4. AN ECONOMIC FRAMEWORK FOR PLANNING IOOS

At a simple level, IOOS will consist of a network of sensors and platforms that feed observations into a data management system. The data system in turn feeds a variety of models that generate forecasts, nowcasts, and other decision support tools, and also supplies data sets for scientific research. An economic approach to planning investment in IOOS begins at the "product and user" end of the system. It assigns to each product (for example, an ENSO forecast) a measure of benefit (marginal increase in social surplus) and cost (marginal cost of collecting and processing the data). Subtracting cost from benefit yields the net benefit of the product. Different products can then be ranked by their net benefit, and IOOS investments structured to produce first those products with the greatest net benefit.

Because of the time value of money, benefits are worth more if they are received sooner rather than later. For example, it is useful to distinguish benefits that derive from routine operational decisions in the short run (whether to route the ship north instead of south), benefits that are realized in the longer term from improved investment decisions (how to design a breakwater), and benefits that accrue over very long periods of time (general economic growth due to better scientific and technical knowledge).

Some benefits are easier to estimate than others. In particular, the long-term benefits from a general increase in scientific and technical knowledge are substantial and well understood, but (by definition) almost impossible to predict at the level of specific investments such as components of IOOS. The economic case for IOOS will focus on those products for which we are able to quantify benefits clearly, but the system's contribution to science and technology benefits to overall economic growth must be noted.

The overall cost of IOOS is an incremental accumulation of the costs of its products, but it is far less than the sum of the costs of individual products. This is an important efficiency that results from the integrated nature of the system. Individual observed variables will feed multiple products at little additional cost, and individual sensors will share platforms at little additional cost. It will help make the case for IOOS to show these efficiencies explicitly by estimating the full cost of individual products and then illustrating the savings possible by an integrated multi-product system.

We show below a simple example of how economic information can inform the IOOS system design process. We have taken a sample of 12 IOOS "products" or "subgoals" defined at the March 2002 Ocean.US IOOS workshop and qualitatively rated their incremental cost and benefit (see table below). Incremental cost is rated according to whether significant new observations and/or significant new modeling/processing effort is needed to provide the product. Benefits are rated according to the frequency of the event (number of people affected, for example) and the magnitude of the economic effect in each event. **Note that this example is for illustrative purposes only; no real significance**

	INCREMENTAL COST		BENEFIT		TIMING OF B	
	MORE OBS.	MORE MODELS	FREQUENCY OF EFFECTS	UNIT MAGNITUDE	SHORT TERM	LON TE
SST variability			HIGH	LOW	X	
ENSO prediction		X	HIGH	HIGH	X	X
sea level		X	HIGH	HIGH		X
HAB prediction	X	X	HIGH	LOW	X	
anthropogenic contaminants	X	X	LOW	HIGH		X
safe & efficient marine ops	X	X	HIGH	HIGH	X	X
SAR and spill response	X		LOW	HIGH	X	
air & waterborne contaminant distribution and dispersion	X	X	LOW	HIGH	X	
risk measures for swimming	X		HIGH	LOW	X	
risk measures for seafood consumption	X		LOW	LOW	X	
fisheries stock assessments	X	X	HIGH	LOW	X	X
natural hazard prediction (storms, etc.)	X	X	HIGH	LOW	X	X

should be attached to this simple assessment of benefits and costs, or to the resulting ranking. At the very least, a preliminary quantitative estimate of costs and benefits should be developed before such a ranking is given serious weight in system design decisions.

From these ratings, products can be sorted into a benefit/cost framework as shown in the following table. Ideally, the benefit and cost dimensions should be in (order of magnitude) numerical dollar terms. In this illustration, we define cost as "low" if a product requires neither significant new data nor new modeling, "medium" if it requires one but not the other, and "high" if it

		BENEFITS		
		LOW	MEDIUM	HIGH
Incremental Costs	Low	3	6 SST variability	9
	Medium	2 risk measures: seafood	3 SAR & spill response risk measures: swim	6 ENSO prediction sea level
	High	1	2 HAB predition anthropo. contaminats air/water contam. disp. stock assessments hazard predictions	3 safe & eff. marine ops

requires both. Benefit is defined as "high" if both frequency and unit magnitude are high, "medium" if only one is high, and "low" if neither is high. For simplicity, we ignore the timing of benefits at this stage.

The number in the top left corner of each field represents a numerical approximation of net benefit (benefit minus cost) of products in this field. Ranking the products by these values leads to the following rough ordering (note that the order of products within each net benefit level is arbitrary):

6	SST variability ENSO prediction sea level
3	SAR & spill response risk measures for swimming safe & efficient marine operations
2	risk measures for seafood HAB prediction anthropogenic contaminants air/waterborne contaminant dispersion fisheries stock assessments hazard prediction

All of these products are worthwhile in the sense that all are likely to produce positive net benefits. If resources are limited and it is not possible to invest in producing all of them at once, this ranking can provide guidance on how to prioritize the investments. Some general guiding principles for IOOS investment planning are:

- Invest first in products that provide the highest net economic benefit, and then work toward products with lower (but positive) net benefit.
- Net benefits are likely to be highest when:
  - A product leads to multiple sources of benefits (multiple uses), and/or
  - Benefits accrue sooner rather than later.
- Use economic guidance in conjunction with assessments of technical impact/feasibility and political priorities to make the ultimate system design decisions.

To develop useful economic characterizations of IOOS products and ultimately conduct a more complete assessment of the economics of IOOS, it will be necessary to develop:

- Data parameters and cost estimates for IOOS itself, and for value-added products to be derived from IOOS, including the means of distributing these products to users, and how the IOOS data and products differ from what is presently available
- A comprehensive list of industrial, recreational, and public administration activities that use products derived (in part) from ocean observation
- Information about how these activities use ocean observation products (at present and, hypothetically, under IOOS) to make economic decisions
- Information about how these decisions affect the (economic) outcome of their operations

APPENDIX:

Recent Work on Benefits from Ocean Observations

Two areas in which the benefits of ocean observation have been shown to be significant are seasonal forecasts for agriculture and hydroelectric generation, and the use of ocean data in coastal management. Seasonal forecasts are one area where good estimates of the value of information exist, while coastal management problems have a tangible impact on the daily lives of millions of Americans who either live near the coast or visit the coast for recreational activities.

In agriculture, many decisions could be improved with a reliable seasonal weather forecast. One recent study found that by incorporating El Niño Southern Oscillation (ENSO) forecasts into planting decisions, farmers in the United States could increase agricultural output and produce benefits to the US economy of $275- 300 million per year. Another study estimated that the value to society of ENSO forecasts on corn storage decisions in certain years may be as high as $200 million—or one to two percent of the value of U.S. agricultural production. A third study on the costs and benefits of ENSO forecasts concluded that for agricultural benefits alone, the real internal rate of return for federal investments in ocean observation for ENSO prediction is between 13 and 26 percent.

While precipitation and temperature depend on the ENSO phase, they also depend on two other less-understood phenomena—the North Atlantic Oscillation, and the Pacific Decadal Oscillation. IOOS would help improve understanding of these two phenomena; if this led to better predictive capabilities, substantial improvements in seasonal forecasts would follow. This is an instance of direct evidence (in contrast to inferred evidence) that the incremental benefits of IOOS would be substantial, possibly of the same order of magnitude as those of the ENSO forecasts.

Because hydroelectric power generation is significantly affected by seasonal precipitation that differs across ENSO phases, an ENSO forecast should have significant value in managing water use for electricity production. For example, in the largest Tennessee Valley Authority reservoirs, winter stream flows in El Niño years can be as much as 30 percent above normal, allowing efficiency gains by switching from thermal to hydro power. Moreover, the benefits of seasonal forecasts for hydroelectric production, like those for agriculture, will increase if the North Atlantic Oscillation and the Pacific Decadal Oscillation can be forecast reliably.

There are a number of other areas where economic benefits from IOOS data may be significant, both from high seas and coastal ocean observations.

Public Health. Protective management of the U.S. coastal zones requires accurate information about contaminant flows in order to develop policy regarding wastewater treatment and disposal, trash disposal, airborne pollution control, beach closures, and public health restrictions on seafood consumption. For example, a new outfall pipe for treated sewage from the metropolitan Boston area is designed to shift waste inputs from Boston Harbor to Massachusetts Bay. However, the prospect of nutrient loading in the Bay has raised concerns about possible effects on marine life and environmental conditions along the heavily used beaches of Cape Cod Bay. To address these concerns, extensive ocean monitoring is necessary to characterize marine environmental conditions in Massachusetts Bay and Cape Cod Bay prior to and after the utilization of the new outfall. IOOS would provide this kind of monitoring capability and help to predict or assess the consequences of alternative waste disposal decisions.

Coastal Management also includes the protection of beaches and public safety in beach use. Millions of Americans use coastal beaches throughout the year as a major source of recreation, and thousands of jobs in almost every coastal state depend on access to safe, clean beaches. Threats to these beaches are directly connected to the movement of ocean waters. In California and much of the east, combined sewer overflows can temporarily close beaches when high levels of untreated sewage are pumped into the sea following storms.

Oil spills are another threat that can damage beaches for months or years. In each of these cases, a thorough understanding of nearshore ocean circulation, which is influenced by larger ocean patterns, is essential to knowing when and where the pollutants will go. In the case of oil spills, deployment of clean-up equipment and strategies depends heavily on oceanographic models that in turn rely on the kind of ocean circulation data that does not exist but that IOOS may provide. While ocean data cannot eliminate beach closures or prevent oil spills, reliable data, analysis and interpretation can help reduce unnecessary precautionary beach closures, reduce the duration of closures, and minimize the potential damages from oil spills. Though direct estimates of the value of ocean data are not available, there is good reason to believe that this value is significant. For example, preliminary estimates of possible benefits from improved ocean observation in the Gulf of Maine are on the order of $30 million per year.

Other sources of economic benefits include the prevention of damage and deaths from storms, the ensuring of safety in design of offshore oil platforms, the facilitating of Naval operations, and monitoring and understanding the processes of global climate change. Improved understanding of ocean processes may also lead to improved management of fishery resources, increasing long-term potential output. Important values are at stake in most of these activities.

The contribution to the U.S. economy of industries and other activities that have been identified as likely beneficiaries of IOOS products is on the order of one trillion dollars.

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APPENDIX VI: COLLATED LIST OF SUBGOALS, PROVISIONAL PRODUCTS AND VARIABLES

(Note: For further explanation of material below see individual background papers.)

CLIMATE CHANGE

CLIMATE CHANGE SUBGOAL 1:

Obtain improved estimates of surface fields and surface fluxes.

- **Product CC-1.1:** Estimates of the global sea surface temperature (SST) field and its variability on monthly, seasonal, interannual, and longer time scales.
- **Product CC-1.2:** Estimates of global distributions of the surface flux of momentum (wind stress) on monthly, seasonal, interannual, and decadal time scales.
- **Product CC-1.3:** Estimates of global distributions of surface fluxes of heat and fresh water on monthly, seasonal, interannual, and decadal time scales.
- **Product CC-1.4:** Descriptions of the global distribution of sources and sinks for atmospheric carbon dioxide and the carbon exchanges within the interior ocean.
- **Product CC-1.5:** Descriptions of the extent, concentration, volume, and motion of sea ice on monthly and longer time scales.

Variables required for Climate Change Subgoal 1 include:

- SST
- Surface Wind Stress
- Surface Gravity Waves
- SSS
- Surface Air Temperature
- Flux Estimates from analyses of atmospheric observations by NWP models
- Surface Weather Measurements to verify and improve NWP models and to calibrate satellite measurements, including SST, surface air temperature, sea level atmospheric pressure, precipitation, solar and longwave radiation, relative humidity, precipitation, and wind velocity time series at selected sites
- River Discharge Rates
- Heat and Freshwater Transports on transocean sections and in selected straits
- Upper Ocean Temperature and Salinity
- Partial Pressure of Carbon Dioxide, Chlorophyll, Beam C, DIC, DOC, and selected samples of $^{13}C/^{12}C$ ratio in surface waters
- Sea Surface Color, Chlorophyll and other phytoplankton products from the water column
- Sea Ice Concentration, Thickness, Velocity, and Age

CLIMATE CHANGE SUBGOAL 2:

Document variability and change and obtain improved ocean analyses and predictions on seasonal and longer time scales.

- **Product CC-2.1:** Global analyses of upper ocean temperature and salinity distributions at monthly intervals.
- **Product CC-2.2:** ENSO prediction.
- **Product CC-2.3:** Global descriptions of upper ocean variability and climate predictions on seasonal to interannual time scales.
- **Product CC-2.4:** Oceanic inventories of heat, fresh water, and carbon on large space and long time scales.
- **Product CC-2.5:** Estimates of the state of the ocean circulation and transports of heat, fresh water, and carbon on long time scales.
- **Product CC-2.6:** Estimates of global and regional sea level.

Variables required for Climate Change Subgoal 2 include:

- SST, Surface Wind Stress, and Air-Sea Heat Flux (products from Subgoal 1)
- Upper Ocean Temperature and Salinity, including Mixed Layer Depth
- Sea Surface Salinity and/or Air-Sea freshwater flux (particularly in regions where salinity is known to be critical)
- Global Sea Level by altimetry and *in situ* observations (including sea level pressure)

- Surface Currents and selected Subsurface Currents in the tropical oceans
- Subsurface Profiles of Temperature, Salinity, DIC, and DOC
- Over the Water Column Time Series of T, S, and carbon related variables at select sites
- Transocean Sections measuring T, S, ^{14}C, and selected tracers
- Repeat Hydrographic Sections in critical regions for water mass formation
- Sea surface Elevation from precision altimeter, including Marine Geoid mission
- Suite of Geocentrically Located Tide Gauges
- Freshwater discharge from land
- Upper Ocean Heat and Freshwater Content (product 2.1)
- Surface Wind Stress and SST (from Subgoal 1)
- Sea ice Concentration, Thickness, and Drift (from Subgoal 1)

Improved products could be obtained by:

- Measurement of inter-basin exchanges
- Boundary current monitoring
- Sea ice thickness monitoring
- Sea surface fluxes of freshwater, heat, and carbon monitoring (from Subgoal 1)
- Sea surface salinity and pCO_2 monitoring (from Subgoal 1)

CLIMATE CHANGE SUBGOAL 3:
Detect and assess the impact of ocean climate change on the coastal zone.

- **Product CC-3.1:** Ocean state estimates tailored to provide offshore boundary conditions for high(er) resolution coastal models.

- **Product CC-3.2:** Benchmark statistics for higher resolution local observing systems (sparse, high-quality time series observations).

- **Product CC-3.3:** Routine analyses of regional sea level change.

Variables required for Climate Change Subgoal 3 include:

- Currents, U(z)
- Density Profiles T(z), S(z)
- Bathymetry
- Nutrients
- O_2
- Air/Sea Exchanges
- $C0_2$ Flux
- Density Profile
- Currents, including Tidal Currents
- GPS receivers at tide gauges
- Air Pressure

CLIMATE CHANGE SUBGOAL 4:
Establish and maintain infrastructure and techniques to ensure that information is obtained and utilized in an efficient way.

This will require the following actions and resulting products:

- **Action CC-4.1:** Providing improved global climatologies (means and variances) of key ocean variables such as temperature, salinity, velocity, and carbon, especially for the purpose of validating probabilistic climate modeling and simulations at decadal and longer time scales.

- **Action CC-4.2:** Providing the system management and communication facilities necessary for routine monitoring, analysis, and prediction of the ocean from monthly to long time scales.

- **Action CC-4.3:** Developing the facilities for processing assembled data sets and providing timely analyses, model interpretations, and model forecasts.

- **Action CC-4.4:** Providing the system with sufficient bandwidth.

- **Product CC-4.1:** Climate quality data. The data system needs to ensure that a) the data are collected and b) they are properly maintained so that the observational data, products, and analyses are of sufficient quality for detecting climate changes, validating climate models and climate forecasting.

- **Product CC-4.2:** Available long records. Climate variability requires long time series of the parameter of interest. In the early years of IOOS this can only be achieved with the historical record. This requires access to existing historical data, long-term maintenance of these data, and recovery of data that have been collected but are not available in digital form or are not accessible directly.

- **Product CC-4.3:** The model and data assimilation systems and data delivery systems necessary to synthesize observations into products and analyses for the purpose of climate monitoring and prediction, e.g. ocean model/analysis systems, hardware-computers, and data delivery/product delivery infrastructure.

The effectiveness of the observing system in meeting Subgoal 4 through these needed actions will have direct consequences on its ability to meet Subgoals

1-3. A more effective methodology for interpolating, extrapolating, and drawing inferences from a measurement system will usually imply a reduced reliance on any one particular observation. Ultimately this synthesis will be performed by ocean general circulation model data assimilation systems that will combine all information from the surface, upper ocean, and deep ocean to produce a multivariate description of the global ocean circulation. This system does not yet exist, so we now rely on a variety of simpler tools.

MARINE OPERATIONS

MARINE OPERATIONS SUBGOAL 1:

Maintain navigable waterways. Maintenance of navigable waterways is a requirement of the safe and efficient use of our coastal areas for transportation, offshore industry and recreation.

- **Product MO-1.1:** WATER LEVEL: Real-time, referenced water level in the coastal area, and its variability on 0.1 hour to interannual and longer time scales.
- **Product MO-1.2:** BATHYMETRY: Monitor coastal bathymetry and its variability on monthly, seasonal, interannual and longer time scales.
- **Product MO-1.3:** ESTUARINE/COASTAL CURRENTS: Real-time currents and the variability on 0.1 hourly to interannual and longer time scales.
- **Product MO-1.4:** ICE: Ice in the coastal area and icebergs in the open ocean and the accumulation of ice on vessel superstructures, and the variability on daily, weekly, monthly, seasonal, interannual and longer time scales.
- **Product MO-1.5:** NATURAL HAZARDS: Monitor the susceptibility of the coastal area to natural hazards such as extreme weather events, flooding and tsunamis.
- **Product MO-1.6:** SURFACE WAVES: Monitor the wave climate to enable assessment of sediment transport.
- **Product MO-1.7:** RIVER FLOW AND SEDIMENT LOAD: River outflow and sediment loading can affect the bathymetry.

The variables required for Marine Operations Subgoal 1 include:

- Dew point
- Humidity
- Pressure
- Air
- Temperature
- Wind
- Bathymetry/Topography
- Ice Concentrations
- Ice Thickness
- Salinity
- Ocean temperature
- Current
- Sea Surface Temperature
- Directional Wave Spectra
- Precipitation Amount
- Precipitation Intensity
- Precipitation Type
- Sea Level
- Current Profile
- Geotechnical Hazard Locations
- Manmade Hazard Locations
- River Discharge
- Sediment Load
- Bottom Type

MARINE OPERATIONS SUBGOAL 2:

Improve search and rescue and emergency response capabilities. Short-term trajectories of hours to days are required in conjunction with hazards in the water in order to assess location and survivability. Timeliness of products, as real-time, historical and forecast fields are mission critical.

- **Product MO-2.1:** SURFACE AND SUBSURFACE CURRENTS: Real-time products are critical as is access to forecast fields up to 12 hours in the future, and historical fields for the 30 days previous.
- **Product MO-2.2:** SURFACE WINDS: Real-time products are critical, as is access to forecast fields up to 12 hours in the future, and historical fields for the 30 days previous.
- **Product MO-2.3:** SEA SURFACE TEMPERATURE: Real-time for survivability models.
- **Product MO-2.4:** SEA STATE: Directional wave information is required for capsizing/swamping modules and drift trajectories of large vessels.
- **Product MO-2.5:** TOXIC/DANGEROUS MARINE ORGANISMS: Abundance and distribution of organisms which might affect survivability.
- **Product MO-2.6:** METEOROLOGY AFFECTING DETECTION: Weather conditions

can affect the ability to locate a target.

The variables required for Marine Operations Subgoal 2 include:

- Aerosol Type
- Average Upper Layer Temperature
- Average Upper Layer Dewpoint
- Boundary Layer Elevation
- Cloud Base Height
- Cloud Density
- Cloud Type
- Dew Point
- Humidity
- Cloud Amounts (low/mid/high)
- Pressure
- Air Temperature
- Wind
- Ice Concentration
- Ice Thickness
- Currents
- Sea Surface Temperature
- Directional Wave Spectra
- Precipitation Amount
- Precipitation Intensity
- Precipitation Type

MARINE OPERATIONS SUBGOAL 3:
Ensure safe and efficient marine operations and activities.

- **Product MO-3.1:** Observations, nowcasts and forecasts of open ocean, coastal and estuarine 4D fields available for real-time operations. Fields include winds, waves, currents, temperature, salinity, visibility, humidity, water levels, and ice.

