INTEGRATED OCEAN OBSERVING SYSTEM

HIGH-LEVEL FUNCTIONAL REQUIREMENTS

VERSION 1.5

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Integrated Ocean Observing System: High Level Functional Requirements

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Executive Summary

The Integrated Ocean Observing System (IOOS) is a coordinated network of observations, analysis and model data on past, present, and future states of the oceans and U.S. coastal waters.[1] The IOOS functions include the systematic and efficient acquisition and distribution of observation data, data management and communications (DMAC), and data analyses and modeling related to oceans and coasts. The Interagency Working Group on Ocean Observations (IWGOO) designated NOAA as the lead federal agency for IOOS.

As a part of the IOOS implementation planning effort, the NOAA IOOS Program collected functional requirements from a variety of existing sources and compiled them into this single document, grouped by activity:

- System design—requirements that address the design, implementation and security of IOOS and its subsystems.
- Data collection—requirements that pertain to data quality control, management, and access.
- Metadata management—requirements that pertain to the way metadata is handled in IOOS and its various subsystems and interfaces.
- Data archive—requirements that pertain to short- and long-term data storage in an archive and to data maintenance. These requirements include guidelines for data retention, data preservation, data catalog services, and data access permissions.
- Data services—requirements that pertain to data transport and delivery, data discovery and searches, data availability, data sharing, and data transmission.
- Standards and interoperability—requirements that pertain to data standards applicable to IOOS and the various subsystems, data integration and linkage, and guidelines on system interoperability and monitoring.

[1] "Coastal" refers to the U.S. Exclusive Economic Zone (EEZ) and territorial waters, the Great Lakes, and estuaries. "Estuaries" refers to all semi-enclosed bodies of water—bays, lagoons, fjords, tidal wetlands, and so on—that are connected to the ocean.

- Portal services—requirements that pertain to the service components of the portal, including education, short- and long-term forecasts for ocean water and weather, ocean observing data, and the IOOS main home page.

- Observing and sensor and non-sensor/data acquisition services—requirements that pertain to the acquisition of IOOS and subsystems core variables and other observations.

- Research, and education services—requirements that pertain to research, education, and outreach services.

- Administrative services—requirements that address system administrative duties.

In addition, the IOOS contains a modeling and analysis services (MAS) component. To date specific requirements have not been covered, but appropriate design principles are addressed.

Although the requirements are collected and organized into this single document, no effort was made to:

- Edit or revise them based on our perceived value of the original content or changes due to time or circumstance

- Judge their applicability or scope

- Ameliorate any deficiencies in scope (e.g., the reader will notice that the bulk of the requirements address the DMAC, some address observation, and very few relate to modeling an analysis. Similarly, there is more emphasis on operational requirements than research)

This document is intended to:

- Retain the value of previous efforts in a single document

- Share this data across the community, and

- Serve as an input into a detailed functional requirements document which in turn will support the national DMAC technical design.

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Chapter 1
Introduction

PURPOSE

The Integrated Ocean Observing System (IOOS) is a coordinated network of observations, analysis and model data on past, present, and future states of the oceans and U.S. coastal waters.[1] The IOOS functions include the systematic and efficient acquisition and distribution of observation data, data management and communications (DMAC), and data analyses and modeling related to oceans and coasts.

As a part of the IOOS implementation planning effort, the NOAA IOOS Program collected functional requirements from a variety of existing sources and compiled them into this single document. This IOOS High-Level Functional Requirements Document (HLFRD) will be used to assist developing more detailed documents as the program focuses its efforts in developing and deploying a National DMAC to serve all IOOS stakeholders.

BACKGROUND

The National Oceanic and Atmospheric Administration (NOAA) was designated, by the Interagency Working Group on Ocean Observations (IWGOO), as the lead federal agency for developing an Integrated Ocean Observing System (IOOS).[2] IOOS is part of the U.S. Integrated Earth Observation System (IEOS), as well as the U.S. contribution to two international programs: Global Ocean Observing System (GOOS) and Global Earth Observation System of Systems (GEOSS). The NOAA IOOS Program mission is to

> lead the integration of ocean, coastal, and Great Lakes observing capabilities, in collaboration with Federal and non-federal partners, to maximize access to data and generation of information products to inform decision making and promote economic, environmental and social benefits to our nation and the world.[3]

NOAA's goal for the IOOS is to "provide continuous data on our open oceans, coastal waters, and Great Lakes in the formats, rates, and scales required by scientists, managers, businesses, governments, and the public to support research and inform decision-making."[4] To realize the goal, the national IOOS has three components:

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[1] "Coastal" refers to the U.S. Exclusive Economic Zone (EEZ) and territorial waters, the Great Lakes, and estuaries. "Estuaries" refers to all semi-enclosed bodies of water—bays, lagoons, fjords, tidal wetlands, and so on—that are connected to the ocean.

[2] Charter, Interagency Working Group on Ocean Observations (IWGOO), December 2006.

[3] NOAA, National Ocean Service, *NOAA Integrated Ocean Observing System (IOOS) Program: Strategic Plan 2008–2012*, October 2007, p. 4.

[4] See http://ioos.noaa.gov/about/.

- *Observing subsystem.* This subsystem comprises the collection of remotely sensed and in situ measurements and their transmission from regional and national backbone platforms and systems that collect sensor and non-sensor data.

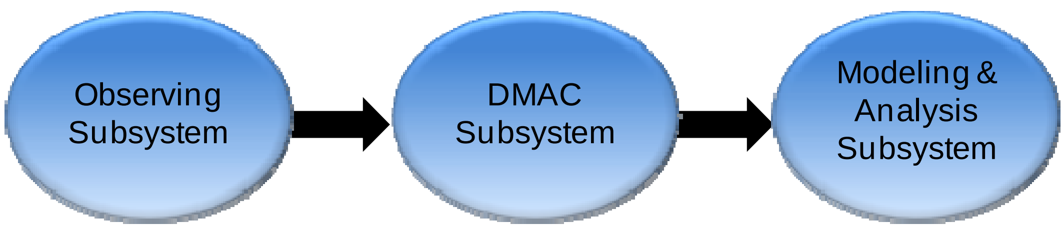
- *Data management and communications (DMAC) subsystem.* This subsystem comprises the information technology infrastructure such as national backbone data systems, regional data centers, and data assembly centers (DACs) connected by the Internet and using shared standards and protocols.

- *Modeling and analysis subsystem.* This subsystem consists of evaluation and forecasting of the state of the marine environment based on assimilated measurements; it also includes decision support.[5]

Each of the subsystems consists of a set of functions, hardware, software, and infrastructures, as well as a variety of entities and programs.

Figure 1-1 shows how the three IOOS subsystems interact to enhance the nation's ability to collect (via the observing subsystem), deliver (via the DMAC subsystem), and use (via the modeling and analysis subsystem) information about the oceans, coastal areas, and Great Lakes.

Figure 1-1. IOOS Components



IOOS Components

The IOOS consists of two interdependent components that use both remote and in situ sensing to make measurements over the broad range of scales needed to detect, assess, and predict the effects of global climate change, weather, and human activities on oceans and coasts:

- The global component, an international collaboration, is being implemented to improve forecasts and assessments of weather, climate, and ocean states, as well as to provide boundary conditions for the coastal component. The global component has been developed and is being implemented under the oversight of the Joint Intergovernmental Oceanographic Commission/World Meteorological Technical Commission for Oceanography and Marine Meteorology (JCOMM) and with scientific guidance from the Global Climate Observing System (GCOS) and the GCOS/Global Ocean Observing System/World Climate Research Program Ocean Observations Panel for Climate (OOPC).

[5] National Office for Integrated and Sustained Ocean Observations, *The First U.S. Integrated Ocean Observing System (IOOS) Development Plan*, Ocean.US Publication 9, January 2006.

- The coastal component is designed to detect, assess, and predict the effects of weather, climate, and human activities on the state of the coastal ocean, its ecosystems and living resources, and the U.S. economy. It consists of both a National Backbone and regional coastal ocean observing systems (RCOOSs).[6] Development of the coastal component is critical to the design and implementation of ecosystem-based management of public health risks, water quality, and living marine resources. The immediate priorities for the next 5 years are establishing the DMAC subsystem, incorporating existing operational assets of the observing subsystem into an integrated system, establishing RCOOSs, and linking IOOS development to Earth science education, training, and public outreach. Enhancements to the National Backbone will occur before, during, and after the "initial DMAC subsystem is operational.

The integrated system will efficiently and effectively link models and model development to observations and establishes a sustained hierarchy of observations across spatial scales from the global ocean to coastal ecosystems. Together, the ocean and coastal components of the IOOS constitute a hierarchy of observations, modeling and analysis required to detect, assess, and predict the effects of large-scale changes in the oceans, atmosphere, and land-based inputs on coastal ecosystems, resources, and human populations.

Regional Associations (RAs) represent the interests of groups that use, depend on, manage, monitor, and study marine systems in their respective regions. For this purpose, RAs engage representatives from federal and state agencies, private-sector entities, nongovernmental organizations (NGOs), tribes, and academia in the design, implementation, operation, and improvement of RCOOSs that enhance the National Backbone based on regional priorities. The National Backbone consists of in situ observations and remote sensing, data management and modeling needed to achieve the goals and missions of federal agencies and to meet the common requirements of RAs. Establishing the National Backbone achieves economies of scale by measuring, managing, and analyzing a set of core variables needed by all or most regions.

IOOS Support of NOAA Missions

The IOOS supports the goals of NOAA's four major missions. Table 1-1 shows the goals and the related performance objectives for each.

Table 1-1. NOAA Goals and Performance Objectives, by Mission

Mission	Goals	Performance objectives
Ecosystem	Healthy and productive coastal and marine ecosystems that benefit society	Increase number of coastal communities incorporating ecosystem and sustainable development principles into planning and management

[6] "The National Backbone links global ocean and coastal ocean observations and establishes a framework for the development of RCOOSs. RCOOSs are designed, implemented, operated and improved by Regional Associations (RAs) to provide data, information and products on marine and estuarine systems deemed necessary by user groups (stakeholders) in the region. Based on these requirements, RCOOSs enhance the National Backbone by increasing the time-space resolution of measurements as well as the number of variables measured." http://www.ocean.us/node/203.

Table 1-1. NOAA Goals and Performance Objectives, by Mission

Mission	Goals	Performance objectives
Climate	A predictive understanding of the global climate system on time scales of weeks to decades with quantified uncertainties sufficient for making informed and reasoned decisions	Improve climate predictive capability from weeks to decades, with an increased range of applicability for management and policy decisions
		Reduce uncertainty in climate projections through timely information on the forcing and feedback contributing to changes in the Earth's climate
Weather and water	Reduced loss of life, injury, and damage to the economy Better, quicker, and more valuable weather and water information to support improved decisions Increased customer satisfaction with weather and water information and services.	Increase lead time and accuracy for weather and water warnings and forecasts
		Improve predictability of the onset, duration, and impact of hazardous and severe weather and water events
		Increase coordination of weather and water information and services with integration of local, regional, and global observation systems
		Increase application and accessibility of weather and water information as the foundation for creating and leveraging public (federal, state, local, tribal), private, and academic partnerships
		Reduce uncertainty associated with weather and water decision tools and assessments
		Enhance environmental literacy and improve understanding, value, and use of weather and water information and services
Commerce and transportation	Safe, secure, and seamless movement of goods and people in the U.S. transportation system	Enhance navigational safety and efficiency by improving information products and services

The following IOOS objectives support the achievement of NOAA mission goals:

- *Ecosystem mission goal.* Integrate the capabilities of an ecological component of the NOAA global earth observing system to monitor, assess, and predict national and regional ecosystem health
- *Climate mission goal.* Integrate the climate observations, analyses, interpretation, and archiving by maintaining a consistent climate record and by improving our ability to determine why changes are taking place
- *Weather and water mission goal.*

  - Improve the reliability, lead-time, and effectiveness of weather and water information and services that predict changes in environmental conditions

  - Work with private industry, universities, and national and international agencies to create and leverage partnerships that foster more effective information services

- *Commerce and transportation mission goal.* Integrate advanced technology monitoring and observing systems, such as weather and oceanographic observations, ice forecasts and "nowcasts," hydrographic surveys, and precise positioning coordinates to provide accurate, up-to-date information.

ASSUMPTIONS AND OPERATING PRINCIPLES

Numerous assumptions and operating principles were identified in NOAA-sponsored industry concept designs for IOOS. This subsection details the assumptions and operating principles relevant to the IOOS functional requirements.

Assumptions

The following are key assumptions concerning the IOOS concept:

- Much of the work done on IOOS by organizations such as Ocean.US (closed as of the end of FY08) and as documented in *The IOOS Development Plan*, *The DMAC Plan*, and many associated documents are generally accepted ideas, concepts, and requirements for IOOS.

- IOOS will have a diverse set of stakeholders that drive or influence its implementation.

- Each stakeholder is an active member of the IOOS community whose systems will contribute to the collection of systems and services that will constitute IOOS.

- IOOS will leverage and reuse, to the maximum extent possible, existing systems in the stakeholder community, including infrastructure assets, technical platforms, and communication networks.

- IOOS will have an authoritative governance body that oversees and coordinates its implementation and ongoing operations.

IOOS development is anticipated to continue incrementally, beginning with the core "infrastructure" service components. The following are key assumptions about IOOS implementation:

- A base set of technical data and metadata standards will be in place prior to the start of implementation.

- Software development and installation (nonrecurring costs) will occur in a development environment employing the following phases: requirements definition, design, implementation with unit tests and peer reviews, integration, verification and test, and installation.

- Good engineering practices will be followed in the development phase to help ensure the production of maintainable software. This implies that development productivity is lower than in a rapid-development or prototype environment but industry and academic experience indicates the overall cost is lower.

- Development and maintenance teams will have average to high levels of experience, skills, and abilities.

- A reusable library of source code will be developed and maintained for use by the horizontal integration assets.

- A lead federal agency will be in place with full responsibility and accountability for the successful implementation of IOOS.

- A core group of system engineering capabilities will be dedicated to IOOS under the operational oversight of the lead federal agency.

Although a high-level functional requirement statement is still needed to better define regional leadership, the following assumptions concern the development of regional observing systems:

- RAs—one per region—will be established to manage the design, implementation, operation, and development of regional ocean observing systems.

- Regional boundaries will be established by the RAs as they develop, with the number of regions being manageable (currently 11) in terms of national coordination.

- RAs will develop their own business and management plans.

- RAs will have a sustained commitment to comprehensive data archiving that is coordinated nationally.

- RAs will support the incorporation of existing assets and capabilities into IOOS.

The following assumption is critical for IOOS success over the long term:

- Recognizing the missions and goals of participating agencies, NOAA will be the primary agency responsible for implementing and operating the National Backbone of observations and data management.

Operating Principles

Several operating principles may influence the development of the IOOS design. Some of these operating principles are technical, and some are program related. The following are the operating principles viewed as most significant:

- NOAA will work in a collaborative manner with the IWGOO, RAs, NFRA, States, U.S. IEOS, and GOOS (Global Component) to ensure an all inclusive and successful IOOS development and implementation.

- The IOOS design should not depend on a specific technology of implementation for its architecture.
- The IOOS design should not depend on any specific vendors and underlying hardware or software products.
- The IOOS design should not exclusively depend on any single specific existing or new local, state, or federal ocean observing system(s).
- The IOOS design should be extendable for additional functions and expansions. The IOOS conceptual design should not be affected adversely by the constraints of an individual existing system.
- The IOOS design should adopt data, metadata, and other applicable standards only after they have been validated and recommended for IOOS use.

Several operating principles may influence the development of the DMAC design; some are technical, and some are program related. The operating principles viewed as most significant to the development of DMAC data transport are as follows:

- The data transport should be designed to work cooperatively with other systems. For example, if a repository already uses a system that depends upon a particular data storage format, that site should not be forced to abandon its system in order to adopt IOOS.
- The data transport shall be designed to operate with minimum reliance on proprietary software.
- The data transport specifications must be fully and openly accessible to the public.
- A general-purpose license for software is preferred.
- The scheme that the data transport adopts for generating syntactic and semantic data models must be flexible and extensible so that any IOOS server can find a way to express its archive’s storage format in an IOOS data model.
- The data transport must support interoperability between geographic information systems and scientific information systems.
- The data transport must support interoperability with other systems developed within other disciplines.