- **Product MO-3.2:** Geotechnical hazards data on slope instabilities, hydrates, and bottom-type characterization.

- **Product MO-3.3:** Maps of fixed subsurface structures and hazards

- **Product MO-3.4:** Updated bathymetry

- **Product MO-3.5:** Monitoring of drifting hazards to navigation

The variables required for Marine Operations Subgoal 3 include:

- Aerosol type
- Average Upper Layer Temperature
- Average Upper Layer Dewpoint
- Cloud Base Height
- Cloud Density
- Cloud Type
- Dew Point
- Humidity
- Cloud Amounts (low/mid/high)
- Pressure
- Air Temperature
- Wind
- Bathymetry/Topography
- Ice Concentration
- Ice Thickness
- Salinity
- Ocean Temperature
- Currents
- Sea Surface Temperature
- Directional Wave Spectra
- Precipitation Amount
- Precipitation Intensity
- Precipitation Type
- Sea Level
- Current Profile
- Geotechnical Hazard Locations
- Manmade Hazard Locations
- River Discharge
- Sediment Load
- Bottom Type
- Heat Flux Components
- Geolocation Type

NATIONAL SECURITY

(Note: The term “coastal” below refers to both “denied” areas around the world, and areas accessible to U.S. *in situ* observations, including the U.S. homeland.)

NATIONAL SECURITY SUBGOAL 1:
Improve the effectiveness of maritime homeland security and warfighting effectiveness abroad, especially in the areas of mine warfare, port security, amphibious warfare, special operations and antisubmarine warfare.

- **Product NS-1.1:** Estimates/predictions of near-surface currents on hourly to seasonal (i.e. climatological) time scales.

- **Product NS-1.2:** Estimates/predictions of near-bottom currents on hourly to seasonal time scales.

- **Product NS-1.3:** Estimates/predictions of tidal period, sea level/water level and velocity fluctuations.

- **Product NS-1.4:** Estimates/predictions of near water clarity on hourly to seasonal time scales.

- **Product NS-1.5:** Estimates/predictions of sediment transport on hourly to seasonal time scales.

- **Product NS-1.6:** Estimates/predictions of acoustic performance, especially on the continental shelf on daily to seasonal timescales.

- **Product NS-1.7:** Estimates/predictions of acoustic detection capability.

  Variables required for National Security Subgoal 1 include:
  - 3-D Vector Currents
  - 3-D Water Temperature
  - 3-D Salinity
  - 3-D Suspended Sediment (for density)
  - Flux Estimates of Momentum, Heat, Moisture/Freshwater, and Radiation
  - Wind Vectors
  - Water Temperature
  - Air Temperature
  - Humidity
  - Long-Wave Radiation
  - Solar Radiation
  - Precipitation Amount
  - River Discharge
  - Bathymetry
  - Sea Level/Ocean-Sea Surface Height
  - Bottom Characteristics (type, vegetation, sediment composition and thickness, acoustic stratigraphy)
  - Ambient Noise
  - Nutrients
  - Bioluminescence
  - Optical Properties
  - Ocean Color
  - Surface Roughness

NATIONAL SECURITY SUBGOAL 2:
Improve safety and efficiency of operations at sea.

- **Product NS-2.1:** Improved wave forecasts at the 3-7 day range, especially for storms and tropical cyclones.

- **Product NS-2.2:** High-resolution (to include variability at scales of meters) shallow-water wave and surf forecasts, especially in denied areas.

- **Product NS-2.3:** Real-time near-surface velocity estimates and forecasts for search and rescue.

- **Product NS-2.4:** Improved navigational products.

  Variables required for National Security Subgoal 2 include:
  - Directional Wave Spectra
  - Bathymetry
  - Wind Vectors
  - 3-D Vector Currents
  - Ice Concentration
  - Ice Thickness
  - Atmospheric Visibility

NATIONAL SECURITY SUBGOAL 3
Establish the capability to detect airborne and waterborne contaminants in ports, harbors, and littoral regions at home and abroad, and to predict the dispersion of those contaminants for planning, mitigation, and remediation.

- **Product NS-3.1:** Background levels of nuclear, biological and chemical (NBC) contaminants.

- **Product NS-3.2:** Analyses and predictions of NBC concentrations on scales from the sub-hourly to weekly.

  Variables required for National Security Subgoal 3 include:
  - 3-D Vector Currents
  - Wind Vectors
  - Water Contaminant Observations (both initial conditions and real-time updates)
  - Bottom Characteristics (sediments composition)

NATIONAL SECURITY SUBGOAL 4:
Support environmental stewardship

- **Product NS-4.1:** Physiological descriptions of sensitivity to and utilization of acoustic signals by classes of marine mammals.

- **Product NS-4.2:** Real-time and climatological marine mammal/protected species distributions.

- **Product NS-4.3:** Real-time velocity fields in locations of hazardous material spills or potential spills.

  Variables required for National Security Subgoal 4 include:
  - Marine Mammal Abundance
  - All variables listed for Subgoals 1 and 3.

National Security Subgoal 5:
Improve at-sea system performance through more accurate characterizations and prediction of the marine boundary layer.

- **Product NS-5.1:** Improved prediction of electromagnetic/electro-optic propagation through the marine boundary layer in support of strike warfare, antiaircraft warfare, and anti-submarine warfare.

- **Product NS-5.2:** Improved prediction of near-surface visibility

  Variables required for National Security Subgoal 5 include:
  - Water Temperature (especially sea surface temperature)
  - Humidity
  - Marine Boundary Layer Height
  - Directional Wave Spectra (especially wave height)
  - Aerosols
  - Atmospheric Visibility

MARINE RESOURCES

Note: The following subgoals, agreed to by the Marine Resources Working Group on March 11, 2002, represent a consolidation of several earlier subgoals identified in the group's working paper and one additional concern related to monitoring the status of endangered species, marine mammals and seabirds.

MARINE RESOURCES SUBGOAL 1:
Measure fluctuations in harvested marine species and improve predictions of abundance, distribution, recruitment and sustainable yield.

MARINE RESOURCES SUBGOAL 2:
Measure and detect changes in spatial extent and condition of habitat, production and biodiversity.

MARINE RESOURCES SUBGOAL 3:
Predict effects of fishing and other human activities on habitat and biodiversity

MARINE RESOURCES SUBGOAL 4:
Improve knowledge of spatial distribution of habitat and of living marine resources.

MARINE RESOURCES SUBGOAL 5:
Improve measurements of abundance and impacts (environmental, human) on endangered species, marine mammals and seabirds.

At the March workshop, products related to these subgoals, variables required for measurement, and methods of observation were identified and placed within the matrix format used by all working groups.

MARINE ECOSYSTEMS

MARINE ECOSYSTEMS SUBGOAL 1:
For each region, establish ecological "climatologies" for sea surface temperature (SST) and sea surface salinity (SSS); surface dissolved inorganic N, P and Si; surface chlorophyll-a concentration and the abundance of harmful algal (HAB) species.

- **Product ME-1.1:** Estimates of the SST field and its variability on monthly, seasonal, interannual and decadal time scales for the coastal ocean within 25 km of the shoreline. (Here and in the following, 25 km is thought to be an arbitrary distance and within any region it likely corresponds to the continental shelf and shelf break.)
- **Product ME-1.2:** Estimates of the SSS field and its variability on monthly, seasonal, interannual and decadal time scales for the coastal ocean within 25 km of the shoreline.
- **Product ME-1.3:** Estimates of surface DIN, P and Si fields and their variability on monthly, seasonal, interannual and decadal time scales for the coastal ocean within 25 km of the shoreline.
- **Product ME-1.4:** Estimates of the chl-a field and its variability on monthly, seasonal, interannual and decadal time scales for the coastal ocean within 25 km of the shoreline.
- **Product ME-1.5:** Estimates of the abundances of HAB species and their variability on monthly, seasonal, interannual and decadal time scales for hot spots (sites where repeated HAB events have occurred).

  Variables required for Marine Ecosystems Subgoal 1 include:
  - SST
  - SSS
  - Surface Concentrations of DIN, DIP, and DISi
  - Surface Chl-a Concentration
  - Cell Densities of HAB Species

MARINE ECOSYSTEMS SUBGOAL 2:
Obtain more timely detection of changes in the areal extent and physiological state of biologically structured habitats (coral reefs, submerged attached vegetation, mangroves, and tidal marshes)

- **Product ME-2.1:** Annual report of areal distribution (GIS) of biologically structured habitats by region and for U.S. coastal waters as a whole (specifically as tidal marsh, mangrove stands, seagrasses, macrobenthic algae, coral reefs, deep-water hard bottom, and shellfish beds as appropriate to the region.

  Variables required for Marine Ecosystems Subgoal 2 include:
  - Seagrass Bottom Area Cover
  - Minimum and Maximum Seagrass Depth
  - Seagrass Canopy Height

- Seagrass Plant Density
- Seagrass Species Composition

MARINE ECOSYSTEMS SUBGOAL 3:
Obtain more timely detection of changes in species diversity of marine and estuarine flora and fauna.

- **Product ME-3.1:** Annually updated inventories of species at reference sites and representative stations for the following groups: macrobenthic animals and plants, microphytoplankton (> 20 um), macrozooplankton (> 200 um), fish, mammals and birds.

- **Product ME-3.2:** Annually updated reports of the number of marine and estuarine species legally defined as at-risk that are increasing, decreasing or stable by region and for U.S. coastal waters as a whole.

  Variables required for Marine Ecosystems Subgoal 3 include:
  - Species composition and abundance based on monthly (plankton), seasonal (fish, birds and mammals), and annual (sub-tidal and intertidal macrobenthose observations

MARINE ECOSYSTEMS SUBGOAL 4:
Obtain more timely detection and improved prediction of coastal eutrophication measured in terms of accumulations of organic matter and oxygen depletion of bottom waters on ecosystem and regional scales for coastal marine and estuarine ecosystems.

- **Product ME-4.1:** Improved estimates of episodic and seasonal inputs of freshwater, N, P and Si from coastal drainage basins and airsheds into semi-enclosed systems and to the coastal ocean within each region.

- **Product ME-4.2:** Seasonal inventories of total organic C, total organic N and P, and chlorophyll-a content of representative semi-enclosed bodies of water and of the coastal ocean within 25 km of the coast line.

- **Product ME-4.3:** Annual estimates of the volume of water that experiences hypoxia (DO < 2 ppm) for 1 month or more in representative semi-enclosed systems and for the coastal ocean (EEZ) in each region.

- **Product ME-4.4:** Annual predictions of the temporal and areal extent of seasonal bottom water hypoxia for selected semi-enclosed and continental shelf systems based on predictions of monthly river and stream flows and the predicted effectiveness of nutrient control efforts.

Variables required for Marine Ecosystems Subgoal 4 include:
- Atmospheric Deposition
- Surface And Groundwater Discharges and associated inputs of organic C and N and Dissolved Inorganic N, P and Si
- SST
- SSS
- Surface Chlorophyll-A Fields
- Vertical Profiles of Temperature
- Salinity
- TOC
- TN
- Chlorophyll-A
- Dissolved Inorganic N, P, And Si
- Dissolved Oxygen

MARINE ECOSYSTEMS SUBGOAL 5:
Obtain more timely detection and improved prediction of the presence, growth, movement, and toxicity of toxic and noxious algal species.

- **Product ME-5.1:** Annual report of the frequency of harmful algal events (blooms of toxic species, HAB induced fish kills and illness in humans) that have high, medium, and low intensity in terms of both spatial and temporal extent for each region and U.S. coastal waters.

- **Product ME-5.2:** For hot spots (areas and seasons that have a history of HAB events), weekly reports on the distribution and abundance of selected HAB species.

- **Product ME-5.3:** For hot spots, weekly forecasts (updated daily) of the formation and trajectory of HABs and where and when the bloom is likely to affect beaches, shellfish beds and aquaculture operations.

  Variables required for Marine Ecosystems subgoal 5 include:
  - Inputs of freshwater sediments and nutrients (surface and groundwater discharges, rainfall)
  - Surface Currents and Waves
  - Incident and Downwelling PAR
  - Vertical Profiles of Salinity, Temperature, Dissolved Inorganic Nutrients, Dissolved Organic Carbon and Nitrogen
  - Surface and Vertical Distributions (abundance, biomass) of HAB Species and Toxin Concentrations
  - Shellfish Bed Closures and Fish Kills caused by HAB species
  - Incidence of human illness caused by the consumption of seafood contaminated by HAB species or by exposure (skin contact,

inhalation) to HAB toxins

MARINE ECOSYSTEMS SUBGOAL 6:
Obtain more timely detection of non-native species and improved predictions of the probability they will become invasive species.

- **Product ME-6.1:** Annual report on the occurrence of non-native species in semi-enclosed bodies of water for each region where occurrence is measured in terms of both surface area affected and number of species relative to the number of native species.

  Variables required for Marine Ecosystems Subgoal 6 include:
  - Number and Distribution (abundance) of native and non-native species per unit area

MARINE ECOSYSTEMS SUBGOAL 7:
Obtain more timely detection and improved predictions of diseases in and mass mortalities of fish, marine mammals and birds.

- **Product ME-7.1:** Annual report on the frequency of strandings and mass mortalities of marine organisms for each region and U.S. coastal waters.

- **Product ME-7.2:** For hot spots (areas and seasons with a history of fish lesions), weekly updates on the incidence of skin lesions in fish populations from semi-enclosed bodies of water.

- **Product ME-7.3:** For hot spots, weekly updates on infection rates of Dermo and MSX in oyster populations.

  Variables required for Marine Ecosystems Subgoal 7 include:
  - Location and Number of organisms involved in each mortality and stranding event
  - Number of fish species and percent of each population with skin lesions
  - Number of oysters infected

MARINE ECOSYSTEMS SUBGOAL 8:
Obtain improved predictions of the effects of habitat modification and loss on species diversity.

- **Product ME-8.1:** Annual report of the species composition and diversity of macrobenthic organisms, macrozooplankton, fishes, mammals and birds in semi-enclosed bodies of water relative to the distribution of biologically structured and abiotic (hard and soft bottom substrates, mud flats) habitats.

- **Product ME-8.2:** Annual report of the distribution and abundance of marine and estuarine species that have been legally identified as at-risk relative to the distribution of biologically structured and abiotic (hard and soft bottom substrates, mud flats) habitats.

  Variables required for Marine Ecosystems Subgoal 8 include:
  - Species Composition and Abundance based on monthly (plankton), seasonal (fish, birds and mammals), and annual (sub-tidal and intertidal macrobenthos) observations
  - Area of Biological Structured and Abiotic Habitats
  - Temporal and Spatial Extent of Hypoxia

Marine Ecosystems Subgoal 9:
Monitor anthropogenic contaminants and their effects on the ecosystem.

- **Product ME-9.1:** Annual report of the distribution and levels of anthropogenic contaminants.

- **Product ME-9.1:** For hot spots (areas and seasons that have a history of contaminations), weekly (daily) reports on the distribution and levels of anthropogenic contaminants.

  Variables required for Marine Ecosystems Subgoal 9 include:
  - Concentrations of Heavy Metals, Endocrine Disrupters, PCBs and Toxins, Marine Debris, Pesticides, Noise, Hydrocarbons, Antibiotics, and Pathogens.

NATURAL HAZARDS

NATURAL HAZARDS SUBGOAL 1:
Provide adequate data gathering capabilities at the temporal and spatial scales required to improve the understanding of the physical and biological nature of natural hazards.

- **Product NH-1.1:** Analyses of climate, weather, and hazard linkages, with special attention to the linkages between weather events and floods and between weather events and storm surges and waves.

- **Product NH-1.2:** Descriptions of the fundamental relationships between ecosystem dynamics and natural hazards, including what ecosystem changes precede and contribute to natural hazards and how these changes, in turn, affect the structure and function of ecosystems and the probability of subsequent events.

- **Product NH-1.3:** Analyses of the interactions between natural hazards, manmade environments and technological systems.

NATURAL HAZARDS SUBGOAL 2:
Improve modeling capabilities and predictions.

- **Product NH-2.1:** Quantitative prediction of tropical cyclones and extratropical systems with respect to formation, track and intensification, landfall intensity (wind and precipitation), timing and duration, and location.
- **Product NH-2.2:** Improved predictive capabilities with regard to ecosystem response to physical and biological events.
- **Product NH-2.3:** Improved fluid mechanic, air-sea-land interactively coupled models of the coastal zone with bays, estuaries and rivers coupled to the open ocean.
- **Product NH-2.4:** Improved wind-wave models, particularly for shallow coastal waters and bays.
- **Product NH-2.5:** Improved flooding and inundation models which couple all the relevant processes including storm surge, surface waves, rainfall, and topography.
- **Product NH-2.6:** Improved beach and dune erosion models.

NATURAL HAZARDS SUBGOAL 3:
Provide timely dissemination and convenient online access to real-time hazards observations and warnings as well as complete metadata and retrospective information on all aspects of natural disaster reduction.

- **Product NH-3.1:** Conversion of meteorological and oceanographic data into useful decision-making information.
- **Product NH-3.2:** Established national and regional databases and information exchanges facilities dedicated to hazard, risk and disaster prevention.
- **Product NH-3.3:** An established network of extension and education regimes to ensure end users have the knowledge and training to collect, manage, and disseminate data, to produce products and services, and to apply those results to addressing their needs.
- **Product NH-3.4:** An established evaluation and feedback mechanism to routinely assess whether or not the observational systems are operating satisfactorily and meeting user requirements.

NATURAL HAZARDS SUBGOAL 4:
Develop new instrumentation to improve the existing systems, i.e., making them workable in wider areas, for longer duration, and with higher reliability, safety, and efficiency.

- **Product NH-4.1:** Improved marine biological measurements, with new instrumentation that can directly measure or sample the biological properties (i.e. chlorophyll vs. fluorescence) and instrumentation for measuring chemical constituents that affect biological productivity.
- **Product NH-4.2:** Increased efficiency of maintaining observations in the ocean environment.
- **Product NH-4.3:** Determination of the optimal mix of observations required to cover the complete suite of important weather and climate variables, broadly defined.

Variables Required for Natural Hazards Subgoals 1-4 include:

- Winds (including wind stress)
- Air Pressure
- Air Temperature
- Surface Waves
- Water Level
- Bathymetry
- Ocean Surface Currents and Waves
- Ocean Surface Roughness
- Coastal and Estuarine Currents
- Sea Surface Temperature
- Sea Surface Salinity
- Sea and Lake Ice: areal coverage and concentration, extent, thickness, and reflectivity
- Color (phytoplankton biomass)
- Nutrients
- Suspended Solids, Turbidity
- pCO_2, O_2
- Plankton Species

PUBLIC HEALTH

PUBLIC HEALTH SUBGOAL 1:
Obtain nationally standardized measures of the risk of

illness or injury from water contact activities in coastal waters (microbiological pathogens, harmful algal bloom toxins, encounters with dangerous marine organisms, and hazardous ocean conditions).

- **Product PH-1.1:** Assessment and prediction of risk from microbial pathogens.

  Variables required for Product PH-1.1 include:
  - Microbiological Indicator and/or Pathogen Levels at beaches around the country
  - Measure of how many people are swimming
  - Reports of swimming warnings and the exceedances these are based on
  - Anecdotal measures of illness rates related to exposure to contaminated waters.
  - Nearshore Circulation
  - Discharge to the Coastal Zone

- **Product PH-1.2:** Assessment and prediction of risk from HAB exposure.

  Variables required for Product PH-1.2 include:
  - Concentration of HAB and HAB products
  - Measure of how many people are exposed
  - Reports of human illness due to HABS
  - Anecdotal measures of illness rates related to exposure to HABs
  - Proxy measures such as fish kills
  - Sea Surface Temperature
  - Nearshore Circulation
  - Chlorophyll

- **Product PH-1.3:** Assessment and prediction of risk from dangerous marine animals.

  Variables required for Product PH-1.3 include:
  - Distribution and density of dangerous marine organisms
  - Incidence rates of deaths and injuries due to contact with dangerous marine organisms

- **Product PH-1.4:** Assessment and prediction of risk from hazardous ocean conditions.

  Variables required for Product PH-1.4 include:
  - Occurrence of hazardous ocean conditions
  - Incidence rates of drownings and/or rescues

PUBLIC HEALTH SUBGOAL 2:
Obtain nationally standardized measures of the risk of illness from consuming seafood.

- **Product PH-2.1:** Assessment and prediction of risk from pathogens in seafood.
  Variables required for Product PH-2.1 include:
  - Microbiological Contamination in the water in shellfish growing areas
  - Microbiological Contamination in shellfish tissue
  - Shellfish Consumption, including data on key demographic groups and geographic regions
  - Number of shellfish beds closed
  - Number of reported illnesses

- **Product PH-2.2:** Assessment and prediction of risk from HAB toxins in seafood.

  Variables required for Product PH-2.2 include:
  - HAB Contamination in the water in shellfish growing areas
  - HAB Toxins in shellfish tissue
  - Shellfish Consumption, including data on key demographic groups and geographic regions
  - Number of shellfish beds closed
  - Number of reported illnesses

- **Product PH-2.3:** Assessment and prediction of risk from anthropogenic contaminants in seafood.

  Variables required for Product PH-2.3 include:
  - Chemical Contamination in the water
  - Chemical Contamination in seafood tissue
  - Seafood Consumption, including data on key demographic groups and geographic regions

APPENDIX VII: MATRIX RANKING

Following the deconfliction of the variables (ie., making sure the same variables are identified by the same terminology across all four matrix working groups), the list from each working group has been sorted by priority by each working group.

The sorted variables have been assigned a ranking based on their prioritization by each working group. The variable with the highest priority has been assigned the highest rank (e.g., the highest ranked variable of the list of 35 has been assigned a ranking of 35, the second highest ranked variable of the list has been assigned a ranking of 34, etc.).

Once each variable in each list was assigned a ranking, the average score of that variable was determined. Example: salinity had a ranking of 28 in Matrix WG 1, 33 in Matrix WG 2, 27 in Matrix WG 3, and 28 in Matrix WG 4. The average rank was 29. The average

MATRIX 1 DECONFLICTED RANKED LIST

MATRIX 1	GRP RANK	BIN RANK	PHYS/BIO
VECTOR CURRENTS	16	3	1
WATER TEMPERATURE	15	3	1
OCEAN COLOR	14	2	2
WIND VECTOR	14	3	1
DIRECTIONAL WAVE SPECTRA	13	3	1
BATHYMETRY/TOPOGRAPHY	12	3	1
SEA LEVEL	12	3	1
SURFACE HEAT FLUX	12	2	1
SUSPENDED SEDIMENTS	12	2	2
DISSOLVED OXYGEN	11	2	2
ICE CONCENTRATION	11	2	1
NUTRIENTS	11	2	2
SALINITY	11	3	1
OPTICAL PROPERTIES	9	2	2
SEDIMENT CONTAMINANTS	9	2	2
WATER CONTAMINANTS	9	2	2
FISH ABUNDANCE	8	2	2
FISH SPECIES	8	2	2
PRECIPITATION AMOUNT	8	2	1
BOTTOM CHARACTERISTICS	7	3	1
PHYTOPLANKTON SPECIES COMPOSITION	7	3	2
RIVER DISCHARGE	7	3	1
AIR TEMPERATURE	6	1	1
BENTHIC ABUNDANCE	6	1	2
BENTHIC SPECIES	6	1	2
pCO_2	6	1	2
SEAFOOD CONTAMINANTS	6	1	2
ZOOPLANKTON ABUNDANCE	6	1	2
ZOOPLANKTON SPECIES	6	1	2
ATMOSPHERIC PRESSURE	5	1	1
BIOACOUSTICS	5	1	2
HUMAN PATHOGENS: WATER	5	1	2
HUMAN PATHOGENS: SEAFOOD	5	1	2
HUMIDITY	4	1	1
SEAFLOOR SEISMICITY	2	1	1

was then multiplied by the number of lists that the variable appeared on. For salinity, since it appeared on all four WG lists, the final score was 116 (29*4). For a variable that was ranked on only three lists, the average score would be multiplied by 3.

The variable with the highest score was considered the variable with highest priority across all four working groups.

MATRIX 2 DECONFLICTED RANKED LIST

MATRIX 2	GRP RANK	BIN RANK	PHYS/BIO
SALINITY	6	3	1
WATER TEMPERATURE	5	3	1
VECTOR CURRENTS	5	3	1
WIND VECTORS	5	3	1
SURFACE HEAT FLUX	5	3	1
SEA LEVEL	4	3	1
PHYSICAL CHARACTERIIZATION OF THE HABITAT	3	3	1
DIRECTIONAL WAVE SPECTRA	3	3	1
BATHYMETRY TOPOGRAPHY	4	2	1
ICE CONCENTRATION	4	2	1
FISH SPECIES // FISH ABUNDANCE	3	3	2
PHYTOPLANKTON SPECIES COMPOSTION	3	3	2
HUMAN PATHOGENS IN WATER	2	2	2
HUMAN PATHOGENS IN SEAFOOD	2	2	2
SURFACE & GROUNDWATER INPUT	2	2	2
NUTRIENTS	2	2	2
CARBON-TOTAL INORGANIC	2	2	2
CARBON-TOTAL ORGANIC	2	2	2
OPTICAL PROPERTIES	2	2	2
BENTHIC ABUNDANCE/BIOMASS	1	2	2
BENTHIC SPECIES	1	2	2
SEAFOOD PATHOGENS	1	2	2
SEAFOOD CONTAMINANTS	1	2	2
ZOOPLANKTON SPECIES	1	1	2
ZOOPLANKTON ABUNDANCE	1	1	2
TOTAL BACTERIAL BIOMASS	1	1	2
CATCH AND EFFORT BY GEAR TYPE	1	1	2
SEDIMENT CONTAMINANTS***	1	1	2
WATER CONTAMINANTS	1	1	2
DISSOLVED OXYGEN	1	1	2
ATMOSPHERIC VISIBILITY	1	1	2
SURFACE SPECTRAL IRRADIANCE (UV & VIS)			2
SEAFOOD CONSUMPTION			2
BEACH USAGE			2
AREAL EXTENT OF COASTAL WETLANDS			2

*exploited, unexplointed, protected, invasive
**freshwater, CO_2, nutrients, air pressure, relative humidity
***organics, metals, etc.
****beach usage, seafood consumption, health warnings
*****inclusive of wetlands

MATRIX 3 DECONFLICTED RANKED LIST

MATRIX 3	GRP RANK	PHYS/BIO
WIND VECTORS	1	1
SALINITY	2	1
ZOOPLANKTON SPECIES	2	2
RIVER DISCHARGE	3	1
BATHYMETRY TOPOGRAPHY	4	1
BOTTOM CHARACTERISTICS	5	1
CARBON-TOTAL ORGANIC	6	2
VECTOR CURRENTS	6	1
DIRECTIONAL WAVE SPECTRA	7	2
WATER CONTAMINANTS	8	2
WATER TEMPERATURE	7	1
OCEAN COLOR	8	1
SEA LEVEL	9	1
AIR PRESSURE	10	1
AIR TEMPERATURE	10	1
HUMIDITY	10	1
SEAFOOD CONTAMINANTS	11	2
AIR-AEROSOL TYPE	12	2
OPTICAL PROPERTIES	11	1
SURFACE SPECTRAL IRRADIANCE UV AND VIS	12	1
AMBIENT NOISE	13	2
SUSPENDED SEDIMENT	14	2
ICE CONCENTRATIONS	13	1
MARINE MAMMALS: ABUNDANCE	14	2
MARINE MAMMALS: MORTALITY EVENTS	15	2
FISH ABUNDANCE/BIOMASS	20	2
FISH SPECIES	20	2
DISSOLVED OXYGEN	21	2
HUMAN PATHOGENS IN WATER	21	2
NUTRIENTS	24	2
OCEAN (INCLUDING COASTAL) SURFACE-CHLOR A	25	2
OCEAN (WATER-COLUMN INCLUDING COASTAL)-TN	29	2
pCO_2	31	2
PHYSICAL CHARACTERIZATION OF HABITAT	32	1
ZOOPLANKTON ABUNDANCE/BIOMASS	32	2
NON-NATIVE SPECIES	33	2
PHYTOPLANKTON ABUNDANCE/BIOMASS	34	2
PHYTOPLANKTON SPECIES	34	2
PHYTOPLANKTON-PRODUCTIVITY	35	2
PRECIPITATION-AMOUNT	36	2

MATRIX 4 DECONFLICTED RANKED LIST

MATRIX 2	GRP RANK	BIN RANK	PHYS/BIO
BATHYMETRY/TOPOGRAPHY	1	3	1
WATER TEMPERATURE	2	3	1
SALINITY	4	3	1
SEA LEVEL	5	3	1
VECTOR CURRENTS	6	3	1
NUTRIENTS	8	3	2
WIND VECTORS	9	3	1
DIRECTIONAL WAVE SPECTRA	10	3	1
ICE-CONCENTRATION	11	2	1
SURFACE HEAT FLUX	12	2	1
OCEAN COLOR	13	2	2
FISH ABUNDANCE/BIOMASS	14	2	2
FISH SPECIES	14	2	2
AIR-TEMPERATURE	15	2	1
RIVER DISCHARGE	16	2	1
PRECIPITATION-AMOUNT	17	2	1
SEAFOOD CONTAMINANTS	18	2	2
BENTHOS--ABUNDANCE	19	2	2
ATMOSPHERIC PRESSURE	20	2	1
ICE-THICKNESS	21	1	1
CONTAMINANTS: SEAFOOD	22	1	2
CONTAMINANTS: SEDIMENTS	22	1	2
CONTAMINANTS: WATER	22	1	2
ZOOPLANKTON ABUNDANCE/BIOMASS	23	1	2
ZOOPLANKTON SPECIES	23	1	2
BOTTOM CHARACTERISTICS	24	1	1
BENTHOS-SPECIES	25	1	2
DISSOLVED OXYGEN	26	1	2
OCEAN-SSH	27	1	1
OPTICAL PROPERTIES	28.5	1	2
OPTICAL PROPERTIES	28.5	1	2
PATHOGENS: SEAFOOD	28.5	1	2
PATHOGENS: WATER	28.5	1	2
MARINE MAMMALS: ABUNDANCE	28.5	1	2
MARINE MAMMALS: MORTALITY EVENTS	32	1	2
CLOUDS: LOW, MID, HIGH AMOUNTS	33	1	1
ATMOSPHERIC VISIBILITY	34	1	1
SEABIRDS: ABUNDANCE			2
SEABIRDS: SPECIES			2

MASTER MATRIX LIST-FINAL CALCULATIONS AND RANKING

VARIABLE	MATRIX 1	MATRIX 2	MATRIX 3
SALINITY	28	33	27
WIND VECTOR	33	30	28
WATER TEMPERATURE	34	32	20
BATHYMETRY/ TOPOGRAPHY	31	26	24
SEA LEVEL	30	29	18
DIRECTIONAL WAVE SPECTRA	32	27	20
VECTOR CURRENTS	35	9	21
ICE CONCENTRATION	27	25	14
WATER CONTAMINANTS	13	31	20
NUTRIENTS	16	18	9
FISH SPECIES	11	24	11
FISH ABUNDANCE	10	23	11
ZOOPLANKTON SPECIES	9	11	26
OPTICAL PROPERTIES	14	18	16
SURFACE HEAT FLUX	29	19	0
RIVER DISCHARGE	24	0	25
SEAFOOD CONTAMINANTS	5	12	17
AIR TEMPERATURE	23	0	17
OCEAN COLOR	18	0	19
BOTTOM CHARACTERISTICS	25	0	23
ATMOSPHERIC PRESSURE	22	0	17
HUMAN PATHOGENS: WATER	3	21	10
DISSOLVED OXYGEN	15	6	10
PHYTOPLANKTON SPECIES COMPOSITION	19	22	3
ZOOPLANKTON ABUNDANCE	8	10	5
PRECIPITATION AMOUNT	26	0	1
BENTHIC ABUNDANCE	6	15	0
SEDIMENT CONTAMINANTS	12	7	0
BENTHIC SPECIES	7	14	0
HUMAN PATHOGENS: SEAFOOD	2	20	0
HUMIDITY	21	0	17
CARBON-TOTAL ORGANIC	0	16	22
PHYSICAL CHARACTERIZATION OF HABITAT	0	28	5
SUSPENDED SEDIMENTS	17	0	16
SURFACE SPECTRAL IRRADIANCE	0	4	16
SEAFOOD PATHOGENS	0	13	0
MARINE MAMMALS ABUNDANCE	0	0	13
MARINE MAMMALS: MORTALITY EVENTS	0	0	12
SEAFLOOR SEISMICITY	20	0	0
pCO_2	4	0	6
SURFACE AND GROUNDWATER INPUT	0	19	0
CARBON-TOTAL INORGANIC	0	17	0
AIR- AEROSOL TYPE	0	0	16
AMBIENT NOISE	0	0	15
ATMOSPHERIC VISIBILITY	0	5	0
ICE THICKNESS	0	0	0
TOTAL BACTERIAL BIOMASS	0	9	0
OCEAN- SURFACE CHLOR A	0	0	8
CATCH AND EFFORT BY GEAR TYPE	0	8	0
OCEAN- WATER COLUMN- TN	0	0	7
OCEAN- SSH	0	0	0
NON- NATIVE SPECIES	0	0	4
PHYTOPLANKTON ABUNDANCE/ BIOMASS	0	0	3
SEAFOOD CONSUMPTION	0	3	0
CLOUDS: LOW/ MID/ HIGH AMOUNTS	0	0	0
PHYTOPLANKTON PRODUCTIVITY	0	0	2
BEACH USAGE	0	2	0
AREAL EXTENT OF COASTAL WETLANDS	0	1	0
BIOACOUSTICS	1	0	0

	MATRIX 4	AVERAGE	HITS	RANK	FINAL RANK	PHYS=1/BIO=2	
	28	29	4	116	1	1	
	24	28.75	4	115	2	1	
	29	28.75	4	115	3	1	
	30	27.75	4	111	4	1	
	27	26	4	104	5	1	
	23	25.5	4	102	6	1	
	26	22.75	4	91	7	1	
	22	22	4	88	8	1	
	10	18.5	4	74	9	2	
	25	17	4	68	10	2	
	19	16.25	4	65	11	2	
	18	15.5	4	62	12	2	
	9	13.75	4	55	13	2	
	4	13	4	52	14	2	
	21	17.25	3	51.75	15	1	
	16	16.25	3	48.75	16	1	
	14	12	4	48	17	2	
	17	14.25	3	42.75	18	1	
	20	14.25	3	42.75	19	2	
	8	14	3	42	20	1	
	12	12.75	3	38.25	21	1	
	4	9.5	4	38	22	2	
	6	9.25	4	37	23	2	
	0	11	3	33	24	2	
	9	8	4	32	25	2	
	15	10.5	3	31.5	26	1	
	13	8.5	3	25.5	27	2	
	10	7.25	3	21.75	28	2	
	7	7	3	21	29	2	
	4	6.5	3	19.5	30	2	
	0	9.5	2	19	31	1	
	0	9.5	2	19	32	2	
	0	8.25	2	16.5	33	1	
	0	8.25	2	16.5	34	2	
	0	5	2	10	35	2	
	4	4.25	2	8.5	36	2	
	3	4	2	8	37	2	
	3	3.75	2	7.5	38	2	
	0	5	1	5	39	1	
	0	2.5	2	5	40	2	
	0	4.75	1	4.75	41	2	
	0	4.25	1	4.25	42	2	
	0	4	1	4	43	2	
	0	3.75	1	3.75	44	2	
	1	1. 5	2	3	45	2	
	11	2.75	1	2.75	46	1	
	0	2.25	1	2.25	47	2	
	0	2	1	2	48	2	
	0	2	1	2	49	2	
	0	1.75	1	1.75	50	2	
	5	1.25	1	1.25	51	1	
	0	1	1	1	52	2	
	0	0.75	1	0.75	53	2	
	0	0.75	1	0.75	54	2	
	2	0.5	1	0.5	55	1	
	0	0.5	1	0.5	56	2	
	0	0.5	1	0.5	57	2	
	0	0.25	1	0.25	58	2	
	0	0.25	1	0.25	59	2	

MATRIX VARIABLE RANKING

VARIABLE	RANK	DISCIPLINE
SALINITY	1	1
WIND VECTOR	2	1
WATER TEMPERATURE	3	1
BATHYMETRY/TOPOGRAPHY	4	1
SEA LEVEL	5	1
DIRECTIONAL WAVE SPECTRA	6	1
VECTOR CURRENTS	7	1
ICE CONCENTRATION	8	1
WATER CONTAMINANTS	9	2
NUTRIENTS	10	2
FISH SPECIES	11	2
FISH ABUNDANCE	12	2
ZOOPLANKTON SPECIES	13	2
OPTICAL PROPERTIES	14	2
SURFACE HEAT FLUX	15	1
RIVER DISCHARGE	16	1
SEAFOOD CONTAMINANTS	17	2
AIR TEMPERATURE	18	1
OCEAN COLOR	19	2
BOTTOM CHARACTERISTICS	20	1
ATMOSPHERIC PRESSURE	21	1
HUMAN PATHOGENS: WATER	22	2
DISSOLVED OXYGEN	23	2
PHYTOPLANKTON SPECIES COMPOSITION	24	2
ZOOPLANKTON ABUNDANCE	25	2
PRECIPITATION AMOUNT	26	1
BENTHIC ABUNDANCE	27	2
SEDIMENT CONTAMINANTS	28	2
BENTHIC SPECIES	29	2
HUMAN PATHOGENS:SEAFOOD	30	2
HUMIDITY	31	1
CARBON-TOTAL ORGANIC	32	2
PHYSICAL CHARACTERIZATION OF HABITAT	33	1
SUSPENDED SEDIMENTS	34	2
SURFACE SPECTRAL IRRADIANCE	35	1
SEAFOOD PATHOGENS	36	2
MARINE MAMMALS ABUNDANCE	37	2
MARINE MAMMALS: MORTALITY EVENTS	38	2
SEAFLOOR SEISMICITY	39	1
pCO_2	40	2
SURFACE AND GROUNDWATER INPUT	41	2
CARBON-TOTAL INORGANIC	42	2
AIR-AEROSOL TYPE	43	2
AMBIENT NOISE	44	2
ATMOSPHERIC VISIBILITY	45	1
ICE THICKNESS	46	1
TOTAL BACTERIAL BIOMASS	47	2
OCEAN-SURFACE CHLOR A	48	2
CATCH AND EFFORT BY GEAR TYPE	49	2
OCEAN-WATER COLUMN-TN	50	2
OCEAN-SSH	51	1
NON-NATIVE SPECIES	52	2
PHYTOPLANKTON ABUNDANCE/BIOMASS	53	2
SEAFOOD CONSUMPTION	54	2
CLOUDS: LOW/MID/HIGH AMOUNTS	55	1
PHYTOPLANKTON PRODUCTIVITY	56	2
BEACH USAGE	57	2
AREAL EXTENT OF COASTAL WETLANDS	58	2
BIOACOUSTICS	59	2

1=PHYS/MET
2=BIO/CHEM

MASTER VARIABLE RANKING-PHYSICAL-METEOROLOGICAL-COASTAL PROCESSES VARIABLES

VARAIBLE	RANK
SALINITY	1
WIND VECTOR	2
WATER TEMPERATURE	3
BATHYMETRY/TOPOGRAPHY	4
SEA LEVEL	5
DIRECTIONAL WAVE SPECTRA	6
VECTOR CURRENTS	7
ICE CONCENTRATION	8
SURFACE HEAT FLUX	15
RIVER DISCHARGE	16
AIR TEMPERATURE	18
BOTTOM CHARACTERISTICS	20
ATMOSPHERIC PRESSURE	21
PRECIPITATION AMOUNT	26
HUMIDITY	31
PHYSICAL CHARACTERIZATION OF HABITAT	33
SURFACE SPECTRAL IRRADIANCE	35
Seafloor Seismicity	39
ATMOSPHERIC VISIBILITY	45
ICE THICKNESS	46
OCEAN-SSH	51
CLOUDS: LOW/MID/HIGH AMOUNTS	55

MASTER VARIABLE RANKING-BIOLOGICAL-CHEMICAL-PUBLIC HEALTH VARIABLE

VARIABLE	OVERALL RANK
WATER CONTAMINANTS	9
NUTRIENTS	10
FISH SPECIES	11
FISH ABUNDANCE	12
ZOOPLANKTON SPECIES	13
OPTICAL PROPERTIES	14
SEAFOOD CONTAMINANTS	17
OCEAN COLOR	19
HUMAN PATHOGENS: WATER	22
DISSOLVED OXYGEN	23
PHYTOPLANKTON SPECIES COMPOSITION	24
ZOOPLANKTON ABUNDANCE	25
BENTHIC ABUNDANCE	27
SEDIMENT CONTAMINANTS	28
BENTHIC SPECIES	29
HUMAN PATHOGENS: SEAFOOD	30
CARBON-TOTAL ORGANIC	32
SUSPENDED SEDIMENTS	34
SEAFOOD PATHOGENS	36
MARINE MAMMALS ABUNDANCE	37
MARINE MAMMALS: MORTALITY EVENTS	38
pCO_2	40
SURFACE AND GROUNDWATER INPUT	41
CARBON-TOTAL INORGANIC	42
AIR-AEROSOL TYPE	43
AMBIENT NOISE	44
TOTAL BACTERIAL BIOMASS	47
OCEAN-SURFACE CHLOR A	48
CATCH AND EFFORT BY GEAR TYPE	49
OCEAN-WATER COLUMN-TN	50
NON-NATIVE SPECIES	52
PHYTOPLANKTON ABUNDANCE/BIOMASS	53
SEAFOOD CONSUMPTION	54
PHYTOPLANKTON PRODUCTIVITY	56
BEACH USAGE	57
AREAL EXTENT OF COASTAL WETLANDS	58
BIOACOUSTICS	59