End Users or Beneficiaries of Program

The key end users and beneficiaries of the IOOS are as follows:

- *Federal, State, Regional, and Local Agencies.* The IOOS will enable agencies to leverage complementary capabilities to improve efficiencies and effectiveness. Further, the public sector will (continue to) use the data and information emanating from IOOS in a direct manner, improving decision support functions in each of the 7 societal goal areas.

- *IWGOO.* The IOOS program will facilitate the development and maintenance of a sustainable relationship between the federal government, industry, and international partners. (There is still a need to clearly define the role of IWGOO with regard to regions.)

- *RAs and RCOOSs.* RAs and RCOOSs will receive guidance and likely some funding for their planning and implementation in support of the IOOS. They also will benefit from the baseline observations taken at the national level.

- *Academia.* The IOOS will provide data for use by university researchers with interests in coastal regions. Scientific understanding gained over the long term can help better predict coastal phenomena that directly affect coastal communities.

- *Private sector.* The IOOS will provide data that are used by the private sector for the production and sale of services and products. The private sector includes retailers that use weather models to determine shelf items and quantities. Further, the private sector will (continue to) use the data and information emanating from the IOOS in a direct manner [e.g., Weather Forecasts, Navigation, Beach Forecasts (Waves and Pathogens), location of Fishing Areas (e.g., seawater temperature regimes).

DOCUMENT ORGANIZATION

This document is organized as follows:

- Chapter 2 discusses the IOOS operational concepts put forward by Ocean.US[7] and industry.

- Chapter 3 addresses design principles that specify the goals and expectations for the design, usage and outputs of the IOOS and its subsystems.

- Chapter 4 presents the high-level functional requirements for IOOS and its supporting systems, including requirements for the IOOS concept, and the national, integrated IOOS program.

- Chapter 5 discusses next steps for the NOAA IOOS Program to use an effective requirements management process to refine the high-level functional IOOS requirements into detailed functional requirements.

Note: Chapter 4 of this document is a compilation of IOOS related requirements as defined in a number of existing documents. We have collected them together and organized them in this single document, but we have not:

[7] Although Ocean.US closed at the end of fiscal year 2008, the IWGOO, and NOAA, will continue to coordinate IOOS efforts.

- Edited or revised them based on our perceived value of the original content or changes due to time or circumstance

- Judged their applicability or scope

- Attempt to ameliorate any deficiencies in scope (e.g., the reader will notice that the bulk of the requirements address the DMAC, some address observation, and very few relate to modeling an analysis. Similarly, there is more emphasis on operational requirements than research)

This document is entitled as an IOOS high-level functional requirements document (HLFRD). It is high-level as it collects mostly general (however some are quite specific) requirements previously identified. They will serve as one of several inputs for developing more comprehensive and detailed functional requirements which in turn will guide a technical design. Lastly, it is an IOOS HLFRD as it includes comments for all three sub-systems. Related follow-on documents will focus on the DMAC sub-system.

Chapter 2
Operational Concept

The Integrated Ocean Observing System (IOOS) is a multidisciplinary system designed to enhance our ability to collect, deliver, and use ocean information. The goal is to provide continuous data on our open oceans, coastal waters, and Great Lakes in the formats, rates, and scales required by scientists, managers, businesses, governments, and the public to support research and inform decision-making in support of the nation's ability to achieve seven societal goals:

- Improve predictions of climate change and weather and their effects on coastal communities and the nation
- Improve the safety and efficiency of maritime operations
- More effectively mitigate the effects of natural hazards
- Improve national and homeland security
- Reduce public health risks
- More effectively protect and restore healthy coastal ecosystems
- Enable the sustained use of ocean and coastal resources.

Achieving these goals depends on the establishment of a robust network of operational observing activities and systems that collect data on appropriate time scales (e.g., biological data) that routinely, reliably, and continuously provides data and information on oceans and coasts, in forms and at rates specified by modeling and analysis entities that use, depend on, manage, and study marine systems; provides multidisciplinary data and information from in situ and remote sensing and other means for describing biological and ecological systems; fosters synergy between research and the development of operational capabilities; transcends institutional boundaries; and improves public understanding of the oceans through sustained communications and education programs. In short, the IOOS must effectively leverage the collective resources of the United States to establish a fully integrated system that addresses all seven societal goals and the goals and objectives of a fully integrated global system.

To meet the goals, the NOAA IOOS Program will adhere to the following fundamental principles:

- Continue development and support of the U.S. IOOS Regional Associations (RAs), which in turn support the development of the Regional Coastal Ocean Observing Systems (RCOOSs)

- Enable data provider and user groups to achieve their missions and goals more effectively and efficiently
- Develop a scientifically sound system with guidance from the public and private sectors
- Begin by integrating existing assets that will improve the nation's ability to achieve the seven societal goals and regional priorities
- Improve the IOOS by enhancing and supplementing the initial system over time based on user needs and advances in technology and scientific understanding
- Routinely, reliably, and continuously provide data and information for multiple applications
- Openly and fully share data and information, in a timely manner
- Ensure data quality and interoperability by meeting federally approved standards and protocols for observations, data telemetry, DMAC, and modeling and analysis
- Establish procedures to ensure reliable and sustained data streams, routinely evaluate the performance of the IOOS, assess the value of the information produced, and improve operational elements of the system as new capabilities become available and user requirements evolve
- Improve the capacity of states and regions to contribute to and benefit from the IOOS through training and infrastructure development nationwide
- Demonstrate that observing systems, or elements thereof, that are incorporated into the operational system either benefit from being a part of an integrated system or contribute to improving the integrated system in terms of the delivery of new or improved products that serve the needs of user groups.

In this context, it is important to note that the IOOS does not encompass all or even a majority of ocean observations. Its purpose is to establish operational oceanography for the public good. Most oceanographic research will continue to be performed independently, while at the same time, providing an ever-growing foundation of knowledge and technology that will enable the development of operational capabilities.

The proof of concept for the IOOS will occur with the establishment of a Data Integration Framework (DIF) initial operational capability (IOC). The IOOS DIF will access and integrate data for seven core variables from various NOAA and regional observation systems and platforms: **salinity, temperature, sea surface currents, ocean color, sea level, winds and waves**. These core variables were selected from a set of 20 core variables defined by the inter-agency IOOS community and laid out in the first IOOS Development Plan[1].

The seven core variables will have data integrated into four models:

[1] In the future, advances to the IOOS Development Plan should be made at least yearly.

- Coastal inundation monitoring and forecasts and hindcasts
- Harmful algal blooms (HAB) monitoring and forecasts
- Integrated Ecosystem Assessments (IEA)
- Hurricane intensity forecasting.

Ideally, the IOC will be a scalable model using generally accepted standards that will support the development of a full-scale capability.

Chapter 3
Design Principles

This chapter presents design principles that specify the goals and expectations for the design, usage and outputs of the IOOS and its subsystems.

The following are general IOOS design principles:

- The IOOS shall comply with the OMB Federal Enterprise Architecture (FEA) Data Reference Model (DRM).
- The IOOS shall adhere to the interoperability specification provided in the GEOSS 10-year implementation plan to ensure interoperability.
- Design and implementation efforts shall remain focused on achieving the seven IOOS societal goals and shall make maximum use of existing IOOS components and other existing federal design artifacts.
- The IOOS shall provide data that is certified IOOS compliant.
- The IOOS shall provide data, products, analyses, and decision tools that meet the needs of the users.
- The IOOS shall provide a reliable, efficient link between the observation subsystem and the modeling and analysis subsystem.
- The IOOS shall support web browsers such as Mozilla Firefox, Microsoft Internet Explorer and others to be determined.
- The IOOS shall consist of coastal and global components that provide observations, products, analyses, and decision tools for the Exclusive Economic Zone, the Great Lakes, and estuaries.
- The IOOS shall enable the production and sale of value-added products by the private sector.
- All systems shall be designed to be compliant with Section 508 of the U.S. Rehabilitation Act (see http://www.section508.gov/).

The following are general IOOS design principles regarding the National Backbone specifications:

- The IOOS shall consist of a National Backbone that establishes the framework for the development of RCOOSs and links global and coastal ocean observations.

- The IOOS shall consist of coastal components including a National Backbone and RCOOS.

- The IOOS shall consist of a National Backbone that provides information required by most regions (i.e., core variables) and provides regional-specific information that is collected regionally by federal agencies".

- RCOOSs shall enhance the National Backbone by increasing the temporal and spatial resolution and variety of variables measured.

The following are shared general IOOS and DMAC design principles:

- The IOOS and DMAC shall provide the capability for the collection and transmission of data from sensor and non-sensor subsystems at entry points where the data become available using DMAC standards and protocols.

- The IOOS and DMAC shall establish simple, clear guidelines and extensible standards for metadata.

The following are general DMAC design principles:

- The DMAC shall provide oversight mechanisms to ensure the proper functioning and smooth evolution of IOOS that include establishment and publicizing of data availability policies and maintain links to other national (e.g., OOI) and international (e.g., GOOS) ocean observation systems.

- The DMAC shall provide capability for the collection and transmission of data from sensor subsystems at entry points where the data becomes available using DMAC standards and protocols either on the Internet or a supplied IOOS backbone, to assembly centers, users, and archive centers in real time (24/7) and delayed mode, for operational, research, and product generation applications.

- The DMAC shall be seamlessly integrated with data and metadata access functions provided by the data transport and metadata management functions, respectively.

- DMAC shall provide web services-based access through which end users can search for IOOS data.

The following are general IOOS design principles regarding archive and access services specifications:

- The IOOS shall provide access to long-term archives, ensure the stewardship of IOOS data sets, and conform to national archive standards, as well as IOOS standards and user requirements.

- The archiving and access service shall process a broad range of data to be included in IOOS (physical, biological, chemical, geological, fisheries, socio-economic) encompassing many different native data formats.

- The archiving and access service shall include guidelines to enable providers developing new data streams to select formats and metadata that can be easily integrated into IOOS. Specifications shall traverse the IOOS data-transport, metadata, and data-discovery components.
  - The system shall consist of a distributed network of archive centers, regional data centers, modeling centers, and data assembly centers, all interconnected to provide efficient flow of data into the IOOS archive and easy access to its data and products.
- All component data centers of the archiving and access service shall be responsible for acquiring and providing data, but only the archive centers will be primarily responsible for preserving data long term. “Long term” is defined as much longer than the typical funding period of an oceanographic research project or the career of a principal investigator.
- Archive centers shall have maintenance strategies that protect the data as storage media and systems change.

The following are general IOOS design principles regarding data transport specifications:

- The data transport methods shall be robust and handle many established common formats.
- The DMAC data transport service shall support:
  - data manipulation, including reprojection (for example, Platte-Care to Mercator)
  - regridding (for example, same projection, different resolution)
  - averaging
  - summing
  - scaling of values such that they are delivered in a consistent system of units (for example, number of specimens/m3, m/s, °C)
  - conversion of time to different representations
  - conversion of latitude and longitude
  - conversion of depth, conversion of missing values.
- The data transport service shall support data restructuring, i.e., any process incorporates a data set described by one data model and maps that data set into another data set described by another data model.
- The data transport service shall support the gathering of performance and usage metrics within the DMAC.

The following are Observing Subsystem design principles:

- Operational programs of the Observing Subsystem shall adhere to the IOOS design principle of enabling user groups from both private and public sectors to achieve their missions and goals more effectively.
- Operational programs of the Observing Subsystem shall adhere to the IOOS design principle of developing the system with guidance, from both data providers and users from public and private sectors that is based on sound science and encompasses a continuum of research to operational activities.
- Operational programs of the Observing Subsystem shall adhere to the IOOS design principle of judiciously integrating existing assets that meet operational stage requirements and address the seven societal goals and regional priorities.
- Operational programs of the Observing Subsystem shall adhere to the IOOS design principle of routinely, reliably, and continuously serving data and information for multiple applications that provide social and economic benefits both to the nation and to a broad spectrum of users from public and private sectors that use, depend on, manage, or study marine and estuarine environments and the natural resources within them.
- Operational programs of the Observing Subsystem shall adhere to the IOOS design principle of meeting federally approved standards and protocols for observations, data telemetry, and DMAC in order to ensure data quality and interoperability.
- Operational programs of the Observing Subsystem shall adhere to the IOOS design principle of openly and fully sharing data and information produced at the public expense in a timely manner at no more than the cost of dissemination.
- Operational programs of the Observing Subsystem shall comply with IOOS design principles.
- Operational programs of the Observing Subsystem shall adhere to the IOOS design principle of establishing procedures to ensure reliable and sustained data streams, to routinely evaluate the performance of the IOOS and assess the value of the information produced, and to improve operational elements of the system as new capabilities become available and user requirements evolve.
- Operational programs of the Observing Subsystem shall adhere to the IOOS design principle of improving the capacity of all states and regions to contribute to and benefit from the IOOS through training and infrastructure development nationwide.
- Operational programs of the Observing Subsystem shall adhere to the IOOS design principle of demonstrating that observing systems, or elements thereof, that are incorporated into the operational system benefit from being a part of an integrated system in terms of the delivery of new or improved products that serve the needs of user groups.

- The Observing Subsystem shall contain mechanisms that allow and promote technology refresh and the incorporation of new observing technologies.
- The Observing Subsystem shall provide data and information over a range of spatial scales from point data through global.
- The Observing Subsystem shall provide data and information over a range of temporal scales from seconds, to minutes, to hours, to decades.
- The coastal and global ocean observing systems shall integrate data and information from diverse sources to improve existing products and generate new products.
- Operational programs of the Observing Subsystem shall provide data and information required by the global module of the GOOS or by one or more of the RAs or new or better products that enable one or more of the seven goals to be achieved more effectively or more efficiently.
- Operational programs of the Observing Subsystem shall have affordable and efficient methods

The following is a general IOOS design principles regarding the portal specification:

- The portal shall allow the look and feel to be modified or customized by system administrators and end users.
- The portal shall conform to federal guidelines on Internet access to the portal.

Chapter 4
Functional Requirements by Activity

This chapter presents the high-level functional requirements for IOOS and its supporting systems, including requirements for the IOOS concept and the national, integrated IOOS program. The requirements, presented in tables, are organized by activity:

- System design
- Data collection
- Metadata management
- Data archive
- Data services
- Standards and interoperability
- Portal services
- Observing and sensor/data acquisition services
- Research and education services
- Administrative services.

Requirements for Modeling Analysis Decision Support tools and other products will be part of the overall IOOS system. To date specific modeling and analysis systems (MAS) requirements have not been covered, but appropriate design principles are addressed. “A sustained and systematic evaluation of the modeling and assimilation component of the IOOS is essential.”[1]

Two additional tables are included that capture system requirements that may be applicable to IOOS:

- Requirements for NOAA’s DIF project, and
- GEOS, GOOS and IEOS system requirements.

Appendix A contains some additional requirements, discovered during our review, that do not fall into any of the activities, may be out of scope, conceptual design requirements or were deleted from the previous version.

[1] *The First U.S. Integrated Ocean Observing System (IOOS) Development Plan*, page 63, Ocean.US, January 2006.

The requirements tables have the following columns:

- Identifier—assigns a unique number to each requirement
- Description—briefly summarizes the requirement
- System—identifies the system to which the requirement applies
- Reference—indicates the source of the requirement (the numbers are from the list of references in Appendix B).

SYSTEM DESIGN

Table 4-1 contains the requirements that address the design, implementation and security of IOOS and its subsystems.

Table 4-1. System Design

Identifier	Description	Sub-System	Reference
4.1.1	The DMAC shall offer a cross-language and cross-platform data access mechanism that is independent of the data repository.	DMAC	15. DMAC Plan p. 70, No. 6.1.9
4.1.2	The DMAC shall provide a backward-compatible, version controlled software environment.	DMAC	15. DMAC Plan p. 69, No. 6.1.6
4.1.3	Essential functions shall include constant monitoring of data streams, accounting for all files and records, and frequent checks of accuracy.	DMAC	15. DMAC Plan p. 81, No. 2.5.3
4.1.4	The archiving and access service shall maintain, in perpetuity, two copies of irreplaceable data in separate archive centers that are under independent data management. One facility will be designated as the primary archive center for a particular data set, and the other as the secondary archive center. The primary and secondary archive centers storing irreplaceable data may operate as mirror sites, both offering the same level of access, or one as the exclusive access center and the other as a "deep" back-up center (e.g., a regional data center could serve as a secondary archive center).	DMAC	15. DMAC Plan p. 84-85, No. 6.3.1.1, 6.3.1.2, 6.3.1.3, 6.3.1.4

Table 4-1. System Design

Identifier	Description	Sub-System	Reference
4.1.5	The archiving and access service shall provide a facility to collect broad-use metrics to evaluate the system effectiveness and gain a sense of how to improve it. Metrics shall include the following as a minimum: ◆ Number of “users.” The anonymous nature of much of the access prevents the true number of users from being collected. ◆ Number of accesses. This is the number of files downloaded or otherwise accessed through the various services. Note that volume of data is not used here; a cornerstone of DMAC data access is to provide subsets, GIS maps, online analyses—in short, only the information required by the user. The data access metric shall also be broken down by data set and service method. ◆ System performance statistics. This includes use of disks and computers as well as work performed (services executed and volume accessed). All archive systems shall have a means of soliciting and capturing user feedback on services and data sets.	DMAC	15. DMAC Plan p. 88, No. 7.9.3, 7.9.3.1, 7.9.3.2, 7.9.3.3, 7.9.3.4.1
4.1.6	The archiving and access service shall provide for measurements of qualitative access.	DMAC	15. DMAC Plan p. 88, No. 7.9.3.4
4.1.7	The archiving and access service shall be a distributed system of interconnected archive and data centers that function collaboratively to receive and preserve the data and to provide easy and efficient access to the data.	DMAC	15. DMAC Plan p. 209
4.1.8	Archive centers shall acquire, preserve, and provide access to IOOS data in perpetuity.	DMAC	15. DMAC Plan p. 81, No. 2.5.1
4.1.9	The data transport service shall be designed and developed to accommodate distributed data storage.	DMAC	15. DMAC Plan p. 78, No. 4.3.2.2
4.1.10	The data transport service shall be designed and developed to accommodate data that resides with the data collector.	DMAC	15. DMAC Plan p. 78, No. 4.3.2.3
4.1.11	The data transport service shall be able to express the structure of the numeric data it will encounter in oceanographic data repositories.	DMAC	15. DMAC Plan p. 162
4.1.12	The data transport service shall be modular, allowing use of capabilities over alternative transport protocols to HTTP.	DMAC	15. DMAC Plan p. 77, No. 3.1
4.1.13	The structure layer protocol of the data transport service shall define the organization of like data objects in a data set.	DMAC	15. DMAC Plan p.77, No. 3.3.1
4.1.14	Operations, and the associated modules in the structure layer of the data transport service, that are discipline neutral shall be logically separated from those that require a semantic understanding of the data.	DMAC	15. DMAC Plan p. 77, No. 3.3.2
4.1.15	The initial DMAC shall use the Open Source Project for a Network Data Access Protocol (OPeNDAP).	DMAC	15. DMAC Plan p. 284
4.1.16	The data transport service shall display, for each data set it contains, the approximate size of the data set selected.	DMAC	15. DMAC Plan p. 78, No. 4.6
4.1.17	The data transport service shall support fault detection and localization within the DMAC.	DMAC	15. DMAC Plan p. 79, No. 4.10

Table 4-1. System Design

Identifier	Description	Sub-System	Reference
4.1.17.1	The DMAC shall provide oversight mechanisms, including fault detection and correction, to ensure the proper functioning and smooth evolution of IOOS.	DMAC	15. DMAC Plan p. 67, No. 2.9
4.1.17.2	The DMAC shall provide oversight mechanisms, including monitoring and evaluation of system performance, to ensure the proper functioning and smooth evolution of IOOS.	DMAC	15. DMAC Plan p. 67, No. 2.9
4.1.17.3	The DMAC shall provide oversight fault detection and correction mechanisms, including provisions for system extensibility, to ensure the proper functioning and smooth evolution of IOOS.	DMAC	15. DMAC Plan p. 67, No. 2.9
4.1.17.4	The DMAC shall provide performance monitoring and oversight evaluation mechanisms, including establishing and maintaining international linkages, to ensure the proper functioning and smooth evolution of IOOS.	DMAC	15. DMAC Plan p. 67, No. 2.9
4.1.18	The DMAC shall provide for the generic treatment of data sources isolating the requesting client from specific representations, unique request semantics, and protocols.	DMAC	15. DMAC Plan p. 69, No. 6.1.7
4.1.19	The data transport service shall provide for online acquisition of data into legacy applications and new applications packages through the syntactic data model.	DMAC	15. DMAC Plan p. 77, No. 4.3
4.1.20	The data transport service shall be capable of binding these metadata to a data request.	DMAC	15. DMAC Plan p. 77, No. 2.10
4.1.21	The selection interface shall enable the user to select from the items returned from the search and to perform subsequent subsetting searches of the returned items.	DMAC	15. DMAC Plan p. 74, No. 4.9.5
4.1.22	Data sets that are stored offline shall be kept accessible and discoverable through the data discovery interfaces. This access to offline data may be initiated by online ordering. Online ordering is a mechanism by which data are ordered and then picked up or delivered later.	DMAC	15. DMAC Plan p. 87, No. 7.6, 7.6.1
4.1.23	The DMAC system shall use the data assembly centers to gather distributed data and process data over a wide range of disciplines, with the assembled data and products then being submitted to archive centers for long-term storage and access.	DMAC	15. DMAC Plan p. 82, No. 2.8.5
4.1.24	The DMAC shall leverage existing communications capabilities or provide dedicated broadband networks between/among the regional data centers, data assembly centers, modeling centers, and archive centers.	DMAC	15. DMAC Plan p. 68, No. 4.2.1
4.1.25	The DMAC shall leverage existing or deploy dedicated IOOS data servers at to-be-determined locations, including up to all of the following: regional data centers, data assembly centers, modeling centers, and archive centers.	DMAC	15. DMAC Plan p. 68, No. 4.1.1
4.1.26	More than one type of center shall be physically collocated; for example, a data assembly center may be an entity at a national archive center.	DMAC	15. DMAC Plan p. 80, No. 2.4
4.1.27	The DMAC shall leverage existing storage or provide aggregate storage to the following: regional data centers, online (to be determine), near-line (e.g., online tape silo) (to be determined), offline (to be determined), data assembly centers, modeling centers, and archive centers	DMAC	15. DMAC Plan p. 68, No. 4.1.2

Table 4-1. System Design

Identifier	Description	Sub-System	Reference
4.1.28	The Observing Subsystem shall contain the necessary infrastructure to satisfy the full spectrum of current and future data telemetry bandwidth requirements.	Observing Subsystem	6. IOOS Development Plan, p. 54
4.1.29	The data transport service shall include an access method that is consistent with that referred to as “web services” in the literature. Other web services requirements are to be determined.	DMAC	15. DMAC Plan p. 75, No. 1.2, 1.3
4.1.30	The portal shall provide mechanisms for accessing web services-enabled functions of the IOOS.	DMAC	15. DMAC Plan p. 74, No. 5.5
4.1.31	The user feedback mechanism shall provide a mechanism for usage tracking.	DMAC	15. DMAC Plan p. 74, No. 5.17.3
	Security		
4.1.32	The IOOS shall comply with Federal Information Security Management Act (FISMA) of 2002.	All	30. FISMA standards
4.1.33	The IOOS shall comply with NIST SP 800-18, *Guide for Developing Security Plans for Information Technology Systems*.	All	31. NIST standards–SP 800-18
4.1.34	The IOOS shall comply with NIST SP 800-37, *Guide for Security Certification and Accreditation of Federal Information Systems*.	All	32. NIST standards–SP 800-37
4.1.35	The IOOS shall comply with NIST SP 800-53, Rev. 1, *Recommended Security Controls for Federal Information Systems*.	All	33. NIST standards–SP 800-53
4.1.36	The IOOS shall comply with NIST SP 800-60, Vol. 1 and 2, *Guide for Mapping Types of Information and Information Systems to Security Categories*.	All	34. NIST standards–SP 800-60
4.1.37	The IOOS shall comply with Federal Information Processing Standards Publications (FIPS Pubs)	All	35. FIPS Pubs
4.1.38	The IOOS shall comply with FIPS PUB 199, *Standards for Security Categorization of Federal Information and Information Systems*.	All	36. FIPS PUB 199
4.1.39	The IOOS shall comply with FIPS PUB 201, *Personal Identity Verification for Federal Employees and Contractors*, February 2005.	All	37. FIPS PUB 201
4.1.40	The data transport service shall support access-restricted, secure transmission of data.	DMAC	15. DMAC Plan p.79, No. 4.9
4.1.41	The DMAC shall provide oversight mechanisms to ensure the proper functioning and smooth evolution of IOOS, including security.	DMAC	15. DMAC Plan p. 67, No. 2.9

DATA COLLECTION

Table 4-2 contains the requirements that pertain to data quality control, management, and access.

Table 4-2. Data Collection

Identifier	Description	Sub-System	Reference
Data Quality Control			
4.2.1	The DMAC shall provide a mechanism for ensuring that data are of known and documented quality. Quality control operations are a partnership among data observation/collection components, processors, analysts, other users, and the DMAC.	DMAC	15. DMAC Plan p. 66, No. 2.2
4.2.2	Regional data centers shall apply quality control measures to data and derive specialized products.	DMAC	15. DMAC Plan p. 81, No. 2.6.3
Data Management			
4.2.3	The data archive system shall detect and correct failures in input data streams.	All IOOS subsystems	15. DMAC Plan p. 40, Data Archive and Access section
4.2.4	The DMAC shall directly or indirectly facilitate activities to rescue, digitize, and provide access to legacy or historical data sets and data in danger of loss due to deteriorating media, out-of-date software, etc.	DMAC	15. DMAC Plan p. 67, No. 2.6
4.2.5	DMAC shall require that all data be delivered in a consistent geospatial data model.	DMAC	15. DMAC Plan Top of p. 38
4.2.6	The DMAC shall provide users access to real-time, delayed mode data and data collected at appropriate time scales that addresses the seven IOOS goals. The system shall provide date/time stamp information for data.	DMAC	15. DMAC Plan p. 213
4.2.6.1	The data transport service shall support access to real-time data as well as access to retrospective (non-real-time) data.	DMAC	15. DMAC Plan p. 77, No. 4.2
4.2.6.2	The AA service shall receive delayed-mode data that arrives later than real-time-mode data, and sometimes much later and has a higher standard of quality control than real-time data	DMAC	15. DMAC Plan p. 213
Data Access			
4.2.7	The DMAC shall provide access to the core and ancillary variables.	DMAC	15. DMAC Plan p. 86, No. 7.3
4.2.8	Regional data centers shall acquire and provide access to IOOS data collected in a specific geographic region.	DMAC	15. DMAC Plan p. 81, No. 2.6.1
4.2.9	The system shall allow human enabled access through a DMAC-enabled browser or directly through a machine. In either case, data transport service shall provide the requisite software capability.	DMAC	15. DMAC Plan p. 77, No. 4.1.1
4.2.10	The DMAC shall use data assembly centers to obtain IOOS data and provide access to it.	DMAC	15. DMAC Plan p. 81, No. 2.8.1
4.2.11	The DMAC shall allow users to rapidly exploit multiple data sets from many diverse data sources.	DMAC	15. DMAC Plan p. 259, No. 4

METADATA MANAGEMENT

Table 4-3 contains the requirements that pertain to the way metadata is handled in IOOS and its various subsystems and interfaces.

Table 4-3. Metadata Management

Identifier	Description	System/ Sub-System	Reference
4.3.1	The data discovery system shall identify a means to create and deliver metadata and data.	IOOS	15. DMAC Plan p. 71, No. 1.2 p. 72, No. 2.3
4.3.2	The data discovery system shall provide the capability to provide “on-the-fly” data sets.	IOOS	15. DMAC Plan p. 73, No. 4.2, 4.7
4.3.2.1	The DMAC shall provide support for users to locate and use data through the definition and maintenance of metadata (data about data).	DMAC	15. DMAC Plan p. 32, first paragraph
4.3.3	The metadata management system (MMS) shall include mechanisms to facilitate the generation of metadata as close as possible to the collection or generation of the source data.	DMAC/MMS	15. DMAC Plan p. 72, No. 2.8
4.3.4	The MMS shall provide automated tools for versioning and configuration management of metadata.	DMAC/MMS	15. DMAC Plan p. 72, No. 2.9
4.3.5	Documentation metadata (bibliographic information about documentation associated with a data set) shall be used for data versioning, data lineage tracking, and information citations.	DMAC	15. DMAC Plan p. 71, No. 1.5
4.3.6	The DMAC shall ensure that changes made to data sets are reflected in corresponding changes to the metadata records.	IOOS	15. DMAC Plan p. 33
4.3.7	The MMS shall provide a mechanism to ensure that metadata found during data discovery are up to date, consistent, and understandable.	DMAC/MMS	15. DMAC Plan p. 71, No. 1.3
4.3.8	A core DMAC function shall be metadata management.	DMAC	15. DMAC Plan p. 72, No 2
4.3.8.1	The MMS shall provide support for parent/child metadata.	DMAC/MMS	15. DMAC Plan p. 72, No. 2.5
4.3.8.2	Data set metadata shall be obtainable in multiple formats, including both machine-readable XML and human-readable text.	DMAC	15. DMAC Plan p. 74, No. 4.10
4.3.9	Data transport (DT) shall be able to transmit all relevant semantic metadata, that is translational use, descriptive use, and search metadata. They must be available in both human-readable and machine readable forms.	DMAC	15. DMAC Plan p. 75
4.3.9.1	The DT function shall support machine-to machine interoperability with semantic meaning, i.e., the DT service shall incorporate some collection of methods that promote the scripted exchange of data between computers, with all computers involved in a transaction capable of determining both the syntax and the semantics of the exchanged data without human intervention.	DMAC	15. DMAC Plan p. 75, No. 1.1
4.3.9.2	The DT service shall provide the metadata needed to transform the data to a consistent semantic form, or it must be capable of delivering the data in a consistent semantic form.	DMAC	15. DMAC Plan p. 76, No. 2.8

Table 4-3. Metadata Management

Identifier	Description	System/ Sub-System	Reference
4.3.10	The DMAC shall provide training and electronic tools to increase end users' and data providers' capacity in metadata generation and management.	DMAC	15. DMAC Plan p. 67, No. 2.5
4.3.11	The metadata shall provide a framework for both semantic and syntactic metadata.	DMAC/MMS	15. DMAC Plan p. 71, No. 1.6
4.3.12	When multiple data sets are aggregated, the data transport service shall provide a mechanism for providing appropriate aggregate metadata.	DMAC	15. DMAC Plan p. 77, No. 4.5.3
4.3.13	The MMS shall provide mechanisms for extensibility of the metadata.	DMAC	15. DMAC Plan p. 71, No. 1.4
4.3.14	The MMS shall provide the capability for data providers to manage their metadata within a local system or through a centralized system via remote-access capabilities.	DMAC/MMS	15. DMAC Plan p. 72, No. 2.2
4.3.15	The MMS shall include an automated metadata maintenance capability for checking URL links and any additional information within the metadata record that can be automated.	DMAC/MMS	15. DMAC Plan p. 71, No. 2.7
4.3.16	The MMS shall provide a mechanism to access existing metadata servers to promote harvesting metadata.	DMAC/MMS	15. DMAC Plan p. 72, No. 2.10
4.3.17	The MMS shall include a metadata catalog that consists of a collective holding of metadata in a distributed catalog.	DMAC/MMS	15. DMAC Plan p. 72, No. 3.1
4.3.17.1	The MMS metadata catalog shall provide for integration of all distributed subcatalogs.	DMAC/MMS	15. DMAC Plan p. 72, No. 3.1
4.3.17.2	The MMS catalog shall provide a capability to generate metadata records from self-describing data sources in which metadata and data have been integrated.	DMAC/MMS	15. DMAC Plan p. 72, No. 3.2
4.3.17.3	The metadata catalog shall include a stable, documented, defined application program interface (API) and a defined access protocol.	DMAC	15. DMAC Plan p. 73, No. 4.5
4.3.17.4	The MMS shall be implemented as a distributed system that connects to all DMAC-compliant metadata holdings within the ocean community.	DMAC	15. DMAC Plan p. 72, No. 2.1
4.3.17.5	The metadata catalog contents shall include items that will be used for discovery.	DMAC	15. DMAC Plan p. 72, No. 3.3
4.3.17.6	The metadata catalog shall provide access control of metadata records, administrative rights and for searching on those records.	DMAC	15. DMAC Plan p. 72, No. 3.3.1
4.3.17.7	The metadata catalog shall allow a catalog search from public search engines.	DMAC	15. DMAC Plan p. 72, No. 3.3.2
4.3.18	The MMS shall include mechanisms to generate, validate, maintain and approve metadata.	DMAC/MMS	15. DMAC Plan p. 72, No. 2.3, 2.6
4.3.19	The MMS shall include a set of controlled vocabularies for items such as keywords, entities and attributes, units, and other items to be determined.	DMAC/MMS	15. DMAC Plan p. 72, No. 2.4
4.3.20	The MMS shall support a linkage between data discovery and data access that an application may utilize transparently to access both remote and local data via the DMAC data transport function.	DMAC	15. DMAC Plan p. 72, No. 2.2.2

Table 4-3. Metadata Management

Identifier	Description	System/ Sub-System	Reference
4.3.21	The IOOS metadata shall be supplied using the guidelines established by the Federal Geographic Data Committee (FGDC) augmented by any applicable supplemental profiles.	DMAC	15. DMAC Plan p. 71, No. 1.1
4.3.22	The IOOS will include an MMS.	DMAC/MMS	15. DMAC Plan p. 72, No. 2
4.3.23	IOOS standards for metadata shall allow different versions of the same data and metadata to be traced by means of information on lineage and version.	IOOS	15. DMAC Plan p. 83, No. 5.4
4.3.24	The MMS shall support multiple standards that exist today and be extensible to include expected future metadata standards. Existing standards shall include FGDC, biological profile, shoreline profile and possible future standards.	DMAC	11.DMAC Plan p. 71-72, No. 1.8, 1.8.1, 1.8.2

DATA ARCHIVE

Table 4-4 contains the requirements that pertain to short- and long-term data archiving and to data maintenance. These requirements include guidelines for data retention, data preservation, data catalog services, and data access permissions.