APPENDIX VIII-A: BIO/CHEM/PUBLIC HEALTH TECHNIQUE CATEGORIZATION

VARIABLE	OVERALL RANK	GROUP	OPERATIONAL	PRE-OPERATIONAL	PILOT	R & D
WATER CONTAMINANTS	9	Human	Mussel Watch; Sediment grab samples	Grab samples (water)	*In situ* filtering; Semi permeable membranes	Electrochemical probes; Fluorescence; Gene probes; Phytotoxics
NUTRIENTS (DISSOLVED INORG)	10	Chem	Moorings, discrete samples, underway sampling		Ships of Opportunity	UV detection of Nitrate AUVs / Gliders
FISH SPECIES	11	Species	ship-based physical collection; ship-based acoustics	AUVs (?)	Ships of Opportunity	ship-based optical systems (H); ship-based laser/LIDAR (H)
FISH ABUNDANCE	12	Species	ship-based physical collection	ship-based acoustics (?)	AUVs (?)	acoustic lens technology (H)
ZOOPLANKTON SPECIES	13	Species	ship-board net sampling; ship-board CPR/UOR (ships of opportunity)	ship-board optics (dedicated) (H)	moored system-optical (?); AUVs optic/acoustic (?)	biochemical species identification (?)
OPTICAL PROPERTIES	14	Optics	Satellites: reflectance Ships/Moorings: AOPs: k, PAR, Ed (l), UV, Visible, IR), IOPs: a,b,c,bb, Fluorescence, solar	Satellite a and bb	Bulk inversion (IOP, CDOM, detritus, phyto, inorganic particles) ; Satellite AOP (k, PAR), visibility ; Satellite IOP inversions (CDOM, phyto) ; LIDAR	Fluorescence (l) [CDOM excitation-emission matrices] ; Fast repitition rate fluor.; Laser linesheets
SEAFOOD CONTAMINANTS	17	Human	Fishery independent surveys (shellfish); Mussel Watch	Sample seafood processors; Sample retail markets; Fishery independent surveys (finfish)	Sample catches of subsistence fishers; Sample catches of recreational fishers	
OCEAN COLOR	19	Optics	1 km will be available for next 20 years	300 m resolution needs commitment		High spatial resolution sensor
HUMAN PPATHOGENS: WATER	22	Human	Indicators by culture	Runoff		Indicators by genetics; Indicators by immunoassay; Pathogens by culture; Pathogens by genetics; Chemical indicators; Pathogens by immunoassay
HUMAN PATHOGENS: WATER	22	Human	Indicators by culture	Runoff		Indicators by genetics; Indicators by immunoassay; Pathogens by culture; Pathogens by genetics; Chemical indicators; Pathogens by immunoassay
DISSOLVED OXYGEN	23	Chem	Moorings, discrete samples, underway sampling		Ships of Opportunity	AUVs/Gliders, optical sensors
PHYTOPLANKTON SPECIES COMPOSITION	24	Optics	HAB counts/State warning systems ; Ships		*In situ* hyperspectral	Moored flow cytometry; Underwater imaging; Genetic tagging
ZOOPLANKTON ABUNDANCE	25	Species	ship-board net sampling (dedicated); ship-board CPR (ships of opportunity); moored systems - acoustics	ship-board optics and acoustics (dedicated) (H)	moored system - optical (M); AUV acoustic/optic (?)	
BENTHIC ABUNDANCE - CORALS, SEAGRASSES, MACROALGAE	27	Species	aerial hyperspectral imaging; aerial visible photography; manual discrete sampling	aerial LIDAR (H)	manned sub discrete sampling (?)	
BENTHIC ABUNDANCE - SEAFLOOR MEGA-, EPI-, AND INFAUNA			aerial hyperspectral imaging; aerial visible photography; manual discrete sampling		manned sub discrete sampling (?)	aerial LIDAR (H)
SEDIMENT CONTAMINANTS	28	Human	Contaminant chronologies; Bulk; Biological measure of chemicals; Pore water; Equilibrium based			
BENTHIC SPECIES - CORALS, SEAGRASSES, MACROALGAE	29	Species	ship-based samples; ship-based photography; ship-based acoustics (multibeam); ROV & manned sub photography; manual discrete sampling (divers)			AUV - photography (H)

BIO/CHEM/PUBLIC HEALTH TECHNIQUE CATEGORIZATION

VARIABLE	OVERALL RANK	GROUP	OPERATIONAL	PRE-OPERATIONAL	PILOT	R & D
BENTHIC SPECIES - SEAFLOOR MEGA-, EPI-, AND INFAUNA			ship-based samples; ship-based photography; ROVs and manned subs - photography; manual discrete sampling (divers)			AUV - photography (H)
HUMAN PATHOGENS: SEAFOOD	30	Human	Indicators by culture; Toxins (HAB); River discharge		Pathogens by culture; Pathogens by genetics	Pathogens by immunoas Indicators by genetics; Indicators by immunoas
CARBON-TOTAL ORGANIC	32	Chem	Discrete sampling			
SUSPENDED SEDIMENTS	34	Optics	Ships and Moorings (ADCP, transmissometer, OBS, LIST); Discrete from moorings and ships.	Satellites (backscatter, reflectance)	AUV with sensors	Video
SEAFOOD PATHOGENS	36	Human				
MARINE MAMMALS ABUNDANCE	37	Species	ship transect visual counts (cetaceans, seabirds); aerial transects visual counts (cetaceans, turtles, manatees); onshore counts (birds, turtles, pinnipeds)	passive acoustics - low frequency (cetaceans) (H)		passive acoustics - high frequency (H)
MARINE MAMMALS: MORTALITY EVENTS	38	Species	observation during marine operations (fishing); shore counts (stranding networks)			
pCO_2	40	Chem	Moorings, discrete samples, underway sampling		Ships of Opportunity	AUVs / Gliders
SURFACE AND GROUND-WATER INPUT	41					
CARBON-TOTAL INORGANIC	42	Chem	Discrete sampling, underway flow-thru sampling			Automated moored sampler
AIR-AEROSOL TYPE	43					
AMBIENT NOISE	44					
TOTAL BACTERIAL BIOMASS	47	Optics	Ships epifluorescence microscopy			Image analysis ; Flow cytometry ; Moored *in si* hybridization
OCEAN-SURFACE CHLOR A	48	Optics	Satellite (basin, shelf); Stationary moorings; Ships	Satellite (coastal); Drifters	Gliders ; Aircraft (coastal)	Animals of opportunity
CATCH AND EFFORT BY GEAR TYPE	49	Species	at-sea observers; self-reporting (log books); dockside monitoring (landings, sales); electronic vessel monitoring (effort)	on-board video recording (H)		
OCEAN-WATER COLUMN-TN	50	Chem	Discrete sampling			
NON-NATIVE SPECIES	52	Species	monitoring for non-native species related to aquaculture; operational biological monitoring; customs inspections			inspection of ballast wat & ship hulls (H); netwo of volunteer naturalists (education)
PHYTOPLANKTON ABUNDANCE/BIOMASS	53	Optics	Conversions (Chl a to biomass; Species to abundance)		*In situ* hyperspectral	Optical inversion and size spectra
SEAFOOD CONSUMPTION	54	Human	USDA survey		Field surveys; Phone surveys	
PHYTOPLANKTON PRODUCTIVITY	56	Optics	R/V (discrete)		Satellite (models)	Solar stimulated Fl, FRR
BEACH USAGE	57		Lifeguard reports		Beach use permits; Chamber of commerce data; Phone surveys	Sales of parking lot tags; Fixed cameras; Dedicate aircraft; Aerial advertiser Satellites
AREAL EXTENT OF COASTAL WETLANDS	58		aerial photography; satellite imagery; manual discrete sampling			

IFA GROUP SUMMARY – BIO-CHEM-PUBLIC HEALTH

VARIABLE	OVERALL RANK	GROUP	ASSESSMENTS SUMMARY
GENERAL COMMENT		Chem	*Assumes the backbone of the national system is ~500 instrumented moorings/ platforms, with regional/ areal targeting of arrays for areas of high inputs (terrestrial, atmospheric); multiple depths for most sensors*
NUTRIENTS	10	Chem	In the long term moored sensors will be more cost effective and the technology is either ready or will be ready within 3 years. AUVs/ gliders with R& D will become more feasible and flexible platforms.
DISSOLVED OXYGEN	23	Chem	In the long term moored sensors will be more cost effective and the technology is either ready or will be ready within 3 years. AUVs/ gliders with R& D will become more feasible and flexible platforms.
CARBON-TOTAL ORGANIC	32	Chem	Depends on discrete samples, inefficient for generating large numbers of analyses, low impact
pCO_2	40	Chem	In the long term moored sensors will be more cost effective and the technology is either ready or will be ready within 3 years. AUVs/ gliders with R& D will become more feasible and flexible platforms.
CARBON-TOTAL INORGANIC	42	Chem	Discrete samples have required precision, precision of underway and moored sampling systems are more problematic
OCEAN- WATER COLUMN- TN	50	Chem	Depends on discrete samples, inefficient for generating large numbers of analyses, impact high for loading estimates.
SEAFOOD CONTAMINANTS	17	Human	Needed for calculating risks to humans of eating seafood. Chemical methods are adequate and there are new methods for toxins that should be accelerated. This variable should be based on integration and standardization of state and federal programs, with the emphasis on state programs. Need more funding stability.
HUMAN PATHOGENS: WATER	22	Human	Present methods are limited by being indirect and suffer from timelags. We recommend acceleration of the ongoing development of new methods that measure indicators more quickly and also measure pathogens directly and quickly. Systems suitable for buoys and platforms will be available in a few years and will be of high feasibility and high impact.
SEDIMENT CONTAMINANTS	28	Human	There is disagreement about the biological interpretation but the methods are very good for describing spatial patterns and temporal trends.
HUMAN PATHOGENS: SEAFOOD	30	Human	This refers to pathogens in seafood that infect humans. Needed for assessing risk to humans of consuming seafood. Present methods are limited by being indirect and suffer from timelags. We recommend acceleration of the ongoing development of new methods that measure indicators more quickly and also measure pathogens directly and quickly.
SEAFOOD PATHOGENS	36	Human	Same as "human pathogens: seafood"
SEAFOOD CONSUMPTION	54	Human	Methods work and the best data come from field surveys. However, these are labor intensive and are best be done at the local level.
OPTICAL PROPERTIES	14	Optics	Utilize a combination of satellite (basin, shelf- scale), moorings (onto existing), and ships (R/ V, VOS, Ferries) measuring optical properties. Place a high priority to move sensors onto gliders and drifters. Make optical measurements on inherent and apparent optical properties (IOPs & AOPs) at as many wavelengths as possible to derive products such as phytoplankton, detritus, CDOM, sediments, etc. These measurements are critical to provide initialization, assimilation, and boundary conditions for the new- generation coupled biological- physical models.
OCEAN COLOR	19	Optics	Satellites producing data with 1 km resolution will be available for next 20 years, at a minimum. A commitment needs to be made to support satellites with 300 m resolution.
PHYTOPLANKTON SPECIES COMPOSITION	24	Optics	Microscopic analysis on discrete samples is standard and used effectively in some state HAB warning systems. Higher- impact techniques are all in pilot or R& D, but sensors with genetic tags or other new detection methods are promising. Taxa from space/ aircraft are moderately feasible though limited in resolution of species; signals are different regionally, but technology/ approach is similar and applicable to a variety of platforms.
SUSPENDED SEDIMENTS	34	Optics	Optical sensors (e. g., tranmissometer, OBS, LIST) and ADCPs on moorings, along with discrete samples from ships and moorings are best operational techniques currently.
TOTAL BACTERIAL BIOMASS	47	Optics	Ships/ moorings with discrete samples and epifluorescence microscopy or image analysis are standard. Moored *in situ* flow cytometer or hybridization are promising but less feasible at present.
OCEAN- SURFACE CHLOR A	48	Optics	Utilize a combination of satellite (basin, shelf- scale), moorings (onto existing), and ships (R/ V, VOS, Ferries) measuring via fluorescence. Place a high priority to move sensors onto gliders and drifters. High importance to upgrade algorithms for Case 2 waters especially for sensors from aircraft. Access international community for 250- m resolution satellite imagery and assure its continuity.
PHYTOPLANKTON ABUNDANCE/ BIOMASS	53	Optics	Conversions from chl a fluorescence (needs C: chl ratio) or from cell volume (needs C: vol ratio) are operational but with uncertainty of conversion ratio. Possible from optical inversions and size spectra but this is still R& D.
PHYTOPLANKTON PRODUCTIVITY	56	Optics	Derived from chlorophyll a as measured by satellites etc., with discrete C- 14 uptake from ships to ground- truth.
FISH SPECIES	11	Species	Ship- based physical collection is routinely employed; many operational systems. Provides simultaneous info on many species accessible to the net. Ship provides platform for numerous other observations. Net provides samples for other analyses.
FISH ABUNDANCE	12	Species	Ship- based physical collection is routinely employed; many operational systems. Provides simultaneous info on many species accessible to the net. Ship provides platform for numerous other observations. Net provides samples for other analyses.
ZOOPLANKTON SPECIES	13	Species	Mix of dedicated ships with nets and ships of opportunity with CPR/ UOR are best option. Proven; mix of spatial and temporal resolution and size classes that is of value.

IFA GROUP SUMMARY – BIO-CHEM-PUBLIC HEALTH

VARIABLE	OVERALL RANK	GROUP	ASSESSMENTS SUMMARY
ZOOPLANKTON ABUNDANCE	25	Species	Mix of dedicated ships with nets and ships of opportunity with CPR/ UOR are best option. Proven; mix of spatial and temporal resolution and size classes that is of value.
BENTHIC ABUNDANCE (CORALS, SEAGRASSES, MACROALGAE)	27	Species	Manual sampling is a well- established method but has limited spatial coverage. LIDAR and hyperspectral imaging have great potential to increase spatial coverage but R& D is necessary to improve species identification.
BENTHIC ABUNDANCE (SEAFLOOR MEGAFAUNA, EPIFAUNA, INFAUNA)	27	Species	Best option is ship- based system combining physical sampling with photography and multi- beam acoustics. Multibeam depends heavily for calibration on physical samples and photography. The goal is to have broad- scale (all US shelf waters) habitat classification maps based on calibrated multibeam.
BENTHIC SPECIES (CORALS, SEAGRASSES, MACROALGAE)	29	Species	Manual sampling is a well- established method but has limited spatial coverage. LIDAR and hyperspectral imaging have great potential to increase spatial coverage but R& D is necessary to improve species identification.
BENTHIC SPECIES (SEAFLOOR MEGAFAUNA, EPIFAUNA, INFAUNA)	29	Species	Best option is ship- based system combining physical sampling with photography and multi- beam acoustics. Multibeam depends heavily for calibration on physical samples and photography. The goal is to have broad- scale (all US shelf waters) habitat classification maps based on calibrated multibeam.
MARINE MAMMALS ABUNDANCE	37	Species	Three operational techniques are available and necessary for the range of species of importance.
MARINE MAMMALS: MORTALITY EVENTS*	38	Species	Operational systems in place and working. Observations during marine operations should be increased.
CATCH AND EFFORT BY GEAR TYPE	49	Species	At- sea observers and dockside monitoring are widely used, with high impact. Self- reporting could be improved with education and buy- in. Electronic vessel monitoring has tremendous potential fo real- time communication of environmental observations in addition to monitoring fishing.
NON-NATIVE SPECIES	52	Species	Introductions from aquaculture are a known problem that could be mitigated to some degree with a monitoring/ reporting system. Operational biological monitoring designed for native species is also applicable to non- native species; however, its feasibility is related to the degree to which the invasion has been established. Inspection of ballast water could be powerful for prevention but R& D is required to make it feasible.
SURFACE AND GROUND-WATER INPUT	41		
AIR- AEROSOL TYPE	43		
AMBIENT NOISE	44		
BEACH USAGE	57		Needed for calculating risk of water contact activities. Lifeguard data are available nationally on the web and could be enhanced by telephone surveys. Additional pilot studies should be carried out for phone surveys.
AREAL EXTENT OF COASTAL WETLANDS	58		Aerial photography and satellite imagery should be used depending on the necessary spatial resolution. In both cases, manual discrete sampling in needed for ground truthing.
BIOACOUSTICS	59		
*** Marine mammal and other organism mortality**			Marine disturbance events and the impact on marine wildlife and dependents are presently the means for which significant changes in water physics and chemistry are sensed (as opposed to nothing). Even when a network of physical and remote sensing systems is eventually deployed. The marine species sensitive and co- evolved to react in concert to changes fill the ever present gaps in a seemingly "24/ 7" discreetly) faux continuous technology- based monitoring (device) regime because their biology picks up what we have unintenionally neglected and without preconception realized are important variables to sense. The HEED MD program for instance retrospectively mined the literature on all such marine disturbance events reported in the coastal zone (except Great Lakes and Pacific) to help set geographic priorities and establish frequency (disturbance regimes) for such events presently reported in the peer- review, gray literature and newspaper accounts.
			Volunteer and professional informal reporting networks such as Gulf of Mexico Aquatic Monitoring Network (GMNET) and riverkeeper/ baykeeper organizations need a unified system for assembling the total cross- regional measurements (observations) that represent proxy indicators for the very disturbances we are most interested in sensing near real time (web portals). Depending upon physiology, some non- legislatively tagged species may even prove more superior to those charismatic protected status species as living biosensors of future mass mortality disturbance events (a R& D priority). The impact and feasibility are both high because these proxies cheaply compensate for system gaps (single web portal for event entry) because the observation networks already saturate the coast. At present even the anecdotal information of occurrence or for statistical validity (non- occurrence) of morbidity, mortality, and disease can provide valuable insights on status and trends contiguous with past observational effort. Sampe size is extremely high and, at the least, if deemed unreliable, does represent perceptual importance

BACTERIA

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Moored flow cytometry • Moored *in situ* hybridization		
MEDIUM		• Ship- discrete samples (epifluorescence microscopy) (image analysis)	
LOW			

BEACH USE

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Fixed cameras • Dedicated Aircraft • Satellites		• Phone surveys
MEDIUM		• Ship- discrete samples (epifluorescence microscopy) (image analysis)	• Lifeguard network • Aerial advertisers
LOW	• Beach use permits	• Parking lots	• Chambers of commerce

*Lifeguard data are available nationally on the web & could be enhanced by telephone \surveys. Additional pilot studies should be carried out.