Table 4-4. Data Archive

Identifier	Description	System/ Sub-System	Reference
	Data Archive		
4.4.1	Archive centers shall be able to create and manage one or more copies of all IOOS data and metadata, both online and offline, according to the specified IOOS data category and according to NARA (U.S. National Archives and Records Administration) and other federal guidelines.	DMAC	15. DMAC Plan p. 84, No. 6.2
4.4.1.1	The DMAC shall provide for the long-term archive and stewardship of IOOS data sets and shall conform to national archive standards, as well as IOOS standards and user requirements	DMAC	15. DMAC Plan p. 67, No. 2.7
4.4.1.2	To qualify as an archive center, a data center shall be able to create and manage multiple copies of the data and metadata.	DMAC	15. DMAC Plan p. 84, No. 6.1.2, 6.1.2.1
4.4.1.3	Although IOOS data may flow into the archive centers over several pathways, at least one copy of each set shall reside in a designated archive center.	DMAC	15. DMAC Plan p. 211
4.4.1.4	Multiple copies of some categories of data shall be stored securely at separate locations under independent data management.	DMAC	15. DMAC Plan p. 82, No. 3.2
4.4.1.5	The DMAC system shall provide archive centers with a capability for the archival of metadata.	DMAC	15. DMAC Plan p. 81, No. 2.5.4
4.4.1.6	When data must be duplicated, a primary and secondary data steward shall be designated in the system.	DMAC	15. DMAC Plan p. 82, No. 3.3

Table 4-4. Data Archive

Identifier	Description	System/ Sub-System	Reference
4.4.1.7	The primary data steward shall typically be an archive center and shall provide the highest level of access.	DMAC	15. DMAC Plan p. 82, No. 3.4
4.4.1.8	The secondary steward need not maintain full access, but shall maintain the data at the same level of integrity.	DMAC	15. DMAC Plan p. 82, No. 3.5
4.4.1.9	The archive system shall use coordinated methods for data collection, quality control, archiving, and user access. Although data may flow from observing systems to any of the four types of centers, at least one copy of each observation desired by IOOS must ultimately reside in an IOOS archive center.	DMAC	15. DMAC Plan p. 80, No. 2.1, 2.3
4.4.2	The DMAC shall allow data repositories to maintain current formats of their holdings.	DMAC	15. DMAC Plan p. 69, No. 6.1.4
4.4.3	Archive centers shall implement mechanisms to ensure integrity and completeness of the archives.	DMAC	15. DMAC Plan p. 80, No. 2.5.2
4.4.4.1	The archiving and access service shall guard against unrecoverable data loss by making data integrity (or security) a primary objective. Byte counts and checksums shall be calculated and used to verify that the data are uncorrupted when transmitted between data centers. These quantities shall again be calculated after every internal process at the archive centers, and then recalculated periodically on all archived data to protect against such problems as hard disk failures, media degeneration, incomplete file transfers, and malicious hacking.	DMAC	15. DMAC Plan p. 83, No. 5.2.4, 5.2.4.1, 5.2.4.1.1
4.4.4.2	The archive system shall implement mechanisms to ensure that all irreplaceable data are sent and that an exact copy is received.	DMAC	15. DMAC Plan p. 83, No. 5.2.1
4.4.5	IOOS DT methods, metadata standards, and data discovery interfaces shall be implemented in the archive system.	DMAC	15. DMAC Plan p. 79, No. 1.2
4.4.6	The data archive system shall receive and provide access to real-time data and metadata.	IOOS	11. IOOS Design & Implementation p. 13
4.4.7	The data archive system shall receive and provide access to delayed-mode data and metadata.	IOOS	11. IOOS Design & Implementation p. 13
4.4.8	The data archive system shall distinguish between the original and upgraded or changed data sets via the standard metadata.	IOOS	15. DMAC Plan Top of p. 43
4.4.9	The archiving and access service shall accommodate data access from any suitable component of the IOOS archive system.	DMAC	15. DMAC Plan p. 86, No. 7.1
4.4.91	The archiving and access service shall implement the protocol for transporting data defined in the data transport requirements.	DMAC	15. DMAC Plan p. 86, No. 7.2
4.4.9.2	The data archive system shall provide uniform access and data discovery for both humans and machines.	IOOS	15. DMAC Plan p. 79, No. 1.2
Data Maintenance			
4.4.10	The system shall maintain irreplaceable data.	DMAC	15. DMAC Plan p. 84, No. 6.3.1

Table 4-4. Data Archive

Identifier	Description	System/ Sub-System	Reference
4.4.11	The archiving and access service shall maintain one copy (residence time in the archive will vary with replacement cycle) and perishable data. The archiving and access service shall maintain one copy until higher quality data are available. When decision-critical data products are derived from data in this class, and it is necessary to reproduce the data product, the perishable data may inherit an extended term for data preservation that is not obvious for the original data alone.	DMAC	15. DMAC Plan p. 85, No. 6.3.2.1, 6.3.3, 6.3.3.1, 6.3.3.2
4.4.12	The system shall maintain virtual data. No copies of the data are necessary, but an archive center and the virtual data provider should maintain separate copies of generation software and documentation.	DMAC	15. DMAC Plan p. 86, No. 6.3.4, 6.3.4.1

DATA SERVICES

IOOS data descriptions and exchange requirements will comply with the OMB Federal Enterprise Architecture (FEA) Data Reference Model (DRM) (per the NOAA Enterprise Architecture, version 3.0). Table 4-5 contains the requirements that pertain to data transport and delivery, data discovery and searches, data availability, data transmission, data aggregation, and data translation.

Table 4-5. Data Services

Identifier	Description	System/ Sub-System	Reference
Transport and Delivery of Data			
4.5.1	The DT service shall be capable of delivering data of a given data type in a structurally consistent form across all data sets in the system.	DMAC	15. DMAC Plan p. 157
4.5.1.1	The DT service shall be designed and developed to accommodate heterogeneous data types and storage formats.	DMAC	15. DMAC Plan p. 160
4.5.2	Data providers shall use only established, fully documented formats, which the data transport methods handle.	DMAC	15. DMAC Plan p. 214
4.5.3	The IOOS data transport system shall provide sufficient mechanisms to ensure accurate transfers of data over the networks.	DMAC	15. DMAC Plan p. 83, No. 5.2.1
4.5.4	The DT service shall provide a push data delivery service.	DMAC	15. DMAC Plan p. 77, No. 4.2.1
4.5.5	The DT service shall support “informed pull” of data.	DMAC	15. DMAC Plan p. 77, No. 4.2.2
4.5.6	The DT service shall be capable of accessing data in a variety of formats.	DMAC	15. DMAC Plan p. 156 and p. 76 No. 2.6
4.5.7	The DT service shall be capable of providing direct access to data via a variety of client programs, communicating directly with the program without the need to create data files.	DMAC	15. DMAC Plan p. 77, No. 4.1

Table 4-5. Data Services

Identifier	Description	System/ Sub-System	Reference
4.5.8	The DT service shall allow users to obtain data subsets as formatted files (formats to be determined) and human-readable ASCII numeric values via a standard Internet browser.	DMAC	15. DMAC Plan p. 78, No. 4.3.1
4.5.9	The DT service shall provide access to metadata in a variety of forms, including the standard FGDC forms of the metadata, to take advantage of the metadata developed by different communities.	DMAC	15. DMAC Plan p. 76, No. 2.9
	Data Discovery and Searches		
4.5.10	The search system shall support to-be-determined types of actual data searches along with metadata searches.	DMAC	15. DMAC Plan p. 73, No. 4.6
4.5.11	The search system shall provide full text and fielded searches, including controlled vocabulary and free-text searches, including the following: single or multiple word searches, Boolean operators on multiple words, and thesauri to support text searches.	DMAC	15. DMAC Plan p. 73, No. 4.7, 4.7.1, 4.7.1.1, 4.7.1.2, 4.7.1.2.1, 4.7.1.2.2, 4.7.1.2.3
4.5.12	The search system shall provide geospatial search.	DMAC	15. DMAC Plan p. 73, No. 4.7.2
4.5.13	The search system shall provide temporal search.	DMAC	15. DMAC Plan p. 73, No. 4.7.3
4.5.14	The search system shall provide thematic search.	DMAC	15. DMAC Plan p. 73, No. 4.7.4
4.5.15	The search system shall provide parameter search.	DMAC	15. DMAC Plan p. 73, No. 4.7.5
4.5.16	The search system shall provide taxonomic information.	DMAC	15. DMAC Plan p. 73, No. 4.7.6
4.5.17	The search system shall provide browsing by thematic areas.	DMAC	15. DMAC Plan p. 73, No. 4.7.7
4.5.18	The search system shall provide iterative and refinement searches.	DMAC	15. DMAC Plan p. 73, No. 4.7.8
4.5.19	The selection interface shall provide a graphical means of viewing a thumbnail of each data set received from the catalog search.	DMAC	15. DMAC Plan p. 73, No. 4.9.4
4.5.19.1	The DMAC data discovery function shall provide a “select” functionality, which refers to those capabilities that allow an end user or data provider to examine data sets revealed from the data search and then choose sets of interest for downloading, browsing online, or accessing via the DMAC data transport function	DMAC	15. DMAC Plan p. 73, No. 4.9
4.5.20	The IOOS shall include a search/query mechanism.	IOOS and DMAC	15. DMAC Plan p. 73, No. 4.0
4.5.20.1	The search interface shall search the metadata catalog for records that meet user-defined criteria.	DMAC	15. DMAC Plan p. 73, No. 4.1
4.5.20.2	The search interface shall allow end users and data providers to search for specific data sets.	DMAC	15. DMAC Plan p. 73, No. 4.2
4.5.20.3	The search interface shall allow end users and data providers to browse metadata about IOOS data holdings.	DMAC	15. DMAC Plan p. 73, No. 4.3
4.5.20.4	The search interface shall allow automated agents search for data.	DMAC	15. DMAC Plan p. 73, No. 4.4

Table 4-5. Data Services

Identifier	Description	System/ Sub-System	Reference
4.5.21	The system shall be extensible to support other specific searches such as search by data quality or native format.	DMAC	15. DMAC Plan p. 73, No. 4.8
4.5.22	The MMS shall provide a metadata query mechanism that supports user access through an interface to any/all metadata fields.	DMAC/MMS	15. DMAC Plan p. 71, No. 1.7
4.5.23	The data transport service shall provide a mechanism for subsetting data sets for retrieval, by parameter, by area, by time window, and by other criteria to be determined.	DMAC	15. DMAC Plan p. 78, No. 4.4
4.5.24	When subsetting data, the data transport service shall provide appropriate metadata.	DMAC	15. DMAC Plan p. 78, No. 4.4.1
4.5.25	The DMAC shall provide a seamless segue from data discovery to data access.	DMAC	15. DMAC Plan p. 95
4.5.26	The user interface shall allow the user to select items for downloading. This will be referred to as the selection interface.	DMAC	15. DMAC Plan p. 73, No. 4.9.1
4.5.26.1	The selection interface shall display and accept selection requests for data sets from the catalog software that meet the search criteria specified by the user in the search interface.	DMAC	15. DMAC Plan p. 73, No. 4.9.2
	Data Availability		
4.5.27	The DMAC shall provide a means for determining what data are available within the IOOS based on queries issued by users and by other systems.	DMAC	15. DMAC Plan p. 86
4.5.28	The archiving and access service shall receive real-time-mode data arriving in real-time or near real-time, with the goal of being made available with minimum delay.	DMAC	15. DMAC Plan p. 82, No. 5.1.1
	Data Transmission		
4.5.29	The data transport service shall be able to transmit numerical data without corruption or loss of precision.	DMAC/DT	15. DMAC Plan p. 75, No. 2.4
	Data Aggregation		
4.5.30	The data transport service shall provide mechanisms for aggregating data, including data of the same type and from same provider and data from different sources that do not or cannot share a single parent metadata record (e.g., observational data from different sources and systems). The system shall provide the capability of delivering structurally consistent data to clients. In this context, structure means the way that the data are organized, for example, grid or array.	DMAC	15. DMAC Plan p. 78, No. 4.5, 4.5.1, 4.5.2 p. 77, No. 3.3
	Data Translation		
4.5.31	The data transport service shall be capable of moving data from a site in which they may be stored in one format to a client application that may require them in another format. Transport between sites will be implemented via an intermediate format, referred to as the data transport syntactic data model, and the data model shall be discipline neutral.	DMAC	15. DMAC Plan p. 77, No. 3.2, 3.2.1
4.5.31.1	The DMAC system shall provide electronic tools and techniques to perform translation among controlled vocabularies.	DMAC	15. DMAC Plan p. 131

STANDARDS AND INTEROPERABILITY

Table 4-6 contains the requirements that pertain to data standards applicable to IOOS and the various subsystems, data integration and linkage on system interoperability and monitoring.

Table 4-6. Standards and Interoperability

Identifier	Description	System/ Sub-System	Reference
	Standards		
4.6.1	IOOS data (data of opportunity) shall comply with IOOS standards (including metadata and quality standards).	IOOS	6. IOOS Development Plan
4.6.2	File-compression techniques used for transferring IOOS data shall use standard protocols with open documentation.	DMAC	15. DMAC Plan p. 84, No. 5.6
4.6.3	Federal Agencies and RAs shall adopt national standards and protocols for collecting observations, data telemetry, data communications, and data management.	Observing Subsystem	6. IOOS Development Plan p.11, No. 3.3.3 (1)
4.6.4	Operational programs of the Observing Subsystem shall provide data quality controlled and managed in compliance with Ocean.US DMAC standards and protocols.	Observing Subsystem	6. IOOS Development Plan, p. 9
	Data Integration and Linkage		
4.6.5	The IOOS shall provide electronic tools for remote content management of the portal structure.	DMAC	15. DMAC Plan p.74, No. 5.10

PORTAL SERVICES

Table 4-7 contains the requirements that pertain to the service components of the portal, including education, short- and long-term forecasts for ocean water and weather, ocean observing data, and the IOOS main home page.

Table 4-7. Portal Services

Identifier	Description	System/ Sub-System	Reference
4.7.1	DMAC shall provide a portal through which end users can search using the Internet for IOOS data and metadata. A portal is an Internet presence (e.g., website) that redirects the user (possibly transparently) to a larger set of access points.	DMAC	15. DMAC Plan p. 74, No. 5.1
4.7.1.1	Simplified versions of the portal shall be available for incorporation into non-IOOS websites to provide the capability to search IOOS data.	DMAC	15. DMAC Plan p. 74, No. 5.4
4.7.1.2	The IOOS portal shall consist of an entry point (a web home page), hierarchically lower level entries (other pages), and links to areas or functions within the IOOS.	DMAC & IOOS	15. DMAC Plan p. 74, No. 5.3
4.7.3	The portal shall provide necessary policy statements and legal disclaimers.	DMAC	15. DMAC Plan p. 74, No. 5.8
	The portal shall provide links to relevant information such as tools available for generation of the metadata required for this specific system.	DMAC	15. DMAC Plan p. 74, No. 5.11

Table 4-7. Portal Services

Identifier	Description	System/ Sub-System	Reference
4.7.4	The portal shall provide information on requirements for IOOS data providers.	DMAC	15. DMAC Plan p. 74, No. 5.12
4.7.5	The portal shall provide links to the supporting organizations.	DMAC	15. DMAC Plan p. 74, No. 5.13
4.7.6	The portal shall provide FAQs.	DMAC	15. DMAC Plan p. 74, No. 5.15
4.7.7	The portal shall provide online documentation.	DMAC	15. DMAC Plan p. 74, No. 5.16
4.7.8	The DMAC system shall provide basic web browsing and visualization capabilities across the breadth of IOOS data.	DMAC	15. DMAC Plan p. 59, No. (2)

OBSERVING AND SENSOR/DATA ACQUISITION SERVICES

Table 4-8 contains the requirements that pertain to the acquisition of IOOS and subsystems core variables and other observations.

Table 4-8. Observing and Sensor/Data Acquisition Services

Identifier	Description	Sub-System	Reference
4.8.1	The Observing Subsystem shall include data from the following sources:	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.1	NOAA Coastal Marine Automated Network (CMAN) programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.2	NOAA National Data Buoy Center (NDBC) programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.3	NOAA Physical Oceanographic Real-Time System (PORTS) programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.4	NOAA National Estuarine Research Reserve System (NERRS) programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.5	NOAA CoastWatch programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.6	NOAA Living Marine Resources-Ecosystems Survey (LMR-ES) programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.7	NOAA National Current Observation programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.8	NOAA habitat assessment programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.9	NOAA hydrographic survey programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.10	NOAA coral reef mapping programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.11	NOAA coral reef monitoring programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25

Table 4-8. Observing and Sensor/Data Acquisition Services

Identifier	Description	Sub-System	Reference
4.8.1.12	NOAA coastal mapping programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.13	NOAA topographic change mapping programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.14	NOAA benthic habitat mapping programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.15	NOAA coastal change assessment mapping programs for the coastal component	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.16	NOAA ecosystem survey programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.17	NOAA protected resources survey programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.18	NOAA national observer program for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.19	NOAA recreational fisheries program for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.20	NOAA commercial fisheries statistics program for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.21	Navy Altimeter Data Fusions Center program for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.22	U.S. Army Corps of Engineers' Coastal Field Data Collection Program for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.23	U.S. Army Corps of Engineers' hydrographic surveying program for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.24	USGS National Streamflow Information Program (NSIP) for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.25	USGS National Stream Quality Accounting Network (NSQAN) program for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.26	USGS stream-gauging programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.27	USGS coral reef mapping and monitoring programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.28	USGS coastal change mapping programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.29	USGS benthic habitat mapping programs for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 25
4.8.1.30	Northeast Regional Association of Coastal Ocean Observing Systems (NERACOOS) for the coastal component.	Observing Subsystem	13. IOOS Development Plan Addendum, p. 39, Table 13
4.8.1.31	Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA) for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 5
4.8.1.32	Southeast Coastal Ocean Observing Regional Association (SECOORA) for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 5
4.8.1.33	Gulf of Mexico Coastal Ocean Observing System (GCOOS) for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 5
4.8.1.34	Great Lakes Observing System (GLOS) for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 5

Table 4-8. Observing and Sensor/Data Acquisition Services

Identifier	Description	Sub-System	Reference
4.8.1.35	Caribbean Regional Association (CaRA) for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 5
4.8.1.36	Southern California Coastal Ocean Observing System (SCCOOS) for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 5
4.8.1.37	Central and Northern California Ocean Observing System (CeNCOOS) for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 5
4.8.1.38	Northwest Association of Networked Ocean Observing Systems (NANOOS) for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 5
4.8.1.39	Alaska Ocean Observing System (AOOS) for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 5
4.8.1.40	Pacific Islands Integrated Ocean Observing System (PacIOOS) for the coastal component.	Observing Subsystem	6. IOOS Development Plan, p. 5
4.8.1.41	NOAA Geostationary Operational Environmental Satellite (GOES) program for the global and coastal components.	Observing Subsystem	6. IOOS Development Plan, p. 22, 25
4.8.1.42	NOAA National Water Level Observation Network (NWLON) and tide gauge programs for the global and coastal components.	Observing Subsystem	6. IOOS Development Plan, p. 22, 25
4.8.1.43	Navy integrated buoy program for the global and coastal components.	Observing Subsystem	6. IOOS Development Plan, p. 22, 25
4.8.1.44	Ocean Biogeographic Information System for the global and coastal components.	Observing Subsystem	6. IOOS Development Plan, p. 23, 31
4.8.1.45	NOAA moored buoy (tropical array) programs for the global component.	Observing Subsystem	6. IOOS Development Plan, p. 22, 44 (3)
4.8.1.46	NOAA drifting buoy array program for the global component.	Observing Subsystem	6. IOOS Development Plan, p. 22, 44 (2)
4.8.1.47	NOAA voluntary observing ships program for the global component.	Observing Subsystem	6. IOOS Development Plan, p. 22
4.8.1.48	NOAA ships of opportunity program for the global component.	Observing Subsystem	6. IOOS Development Plan, p. 22, 44 (4)
4.8.1.49	NOAA dedicated ships program for the global component.	Observing Subsystem	6. IOOS Development Plan, p. 22, 44 (9)
4.8.1.50	NOAA Arctic sea ice flux program for the global component.	Observing Subsystem	6. IOOS Development Plan, p. 22, 44 (6)
4.8.1.51	Global Tide Gauge Program for the global component.	Observing Subsystem	6. IOOS Development Plan, p. 22, 44 (1)
4.8.1.52	GEOSAT Follow On program for the global component.	Observing Subsystem	6. IOOS Development Plan, p. 22
4.8.1.53	Navy ocean survey ship program for the global component.	Observing Subsystem	6. IOOS Development Plan, p. 22
4.8.1.54	Joint WINDSAT program for the global component.	Observing Subsystem	6. IOOS Development Plan, p. 22
4.8.1.55	NSF OOI program when it reaches the pre-operational phase.	Observing Subsystem	6. IOOS Development Plan, p. 44 (7)

Table 4-8. Observing and Sensor/Data Acquisition Services

Identifier	Description	Sub-System	Reference
4.8.1.56	Full Depth Ocean Surveys and Ocean Carbon Monitoring program once it reaches pre-operational phase.	Observing Subsystem	6. IOOS Development Plan, p. 44 (8)
4.8.1.57	NOAA Polar Operational Environmental Satellite (POES) program for the global and coastal components.	Observing Subsystem	6. IOOS Development Plan, p. 22, 25
4.8.2	The Observing Subsystem shall leverage existing assets operated by federal and state agencies, universities, coastal laboratories, and other organizations.	Observing Subsystem	6. IOOS Development Plan, p. 19
4.8.3	The Observing Subsystem shall provide for the ability to serve data of opportunity from a variety of untraditional sources.	Observing Subsystem	6. IOOS Development Plan
4.8.3.1	Data of opportunity shall support IOOS core variables and apply to societal goals.	Observing Subsystem	6. IOOS Development Plan
4.8.4	The Observing Subsystem shall measure core variables including data and information from subsystems.	Observing Subsystem	6. IOOS Development Plan, p. 20
4.8.5	The Observing Subsystem shall initially consist of a set of mature pre-operational and operational observing programs.	Observing Subsystem	6. IOOS Development Plan, p. 22
4.8.6	The Observing Subsystem shall provide a fusion of remotely sensed and *in situ* observations.	Observing Subsystem	6. IOOS Development Plan, p. 21
4.8.7	The Observing Subsystem shall be developed with the flexibility to handle the expansion of in situ and remotely sensed observations in the global component.	Observing Subsystem	6. IOOS Development Plan, p. 43
4.8.8	The Observing Subsystem shall provide for the ability to serve data from applicable research systems as they mature to pre-operational status.	Observing Subsystem	6. IOOS Development Plan, Part III
4.8.8.1	Network of HF radar nodes for coastal current mapping nationwide.	Observing Subsystem	6. IOOS Development Plan, Part III page 63
4.8.9	EPA's National Estuary Program (NEP > http://www.epa.gov/nep/)	Observing Subsystem	OOS Development Plan ADDENDUM, p. 65
4.8.10	EPA's National Coastal Assessment Program (NCAP >http://www.epa.gov/emap/nca/):	Observing Subsystem	IOOS Development Plan ADDENDUM (Table II.4, pages 20, 22)
4.8.11	EPA's Beach Environmental Assessment and Coastal Health (BEACH) Program	Observing Subsystem	IOOS Development Plan ADDENDUM (Table II.4, pages 20, 23
4.8.12	EPA's (and NOAA) National Marine Debris Monitoring Programs (NMDMP)	Observing Subsystem	IOOS Development Plan ADDENDUM (Table II.4, p. 20
4.8.13	National Water Quality Monitoring Network (NWQMN > http://acwi.gov/monitoring/network/)	Observing Subsystem	IOOS Development Plan ADDENDUM [p. 22, Box III. 2 (p. 49)

RESEARCH AND EDUCATION SERVICES

Table 4-9 contains the requirements that pertain to research and education services.

Table 4-9. Research and Education Services

Identifier	Description	System/ Sub-System	Reference
4.9.1	The IOOS shall provide information relevant to the education sector.	IOOS	13. First IOOS Development Plan Addendum, p. 40
4.9.1.1	The IOOS shall provide the education sector with guidelines and policies for citing IOOS-obtained information in publications.	IOOS	13. First IOOS Development Plan Addendum, p. 40
4.9.1.2	Educational materials available via IOOS shall be highlighted with the intended audience (parents, teachers, students) and expertise level (grade, undergraduate, etc.).	IOOS	13. First IOOS Development Plan Addendum, p. 42
4.9.2	The IOOS portal's graphical user interfaces (GUIs) shall be simple to use for a broad spectrum of users.	DMAC and IOOS	15. DMAC Plan p. 74, No. 5.2

ADMINISTRATIVE SERVICES

Table 4-10 contains the requirements that address system administrative duties.

Table 4-10. Administrative Services

Identifier	Description	System/ Sub-System	Reference
	General		
4.10.1	The IOOS shall establish priorities for detecting, measuring, and predicting ocean parameters and phenomena at the national and regional levels.	IOOS	6. IOOS Development Plan, p. 4 (7)
4.10.2	Data products shall include assimilation-friendly, real-time measurements, model nowcasts and forecasts, GIS layers, and climatological reference fields. * Products shall be defined as data products, graphical information products, or text information products (was 3.14.11).	DMAC	15. DMAC Plan p. 66, No. 2.4
4.10.3	Graphical information products shall include scientific plots and maps, imagery, and photographs.	DMAC	15. DMAC Plan p. 66, No. 2.4
4.10.4	Text information products shall include written forecasts and numerical tables.	DMAC	15. DMAC Plan p. 66, No. 2.4
4.10.5	Acceptable tools and procedures shall include the following.	DMAC	15. DMAC Plan p. 83, No. 5.2.2
4.10.5.1	Receipts and reconciliation reports for transfers over networks		15. DMAC Plan p. 83, No. 5.2.2.1
4.10.5.2	Skilled staff to review metrics (e.g., how much of the expected data were received and how much of the data set was made available)	DMAC	15. DMAC Plan p. 83, No. 5.2.2.2
4.10.5.3	Byte counts, inventories of data files, and checksums of records or files	DMAC	15. DMAC Plan p. 83, No. 5.2.2.3

Table 4-10. Administrative Services

Identifier	Description	System/ Sub-System	Reference
4.10.5.4	Test files that can be confirmed against archived data and used to verify local software, accuracy relative to other data sources (i.e., whether a set of data falls within acceptable ranges or compare acceptably with other data known to be correct).	DMAC	15. DMAC Plan p. 83, No. 5.2.2.4, 5.2.2.5

NOAA

Table 4-11 contains NOAA high-level requirements that are either DIF specific or extracted from the NOAA Strategic Plan.

Table 4-11. NOAA Requirements

Identifier	Description	System/ Sub-System	Reference
4.11.1	The IOOS shall provide a mechanism for aggregating and buffering data streams over useful spans of time and space.	DMAC	15. DMAC Plan p. 66, No. 2.3
4.11.2	The IOOS shall transmit timely wind observations to the models. This is to minimize data latency.	IOOS	9. Hurricane Intensity Modeling Draft Report, p. 4
4.11.3	The IOOS shall comply with NOAA data standards and ensure that data providers deliver data of a known quality.	IOOS	9. Hurricane Intensity Modeling Draft Report, p. 4
4.11.4	The IOOS shall provide a mechanism for ensuring that data are of known and documented quality.	IOOS	15. DMAC Plan p. 66, No. 2.2
4.11.5	The DIF shall provide data of known quality from sources of Seven core variables that are needed by the four models/assessments/products.	DIF	8. NOAA IOOS Project Requirements Document, p. 13, No. 5.1.6
4.11.6	The DIF shall provide access and delivery from the Seven core variables such that it can be incorporated into the customer-identified hurricane intensity model or process.	DIF	8. NOAA IOOS Project Requirements Document, p. 13, No. 5.2.1
4.11.7	The IOOS shall directly or indirectly facilitate activities to rescue, digitize, and provide access to legacy or historical data sets and data in danger of loss due to deteriorating media, out-of-date software, etc.	IOOS	15. DMAC Plan p. 67, No. 2.6
4.11.8	The IOOS shall provide access to historical data not currently available in the archives.	IOOS	10. IEA Draft Requirements for IOOS, p. 2
4.11.9	The IOOS shall provide access to fishery data.	IOOS	10. IEA Draft Requirements for IOOS, p. 4
4.11.10	The IOOS shall help improve access to regional and other non-NOAA data resources (to address data gaps).	IOOS	9. Hurricane Intensity Modeling Draft Report, p. 4

Table 4-11. NOAA Requirements

Identifier	Description	System/ Sub-System	Reference
4.11.11	The IOOS shall provide streamlined access to bathymetry and topography data.	IOOS	20. Coastal Inundation Modeling, p. 5, part III A.
4.11.12	The archiving and access service shall provide access to data using core protocols (FTP, HTTP, OPeNDAP) along with other IOOS data transport protocols.	DMAC	15. DMAC Plan p. 86, No. 7.4
4.11.13	The DIF shall provide access and delivery of data from the Seven core variables such that it can be incorporate into the customer-identified Harmful Algal Bloom (HAB) model or process.	DIF	8. NOAA IOOS Project Requirements Document p. 13, No. 5.4.1
4.11.14	The DIF shall provide access and delivery of data from the Seven core variables such that it can be incorporated into the customer-identified IEA model or process.	DIF	8. NOAA IOOS Project Requirements Document p. 14, No. 5.5.1
4.11.15	All archive systems shall have a means of soliciting and capturing user feedback on services and data sets.	IOOS	15. DMAC Plan p. 88, No. 7.9.3.4.1
4.11.16	The DMAC shall provide training and electronic tools to increase end users' and data providers' capacity in metadata generation and management.	DMAC	15. DMAC Plan p. 67, No. 2.5
4.11.17	The DIF shall provide metadata for data and products derived from the Seven core variables that are needed by the four models/assessments/products.	DIF	8. NOAA IOOS Project Requirements Document, p. 13, No. 5.1.7
4.11.18	The DMAC shall provide a means for determining what data are available within the IOOS based on queries issued by users and by other systems.	DMAC	15. DMAC Plan p. 67, No. 2.8
4.11.19	The DIF shall allow for discovery, access, and delivery (transport) of selected data sources external to NOAA for the Seven core variables that are needed by the four models/ assessments/products.	DIF	8. NOAA IOOS Project Requirements Document, p. 12, No. 5.1.3
4.11.20	The DIF shall allow for discovery, access, and delivery (transport) of both real time (24/7) and delayed mode data for NOAA and selected non-NOAA data sources of the Seven core variables that are needed by the four models/assessments/ products.	DIF	8. NOAA IOOS Project Requirements Document, p. 13, No. 5.1.5
4.11.21	The IOOS shall transmit data as close to the time of collection as possible. The utility of certain data sets will degrade faster than others; however, providers should always attempt to minimize the lag time between the observation and the point at which it is delivered to the processing centers.	IOOS	9. Hurricane Intensity Modeling Draft Report, p. 5
4.11.22	The IOOS shall transmit data as close to the time of collection as feasible to prevent certain data sets from degrading.	IOOS	20.Coastal Inundation Modeling, p. 6, letter D
4.11.23	Data assembly shall allow users to exploit real-time data, especially data from distributed sensor arrays.	DMAC	15. DMAC Plan p. 66, No. 2.3
4.11.24	The IOOS shall provide the capability for the collection and transmission of data from sensor subsystems at entry points where the data become available using DMAC standards and protocols. (3.6.59 - 10. IOOS Data Integration Framework)	DIF	15. DMAC Plan p. 66, No. 2.1