BENTHIC SPECIES ABUNDANCE: CORALS, SEAGRASSES, MACRO-ALGAE

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Aerial LIDAR (abundances)	• Hyperspectal photography (abundance)	• Manual/ Discrete Sampling (Species)
MEDIUM	• Submersible discrete sampling (species)	• Aerial photgraphy (abundance)	
LOW	• Submersible discrete sampling (abundance) • LIDAR Aerial photography Hyperspectural photo (species)		• Manual/ Discrete Sampling (Abundance)

BENTHOS (SEAFOOD-MEGA, EPI, INFAUNA)

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• Shipboard • Grab/ Dredge (abundance/ species)	• Shipboard multibeam and other acoustics (abundance)
MEDIUM	• AUV's (abundance + species)		• Shipboard photographic (abundance + species)
LOW		• Submersions/ ROV's w/ photographic (abundance + species)	• Manual discrete sampling (abundance + species)

CHLa

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Aircraft (coastal) (f1, AOP)	• Satellite (250M coastal) -tap into existing systems improved -algorithm, forecasts -f1, AOP • Mobile (active AUV & passive Drifters)	• Satellite (basin, shelf) -f1, AOP • Stationary Moorings -coastal, basin, shefl (enhancing existing moorings: f1, AOP, IOP)
MEDIUM	• Animals of Opportunity (f1, AOP)	• SHIPS (* all ships should be used) (RV, VOS, ferries) (f1, IOP, AOP, discrete)	
LOW			

DISSOLVED OXYGEN, INORGANIC NUTRIENTS (DIN, DIP, DSI, Fe) AND pCO_2

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• U. V. NO 3 Detection (R +D) • discrete • AUV/ gliders	• 1. shipboard, towed • 2. shipboard, vertical, profiles, CTD • 3. shipboard, vertical by pumping or • Niskin	• Moored (*in situ*) (~ 500 in nationwi network target some areas where most of the input coming to coasta ocean incl. rivers cities) • Multiple depths, but pCO_2 , just surface
MEDIUM		• Ship of opportunity for surface nutrient mapping (self- contained)	
LOW		• Ship of opportunity for surface O_2 (Self- contained w/ electrode)	

~ 500 platforms w/ all 3 of these variables measured

COASTAL WETLANDS: AREA (MANGROVE, MARSHES)

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH			• Aerial Photography
MEDIUM		• Satellite imagery	
LOW			• Manual discrete sampling

FISH AND SHELLFISH (RESOURCES)

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Optics (visual) • LIDAR • Acoustics Lens Technology (Abundance and species)		• Shipboards NETS/ DREDGE (Abundance & Species)
MEDIUM	• Shipboard Acoustics (Species)	• Shipboard Acoustics (Abundance)	
LOW	• Vehicles (Abundance and species)		

FISHING CATCH AND EFFORT

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• At Sea Observers	• Dockside monitory (Landings only)
MEDIUM	• Shipboard • Video observations • Fishing operations		• Self- reporting (e. g. logbooks) • Electronic vessel monitoring (effort)
LOW			

MAMMALS, ENDANGERED SPECIES, BIRDS

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH			• Visual counts (birds, turtles, pinnepids)
MEDIUM	• Passive acoustics (mammals)	• Aircraft visual counts (cetaceans, turtles, manatees)	• Shipboard visual counts (cetaceans, seabirds)
LOW			

MAMMALS MORTALITY & ENDANGERED SPECIES

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH			• Observations during marine operators (e. g. fishing) Stranding network
MEDIUM			
LOW			

HUMAN PATHOGENS: SEAFOOD + SEAFOOD PATHOGENS

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• 2. Indicator by genetics • 3. Indicator by immunoassay • *4. Pathogens by culture • *5. Pathogens by genetics • *6. Pathogens by immunoassay	• 1. Indicators by culture • ** 7. Toxins (HAB)
MEDIUM			• 8. River discharge
LOW			

*Direct pathogen detetection better than indicator
** Chemical assay methodology development needs accelerated, phase out mouse bioassay
EXISTING SYSTEM PROVIDES ADEQUATE PUBLIC HEALTH PROTECTION HOWEVER GAP EXISTS IN MONITORING IMPLEMENTATION

NON-NATIVE SPECIES

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH			• Monitoring non- native species in aquaculture
MEDIUM		• Operational Biological Monitoring	• Custom inspector
LOW	• Inspector of ballest water	• Network of volunteer naturalists	

OCEAN COLOR

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• 300M Resolution (coastal shelf) -oceansat	• 1km Resolution (basin, shelf) -SeaWIFS -MODIS -NPOES
MEDIUM			• 1km resolution (unicallibrated) (basin, shelf) -FYI- C -FYI- D
LOW			

PHYTOPLANKTON ABUNDANCE

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• (See Phytoplankton Species) Converstion species -----> abundance • Optical inversion and size spectra		• (see CHLA) • Conversion CHLA------> abundance
MEDIUM			
LOW			

PATHOGENS THAT MAKE HUMANS SICK (HUMAN PATHOGENS: WATER) (NEEDED T ASSESS HUMAN HEALTH RELATED TO WATER CONTACT AND SEAFOOD CONSUMPTIO

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• Bacteria by culture • Pathogens by genetics	
MEDIUM		• Indicators by genetics • Indicators by immunoassay • Viruses by culture • Pathogens by immunoassay • Viruses by culture • Pathogens by immunoassay	• Indicators by culture runoff
LOW			• Chemical indicato

*Present methods are limited by being indirect and suffer from time lags. New methods that measure pathogens directly and quickly are under deve opment.
Systems suitable for buoys and platforms will be available in a few years and will be high feasibility and high impact.

OPTICAL PROPERTIES

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Aircraft (coastal) • Laser- line sheets	• Satellite (300M coastal) • Mobile (active- AUV, passive- drifter)	• Satellite (basin, shelf) • Stationary moorings, coastal
MEDIUM	• Animals or opportunity • ICONIS imagaing of beach goers	• Ships	
LOW			

PHYTOPLANKTON SPECIES

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Underwater imaging Moored cytometers Genetic tagging	• HAB- counts/ state warning systems	
MEDIUM		• Ships (net tows + counts)	
LOW		• *In situ* autonomous sampler • *In situ* hyper spectral* • Aircraft/ satellite* taxa from space	

PRODUCTIVITY (IN 3-D ON WEEKLY SCALES DERIVED)

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• Satellite (basin, shelf)	
MEDIUM		• Ships C 14 , FRR (fast repetition rate fluoraometer) • Discrete samples	
LOW			

WATER CONTAMINANTS – CHEMICALS & TOXINS

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Gene Probes	• Electrochemical probes (metals only) • Mussel watch	
MEDIUM		• Fluorescence (PAH, aromatics) • *In Situ* filtering • Semi- Permeable membranes • Grab samples (water) • Sediment grab samples	
LOW	• Phytotoxics (HPLC)		

Not an effective variable in the marine environment for public health. Mussel watch & sediments are more readily indicative of conditions in water

*No highly feasible method at present for integrating across time and space at the low concentrations that exist in the water column.

SUSPENDEND SEDIMENT

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Video	• Satellites	• Stationary Moorings (ADCP, transmissometer)
MEDIUM		• Ships (ADCP, optical systems) • Discrete • Discrete moored samples	
LOW			

SEDIMENT CONTAMINANTS (IMPORTANT INDICATOR OF ECOSYSTEM HEALTH, CONTAMINANT SOURCES, AND WATER QUALITY)

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	•	• 4. Contaminant chronologies	• 1. Bulk Biologica measure of chemicals
MEDIUM	• 2. Porewater	• 3b. Equilibrium Based (SEM/ AVS)	• 3a. Equilibrium based (organic)
LOW			

SUMMARY: Great for trends, disagreement over biological interpretation statement
RECOMMENDATION: Need scientifically defensible criteria

SEAFOOD CONTAMINANTS – CHEMICALS & BIOTOXINS (NEEDED FOR CALCULATION OF RISK TO HUMANS FROM EATING SEAFOOD)

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• Retail markets • Subsistence fisheries	• Seafood processors
MEDIUM			• Recreational fishers • Fishery independent surveys • Mussel Watch
LOW			

*Should be based on integration and standardization of state and federal programs with the primary emphasis on state programs. Need more funding stability

SEAFOOD CONSUMPTION

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• Field Surveys	
MEDIUM		• Phone Surveys	• USDA (?) Food survey
LOW			

ZOOPLANKTON

IMPACT	FEASIBILITY: LOW	FEASIBILITY: MEDIUM	FEASIBILITY: HIGH
HIGH	• Dedicated ship • Ship optics (Abundance and species)	• Dedicated ship • Net Sampling (Abundance and Species)	
MEDIUM	• Dedicated ship (Abundance and species)		• VOS • CPR/ VOR
LOW	• AUV w/ acoustics/ optics (Abundance and species)		• Moored acoustics (Abundance) • Mooring optical (Species and abundance)

HUMAN IMPACTS/ RISKS

- Seafood Contaminants
- Human Pathogens - Water
- Sediment Contaminants
- Human Pathogens - Seafood
- Seafood Pathogens
- Seafood Consumption
- Beach Usage

OPTICS

- Optical Properties
- Ocean Color
- Phyto Species Composition
- Suspensed Sediments
- Total Bacterial Biomass
- Ocean Surface Chloro a
- Phyto Abundance/ Biomass
- Phyto Productivity

CHEMISTRY NUTRIENTS

Dissolved Oxygen
Total Organic Carbon
Partial Pressure Carbon Dioxide
Total Inorganic Carbon
Water Column Total Nitrogen

SPECIES

- Fish Species/ Abundance
- Zooplankton Species/ Abundance
- Benthic Abundance (corals, grass, macro.)
- Benthic Abundance (fauna)
- Benthic Species (corals, grass, macro.)
- Benthic Species (fauna)
- Marine Mammals (abundance, mortality event)
- Catch and Gear Type
- Non- native Species

ASSUMPTIONS/ NOTES/ GROUND RULES/ ETC.

- Chemical Measurements - 500 locations, moorings, platforms, etc. - not equally spaced - selected regions targeted
- Temporal requirements - monthly, seasonal, annual
- Biology / Chemistry - data poor
- Most biology/ chemical sensors/ measurements require significant training

CHEMISTRY MEASURES

Nutrients

Dissolved Oxygen

Partial Pressure Carbon Dioxide

Operational - Moorings, discrete, underway sampling

Pilot - VOS

R& D - Autonomous vehicles new sensor types

Total Organic Carbon(TOC)

Total Inorganic Carbon (TIC)

Water Column Total Nitrogen

Operational - discrete, underway sampling (TIC)

Pilot - VOS (pCO_2)

R& D - Autonomous (moored - TIC)

HUMAN IMPACT/RISKS

Seafood Contaminants

Human Pathogens - Water

Sediment Contaminants

Human Pathogens - Seafood

Seafood Pathogens

Seafood Consumption

Beach Usage

Reactive rather than proactive, sustained, routine, etc.

R& D possibilities for near real- time assessment of selected components

BIO-CHEM SUBGROUP 2

1. Some content was lost in the translation from the 2D matrix to 1D table

2. Criteria for “operational” vs. “operational- able ” were not consistent among groups or across techniques

3. Definition of operational differs: “Ph. D. involvement in the measurement” vs. “24/ 7”

DIVERSITY OF PLATFORMS

* **direct human involvement:**
  - feet (intertidal sampling) or fins (divers)
  - ships and boats –> water samples, nets, on- board eyeball observations
  - NB: many networks & sampling programs in place
* **autonomous**
  - moorings
  -gliders- -drifters- -AUV-
  (issues: frequency of servicing and S/ T scaling)
* **space based**
  - spatial scale needed for coastal zone vs. open ocean

HOW TO "SCALE UP" RESULTS?

Is there a suite of physical measurements that should be made at all sites (that did not make Group 1's operational list)

that would enable biological/ chemical observations from one site (mooring or ship sampling) to be scaled up to larger areas

via models and statistical tools?

HOW TO MAXIMIZE THE IMPACT OF SHIPS?

Is there a suite of robust sensors that could be incorporated into profiling systems or underway sampling systems to systematically and autonomously collect biological/ chemical data?

SPECIES AND ABUNDANCE

Fish (ship- based)

physical collection (trawls & nets) and acoustics

R& D on acoustics, lidar, optical detection; smart AUVs)

Zooplankton (ship- based, both dedicated and opportunistic)

net sampling & acoustics; R& D acoustics, optic, biochem.

Benthos (satellite, aircraft, ship- based, AUV, ROV, divers)

corals, seagrasses, macroalgae

seafloor megafauna, epifauna, infauna

hyperspectral imaging and photography

Lidar; multi- beam acoustics

manual sampling & visual species identification

SPECIES AND ABUNDANCE

Marine Mammals (ship, shore, airplane)

manual counts

Mammal Mortality (ship and shore)

observations during other marine operations

shore counts via stranding networks

Non- native or invasive species

monitoring; aquaculture alert; customs inspections

(usually detected when abundance is high)

Catch and Effort by Gear Type

manual – at sea observers; log books; dockside monitoring;

electronic monitoring of vessels

SPECIES AND ABUNDANCE

Bacteria (total community biomass)

discrete samples – microscope counts

new molecular techniques will revolutionize approach

Phytoplankton

species discrete samples – microscope counts

typically for HABs; state warning systems

chlorophyll a biomass – optical sensors

Primary Productivity

discrete (^{14}C)

R& D satellite and fluorescence approaches

OPTICS**

Satellite ocean color

1- km operational; 300- m needs to be operational

Chl a fields; sediments

Optical Sensors: phytoplankton, sediments,

dissolved organics, primary production

spectral absorption and scattering meters

spectral UV, VIS, IR radiation sensors

Fluorescence

** NB: optics is ready to go all platforms: satellites, ships, mooring, gliders, drifters

APPENDIX VIII-B: PHYS/MET/GEOLOGICAL TECNIQUES CATEGORIZATION

VARIABLE	TECHNIQUE: OPERATIONAL	PRE-OPERATIONAL (HIGH IMPACT)	PRE-OPERATIONAL (MEDIUM IMPACT)	PILOT	R & D
SALINITY		Profiling floats (B+ C) Shipboard CTD (B)	Ship: Temp- Salinograph (B+ C)	Shipboard CTD (C) Moorings (B+ C) XCTD (B) Drifters (B)	Satellite SSS (B) Aircraft SSS (C) Profiling mooring (
WIND VECTORS (SPEED PLUS MODEL)	SAT Scatterometer (B)	Hi- Res moorings (C) Hi- Res surface drifters w/ pressure (B)	moorings (C) shore sites (C) Hi- Quality VOS (B) surface drifters w/ pressure (B) passive microwave (B)	Hi- Res moorings (B) moorings (B) VOS (B)	SAT SAR
WATER TEMPERATURE (WATER COLUMN, SEA SURFACE)	Profiling floats (B+ C) XBT (B) surface drifters (B) *AVHRR+ GOES (B+ C)	Hi- Res moorings (C) CTD (B) Hi- Res XBT (C)	XBT (C) moorings (C) moorings (C) Ship: Temp- Salinograph (B+ C) Surface Drifters (C)	CTD (C) moorings (B) moorings (B) Ship: hull- mounted temp (B+ C) *Microwave radiometer (B) *Airborne radiometer (C)	Drifting Temperatur Chain (C)
BATHYMETRY/ TOPOGRAPHY	>12kHz Multibeam Sonar Satellite Altimetry (B) Interferometic Side Scan (C) Side Scan (C, F) Multibeam Sonar (C, F) SAR (C, F)	LIDAR Bathymetry (C) Satellite Multispectral (C)	Land- based video (C, F) Echo sounder (C) Interferometric Side Scan (B) Sidescan (B) Airborne video (C) Multispectral (C) Multibeam (B)	Synthetic Aperature Sonar [Hi Res] (C)	
SEA LEVEL (REFERENCED, GEOLOCATED)	Tide Gauges (C) Precision Tide Gauges (B) Precision SAT Altimetry (B)	*Bottom Pressure (B) [for Tsunami] Bottom Pressure (C) *not referenced			Delay- Doppler SAT Altimetry (C) Airborne Altimetry (GPS Reflectometry
DIRECTIONAL SURFACE WAVES (WAVES PLUS DIRECTIONS)		Bottom- mounted ADCP (C) Hi- Res Pitch- and- Roll buoy (B+ C)	Pitch- and- Roll buoy (B+ C) platform- based 1- D meas (C) SAT Altimeter (B) moored accelerometers (B+ C)	moored currents (B+ C)	Platform- based arrays (C) Bottom- mounted arra HF Phased Radars (
VECTOR CURRENTS (WATER COLUMN, SEA SURFACE)		Hi- Res Fixed sensors (C) Hi- Res surface drifters (B)	Fixed (ADCP or point) sensors (C) surface drifters (B)	HF Radar (C) Fixed ADCP or point sensors (B) floats (B) geostrophy (B) Hi- Res surface drifters (C)	
ICE CONCENTRATION	Satellite Microwave Satellite SAR		Satellite Visible Aircraft Visible		
SURFACE HEAT FLUX		Indirect measurement: Moored buoys (B+ C) Fixed platforms (C)		High Quality VOS (B+ C) High Resolution Numerical Weather Prediction (B+ C)	
RIVER DISCHARGE		Hi- Res (more stations) USGS measurement network	USGS Measurement Network	Horizontal ADCP	Acoustical measured bending
AIR TEMPERATURE			Moored (B+ C) Shore Station (C)	High Quality VOS (B+ C) Surface Drifters (B)	
BOTTOM CHARACTERIZATION	Interferometric Side Scan (C) Multichannel Seismic (B+ C) Chirp (C) Video (B+ C) Core, Grab sample (B+ C) Offshore Drilling Program (B)	Multispectral Satellite (C) Line- scan Laser (C) XBP: Expendable bottom penetrometer (C) Instrumented Bore Hole (B+ C)	Seabeam	Hyperspectral Satellite (C)	
ATMOSPHERIC PRESSURE	Moored (C) Surface drifters (C+ B) VOS		Shore Station (C) Moored (B)		
PRECIPITATION			Point Gauges (B+ C) Doppler Radar (C)	TRMM (B)	Ambient Noise (B+
HUMIDITY			Shore Station (C) Mooring (B+ C)	High quality VOS	
SUSPENDED SEDIMENTS		Satellite MS+ Color		Aircraft MS+ Color	Bottom mounted or moored Acoustic/ Optics
SEAFLOOR SEISMICITY	SOSUS (B) International Monitoring System (IMS) Hydrophones (B)	OBS: Ocean Bottom Seismographs (B)		Real- time seismometers/ arrays (B+ C) Borehole seismometers (B) Real- time hydrophones/ arrays (B+ C)	
ATMOSPHERIC VISIBILITY			Satellite Visible/ Infrared (C+ B) Visual (C)		
ICE THICKNESS				Submarine sonar Moored sonars Drilling	UUV Sonar Satellite Laser
CLOUDS			Satellite Visible/ Infrared (B+ C) Visual (B+ C)		

AIR TEMPERATURE

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH			
MEDIUM		• High Quality VOS (B+ C) • Surface Drifters (B)	• Moored (B+ C) • Shore Station (C)
LOW			

ICE CONCENTRATION (BASIN)

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH			• Satellite Microwave • Satellite SAR
MEDIUM			• Satellite Visible • Aircraft Visible
LOW	• Upward looking sonar	• Satellite Altimetry	• VOS

HUMIDITY

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH			
MEDIUM		• High quality VOS	• Shore Station (C) • Mooring (B+ C)
LOW			

CLOUDS

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH			
MEDIUM			• Satellite Visible/ Infrared (B+ C) • Visual (B+ C)
LOW	• LIDARs (C)	• Upward- looking ceilometers (C)	

BOTTOM CHARACTERIZATION

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Hyperspectral Satellite (C)	• Multispectral Satellite (C) • Line- scan Laser (C) • XBP: Expendable bottom penetrometer (C) • Instrumented Bore Hole (B+ C)	• Interferometric Side Scan (C) • Multichannel Seismic (B+ C) • Chirp (C) • Video (B+ C) • Core, Grab sample (B+ C) • Offshore Drilling Program (B)
MEDIUM			• Seabeam
LOW	• Divers (C)		• Single channel seismics (C)

BATHYMETRY & TOPOGRAPHY ('F' INCICATES "FEATURES)

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Synthetic Aperature Sonar [Hi Res] (C)	• LIDAR Bathymetry (C) • Satellite Multispectral (C)	• >12kHz Multibeam Sonar Satellite Altimetry (B) • Interferometic Side Scan (C) • Side Scan (C, F) • Multibeam Sonar (C, F) • SAR (C, F)
MEDIUM			• Land- based video (C, F) • Echo sounder (C) • Interferometric Side Scan (B) • Sidescan (B) • Airborne video (C) • Multispectral (C) • Multibeam (B)
LOW			• Echo sounder (B) • Aerial photography, inferred from waves (C)

ATMOSPHERIC PRESSURE

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH			• Moored (C) • Surface drifters (C+ B) • VOS
MEDIUM			• Shore Station (C) • Moored (B)
LOW			

ICE THICKNESS

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Submarine sonar		
MEDIUM	• UUV Sonar • Satellite Laser	• Moored sonars • Drilling	
LOW		• Aircraft	

SURFACE SPECTRAL IRRADIANCE

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH			
MEDIUM			
LOW	• Point sensors (B+ C)		

SEAFLOOR SEISMICITY

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• Real- time seismometers/ arrays (B+ C) • Borehole seismometers (B) • Real- time hydrophones/ arrays (B+ C)		• SOSUS (B) • International Monitoring System (IMS) • Hydrophones (B)
MEDIUM			• OBS: Ocean Bottom Seismographs (B)
LOW			

SEA LEVEL (ALL REFERENCED TO THE ELLIPSOID, GEOID; GEOLOCATED; WITH SOME METEOROLOGY; EXCEPT *)