Table 4-11. NOAA Requirements

Identifier	Description	System/ Sub-System	Reference
4.11.25	IOOS shall provide for communications of metadata among components of the system.	DMAC	15. DMAC Plan p. 67, No. 2.5
4.11.26	The DIF shall support the testing and validation of the customer-identified hurricane intensity model or process.	DIF	8. NOAA IOOS Project Requirements Document, p. 13, No. 5.2.2
4.11.27	The DIF shall support the testing and validation of the coastal inundation customer-identified model or process.	DIF	8. NOAA IOOS Project Requirements Document, p. 13, No. 5.3.1
4.11.28	The DIF shall support the testing and validation of the HAB customer-identified model or process.	DIF	8. NOAA IOOS Project Requirements Document, p. 13, No. 5.4.2
4.11.29	The DIF shall support the testing and validation of the IEA customer-identified model or process.	DIF	8. NOAA IOOS Project Requirements Document, p. 14, No. 5.5.2
4.11.30	The DIF shall allow for subsetting of data in space and time from the Seven core variables that are needed by the four models/assessments/products.	DIF	8. NOAA IOOS Project Requirements Document, p. 12, No. 5.1.4
4.11.31	The DIF shall provide a capability to merge or overlay disparate sources of data for each of the core variables into geo-registered products that are needed by the four models/ assessments/products.	DIF	8. NOAA IOOS Project Requirements Document, p. 13, No. 5.1.6
4.11.32	The DIF shall allow the four models/assessments/products to be validated in an operational mode.	DIF	8. NOAA IOOS Project Requirements Document, p. 13, No. 5.1.8
4.11.33	The IEOS shall provide information critical to improving mitigation strategies and providing systematic and sustained monitoring of regions at risk.	IEOS	5. Strategic Plan for the IEOS, p. 81, letter B
4.11.34	The IOOS shall provide documentation to ensure utility of the data.	IOOS	9. Hurricane Intensity Modeling Draft Report, p. 4
4.11.35	The DIF shall implement NOAA GEO-IDE and other NOAA requirements for security and data management necessary to serve the requirements of the four models/assessments/ products.	DIF	8. NOAA IOOS Project Requirements Document, p. 12, No. 5.1.1
4.11.36	The IOOS shall provide documentation to ensure utility of the data.	IOOS	9. Hurricane Intensity Modeling Draft Report, p. 4
4.11.37	The IOOS shall provide oversight mechanisms to ensure the proper functioning and smooth evolution of IOOS. Those mechanisms include fault detection and correction, security, monitoring and evaluation of system performance, providing for system extensibility, establishment and publicizing of data availability policies, soliciting and responding to user feedback, and establishing and maintaining international linkages.	DMAC	15. DMAC Plan p. 67, No. 2.9

Table 4-11. NOAA Requirements

Identifier	Description	System/ Sub-System	Reference
4.11.38	Real-time NWLON data shall be used during the event to monitor the water level and for post-verification of the model to determine how well the model is operating.	IOOS	20. Coastal Inundation Modeling, p. 3, No. III
4.11.39	Forecasting winds shall be used to establish forcing and boundary conditions for the models.	IOOS	20. Coastal Inundation Modeling, p. 4
4.11.40	Bathymetry and topography shall be used to initialize the SLOSH (Sea, Lake and Overland Surges from Hurricanes) and ADCIRC (Advanced Circulation) ADCIRC grid and configure the model.	IOOS	20. Coastal Inundation Modeling, p. 4
4.11.41	One of the parameters shall be used to estimate storm surge heights and compare the difference between the storm's central pressure and the surrounding undisturbed atmosphere.	IOOS	20. Coastal Inundation Modeling, p. 5

GEOSS, GOOS AND IEOS

Table 4-12 contains high-level GEOSS, GOOS and IEOS system requirements.

Table 4-12. GEOSS, GOOS, IEOS Requirements

Identifier	Description	System	Reference
4.12.1	The GEOSS shall make data, metadata, and products available with minimal time delay and at minimal cost.	GEOS	1. GEOSS 10 Year Implementation Plan, p. 8, No. 5.4
4.12.2	The GEOSS shall provide research and education entities with shared data, metadata, and products free of charge or at no more than the cost of reproduction.	GEOS	1. GEOSS 10 Year Implementation Plan, p. 8, No. 5.4
4.12.3	The GEOSS shall provide full and open exchange of data, metadata, and products shared within GEOSS, recognizing relevant international instruments and national policies and legislation.	GEOSS	1. GEOSS 10 Year Implementation Plan, p. 8, No. 5.4
4.12.4	GEOSS shall use existing international standards for interoperability. Those standards include objectives issued by such organizations and institutes.	GEOSS	1. GEOSS 10 Year Implementation Plan, p. 7, No. 5.3
4.12.5	GEOSS shall draw on existing Spatial Data Infrastructure components as institutional and technical precedents in areas such as geodetic reference frames, common geographic data, and standard protocols.	GEOSS	1. GEOSS 10 Year Implementation Plan, p. 7, No. 5.3
4.12.6	The GOOS shall provide a free exchange of data.	GOOS	3. User Requirements for the GOOS, p. 24
4.12.7	The GOOS Living Marine Resources module shall provide a system that monitors marine ecosystems and the biological, chemical, and physical parameters controlling their variability.	GOOS	2. Strategic Plan and Principles for the GOOS, p. 7

Table 4-12. GEOSS, GOOS, IEOS Requirements

Identifier	Description	System	Reference
4.12.8	The GOOS Climate module shall monitor and describe the physical and bio-geochemical processes that determine ocean circulation and its influence on the carbon cycle as well as the effects of the ocean on seasonal to multi-decadal climatic changes.	GOOS	2. Strategic Plan and Principles for the GOOS, p. 7, No. (i)
4.12.9	GOOS shall provide international communication networks and efficient, standard formats and codes.	GOOS	3. User Requirements for the GOOS, p. 8
4.12.10	GOOS shall provide an integrated international database.	GOOS	3. User Requirements for the GOOS, p. 8
4.12.11	The GOOS Health of the Ocean (HOTO) module shall access available data on contaminant levels and community response at regional and national levels to provide baselines to underpin monitoring.	GOOS	2. Strategic Plan and Principles for the GOOS, p. 7, No. (iv)
4.12.12	The GOOS HOTO module shall develop a set of reliable, applicable biological distress indicators of the health of the environment.	GOOS	2.Strategic Plan and Principles for the GOOS, p. 7, No. (i)
4.12.13	GOOS shall provide a design that is flexible, expandable, and adaptable to changing needs, technology, and implementation constraints.	GOOS	2. Strategic Plan and Principles for the GOOS, p. 6, No. 3.1
4.12.14	GOOS shall provide accurate descriptions of the present state of the oceans, including living resources.	GOOS	2. Strategic Plan and Principles for the GOOS, p. 3, 7
4.12.15	GOOS shall provide continuous forecasts of the future conditions of the sea for as far ahead as possible.	GOOS	4. GOOS Data & Information Strategy Plan
4.12.16	The GOOS Services module shall assist the other module panels with establishing services and products and ways in which the provision of existing services and products can be improved.	GOOS	2. Strategic Plan and Principles for the GOOS, p. 8
4.12.17	GOOS shall be implemented in a phased approach.	GOOS	2. Strategic Plan and Principles for the GOOS, p. 3, No. 1.6
4.12.18	The GOOS Climate module shall provide the observations needed for the prediction of climate variability and climate change.	GOOS	2. Strategic Plan and Principles for the GOOS, p. 7, No. (ii)
4.12.19	The GOOS Coastal module shall take into account and integrate the plans and recommendations of the climate, HOTO, and LMR panels.	GOOS	2. Strategic Plan and Principles for the GOOS, p. 7
4.12.20	GOOS shall provide the basis for forecasts of climate change.	GOOS	4. GOOS Data & Information Strategy Plan, p. 9, No. 2.4
4.12.21	The GOOS Coastal module shall take into account the needs of a wider range of users, for instance, the communities involved in coastal management, environmental protection, ports, and shipping. Monitoring, documenting, and forecasting change in this environment will require integration of physical, chemical, biological, and geological observations and consideration of socio-economic requirements.	GOOS	2. Strategic Plan and Principles for the GOOS, p. 7

Table 4-12. GEOSS, GOOS, IEOS Requirements

Identifier	Description	System	Reference
4.12.22	The IEOS data shall be available for the operational, research, commercial, and academic communities with minimal time delay and at minimal cost.	IEOS	5. Strategic Plan for the IEOS, p. 35, letter A
4.12.23	The IEOS shall provide full and open access to data in accordance with OMB Circular A-130.	IEOS	5. Strategic Plan for the IEOS, p. 35, letter A
4.12.24	The IEOS shall facilitate the sharing and applied usage of global, regional, and local data.	IEOS	5. Strategic Plan for the IEOS
4.12.25	The IEOS shall facilitate the sharing and applied usage of data from satellites, ocean buoys, weather stations and other surface and airborne earth observing instruments and predictive models.	IEOS	5. Strategic Plan for the IEOS, Letter from John Marburger, III
4.12.26	The IEOS shall provide a monitoring system that supports risk assessment surveys.	IEOS	5. Strategic Plan for the IEOS, p. 81, letter B
4.12.27	The IEOS shall conform to regulations and policies, including OMB Circular A-16, Federal Enterprise Architecture (FEA), Data Quality Act, and OMB's information quality guidelines.	IEOS	5. Strategic Plan for the IEOSS
4.12.28	The IEOS shall record and store observations and products in clearly defined formats, with metadata and quality indications to enable search and retrieval, and shall archive them as accessible data sets. Prioritization for detecting, measuring, and predicting ocean parameters and phenomena shall be established at the national and regional levels.	IEOS	5. Strategic Plan for the IEOS, p. 45
4.12.29	The IEOS shall integrate the wide variety of Earth observations across disciplines, institutions, and temporal and spatial scales.	IEOS	5. Strategic Plan for the IEOS, p. 59-60
4.12.30	The IEOS shall provide data management.	IEOS	5. Strategic Plan for the IEOS, p. 59-60

Chapter 5
Requirements Refinement and Management

Having developed a consolidated list of high-level IOOS requirements, NOAA's next step is to refine them into detailed functional requirements using an effective requirements management process. The goal is to develop the Functional Requirements Document (FRD) for the IOOS solution. The FRD will contain the finalized functional requirements and architecture products for system development.

OVERVIEW

In accordance with NOAA Administrative Order 216-108, "Requirements Management," and industry best practices such as the IBM Rational Unified Process (RUP),[1] the NOAA IOOS Program Office will decompose the high-level IOOS requirements to develop a concept of operations (CONOPS) for IOOS. The CONOPS will serve as an input for identifying IOOS actors and developing use cases:

- An "actor" is an entity—a person, a group, or a system—that interacts with the system. The actor provides input to or obtains output from the system.
- A "use case" describes a set or series of actions performed by a system that result in an observable result or value to a particular actor.[2] A use case specifies the requirements of a system in plain English by describing the interaction between the actor and the system. In other words, a use case defines what a system must do. A use case does not specify how the system will be designed, nor does it specify user interface details or implementation details.

After the use cases have been developed, the detailed functional and system requirements can be identified. To meet industry-standard quality measures, these requirements must have the following characteristics:

- *Unambiguous.* The requirement is clear and is not misinterpreted.
- *Complete.* A requirement is complete when it is measurable and testable.
- *Consistent.* The requirement does not conflict with other requirements.
- *Prioritized.* The requirement is ranked for business importance and stability.

[1] RUP is an adaptable framework for iterative software development; it is not a single concrete prescriptive process. With RUP, the development organization and software project team can select the elements of the process that are appropriate for their needs.

[2] Grady Booch, James Rumbaugh, and Ivar Jacobson, *The Unified Modeling Language User Guide* (Addison Wesley, 1999).

- *Verifiable.* The requirement is met in the system.
- *Modifiable.* In iterative development, requirements are reassessed at the end of each iteration and could be modified. A requirement must not be rigid and the project plan must allow for changing the requirements and managing requirements throughout the development life cycle.
- *Traceable*. The source of the requirement is documented and the requirement can be referenced throughout the system. The automated requirements tool should enable finding the location in the system where each requirement is met.
- *Understandable.* The requirement contains terms that are clearly defined and the meaning can be comprehended.

An Integrated Product Team (IPT) that represents the stakeholder community will need to be established to oversee the refinement and management of the IOOS requirements. The IPT will then review and discuss the requirements in order to identify actions needed to resolve identified issues, and it will conduct meetings and interviews with representatives from the various stakeholder groups to identify actors and obtain other information needed to develop the use cases. In addition, the IPT will be responsible for providing approvals throughout the requirements management process.

To track and manage the requirements, it is recommended that the NOAA IOOS Program use automated tools, such as Rational RequisitePro. Rational RequisitePro uniquely identifies each requirement and generates a requirements traceability matrix (RTM), which can be used to manage the requirements throughout the system life cycle.

APPROACH

It is recommended that the NOAA IOOS Program use the following specific steps to refine and manage the IOOS requirements:

- Obtain scope buy-in
- Develop an IOOS CONOPS
- Conduct meetings and develop use cases
- Validate and prioritize requirements
- Manage requirements.

Obtain Scope Buy-In

The requirements management process begins with the IOOS IPT reviewing and obtaining consensus on the project scope, the constraints, and acceptance criteria for the IOOS requirements. Although the IOOS scope has been broadly defined, specific boundaries are needed to clearly identify and prioritize requirements that will be within the scope of the next phase of the IOOS project. These user needs and system requirements may be met by procuring COTS or government off-the-shelf (GOTS) products, through a software development effort, or with a combination of COTS/GOTS products and custom development. The IPT will need to decide if existing systems and models will be replaced by the IOOS and are therefore within scope, or if these systems and models will simply interface with the IOOS. One approach to creating and gaining consensus on the scope is to use scope diagramming techniques.

Develop Concept of Operations

The NOAA IOOS Program will then develop a draft CONOPS based on the refined, functional requirements as defined by the IOOS stakeholders. The draft CONOPS will include the following items:

- Current business understanding via end-to-end business process or operations
- Business entities and actors
- Process diagrams or flow charts
- Business rules
- System context, highlighting envisioned interaction of IOOS with other systems
- System boundaries or scope, highlighting major functional use cases.

Conduct Meetings and Develop Use Cases

To develop the use cases, the NOAA IOOS Program should then sponsor facilitated sessions, interviews, and teleconferences to gather information from customers, users, and other potential stakeholders about their needs for the IOOS. This information, along with input from the DIF initiative, will enable the IPT to validate the CONOPS, validate the process flows, and update the diagrams. In addition, the IPT will help to identify and define actors and stakeholders for each use case. This will include the name of each actor and a description of the actor’s interaction with the IOOS. Stakeholders are anyone who will be affected by the implementation of the IOOS and can be direct or indirect users of IOOS. Actors may be identified from the stakeholder group.

The facilitated sessions and interviews include discussions of recommended changes, improvements, commonalities, and exceptions. Requirements will be evaluated, revised (if necessary), and baselined to ensure that the requirements accurately represent those of the stakeholders, especially customers and potential system end users.

The NOAA IOOS Program must coordinate with the IPT to review the high-level IOOS requirements to identify gaps and assess areas in which additional detail or clarification is needed before the requirements can be decomposed. High-level process flows or swim-lane diagrams will be developed to depict IOOS process flows through activity diagrams. Activity diagrams—pictorial representations of use cases and business processes—can be used to ensure that critical information is identified and captured in the FRD and that a common functional understanding of the IOOS requirements exists.

Use cases will be developed based on the activity diagrams and the high-level business process areas. Basic use-case specifications will be outlined following the use case template provided in Appendix C. The NOAA IOOS Program will provide input for additional clarifications or validations. When the use cases are stable, the documents will be imported into Rational RequisitePro for tracking and managing throughout the IOOS life cycle. Each requirement will be uniquely identified and numbered within the Rational RequisitePro database. Attributes will be established to track the status of each requirement and to maintain traceability.

Validate and Prioritize Requirements

Once the NOAA IOOS Program and IPT have gained consensus on the IOOS functional requirements, a draft FRD will be developed that includes the CONOPS, use cases, and RTM. The FRD, which will be reviewed by the NOAA IOOS Program and the IPT, will become the baseline set of system requirements identifying the user needs to be implemented in the IOOS.

Feedback from the reviews will be incorporated into the use-case specifications and other documentation, such as diagrams, as necessary. The functional requirements will then be revised and finalized. A finalized FRD will be generated with the changes incorporated. The NOAA IOOS Program and IPT will work together to prioritize requirements.

Manage Requirements

The traceability of each requirement is essential to ensure that the IOOS objectives are met and that the requirements have been fully implemented. By using automated tools, such as RequisitePro, traceability will be assigned between requirement types as follows:

- *High-level requirements to functional requirements.* This involves tracing high-level requirements representing user needs or preferences to functional requirements documented in the use cases. This ensures that the system will be based on users' preferences and understanding of operations.

- *Functional requirements to technical requirements.* This traces technical requirements of the system, wherever appropriate, to the functional requirements.

- *Functional requirements to data requirements.* This involves tracing functional requirements to the data requirements developed during requirement analysis. The data model design will conform to the functional requirements.

- *Functional requirements to design artifacts.* This shows traceability between the functional use-case requirements and the design artifacts. This will ensure that the design conforms to the functional requirements of the system.

- *Functional requirements to report requirements.* This involves tracing reporting requirements to reporting processes to ensure coverage and consistency when reports are developed.

- *Test cases to functional requirements.* This provides traceability from test cases to use cases to ensure that test coverage over the IOOS requirements is complete and that the system meets user needs.

Requirement changes can be requested at any point during the IOOS program. Configuration management and changes to requirements, along with the reason for the change, should be documented within the chosen automated requirements management tool. A Configuration Control Board (CCB) needs to be established by the NOAA IOOS Program to manage change requests for requirements through the project life cycle. Any changes to the requirements as a result of CCB approval will be updated in the CONOPS, along with the corresponding architecture products.[3]

REQUIREMENTS LINKAGE

The purpose of the requirements management process will be to take all inputs from relevant stakeholders and translate the inputs into technical requirements. The process will allow the NOAA IOOS Program to work with the users to establish and refine operational needs, attributes, performance parameters, and constraints, and then ensure that all relevant requirements are addressed. Together with the users, the NOAA IOOS Program will translate "customer needs" into the following program and system requirements:

- Performance parameter objectives and thresholds
- Affordability constraints
- Scheduling constraints
- Technical constraints.

Since some of the requirements may become defined only through system decomposition at later stages of the program, iterative application of rigorous systems engineering will be key. The following describes the linkages between the requirements management process and the Key Decision Point (KDP) process for program management of the NOAA IOOS Program:

- *KDP-1—Needs Identification and Definition.* The requirements linkage to program objectives listed above are critical to the establishment of entrance and exit criteria during program reviews throughout the lifecycle of IOOS and the KDP 1 decision. The CONOPS will be critical in creation of the FRD, and used as the basis for validation of the *Needs Identification and Definition* Phase for program reviews.

- *KDP-2—Solution Alternatives Identification.* An integral part of defining and refining requirements is to provide technical support to the market research required early in the

[3] The specific details for managing requirements will be documented in a requirements management plan.

program life cycle. Systems engineers within NOAA analyze if and how an existing product, such as a COTS solution, can meet user requirements. This analysis ensures that open systems principles are applied to the maximum extent possible to reduce both life-cycle costs and development cycle time. These requirements analyses will the basis of an Analysis of Alternatives, and the critical component of exit criteria for the KDP 2 decision.

- *KDP-3—Solution Selection.* For the KDP 3 decision, requirements are analyzed against possible design solutions. This analysis is conducted at each level of the system structure, and then applied recursively to lower levels of the physical architecture throughout development. The objective is to help ensure that the requirements derived from the customer-designated capabilities are feasible and effective, as well as updated, as more information is learned about the requirements and interfaces through analysis. Upon completion of the analysis, the preferred outcome can be recommended and developed for implementation during the Acquisition/Implementation Approval Phase.

SUMMARY

By tracking and managing the requirements throughout the life cycle, the NOAA IOOS Program can manage program risks by determining potential cost or technical impacts for proposed changes prior to approving the change. The NOAA IOOS Program will be better able to provide program control and oversight for the implementation of the IOOS and ensure that the IOOS meets stakeholder needs. Furthermore, this program control is critical to ensure successful completion of major program reviews, and ensure continued progress of IOOS through the KDP process.

By documenting the functional requirements with the use-case method, obtaining stakeholder buy-in, and managing the requirements process throughout the IOOS project life cycle, the NOAA IOOS Program can more effectively manage the IOOS implementation to meet the needs of stakeholders.

Appendix A
Supplemental Requirements

During our review, we discovered some additional requirements that do not fall into any of the activities or may be out of scope. They are presented in three tables:

- Table A-1 lists requirements that do not apply to any of the activities covered by our review.
- Table A-2 lists requirements that are out of scope because they are too detailed.
- Table A-3 lists non-system requirements.
- Table A-4 lists conceptual design requirements that were captured from industry studies.
- Table A-5 lists deleted requirements that were duplicative of other requirements listed in Chapter 4.

Table A-1. Requirements That Are Not Clear

Identifier	Description	Reference
A.1.1	A core DMAC function shall be to enable product generation and promote product distribution.	15. DMAC Plan p. 66, No. 2.4
A.1.2	The DMAC shall provide a minimal level product-generation capability, only—the guarantee of a uniform, interactive, geo- and time referenced browse capability suitable for quick evaluation of data by IOOS scientists.	15. DMAC Plan p. 66, No. 2.4

Table A-2. Requirements That Are Out of Scope

Identifier	Description	Reference
A.2.1	The characteristics for each of these core services are: FTP–Direct downloads of data files, unrestricted public access, and no application support, HTTP–Direct downloads of data files, restricted or unrestricted access, and no application support, OPeNDAP–Application-layer protocol that supports a number of data storage formats and allows a number of client applications to access data transparently.	15. DMAC Plan, p. 86, No. 7.4.1, 7.4.2, 7.4.3

Table A-2. Requirements That Are Out of Scope

Identifier	Description	Reference
A.2.2	The AA shall use the IOOS DT protocols to offer the following extended services: Spatial subsetting–Extracting spatial sub regions from data sets for larger geographic areas, Parameter subsetting–Extracting one or more variables from data sets containing many variables, Temporal subsetting–Extracting short periods from data sets covering longer periods, Temporal aggregation–Creating a longer time series from data files for shorter periods, Geographic Information System (GIS) products–Depicting data projected, interpolated, and rendered onto a map with GIS protocols, On-line analysis–Analyzing online by using tools on the data server such as the Grid Analysis and Display System (GrADS) or the Live Access Server (LAS). The resulting data or graphics can then be downloaded.	15. DMAC Plan, p. 87, No. 7.5 (from 7.5.1–7.5.6)
A.2.3	The Global Tide Gauge Network shall maintain a network of 170 stations, an infrastructure to process and analyze the data, and deliver annual sea level reports.	6. IOOS Development Plan, p. 44, No. (1)
A.2.4	The Global Tide Gauge Network shall increase its number of remote reporting tide gauges from 39 to 86.	6. IOOS Development Plan, p. 44, No. (1)
A.2.5	The Global Surface Drifting Buoy Array shall increase the number of buoys from 900 to 1250 and add wind, pressure, and precipitation measurement capabilities.	6. IOOS Development Plan, p. 44, No. (2)
A.2.6	The Tropical Moored Buoy Network shall expand from 79 to 115 stations and span the Atlantic, Pacific, and Indian Oceans.	6. IOOS Development Plan, p. 44, No. (3)
A.2.7	The Global Ships of Opportunity program shall improve meteorological measurement capabilities, increase the accuracy and frequency of a subset of lines, and build a climate-specific subset from 29 to 41 lines.	6. IOOS Development Plan, p. 44, No. (4)
A.2.8	The Integrated Arctic Observing System shall increase from 11 ice-tethered buoys to 51 to measure ice drift and thickness.	6. IOOS Development Plan, p. 44, No. (6)
A.2.9	The Observing Subsystem shall be flexible enough to respond to more robust data requirements, evolving priorities, and new technologies.	6. IOOS Development Plan, p. 45
A.2.10	The data transmission rates required by current in situ platforms in the Observing Subsystem shall range from a few bytes to megabits per second.	6. IOOS Development Plan, p. 54
A.2.11	The Observing Subsystem shall contain the necessary infrastructure to satisfy the full spectrum of current and future data transmission periodicity requirements. The transmission periodicity requirements for current Observing Subsystem platforms include occasional (daily, weekly, monthly, etc.) bursts and continuous real time (24/7) and near-real time streaming.	6. IOOS Development Plan, p. 54
A.2.12	The Observing Subsystem shall utilize any applicable current or future telemetry technologies.	6. IOOS Development Plan, p. 54
A.2.13	The offshore coastal (> 25 km) and over-the-horizon global components shall employ HF, HF-DSC, and communications satellite channels.	6. IOOS Development Plan, p. 54
A.2.14	Subsurface sensors shall employ electro-optical cables terminating at shore or at telemetry buoys.	6. IOOS Development Plan, p. 54
A.2.15	Data assembly shall include such activities as digitizing information, conversion of raw instrument readings into physical units, or calculating anomalies.	6. IOOS Development Plan, p. 55

Table A-2. Requirements That Are Out of Scope

Identifier	Description	Reference
A.2.16	The global component of the Observing Subsystem shall provide data and information required to produce products for detecting changes in inventories of carbon, heat, and salinity in ocean basins on a decadal scale.	6. IOOS Development Plan, p. 22
A.2.17	The global component of the Observing Subsystem shall provide data and information required to produce products for monthly mean sea level trends for the past 100 years with 95% confidence.	6. IOOS Development Plan, p. 22
A.2.18	The global component of the Observing Subsystem shall provide data and information required to produce products for mean monthly sea surface temperature anomalies at 50 km resolution and 0.2°C accuracy.	6. IOOS Development Plan, p. 22
A.2.19	The global component of the Observing Subsystem shall provide data and information required to produce products for weekly analyses of precipitation and evaporation at 50 km resolution and 5 cm per month accuracy.	6. IOOS Development Plan, p. 22
A.2.20	The archiving and access service shall provide a failover mechanism for failed data transmissions.	15. DMAC Plan p. 83, No. 5.2.3
A.2.21	The DMAC services shall maintain metadata. The DMAC services will include the following types of metadata: use metadata (the semantic and syntactic information about a data set); and discovery metadata (standard structured information describing a data set), including data set lineage history (e.g., which irreplaceable data set was used to create this current data set), data category specification, which determines the storage requirements, release date, which is the date to remove temporary restricted access, version number and description of the version number, description of the file naming convention; unique IOOS-wide data set name or identification; and mechanisms for correct publication citation and reference tracking.	15. DMAC Plan p. 85, No. 6.4, 6.4.1, 6.4.2 (6.4.2.1–6.4.2.7)
A.2.22	For each data set returned from a search of the catalog, the selection interface shall display the data set title and relevant metadata, including spatial and temporal coverage and a method for viewing the metadata from that data set.	15. DMAC Plan p. 73, No. 4.9.3

Table A-3. Non-System Requirements

Identifier	Description	Reference
A.3.1	Data stewards at the archive centers shall maintain constancy in formats and software to prevent condition that could make accessing the data more difficult, more costly or impossible.	15. DMAC Plan p. 81, No. 2.5.6
A.3.2	Virus checks shall be performed on the data before archiving, then periodically on all data kept online.	15. DMAC Plan p. 83, No. 5.2.5
A.3.3	The Data Archive system will have a data and metadata migration plan to accommodate media and system evolution and assure long-term preservation of irreplaceable data.	15. DMAC Plan p. 43
A.3.4	Metadata shall be dynamic to accommodate through numerous incremental updates, modifications, corrections, and occasionally, full replacements.	15. DMAC Plan p. 86, No. 6.4.4
A.3.5	Regional data centers shall fulfill the long-term archive obligation if they meet the IOOS standards for data integrity and stewardship or if they systematically transfer the data to an archive center.	15. DMAC Plan p. 81, No. 2.6.4

Table A-3. Non-System Requirements

Identifier	Description	Reference
A.3.6	The DMAC shall develop a plan that addresses evolving mass storage technology.	15. DMAC Plan p. 68, No. 5.2
A.3.7	The DMAC shall develop a plan that addresses strategies for storage media migration.	15. DMAC Plan p. 68, No. 5.2.1
A.3.8	The IOOS shall demonstrate assets incorporated into the enterprise either benefit from being a part of an integrated system or contribute to improving the integrated system in terms of the delivery of new or improved products that serve the needs of user groups.	7. IOOS Final Report, p. 7, OP11
A.3.9	The IOOS shall establish procedures to ensure reliable and sustained data streams, to routinely evaluate its performance, to assess the value of the information products and services that are produced or exposed through the enterprise, and to improve the capability and performance of the system as new capabilities become available and user requirements evolve.	7. IOOS Final Report, p. 6, OP5
A.3.10	The MAS shall include a process of independent validation and verification (IV&V) for models prior to being published for public consumption.	12. IOOS Conceptual Design, p. 157, No. 4.3.2
A.3.11	IOOS Managers shall ensure that all IOOS data streams undergo primary data assembly and quality control prior to making them available.	6. IOOS Development Plan, p. 55, last paragraph
A.3.12	The IOOS shall establish procedures to ensure reliable and sustained data streams, to routinely evaluate its performance, to assess the value of the information products and services that are produced or exposed through the enterprise, and to improve the capability and performance of the system as new capabilities become available and user requirements evolve.	7. IOOS Final Report, p. 6, OP5
A.3.13	The MAS shall include a research and development component.	12. IOOS Conceptual Design, p. 157, No. 4.3
A.3.14	Data Providers for the IOOS shall use existing Internet capacity to push data holdings to the Regional Nodes and National Backbone.	15. DMAC Plan p. 68, No. 4.2.2
A.3.15	The DMAC shall develop a plan that addresses evolving mass storage technology.	15. DMAC Plan p. 68, No. 5.2
A.3.16	The DMAC shall develop a plan that addresses strategies for storage media migration.	15. DMAC Plan p. 68, No. 5.2.1
A.3.17	Virus checks shall be performed on the data before archiving, then periodically on all data kept online.	15. DMAC Plan p. 83, No. 5.2.5
A.3.18	Each center shall provide and maintain software for accessing each native format.	15. DMAC Plan p. 84, No. 5.5.3
A.3.19	Centers shall maintain configuration management of the software in order to maintain currency with changing data formats.	15. DMAC Plan p. 84, No. 5.5.3.1
A.3.20 A.3.21	This software shall also provide further documentation of data sets and changes in their lineage.	15. DMAC Plan p. 84, No. 5.5.3.2
	Archive centers shall provide some real-time services, and enhance data discovery by using the IOOS metadata standards and data discovery techniques.	15. DMAC Plan p. 82, No. 4.2
A.3.22	Modeling centers shall procure and synthesize observational data to produce products such as analyses, predictions, or hindcasts that may span a wide range of spatial and temporal scales.	15. DMAC Plan p. 81, No. 2.7.1