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• *Bottom Pressure (B) [for Tsunami] • Bottom Pressure (C)	• Tide Gauges (C) • Precision Tide Gauges (B) • Precision SAT Altimetry (B)
MEDIUM	• Delay- Doppler SAT Altimetry (C) • Airborne Altimetry (C) • GPS Reflectometry (C+ B)		
LOW	• Airborne Altimetry (B)	• Bottom Pressure (B)	• Tide Gauges (B)

SALINITY

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• Profiling floats (B+ C) • Shipboard CTD (B)	
MEDIUM	• Satellite SSS (B) • Aircraft SSS (C) • Profiling mooring (C)	• Shipboard CTD (C) • Moorings (B+ C) • XCTD (B) • Drifters (B)	• Ship: Temp- Salinograph (B+ C)
LOW	• Shipboard Titration (B+ C) • Drifters (C) • Aircraft SSS (B) • Satellite SSS (C)	• UUVs (C)	

RIVER DISCHARGE (COASTAL)

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• Hi- Res (more stations) USGS measurement network	
MEDIUM	• Acoustical measured ray bending	• Horizontal ADCP	• USGS Measurement Network
LOW	• Ocean color		

PRECIPITATION

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH			
MEDIUM	• Ambient Noise (B+ C)	• TRMM(B)	• Point Gauges (B+ C) • Doppler Radar (C)
LOW	• Surface Salinity (B)	• Satellite Microwave+ Infrared (B)	

SURFACE HEAT FLUX

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• Indirect measurement: Moored buoys (B+ C) • Fixed platforms (C)	
MEDIUM		• High Quality VOS (B+ C) • High Resolution Numerical Weather Prediction (B+ C)	
LOW	• Direct Tubulent Flux (B+ C)		• Numerical Weather Prediction (B+ C)

DIRECTIONAL SURFACE WAVES: WAVES + DIRECTIONS

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• Bottom- mounted ADCP (C) • Hi- Res Pitch- and- Roll buoy (B+ C)	
MEDIUM	• Platform- based arrays (C) • Bottom- mounted arrays (C) • HF Phased Radars (C)	• moored currents (B+ C)	• Pitch- and- Roll buoy (B+ C) • **platform- based 1-D meas (C)** • **SAT Altimeter (B) moored accelerometers (B+ C)**
LOW	• Airborne sensors (B+ C) • **SAT SAR (B+ C)** • **GPS Reflectivity (B+ C)**	• **shipborne radar**	• VOS: visual

WATER TEMPERATURE WATER COLUMN, SEA SURFACE (1M)(*SKIN TEMPERATURE)

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• High Hi- Res moorings (C) • CTD (B) • Hi- Res XBT (C)	• Profiling floats (B+ C) • XBT (B) • **surface drifters (B)** • *AVHRR+ GOES (B+ C)
MEDIUM	• Drifting Temperature Chain (C)	• CTD (C) • moorings (B) • moorings (B) • **Ship: hull- mounted temp (B+ C)** • ***Microwave radiometer (B)** • ***Airborne radiometer (C)**	XBT (C) moorings (C) moorings (C) Ship: Temp- Salinograph (B+ C) Surface Drifters (C)
LOW	• Drifting Temperature Chain (C) • AXBT (B+ C) • *** Shipborne radiometer (C+ B)**	• UUV (C) • **UUV (C)**	• **Ship: bucket (B+ C)** • **Ship: intake (B+ C)**

ATMOSPHERIC VISIBILITY

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• Satellite Visible/ Infrared (C+ B) • Visual (C)	
MEDIUM			
LOW			

VECTOR CURRENTS: WATER COLUMN, SEA SURFACE

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH	• HF Radar (C)	• Hi- Res Fixed sensors (C) • Hi- Res surface drifters (B)	
MEDIUM		• Fixed ADCP or point sensors (B) • floats (B) • geostrophy (B) • **Hi- Res surface drifters (C)**	• Fixed (ADCP or point) sensors (C) • **surface drifters (B)**
LOW	• Lowered ADCP (B+ C) • XCP (B+ C) • UUV+ ADCP (C) • **near- shore image analysis** (C)	• Hi- Quality VOS ADCP (B+ C) • **open- ocean image analysis** (B)	• **Surface drifters (C)**

TURBIDITY/SUSPENDED SEDIMENTS (COASTAL)

IMPACT \ FEASIBILITY	LOW	MEDIUM	HIGH
HIGH		• Satellite MS+ Color	
MEDIUM	• Bottom mounted or moored Acoustic/ Optics	• Aircraft MS+ Color	
LOW	• Shipboard sampling Secchi Disk		

WIND VECTOR (SURFACE): SPEED PLUS MODEL

IMPACT	LOW	MEDIUM	HIGH
HIGH	• High Hi- Res moorings (B)	• Hi- Res moorings (C) • Hi- Res surface drifters w/ pressure (B)	• SAT Scatterometer (B)
MEDIUM	• SAT SAR	• moorings (B) • VOS (B)	• moorings (C) • shore sites (C) • Hi- Quality VOS (B) • surface drifters w/ pressure (B) • **passive microwave (B)**
LOW	• Windsat (B) • surface drifters w/ anemometers (B+ C) • GPS Reflectivity (C+ B) • **ambient noise (B+ C)** • **HF Radar (C)**	• VOS (C)	• Hi- Quality VOS (C) • SAT Scatterometer (C)

FEASIBILITY

PHYSICAL, MET, GEOLOGICAL

Salinity	1	*Bottom Characteristics	20
Wind Vector	2	Atmospheric Pressure	21
Water temperature	3	Precipitation amount	26
*Bathymetry/ Topography	4	Humidity	31
Sea Level	5	physical characterization of habitat	33
Directional Wave Spectra	6	surface spectral irradiance	35
Vector Currents	7	*Seafloor Seismicity	39
Ice concentration	8	atmospheric visibility	45
Surface Heat Flux	15	ice thickness	46
River discharge	16	ocean- SSH	51
Air Temperature	18	clouds: low/ mid/ high amounts	55

(also did Suspended Sediments 34)

* Done in parallel by geology group

PHYSICAL, MET, GEOLOGICAL

Process

- Plenary: used Sea Level and Suspended Sediment as learning tools
- Did NOT use techniques from thematic groups!
- Geology group broke out in parallel with 3 variables; returned to plenary when done
- Finished all variables at 5: 38pm!
- Agreed on Categorization methodology
- Prepared Categorization of Techniques
- Did sanity checks on Categorization results
- Finished at 6: 35pm
- Edits, inputs, cleanups after dinner

PHYSICAL, MET, GEOLOGICAL

Issues #1

- Some confusion on "Impacts," less so on "Feasibility"
  – Main problem: scalability to the National program… meant few of our techniques were High Impact
  – Secondary problem: did High Impact mean it <u>might</u> be possible, or it had to have been already demonstrated?
- Had to separate coastal and basin
- Had to separate water column and surface
- Something currently operational was clearly High Feasibility, but not necessarily High Impact (often due to inadequate spatial sampling)
- Routinely found "diagonal" pairs: Med Impact could go to High Impact with more sampling, but Feasibility would then drop a category

PHYSICAL, MET, GEOLOGICAL

Issues #2

- Geological variables do not cleanly fit into the "sustained, continuing" framework
  –<u>Example:</u> bathymetry, bottom characteristics
  Needed as critical variables, but except relatively near- shore only needs to be done "once," or repeated rarely
  – Suggest treating as preparatory phase, early effort
- Seismicity DOES fit the framework; changes with time, needs monitoring; keep it as a "real" variable
- Acoustic tomography to get ocean temperatures did not make it through the filters (especially the Feasibility axis); is this the right answer, or just the traditional answer?

PHYSICAL, MET, GEOLOGICAL

- Defined "operational" as meaning "operationable," or "could be operational now"
  - Used High Impact, High Feasibility category
- Defined "Pre- Operational" as one category away from Operational
- Defined "Pilot Program" as one category less feasible than Pre- Operational
- Defined "R& D" as Medium Impact, Low Feasibility
- All else was "Watch and Wait"

PHYSICAL, MET, GEOLOGICAL

IMPACT

Pilot Program	Pre-operational	Operational
R&D	Pilot Program	Pre-operational
Watch and Wait	Watch and Wait	Watch and Wait

FEASIBILITY

PHYSICAL, MET, GEOLOGICAL

Top Operational Techniques (cross- cut)

- XBT
- Surface Drifters
- SAT winds, altimeter, SST
- Coastal moorings

Contenders

- VOS (for air pressure)
- SAT SAR (for ice)
- Profiling floats (for temp and salinity)
- SOSUS and IMS hydrophones (for seismicity)

PHYSICAL, MET, GEOLOGICAL

Top Techniques needing R& D

- Drifting temperature chains (robustness)
- Shipborne radiometer (bulk vs skin issue)
- UUV sonar (for ice)
- SAT laser (for ice)
- Ambient noise (for precipitation)
- Acoustics (for river discharge)
- Phased arrays (for directional surface waves)

PHYSICAL, MET, GEOLOGICAL

Post- operational Variables

- Bucket temperatures
- Ship's intake temperatures
- Mark I eyeball for surface waves
- Cloud fields from NWP
- Single- channel seismics

And the all- time Winner:

- Secchi disks

WORKING GROUP 1:

PLATFORM BASED PLAN

(Forecast models were goal - but approached through platforms)

- **Moored buoys**
- **Ships**
- **Gliders**
- **Satellites**
- **Aerial surveys**
- **Shore- based**
- **Tide gages**

MOORED BUOYS

- **Enhanced NDBC array**
  - 500 stations (60 now), ~150 mi spacing
- **Existing Package**
  - Surface Meteorology
- **Enhancement Package**
  - water temperature, salinity, current profile, optical properties, directional waves, dissolved oxygen, zooplankton (by ADCP), nutrients, over- water air quality (1 yr)
- **Additional Enhancement**s
  - Temperature profile, Fluorometer, Artificial livers, nutrients (3 yr), mussels

MOORED BUOYS

- **Cost**
  - Standard Buoy
    - 200k initial
    - 50k/ year to maintain
  - Enhancement Package
    - 100k
- **R& D needed for Enhanced Buoy**
- **New buoy operation paradigm required**
  - Existing buoys visited every 2.3 years
- **Implementation – phased over 3- 5 years**

SHIPS

- **System Enhancements**
  - Standard sensor packages (1- 2 yr)
    - Research Vessels
      - Enhanced profiling & flow- through or hull mounted
      - 25 ships @ $50k+$ 50k
    - Ships of opportunity
      - Integrated, telemetered, flow- through or hull mounted
      - Pilot: 10 packages @ $100k ea / year?
- **Research Vessels outfitted with multibeam sonars**
  - $500k/ ship, some have already
  - to engage public
- **Standard "Fish" sensor package (Research Vessels)**
  - ADCPs for fish and zooplankton
- **Repeated national cross- shelf transects**
  - (O) 300 mi spacing, both coasts
  - Periodic month to 5 years
  - Use enhanced instruments
  - Take advantage of/ enhance existing Fisheries surveys
  - Dedicated UNOLS or HQ VOS
    - 1 ship/ yr/ coast @ $3M = $6M/ yr (2 coasts)
- **National Habitat Map**
  - Benthic habitats, topography, bottom features
  - Repeated periodically
  - Multibeam and AUV
- **Event- driven response capability**
  - Natural, anthropogenic events

GLIDERS

- **Pilot Project**
  - 1- 3 year time frame
  - 2 Pilots @ $2M+$ 1M (hardware) = $5M
- **Implementation**
  - 3- 5 years
  - $100k/ glider
  - How many?

SATELLITES

- **Establish one "place" to access data (3 yr)**
  - SST, wind, chlorophyll, SSH, suspended solids, waves, ice
- **Augment existing "constellations" to gather coastal data (e. g. 1- km resolution data)**
  - possibly from other countries (1 yr)
- **Make 1 km SeaWIFFS data more accessible**
  - Preprocessed (1 yr).
- **Sustained measurement of 300 m data (1- 2 yr).**
- **Delayed Doppler Altimeter (5- 10 yr)**
- **Include access to SAR for ice (1 yr)**

AERIAL SURVEYS

- **Sensor Types**
  - IR photography, Hyperspectral
- **Enhance use of Aircraft of Opportunity**
  - Navy training flights, commercial, state patrol aircraft
  - Standard compact sensor package
  - Start R& D (3- 5 yr)
- **Use for periodic resource tracking**
  - Seagrass mapping, reference surveys (2- 3 yr)
- **Accomplished in sync with comprehensive "*in situ*" measurements**
- **Assess current use of aerial surveys (1 yr)**
- **$3M/ yr for aerial surveys**

TIDE GAUGES

- **Desire enhanced national system**
- **Look at NOS build out plan**
  - Would it suffice?
  - Expand number
- **All Gauges brought to absolute reference.**
- **Potential sites for additional sensors**
- **Costs**
  - to be determined by NOS

SHOREBASED

- **Standard package system (1- 5 yr)**
  - cabled or flow through
- **River discharge (fresh water inflows) monitoring**
  - enhanced USGS system (1- 3 yr)
  - contaminant monitoring (5 yr)
- **Mussel Watch Program ($ 3M/ yr, 1- 3 yr)**
  - Enhancement of space and time sampling
  - Surface grabs & cores for contaminated sediments.
- **High frequency radar**
  - Pilot projects (5 yr)
- **Demonstrate 24/ 7 operation, multiple systems**
- **3 or 4 Pilots @ $4M/ yr**
  - Nationwide network (10 yr)
- **Ring country with Long Range HF**
- **$20M capital cost, $5M/ yr to operate**
- **National Seafood Monitoring**
  - Consolidate Existing Data
  - Enhance/ Standardize program

GOVERNANCE

- **Interagency operational office**
  - Modeled after National Ice Center (NIC)
- **Aggregation of data to be dealt with at Governance level**
- **Part of capacity building role for National backbone is establishment of standards.**
  - Standards include calibrations, sensor specification.
  - Included data must meet standards
- **Concerns about liability: dealt with by Agencies**
- **Concern about sustained involvement of partners**
  - Regional inclusion, sustainability

NECESSARY PRINCIPLES

- **Platforms to be multi- use**
- **All data transparent to all researchers**
- **National backbone has dual purpose**
  - Operations and Research
  - May require system upgrade for research quality data
- **Entrainment of regional systems**
  - More data for all
- **Regional data to be moved to a "national" or "deep" archive**
  - Requires some $ support to facilitate
- **Education and outreach**
  - Possible cost to consider (5 %)
- **Include Alaska, Gulf of Mexico, Pacific Island & Great Lakes!!!**

DID NOT DO

- **Infrequent geophysical mapping requirements (e. g. bathymetry)**
- **Consider GOOS or linkages to GOOS**
- **System Design**
  - Spatial/ temporal coverage
- **User products**
- **Total Cost**
- **Phased implementation plan**
- **and much more ……**

HYPOTHESIZED COST BREAKDOWN

• **R& D**	**15%**
• **O& M**	**50%**
• **Technology development**	**20%**
• **Data**	**10%**
• **Education/ Outreach**	**5%**

Note: Data % probably low since has to also include data from regional centers

ADDITIONAL CONCERNS NOT DISCUSSED

- **Corps coastal wave measuring program not included**
  - Its regional – but Corps has a national requirement
  - NOS PORTS similarly not included
- **This fact emphasizes the importance of the Regional Programs to the National Program**
  - User Benefits are at the coast!
  - Sustained Funding for regional systems as important, or more important than national backbone
  - Regional issues not discussed in our group

WORKING GROUP 1-IMPLEMENTATION PLAN TIMELINE

PLATFORM	VARIABLE/TECNIQUES/PROCEDURES/ISSUES	TIMELINE (YEARS)	QTY	COST (MILLION)	TOTAL	PACKAGES
MOORED BUOYS	meteorology pkg, water temperature, salinity, currents, optical properties, directional waves, dissolved oxygen, zooplankton (by ADCP), nutrients, airborne contamination/ air quality Enhancements Temperature profiles Fluorometer Artificial livers	3	500	100		ADCPS 20, O 5, optic 5, nutrients, 10, CTD 10, Waves 14, CO_ 2 10: 100K
	R& D to add modular sensor packages to buoys	1				
TIDE GAUGES	Look at NOS build out Gauges require absolute reference. Are they fully integrated with necessary and sufficient sensor packages?			OBE		
GLIDERS	Implementation	3 to 5 years	~ 500	100		
	Glider pilot project	1- 3 years	2	3	6	2M ops/ 1M hardware/ 2 pilots
SATELLITES	Establish one "place" to access data. (Temperature wind chlorophyl water height suspended solids, waves, ice)	3				
	Augment existing "constellations" to gather coastal data (e. g. 1Km resolution)- possibly from other countries (1)	1				
	Access to 1 km SeaWIFFS should be made easier (1)	1				
	Sustained measurement of 300 m data	1 to 3				
	Delayed Doppler Altimeter	5 to 10 years				
	Access to SAR for Ice	1		4	Annual Satellite use cost (all applications)	
SHIPS	Benthic habitats/ topography/ relief/ multibeam	repeated and periodic				
	event- driven response (natural, man- made)	NO TIMELINE GIVEN				
	standard package for ships of opportunity	1 - 2 Years				cruise ships
	ADCPS for fish and zooplankton (enhanced multi disc packages)	1				
	Repeated national transects across shelf on the order of 300 mi, periodic month to 5 years, with enhanced instruments	5 to 10	1 ship per year per coast	6		routine use of UNOLS ships dedicated ships, high quality VOS
	Research Vessels (UNOLS) should be equipped with multibeam (especially to engage public)		20	0.5	10	
AERIAL SURVEYS	Accomplished in sync with comprehensive "*in situ*" measurements, maybe VOA, resource tracking, photography, IRI, HSI,			3		
	Ref surveys	3				
SHOREBASED	cabled or flow through standard package system	1 to 5				
	river discharge - USGS enhanced beach monitoring enhanced river monitoring river discharge and contaminant monitoring	5				
	continuing and enhancement of space and time mussel watch program			3		
	High frequency radar (dual use technology)	3 to 5 years				
	HF RADAR pilot			4		
	nationwide network of HF radar	10		20		
	surface grabs and sediment cores maybe with mussel watch for contaminated sediments.			243.5		
DATABASES	national background information- national seafood monitoring					
NOT DONE	maps					
	User products					
R& D		15				
O& M		50				
TECHNOLOGY DEVELOPMENT		20				
DATA		10				
EDUCATION/ OUTREACH		5				

WORKING GROUP 2:

PURPOSE OF A NATIONAL OCEANOGRAPHIC OBSERVING SYSTEM

- **Contribute to the international, global climate module of GOOS**
- **Build a coastal component of the observing system that will:**
  - Provide a network of reference and sentinel stations and sites
  - Establish accepted standards & protocols for measurements, data exchange and management
  - Link global and coastal scale observations
  - Benefit regional systems, minimize duplication, and provide economics of scale
  - Provide information coherence of events and changes on a national scale

CHARGE FOR THIS AFTERNOON/EVENING

- **Implement a scenario – game plan**
- **Build a implementation timeline**
- **Identify**
  - Gaps in monitoring and data accessibility
  - End-to-end system capacity building needs (e.g., tech and management)
- **Consider**
  - how a regional system may benefit from a national system
  - The governance of the coastal component of the system

WHERE WE ARE NOW

✓ Identified Goals/Products

✓ Identifed Important Variables

✓ Identified and Classified Techniques

  ✓ Impact/Feasibility (operational,pre-op, etc)

✓ Began the Framework for Data Design/ Management

✓ Began the Framework for Economics

✓ Strawman IOOS Implementation Plan

STRAWMAN IMPLEMENTATION PLAN (THREE MAJOR COMPONENTS OF A "SYSTEM")

- IOOS Management
- Data Management, Design, and Dessimination
- Monitoring/Measurements

ISSUES

- **National versus regional**
  - National provides a backbone of reference and sentinel measures and one-stop shopping

- **Governance**
  - Multi-layered fed, state, local cooperation/funding
  - Authority, responsibility, accountability: is the CORE document the strawman?

SCALE

Solve vs. Support

Most problems won't be solved by the national backbone; many will be supported

Systems (Network)*

Economies of scale; national standards for data & techniques

Synergies

"Cross Instrumentation" of platforms

Scenarios

***Connection into areas/problems requiring (very) high resolution observations that will benefit from linkages and data exchange**

PROCESS

- **All identified a product we wanted to see from IOOS and the user group it supported**
- **Defined elements of National Backbone**
- **Made recommendations for immediate action regarding elements**
- **All defined vision for National Backbone**

PRODUCTS AND USER GROUPS

Three examples:

- **Weekly map of upwelling**
  - Fisheries agencies, Ecosystem modeling
- **Chemical contamination in seafood**
  - Seafood industry, Consumers
- **Wave forecasts**
  - Fishing safety, Erosion control, Surfers

THE NATIONAL BACKBONE: IMPORTANT ELEMENTS

- **Moorings**
- **Mapping**
- **Mobile platforms**
- **Satellite and shore- based RS**
- **Standardizations and Infrastructure**

OUR VISION: A CONSENSUS OF 14 INDIVIDUAL OPINIONS

- Enhance existing mooring system, ultimately 150+ cross-shelf moorings with automated sensors and real-time communication
- Ship surveys for biology and servicing
- Pilot programs for gliders and HF radar
- Standard package of sensors to be used on variety of platforms (VOS, moorings, R/V)
- Satellites optimized for coasts: improve resolution (300 m); more frequent views

OTHER CONSIDERATIONS…

- Use models to help define sampling refinements
- Keep National Backbone in context of global system
- Select key sites in diverse environments
- Create data portals rather than data centers

IMMEDIATE ACTIONS TIMELINE - MOORINGS

OP	PRE-OP	PILOT	R&D
Network existing moorings (e. g., NDBC and any that meet standards); codify these as National Backbone. Support existing PORTS systems.	Augment mooring program to cover new areas. Support NDBC to have depth resolution. Enhance PORTS to new areas.	Test sensors in a variety of environments (e. g., coral, polar, deep, fresh, etc.). Cabled systems	Host regional meetings with user groups to discuss locations and sensors for moorings.

IMMEDIATE ACTIONS TIMELINE – SATELLITES AND SHORE- BASED RS

OP	PRE-OP	PILOT	R&D
Integrate (assemble) and utilize existing satellite data.	Make satellite data more applicable to coastal region, e. g., gain 300 m resolution, validation.	Develop staring satellite for EEZ. Develop HF radar for surface currents.	

IMMEDIATE ACTIONS TIMELINE - MAPPING

OP	PRE-OP	PILOT	R&D
Conduct multibeam surveys in key areas at high resolution.		Nested technology to develop bottom maps of biology (bathymetry first, then video at selected areas).	

IMMEDIATE ACTIONS TIMELINE – MOBILE PLATFORMS

OP	PRE-OP	PILOT	R&D
Optimize existing shipboard surveys e. g., CalCOFI, NMFS.	Intensify stock assessments nation- wide. Optimize VOS system.	Develop newer technologies for stock assessments. Pilot for autonomous spatial surveys of physical/ optical properties; recommend gliders.	Autonomous bottom- crawler Aircraft for optics, habitat assessments, SST, shoreline definition, aerial mapping, bathym., LIDAR.

IMMEDIATE ACTIONS TIMELINE - STANDARDIZATIONS AND INFRASTRUCTURE

OP	PRE-OP	PILOT	R&D
Provide assessment of Iridium system to DOD.	Test and develop Iridium- like global cellular communication system for at- sea application.	Develop standard sensor package that can be used on variety of platforms.	Make sensors (esp O_2 and nutrients) more operational (e. g., resistant to bio-fouling).

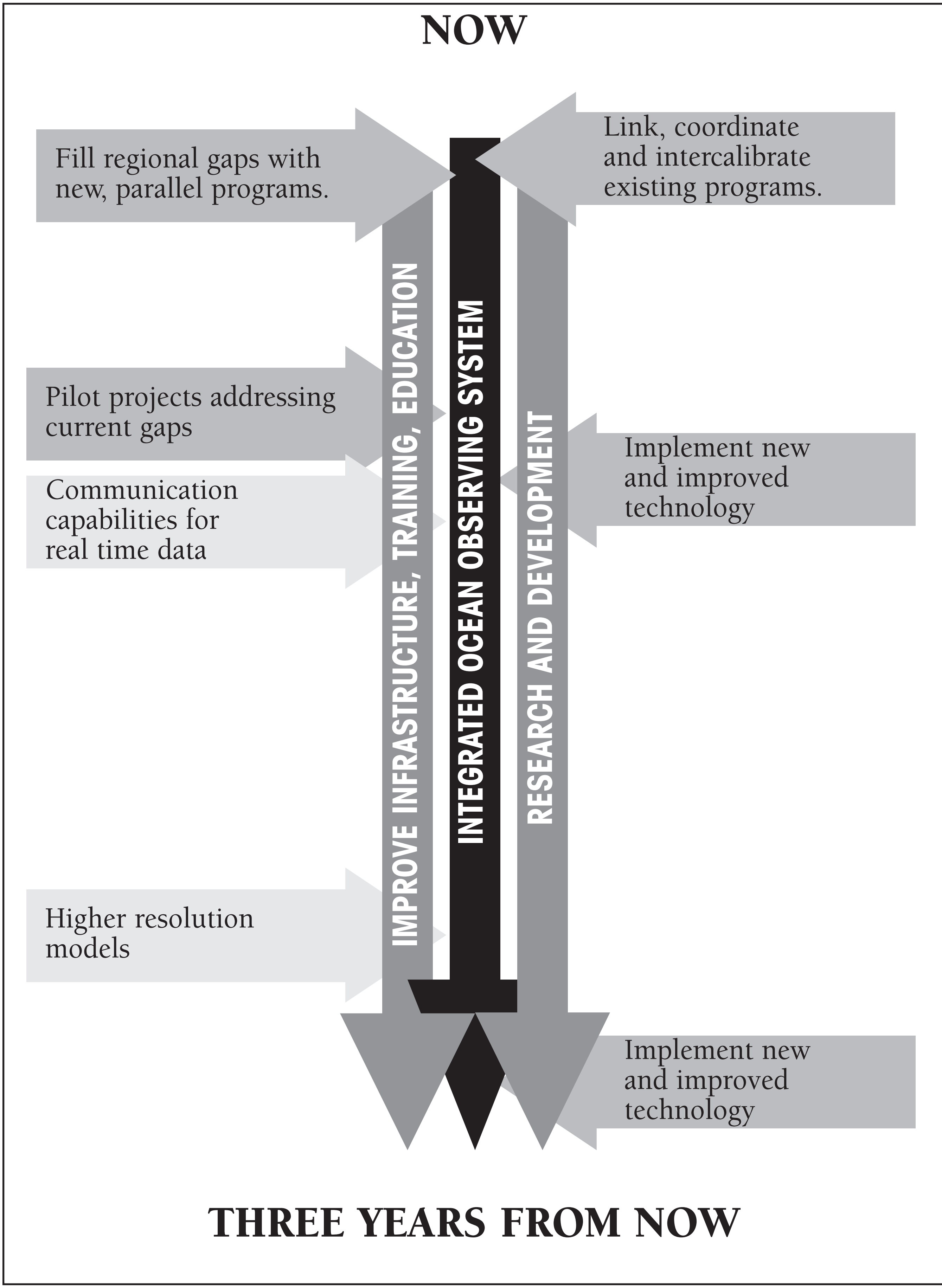
WORKING GROUP 4:

AN INTEGRATED OCEAN OBSERVING SYSTEM THAT:

• Improves navigation safety	• Predictions of waves, currents,tides, sea level
• Improves weather predictions	• Models of fluxes
• Makes tourism safe and fun	• Predictions of ocean conditions
• Assures that people do not swim in unsafe waters	• Monitoring of bacteria
• Improves fisheries yields	• Mapping fisheries populations
• Protects rare and endangered species	• Surveying marine mammals, turtles
• Minimizes anthropogenic impacts to coastal plant and coral systems	• Mapping coral, seagrass, macroalgae and marsh distribution
• Contributes to the education of our citizens	• Data, maps and models available on the Internet

IMPLEMENTATION PLAN DEVELOPED FOR:

- **Weather and marine conditions for recreational users**
- **Waves**
- **3- D coastal circulation model to support regional models**
- **Predictions of coastal sea level**
- **Warning system for water safety for human contact**
- **Quantifying living marine resources and endangered marine species**
- **Mapping of coastal vegetation**
- **Modeling water column ecosystems in nearshore and offshore areas**


NOW
Fill regional gaps with new, parallel programs.
Link, coordinate and intercalibrate existing programs.
Pilot projects addressing current gaps
Communication capabilities for real time data
Implement new and improved technology
Higher resolution models
IMPROVE INFRASTRUCTURE, TRAINING, EDUCATION
INTEGRATED OCEAN OBSERVING SYSTEM
RESEARCH AND DEVELOPMENT
Implement new and improved technology
THREE YEARS FROM NOW

TEN YEARS FROM NOW

- a well funded (sustainable) program
- an extensive list of users
- robust infrastructure (satellites, planes, vessels, buoys, platforms) and database
- a highly automated system (extensive new technology)
- a highly integrated system
- inter- calibrated instrumentation
- well- trained personnel
- strong educational component
- high resolution models
- 200 meteorological buoys
- 50 drift buoys per year
- 40 fixed current meter moorings (3 month) per year
- 1,000 sea level monitoring stations
- 6,000 ship days/ year to quantify fisheries resources (current 3,000)
- 500 aircraft days/ year to quantify marine mammals, turtles, etc

APPENDIX X: DATA AND COMMUNICATIONS REPORT

A PROCESS FOR THE DEVELOPMENT OF A PLAN FOR THE DESIGN AND PHASED IMPLEMENTATION OF THE DATA AND COMMUNICATIONS SUBSYSTEM OF THE INTEGRATED AND SUSTAINED OCEAN OBSERVING SYSTEM

INTRODUCTION.
Implementation of the Integrated and Sustained Ocean Observing System (IOOS) requires that a Plan be submitted to Congress in 2002. The Plan must include a phased approach for addressing Data and Communications issues, including cost estimates, mechanisms for allowing continued oversight, processes for evaluating system performance and incorporating user feedback, definition of a path for introduction of new technologies, and consensus agreement on a policy statement on data release and distribution. The Plan must redress major deficiencies of the present system as well as improve the efficiency and efficacy of system elements that are functioning now.

In this report, we outline a vision for a Data and Communications (DAC) subsystem that addresses the issues identified above. The DAC subsystem is the essential integrating component of the IOOS – carrying observational data to operational modeling activities, product-generation activities, and users in a standardized manner that includes consideration for metadata and quality assurance. The vision embraces the need to link observations from a broad range of platforms (buoys, drifters, autonomous vehicles, ships, aircraft, satellite, and cabled instruments on the sea floor). The observations will include biological and geological specimens and samples, point measurements, continuous measurements, movies, photographs, and imagery, in real-time, near-real-time, and delayed-mode. The vision is not limited to the collection of data; it includes the Data and Communications needed to move data among systems and users in a distributed environment. Finally, the vision embraces the need to provide products, which are so essential to users who require information for decision-making and education, rather than data per se. The vision is global in scope, linking US coastal networks seamlessly with international global ocean observing plans.

In this report, we define the Process that will turn this vision into a detailed, rational design for the future IOOS system. The Process will be inclusive. It will build upon existing systems and data management institutions and centers. It will draw input from users and user groups. It will draw upon technical experts to assess and provide guidance on current and emerging technologies. Many of the pieces of the vision already exist in regional, academic, research, and national systems, and these will be used as widely as possible as building blocks of the new IOOS system. Some key components, however, need to be assessed and/or developed before an overall operational system can be designed and delivered. At its completion the Process will provide a blueprint for establishing a nationwide, distributed information management system that utilizes existing and

COMPONENTS OF THE INTEGRATED AND SUBSTAINED OCEAN OBSERVING SYSTEM

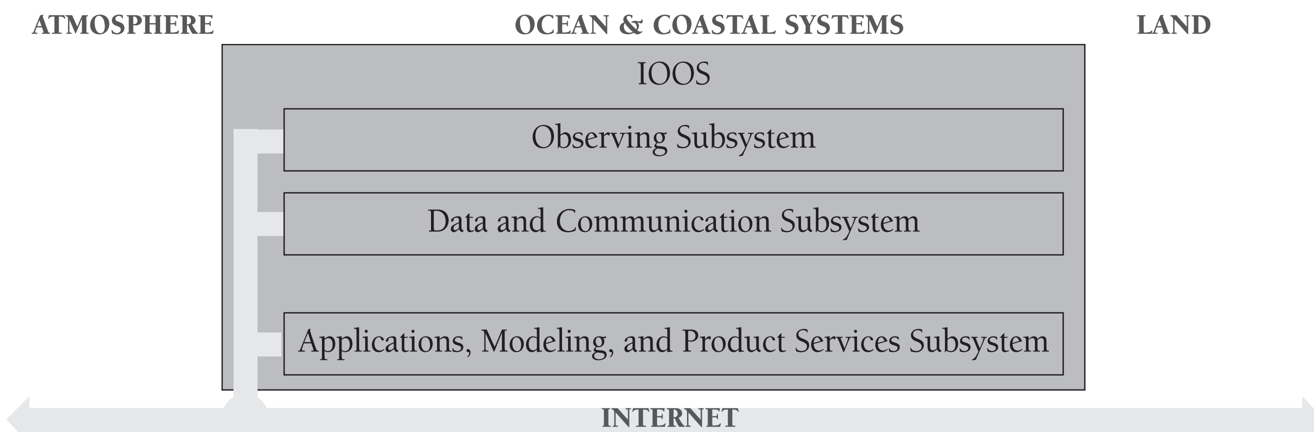


Figure 1. Components of the Integrated and Sustained Ocean Observing System.

emerging technologies, which have gained acceptance for communications, data, and commerce.

The "Data and Communications Subsystem" is envisioned to provide the data management and communications to support the "Observing Subsystem" and the "Application, Modeling, and Product Services Subsystem". The three subsystems collectively compose the IOOS (Figure 1).

A PROCESS LEADING TO A PLAN

The Process begins with the appointment by Ocean.US of i) a Data And Communications Steering Committee (DACSC), ii) four Expert Teams, and iii) two virtual Outreach Teams led by rapporteurs.

The Expert Teams will have the task of evaluating available technologies and making recommendations in the form of White Papers. The four Expert Teams will be the:

1. Data Transport Expert Team
2. Data Discovery / Metadata Management Expert Team
3. Applications Expert Team
4. Data Archival Expert Team

The virtual Outreach Teams will be established to provide guidance and critical feedback to the DACSC, through the rapporteurs, from established National and Regional data centers and from stakeholding user groups that have serious interests in ocean data products:

1. Data Facilities Management Team
2. User Outreach Team

The DACSC will consist of i) the Rapporteurs from the Outreach Teams, ii) the Chairs of the Expert Teams, and iii) other persons as appointed by Ocean.US. To ensure continuity of the planning process at least two of the DACSC members should be drawn from the Ocean.US Workshop (March 10-15, 2002) DAC Working Group.

The DACSC, the four Expert Teams and the two virtual Outreach Teams will begin work in April-May, 2002 (Figure 2). Based upon the consensus documents developed at the Ocean.US Workshop the DACSC will assign the Expert Teams with areas of responsibility that must be addressed and guidance on specific aspects of the assigned topics (summarized below). The Expert Teams will meet in person and by conference calls to develop White Papers that thoroughly address their assigned topics, by September 1, 2002.

Each Outreach Team rapporteur has the task of consulting with their respective communities in order to develop Community Issues Lists representing the areas of concern that the Data And Communications Plan should address. Should issues arise in the Outreach Team discussions that might impact the technical conclusions of the Expert Teams, the Outreach rapporteurs should promptly bring these issues to the attention of the DACSC (which includes the Expert Team chairs). The DACSC will meet as required in person or by telephone to resolve these issues. Final versions of the Community Issues Lists should also be delivered to the DACSC by September 1, 2002.

Following receipt of the White Papers and Community Issues Lists the Steering Committee must meet in person and/or by telephone and email to write the Plan by October 1, 2002. The Plan will be circulated for review and comment during October, followed by a meeting to be hosted by Ocean.US in November to review the Plan in a public forum. The DACSC should deliver the Plan in final form to Ocean.US in December, 2002.

TIMELINE FOR PLAN DEVELOPMENT

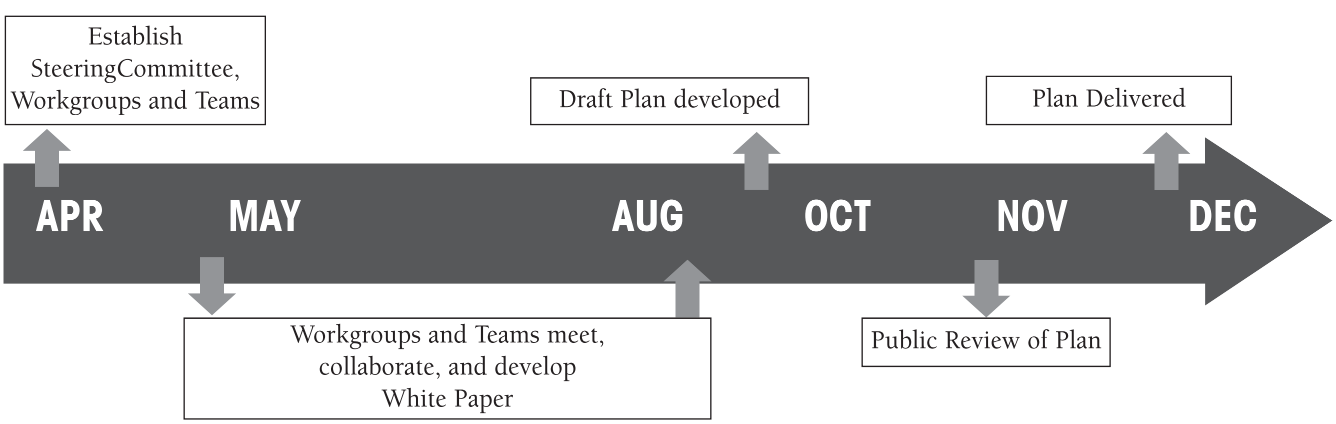


Figure 2. Timeline for Plan Development

As a practical matter there is a need for rapid deployment of the DAC subsystem because the streams of ocean measurements are already in a state of rapid growth both nationally and internationally. To address this time-critical need several pilot projects are recommended to be undertaken in parallel with the planning process. The pilot projects will be conducted on a volunteer basis; other projects may be added as the planning proceeds. The DACSC should monitor the progress of these pilot efforts and provide feedback accordingly to the Expert Teams. The intent is that the pilot projects will provide valuable feedback to the planning process, while also shortening the overall time required to achieve operational status for the DAC subsystem.

THE DAC STEERING COMMITTEE AND TEAMS – RESPONSIBILITIES, GUIDANCE, AND PILOT PROJECTS

GENERAL

Sensitive (classified or proprietary) data may require special management considerations in this system.

Standards developed within the IOOS framework should be consistent as far as practical with those developed by international elements of GOOS. Where necessary standards do not exist IOOS should work in coordination with international groups to help develop these standards.

THE STEERING COMMITTEE (DACSC):

Responsibilities:

- Oversight of the planning process
- Oversight of initial pilot projects (described under Pilot Projects, below) and possible identification/ initiation of new ones
- Providing areas of responsibility, and guidance verbally and in writing to the Expert Teams
- Assigning issues, and guidance verbally and in writing to the Outreach Teams
- Assigning consultation to both the Expert Teams and the Outreach Teams as needed during their deliberations
- Consideration of cross-cutting issues including security, standards, design tradeoffs, networks, existing systems, interoperability, maintainability, flexibility, cost, system administration functions, system performance monitoring
- Designing and writing the draft Plan
- Circulating the draft Plan widely for public review
- Presenting and discussing the draft Plan at the Public Review Meeting
- Modifying the Plan as appropriate based upon feedback received during the review process, in order to achieve a reasonable consensus solution
- Writing the final Plan and presenting it to Ocean.US by December 2002
- Addressing the issues of Governance of the IOOS DAC subsystem

Expert Teams' responsibilities are to evaluate the status and trends of the technology areas named below in the context of guidance to be provided:

DATA TRANSPORT EXPERT TEAM

Responsibilities:

- Conventions for encoding metadata
- Diversity of data types
- Scientific Information System – Geographic Information System interoperability
- One or more data transport protocols
- Multi-protocol interoperability gateways
- Subsystem performance
- Special data types (video, acoustic, complex data structures)
- Server functionality
- Subsetting
- Aggregation
- Metrics to calibrate usage of the system and specifications of how ongoing tracking can be achieved

Guidance:

- XML is the Ocean.US workshop recommendation for transport of metadata
- The National Virtual Ocean Data System (NVODS) is the Ocean.US workshop recommendation for transport of data with consideration for alterations as necessary to accommodate the needs of biological data that have been identified through the Ocean Biological Information System (OBIS).
- Interoperability with Open GIS (OGIS) data transport is essential (though it is recognized that OGIS is not sufficient for many classes of ocean data)
- There is a requirement for operational, mission-critical data "push". Primary candidate technologies include GTS, next-generation GTS, and the Internet Data Distribution (IDD) system.
- Clarification: The DAC subsystem will not address problems of platform-specific telemetry for sensors (e.g. getting ARGO data to shore). We define this communications step as an aspect of the sensor subsystem.

Pilot Projects:

- Pilot project: Recommend an NVODS and OBIS/GBIF exchange standard.
- Pilot Project: Transport data from NDBC Hub (70 moored buoys and 60 C-MAN shore sites-transporting hourly observations) via NVODS and provide metadata access/data discovery via the NCDDC portal

DATA DISCOVERY / METADATA MANAGEMENT EXPERT TEAM

Responsibilities:

- Controlled vocabulary

- Semantic keywords and data dictionaries
- Existing standards and standards frameworks
- Adaptive metadata – merged data, products, etc.
- Metadata for non-traditional data types
- Metadata as data
- Portal concept
- Maintainability of system
- Metadata versioning strategy

Guidance:
- FGDC is the Ocean.US workshop recommendation for a metadata content standard (with the option of defining formal profiles).
- The metadata requirements for data providers to participate in the IOOS must be clear and simple.

Pilot Projects:
- Pilot project: A pilot project is encouraged that will begin to provide for a catalog and data access portal at NOAA's National Coastal Data Development Center.

APPLICATIONS EXPERT TEAM
Responsibilities:
- Quality Control
  - Data of known quality
  - Some level of quality requirements for each data type
  - Need data maps to ensure data that are expected are available
  - Feedback from users on data quality and system integrity
  - Online data entry forms to improve data quality
- Data Assembly
  - Data in distributed locations must be made parallel in format and quality
  - Version control for assembled data collections
  - Software interfaces must assist data assembly process
- Product Generation
  - Data products that will be the responsibility of the DAC are related to DAC operations (i.e. data inventories, procedures, standards, process, standards)
  - Technical products are the responsibility of the "application subsystem"

Guidance:
- Clarification: The DAC subsystem is responsible for delivering input data for models and delivering model output as data to users. It is not responsible, however, for the running of models or the production of numerical data products.
- Clarification: QC procedures must be developed as a partnership between the operations, and DAC.

Pilot Projects:
- Pilot project: The US Global Ocean Data Assimilation Experiment (GODAE) server, which is co-located with US Navy Fleet Numerical Meteorology and Oceanography Center (FNMOC) in Monterey, California, should be regarded as a pilot project within the IOOS for the assembly of real time observations in support of operational modeling.

DATA ARCHIVAL EXPERT TEAM
Responsibilities:
- Data duplication between centers and within centers
- Complete disciplinary archives
- Metadata completeness
- Operational resources
- Incentives for users to submit data
- Coordination between Centers
- Capability for real-time acquisition
- Model input and output data
- Archeology and mining of external data

Guidance:
- The Ocean.US workshop recommendation is "Initially, don't look back!"
  Emphasize pilot projects to introduce new approaches to archiving data

Pilot Projects:
- Define pilot projects at existing archive centers after IOOS standards are defined

DATA FACILITIES MANAGEMENT TEAM

Responsibilities:
- Encouraged to provide inputs and issues to technical teams
- Keep team informed of progress on a regular basis
- Consider pilot projects that would begin implementation of the Plan
- Solicit inputs to the Plan

USER OUTREACH TEAM
Responsibilities:
- Recommend to DAC Steering Committee requirements of users, represented by centers producing products and services
- Keep team informed of progress on a regular basis
- Consider pilot projects that would begin implementation of the Plan
- Solicit inputs to the Plan
- Make recommendations to the DACSC on a structure that ensures ongoing communications between IOOS DAC managers and user groups – identifying new user needs and providing feedback on inadequacies within the system.

ECONOMIC CONSIDERATIONS IN BUILDING OCEAN OBSERVING SYSTEMS

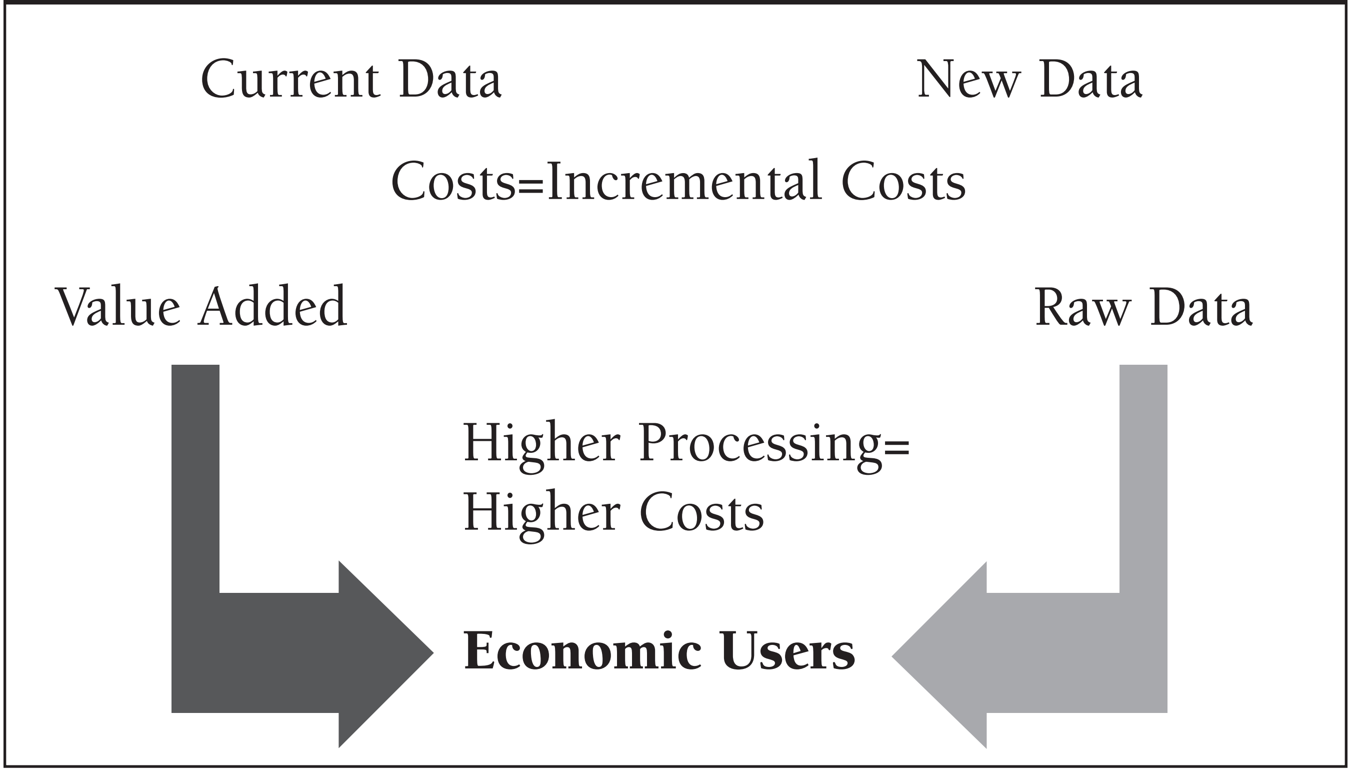
MAJOR ECONOMIC QUESTIONS

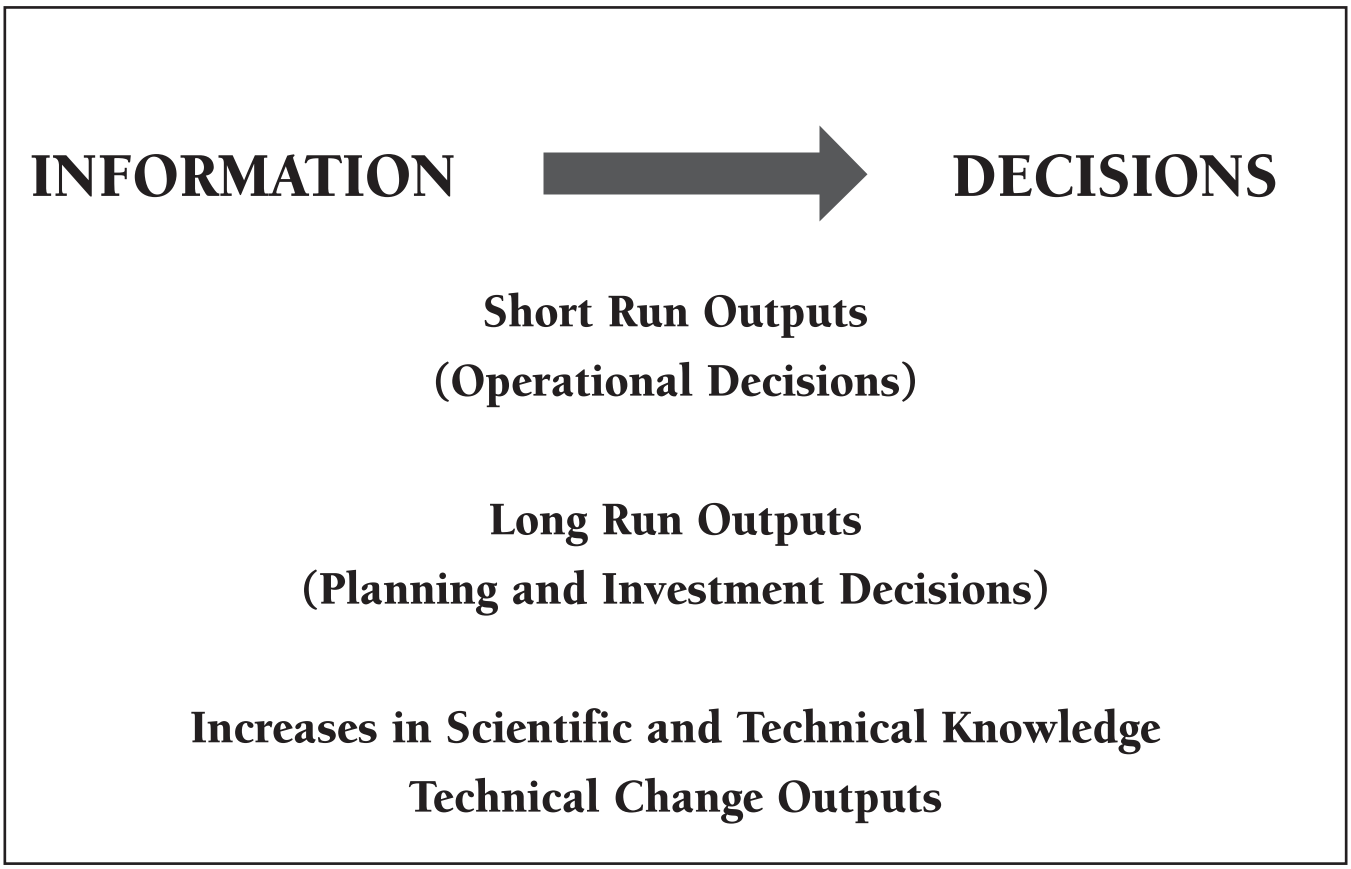
- **Do the benefits of the system exceed the costs?**
- **Among those elements where the benefits exceed the costs, which should have highest priority?**
- **What products have the greatest net economic benefit?**

Benefits

- Costs
- Timeliness

A SIMPLE COST FRAMEWORK





ECONOMIC BENEFITS

- **Changes in Social Surplus**
  - **Producer Surplus**
    - What producers receive less what it costs to produce
  - **Consumer Surplus**
    - What consumers would be willing to pay less what they actually pay
  - **Net Change in Economy**
- **Increased Goods and Services**
- **Lower Cost Goods and Services**

A BENEFITS FRAMEWORK

	Q	P	SR	LR	TC
SAR & ER	L	H	X		
Recreation	H	L	X		
Living Res	L	H		X	X
Trans	H	L	X		
Energy	H	H	X		
Public Health	L	H	X	X	X
Other					

EXAMPLE OF PRODUCT EVALUATION

		COSTS		BENEFITS			
		add'l obs	VA proc	freq	unit $	[$]	
1.1	SST variability					HIGH	SHORT & LONG RUN
2.2	ENSO prediction		X	HIGH	HIGH		SHORT RUN
2.3	Upper ocean variability/ climate predictions	X	X	HIGH	HIGH		
2.6	Global/regional sea level		X	HIGH	HIGH		LONG RUN
5	Detection/prediction of harmful algal species	X	X	HIGH	LOW?		SHORT & LONG RUN
9	Anthropogenic Contaminants	X	X	LOW	HIGH		MORE COST-EFFECTIVE RESPONSE
1	Ensure safe and efficient marine ops and activities	X	X	HIGH	HIGH		SHORT & LONG RUN
2	Maintain navigable waterways	X		HIGH	HIGH?		SHORT & LONG RUN
3	SAR and Emergency Spill Response	X		LOW	HIGH		SHORT RUN
4	Airborne/waterborne contaminant distribution and prediction	X	X	LOW	HIGH		SHORT RUN
2	Modeling capabilities/predictions/ uncertainty	X	X	LOW	HIGH		
1	Nationally standardized risk measures/swimming	X		HIGH	LOW		
2	Nationally standardized risk measures/seafood consumption	X		LOW	LOW?		
1	Measure fluctuations in harvested marine species	X	X	HIGH	HIGH		SHORT & LONG RUN
5	Improve measurements of abundance and impacts	X	X	HIGH	LOW		SHORT & LONG RUN

AN EXAMPLE OF A BENEFIT/COST MATRIX

		BENEFITS		
		LOW	**MEDIUM**	**HIGH**
INCREMENTAL COSTS	**LOW**	3	6	9 SST Variability
	MEDIUM	2 Pub Health Seafood	3 SAR/Emergency Response Public Health Swimming	6 Fore Prediction Sea Level Navig Waterways
	HIGH	1	2 HAB Prediction Antropogenic Contam Air/Water Contam Hazard Prediction Endangered Species	3 Upper Ocean Climate Safe/Eff Marine Stock Assessment

AN EXAMPLE OF A RANKING BY NET BENEFITS

	NET BENEFITS
SST Variability	9
Enso Prediction	6
Sea Level	6
Navig Waterways	6
Upper Ocean Climate	3
Safe/Eff Marine	3
Stock Assessment	3
SAR/Emergency Response	3
Pub Health Seafood	2
HAB Prediction	2
Anthropogenic Contam	2
Air/Water Contam	2
Hazard Prediction	2
Endangered Species	2
Public Health Swimming	2

SOME GUIDING PRINCIPLES

- **Produce products which have a high net economic benefit first**

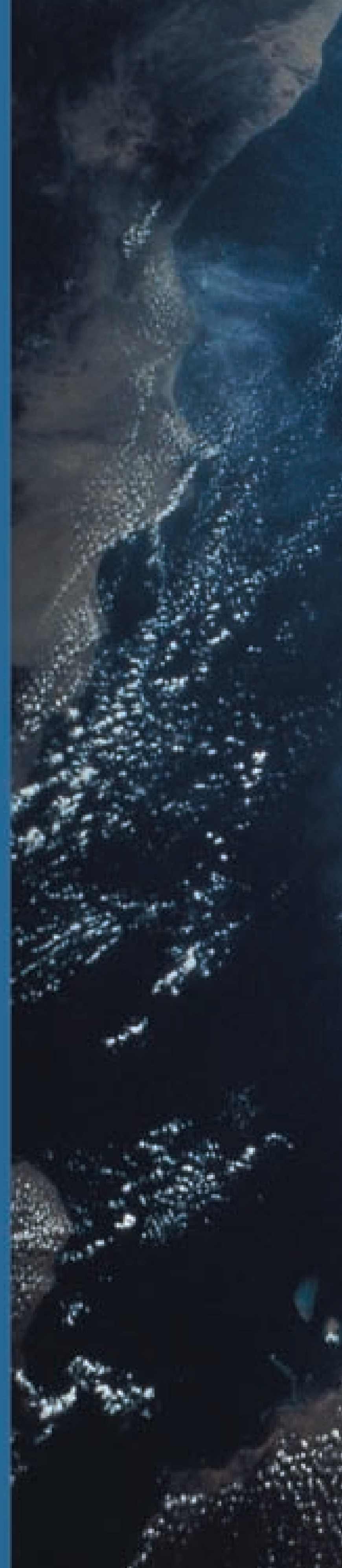
- **Net Benefits are likely to be highest when:**
  - **There are multiple sources of benefits**
  - **Information gets to decision makers sooner rather than later**

- **Build towards products that provide lower economic benefits**

- **Economic screening adds to, does not replace screening based on:**
  - **Scientific/Technical Impact and Feasibility**
  - **Policy Imperatives**

NOTES

ADCP Acoustic Doppler Current Profiler
ADEOS Advanced Earth Observing Satellite
AOP Apparent Optical Properties
ASAPP Automated Shipboard Aerological Programme Panel
ATSR Along Track Scanning Radiometer
AUV Autonomous Underwater Vehicle
AVHRR Advanced Very High Resolution Radiometer
CalCOFI California Cooperative Oceanic Fisheries Investigation
CDOM Colloidal Dissolved Organic Matter
C-GOOS Coastal component of GOOS
CLIVAR Climate Variability and Predicability Programme (part of WCRP)
CPR Continuous Plankton Recorder
CTD Conductivity-Temperature-Depth
DAC Data and Communications
DACSC Data and Communications Steering Committee
DBCP Data Buoy Cooperation Panel
DIC Dissolved Inorganic Carbon
DIN Dissolved Inorganic Nitrogen
DM Data Management
DO Dissolved Oxygen
DOC Dissolved Organic Carbon
EEZ Exclusive Economic Zone
EOS Earth Observing System
EXCOM Executive Committee
FGDC Federal Geographic Data Committee
FNMOC Fleet Numerical Meteorology and Oceanography Center
FOFC Federal Oceanographic Facilities Council
FTP File Transfer Protocol
GBIF Global Biodiversity Information Facility
GCOS Global Climate Observing System
GIS Geographic Information System
GLOSS/GE The Group of Experts on the Global Sea-Level Observing System
GMNET Gulf of Mexico Aquatic Monitoring Network
GODAE Global Ocean Data Assimilation Experiment
GOES Geostationary Operational Environmental Satellite
GOOS Global Ocean Observing System
HAB Harmful Algal Bloom
HABSOS Harmful Algal Blooms Observing System
HOTO Health of the Ocean
HSI Hyper Spectral Imagery
HTTP Hypertext Transfer Protocol
IFA Impact-Feasibility Analysis
ICSU International Council of Scientific Unions
IMS International Monitoring System
IOC Intergovernmental Oceanographic Commission
IODE International Oceanographic Data and Information Exchange
IOP Inherent Optical Properties
IOOS Integrated and Sustained Ocean Observing System
IRI International Research Institute for Climate Prediction
IWG Interagency Working Group
JCOMM Joint Technical Commission for Oceanography and Marine Meteorology
LMR-GOOS Living Marine Resources panel within GOOS
MPERSS Marine Pollution Emergency Response Support System
NAO North Atlantic Oscillation
NDBC National Data Buoy Center
NOPP National Oceanographic Partnership Program
NORLC National Ocean Research Leadership Council
NPDO North Pacific Decadal Oscillation
NRC National Research Council
NVODS National Virtual Ocean Data System
NWS National Weather Service
OBIS Ocean Biogeographic Information System
OBS Ocean Bottom Seismographs
OOPC Ocean Observations Panel for Climate
OOSDP Ocean Observing System Development Panel
OPeNDAP Open source Project for a Network Data Access Protocol
ORAP Ocean Research Advisory Panel
PA Program Area
pCO_2 Partial Pressure of CO_2
PORTS The Physical Oceanographic Real-Time System
QC Quality Control
ROV Remotely Operated Vehicle
RS Remote Sensing
SAR Synthetic Aperture Radar
SC Steering Committee
SMTP Simple Mail Transfer Protocol
SOOP Ship of Opportunity Program
SOOPIP Ship of Opportunity Program Implementation Panel
SOSUS SOund SUrveillance System
SSH Sea Surface Height
SSS Sea Surface Salinity
SST Sea Surface Temperature
TAO Tropical Atmosphere Ocean project
TIC Total Inorganic Carbon
TOC Total Organic Carbon
TOGA Tropical Ocean Global Atmosphere
TN Total Nitrogen
TRITON Triangle Trans-Ocean Buoy Network
TRMM Tropical Rainfall Measuring Mission
UNCED UN Conference on Environment and Development
UNFCC United Nations Framework Convention on Climate Change
USGSC U.S. GOOS Steering Committee
UUV Unmanned Underwater Vehicle
VOS Voluntary Observing Ship
WCRP World Climate Research Program
WMO World Meteorological Association
WOCE World Ocean Circulation Experiment
XCTD Expandable Conductivity, Temperature and Depth profiling system
XSV Expendable Sound Velocimeter



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