Table A-3. Non-System Requirements

Identifier	Description	Reference
A.3.23	Modeling centers may provide access to their products, but their mission does not include long-term archiving.	15. DMAC Plan p. 81, No. 2.7.2
A.3.24	Model products that are essential to IOOS goals shall be transferred and preserved at an appropriate archive center.	15. DMAC Plan p. 81, No. 2.7.1
A.3.25	Institutions or organizations that operate operational programs of the Observing Subsystem shall have clearly identified strategies for sustained funding.	6. IOOS Development Plan, p. 9
A.3.26	Observing Subsystem programs shall have sustained funding and agency or program sponsorship.	6. IOOS Development Plan, p. 21, No. (5)
A.3.27	Proprietary formats (with undisclosed internal structure and typically with proprietary software) shall be unacceptable for long-term archiving and are prohibited.	15. DMAC Plan p. 84, No. 5.5.2
A.3.28	The DMAC shall develop a plan to address technology infusion.	15. DMAC Plan p. 68, No. 5.1
A.3.29	The DMAC shall develop a plan that includes mechanisms for member-provided technology infusion, as well as that which is centrally funded and maintained.	15. DMAC Plan p. 68, No. 5.1
A.3.30	The plan shall consider new technologies in networks, computing systems, and evolutions in software.	15. DMAC Plan p. 69, No. 5.3
A.3.31	The plan shall account for Technology Upgrades–A change that incorporates the next generation product or product upgrade to an existing technology or component which improves overall system functionality.	15. DMAC Plan p. 69, No. 5.4.1
A.3.32	The plan shall account for Technology Refreshers–A change that incorporates a new product to avoid an ensuring end of life or product/COTS obsolescence, or to correct a problem identified via a customer.	15. DMAC Plan p. 69, No. 5.4.2
A.3.33	The plan shall account for Technology Insertion–A change that incorporates a new product or function capability which is a result of industry growth or advanced development.	15. DMAC Plan p. 69, No. 5.4.3
A.3.34	The plan shall account for Technology Refreshers–A change that incorporates a new product to avoid an ensuring end of life or product/COTS obsolescence, or to correct a problem identified via a customer.	15. DMAC Plan p. 69, No. 5.4.2
A.3.35	The plan shall account for Technology Insertion–A change that incorporates a new product, function or capability which is a result of industry growth or advanced development.	15. DMAC Plan p. 69, No. 5.4.3
A.3.36	To qualify as an archive center, a data center shall be able to verify and generate metadata as well as preserve them with their associated data.	15. DMAC Plan p. 84, No. 6.1.2.2
A.3.37	To qualify as an archive center, a data center shall be able to frequently check data integrity.	15. DMAC Plan p. 84, No. 6.1.2.3
A.3.38	To qualify as an archive center, a data center shall be able to plan for evolution of technology.	15. DMAC Plan p. 84, No. 6.1.2.4
A.3.39	As the amount of IOOS data steadily increases, the old and new systems of access must remain compatible in order to maintain the high levels of service and allow users to fully discover the archived data.	15. DMAC Plan p. 79, No. 1.3
A.3.40	The data discovery component will be accessible by both humans and machines.	15. DMAC Plan p. 79, No. 1.2
A.3.41	The DIF shall directly or indirectly facilitate activities to rescue, digitize, and provide access to legacy/historical data sets; retrieve data in danger of loss due to deteriorating media, out-of-date software, not in digital format, etc.	15. DMAC Plan p. 67, No. 2.6

Table A-3. Non-System Requirements

Identifier	Description	Reference
A.3.42	The AA shall accommodate maximum latency periods as defined in the metadata. For IOOS access latency is defined as the time between the earliest primary observation (not counting ancillary data) in a data file and the availability of that file to users.	15. DMAC Plan p. 88, No. 7.7, 7.7.1
A.3.43	Latency requirements shall be assessed and suitably defined in the metadata.	15. DMAC Plan p. 88, No. 7.7.2
A.3.44	The AA shall provide unrestricted access under normal circumstances.	15. DMAC Plan p. 88, No. 7.8
A.3.45	The AA shall restrict access under special circumstances including: Proprietary embargo–Data are available only for sale from commercial companies, National security–Data are available only for defense purposes, Calibration and validation–Data are available only to the science team while they calibrate or validate instruments, data, or models, Non-commercial use only–Data are available for government applications and academic research, but not for resale.	15. DMAC Plan p. 88, No. 7.8.1, 7.8.1.1–7.8.1.4
A.3.46	The AA shall provide user services and use metrics.	15. DMAC Plan p. 88, No. 7.9
A.3.47	Additional background information shall be available through references and citations in the metadata.	15. DMAC Plan p. 88, No. 7.9.2
A.3.48	When regional, modeling, and data assembly centers provide access on schedules that meet the IOOS goals, duplication of this effort is not a requirement for the archive centers; however, the archive centers will ultimately receive the data, provide for their long-term preservation, and provide access to full archived data set.	15. DMAC Plan p. 82, No. 4.3
A.3.49	Access services for IOOS users shall be provided from most centers in the Archive System.	15. DMAC Plan p. 82, No. 4.1
A.3.50	Data assembly centers shall typically specialize in certain types of data, and often provide quality control and data products in their area of expertise.	15. DMAC Plan p. 81, No. 2.8.2
A.3.51	The objective of the MAS shall be to provide more accurate estimates of the distributions of state variables.	12. IOOS Conceptual Design, p. 156, No. 4.2.2
A.3.52	The data requirements of the MAS shall, in part, drive the observational requirements of the Observing Subsystem.	12. IOOS Conceptual Design, p. 156, No. 4.2.1
A.3.53	Observing Subsystem programs shall measure one or more of the core variables (i.e. if it doesn't contribute a core variable, it shouldn't be part of IOOS).	6. IOOS Development Plan, p. 21, No. (2)
A.3.54	Primary Data Assembly and Quality Control (PDAQC) responsibilities at this time shall be shared between the DMAC Subsystem and the Regional Associations with quality control procedures residing in the DMAC subsystem.	6. IOOS Development Plan, p. 55
A.3.55	Metadata shall be dynamic to accommodate through numerous incremental updates, modifications, corrections, and occasionally, full replacements.	15. DMAC Plan p. 86, No. 6.4.4
A.3.56	Metadata shall be inclusive of sufficient information to provide an end-to-end lineage record, starting with the measurements or computation through the change and modification history and eventually to established scientific or public knowledge.	15. DMAC Plan p. 86, No. 6.4.5

Table A-3. Non-System Requirements

Identifier	Description	Reference
A.3.65	The DMAC shall not adversely impact existing data access methods or systems of the data providers.	15. DMAC Plan p. 69, No. 6.1.3
A.3.66	The MMS shall require the data provider to maintain one copy of meta-data that is in two or more systems.	15. DMAC Plan p. 72, No. 2.2.1
A.3.67	Operational programs of the Observing Subsystem shall provide data and products delivered on schedule according to predetermined dead-lines.	6. IOOS Development Plan, p. 9
A.3.68	Operational programs of the Observing Subsystem shall provide dedi-cated personnel responsible for acquisition and quality control of data and dissemination of products.	6. IOOS Development Plan, p. 9
A.3.69	Operational programs of the Observing Subsystem shall provide ex-pected benefits realized on a predetermined time schedule.	6. IOOS Development Plan, p. 9
A.3.70	A national education coordinating office shall foster a collaborative ocean education and communication network.	13. First IOOS Development Plan Addendum 14. Improving the IOOS, p. 41
A.3.71	Online documentation and knowledgeable personnel shall be available to provide assistance and advice on both access and content.	15. DMAC Plan p. 88, No. 7.9.1
A.3.72	The IOOS shall provide a mechanism to solicit and receive user feed-back concerning the operation of the system, data quality, portal content, and other issues.	15. DMAC Plan p. 74, No. 5.17
A.3.72.1	The IOOS shall make user comments on data sets accessible to the IOOS staff for review.	15. DMAC Plan p. 74, No. 5.17.1
A.3.73	The DMAC shall provide oversight mechanisms (including receiving and responding to user feedback) to ensure the proper functioning and smooth evolution of IOOS.	15. DMAC Plan p. 67, No. 2.9
A.3.74	The user feedback mechanism shall provide a “help” function.	15. DMAC Plan p. 74, No. 5.17.1
A.3.75	The DMAC shall provide oversight mechanisms, including receiving and responding to user feedback, to ensure the proper functioning and smooth evolution of IOOS.	15. DMAC Plan p. 67, No. 2.9
A.3.76	The DMAC shall provide oversight mechanisms, including monitoring and evaluation of system performance, to ensure the proper functioning and smooth evolution of IOOS.	15. DMAC Plan p. 67, No. 2.9
A.3.77	The DMAC shall provide oversight mechanisms, including provisions for system extensibility, to ensure the proper functioning and smooth evolu-tion of IOOS.	15. DMAC Plan p. 67, No. 2.9
A.3.78	The DMAC shall provide oversight mechanisms, including establishing and maintaining international linkages, to ensure the proper functioning and smooth evolution of IOOS.	15. DMAC Plan, p. 67, No. 2.9
A.3.79	The DMAC shall provide user mechanisms to solicit and respond to user feedback.	15. DMAC Plan p. 74, No. 5.17

Table A-4. Conceptual Design

Description	System	Reference
The IOOS shall be compliant with the World Wide Web Consortium's guidelines about web content.	IOOS	12. IOOS Conceptual Design. p. 155, No. 3.10.4.1
The IOOS design shall be developed with guidance derived from both data providers and data users encompassing both the public and private sectors; it shall be based on sound science and encompass a continuum of research to operational activities.	IOOS	7. IOOS Final Report p. 6, OP8
The IOOS design shall enable and not constrain innovation or creativity in local implementation.	IOOS	7. IOOS Final Report p. 6, OP9
The IOOS design shall enable the integration of any type of asset into the enterprise; the robustness of that integration can vary based upon reasonable cost-benefit trades. Assets that plug into the IOOS enterprise shall meet federally approved or vetted community-based standards and protocols for observations, data telemetry, and DMAC in order to ensure data quality and interoperability.	IOOS	7. IOOS Final Report p. 7, OP11
The IOOS design shall be capable of graceful evolution in the face of ever-expanding technological innovation and ever more complex environmental, sociological, and political challenges.	IOOS	7. IOOS Final Report p. 6, OP5
IOOS shall have a flexible, scalable, and extensible design capable of supporting legitimate end use (public good, commercial, and so on).	IOOS	7. IOOS Final Report p. 6, OP10
The IOOS design should enable the judicious integration of existing assets that meet requirements that address the seven societal goals and regional priorities.	IOOS	7. IOOS Final Report p. 6, OP10
The IOOS design shall promote local and regional autonomy yet promulgate global interoperability.	IOOS	7. IOOS Final Report p. 7, OP12
The IOOS design shall enable the generation of tailorable interfaces capable of addressing the needs of communities of interest.	IOOS	7. IOOS Final Report p. 7, OP13
Data assembly shall be a function of the MAS.	MAS	12. IOOS Conceptual Design, p. 157, No. 4.5
The IOOS shall provide the capability for user groups from the private and public sectors, academia, and NGOs to easily discover and readily access relevant data, products, information, and services that are part of the IOOS enterprise in order to achieve their missions and goals more effectively.	IOOS	7. IOOS Final Report p. 6, OP2
Data and information shall be available in layers that can be toggled on and off with appropriate symbology keys.	IOOS	12. IOOS Conceptual Design, p. 155, No. 3.10.4.5
The DMAC shall make data available in multiple formats, including the data's native form. (Define types of "multiple formats")	DMAC	15. DMAC Plan p. 69, No. 6.1.8
The IOOS shall openly and fully share data and information produced at the public expense in a timely manner, at no more than the cost of dissemination. (Define "timely")	IOOS	7. IOOS Final Report p. 6, OP3
Information available from IOOS shall be presented in a simple, organized fashion due to potential limited bandwidth and restrictions on web applications in some educational arenas.	IOOS	12. IOOS Conceptual Design, p. 155, No. 3.10.4.3

Table A-4. Conceptual Design

Description	System	Reference
The IOOS shall routinely, reliably, and continuously serve data, information, products, and services for multiple applications that provide social and economic benefits both to the nation and to a broad spectrum of users from public and private sectors that use, depend on, manage, or study marine and estuarine environments and the natural resources within them.	IOOS	7. IOOS Final Report p. 5, OP1
The modeling and analysis service shall provide models, analysis tools, decision support tools, and products that support the seven societal goals of IOOS.	MAS	12. IOOS Conceptual Design, p. 156, No. 4.2
The modeling and analysis service shall initialize and update models for improved forecasts of coastal environmental conditions and, ultimately, changes in ecosystem health and living resources.	MAS	12. IOOS Conceptual Design, p. 157, No. 4.2.3
The modeling and analysis service shall consist of a loose federation of marine models, decision support tools, analysis tools, and products.	MAS	12. IOOS Conceptual Design, p. 156, No. 4.1
The modeling and analysis service shall include a regional association component of models, analysis tools, and products owned, operated, and developed by the local RA and applicable for regional or local applications.	MAS	12. IOOS Conceptual Design, p. 156, No. 4.1.1
The modeling and analysis service shall provide the capability for each of the RAs to maintain their own respective modeling and analysis service component.	MAS	12. IOOS Conceptual Design, p. 156, No. 4.1.1.1
The modeling and analysis service shall include a federal or national component of models, analysis tools, and products that are owned, operated, and developed by a federal entity and applicable on global, national, regional, and local scales.	MAS	12. IOOS Conceptual Design, p. 156, No. 4.1.2
The modeling and analysis service shall initially incorporate mature modeling and analysis programs, including the U.S. Global Ocean Data Assimilation Experiment (GODAE).	MAS	12. IOOS Conceptual Design, p. 156, No. 4.1.2.1, 4.1.2.1.1
The modeling and analysis service shall include a library function in which and through which models, algorithms, and decision aids can be cataloged, discovered, and checked in or checked out.	MAS	12. IOOS Conceptual Design, p. 157, No. 4.4
The IOOS shall provide accessibility guidelines for the education sector.	IOOS	12. IOOS Conceptual Design, p. 155, No. 3.10.4.1
The modeling and analysis service shall provide a medium to develop, test, and validate models.	MAS/DMAC	12. IOOS Conceptual Design, p. 157, No. 4.3.1
The IOOS shall include a thorough development of informational requirements and technological limitations/requirements of the education sector.	IOOS	12. IOOS Conceptual Design, p. 155, No. 3.10.3
The IOOS security service shall provide for identity management using a standard protocol such as LDAP to verify user's credentials for identification and authentication for IOOS services.	IOOS	12. IOOS Conceptual Design, p. 38, Table 2.3-2
The IOOS security service shall support single sign-on. This shall be based on the topology of the overall IOOS identify management.	IOOS	12. IOOS Conceptual Design, p. 38, Table 2.3-2
The IOOS shall have an encryption service that enables the encryption and decryption of data for transmission between IOOS and external systems and provides confidentiality of datasets.	IOOS	12. IOOS Conceptual Design, p. 38, Table 2.3-2

Table A-4. Conceptual Design

Description	System	Reference
The IOOS security service shall issue digital signatures and maintain integrity and authenticity of its content.	IOOS	12. IOOS Conceptual Design, p. 38, Table 2.3-2
The IOOS security service shall provide PKI services that support data exchange through the use of a public and a private cryptographic key pair.	IOOS	12. IOOS Conceptual Design, p. 38, Table 2.3-2
The IOOS security service shall provide data network security controls that manage and control security for systems and applications.	IOOS	12. IOOS Conceptual Design, p. 38, Table 2.3-2
The IOOS shall provide additional service controls associated with the IOOS security plan, once it is established.	IOOS	12. IOOS Conceptual Design, p. 38, Table 2.3-2
The IOOS shall enable the use or exploitation of ocean-relevant data, products, information and services beyond their original intent.	IOOS	7. IOOS Final Report p. 5, OP2
The IOOS shall leverage existing assets as much as practical.	IOOS	7. IOOS Final Report p. 6, OP7

Table A-5. Deleted Requirements

Duplicate of Req #	Description	System	Reference
3.5.1	The data archive shall manage multiple copies of the data and metadata.	IOOS	15. DMAC Plan p. 84, No. 6.1.2.1
3.4.9	The data transport service shall be capable of providing access to metadata from a site other than that of the data server together with the data.	DMAC	15. DMAC Plan p. 76, No. 2.9
3.4.9	The DMAC shall provide for communication of metadata among components of the system.	DMAC	15. DMAC Plan p. 67, No. 2.5
3.4.1	The IOOS and DMAC shall ensure that reliable linkages between data and metadata are maintained.	DIF and DMAC	15. DMAC Plan p. 67, No. 2.5
3.4.16	The MMS shall provide mechanisms for extensibility of the metadata.	DMAC/MMS	15. DMAC Plan p. 67, No. 2.5
3.4.13	The archiving and access service shall receive metadata with its associated data.	DMAC	15. DMAC Plan p. 215
3.4.5	The data transport service shall be able to transmit all relevant semantic metadata: translational use, descriptive use, and search metadata. They must be available in both human-readable and machine-readable forms.	DMAC	15. DMAC Plan p. 75, No. 2.2
	Data assembly centers shall be permanent, for example, National Data Buoy Center (NDBC), or they may exist for only limited periods for example, World Ocean Circulation Experiment (WOCE) data assembly centers.	DMAC	15. DMAC Plan p. 81, No. 2.8.3
	IOOS shall be seamlessly integrated with data and metadata access functions provided by the data transport and metadata management components, respectively.	IOOS	15. DMAC Plan p. 67, No. 2.8

Table A-5. Deleted Requirements

Duplicate of Req #	Description	System	Reference
	The DMAC shall include a variety of physical, biological, and chemical ocean data that are collected by the regional centers and used to support scientific, public, and commercial interests in the area.	DMAC	15. DMAC Plan p. 81, No. 2.6.2
	The data transport service shall provide a semantic data model, defined as the semantics implicit in the structural transformations that the system provides and the semantic information transported in the data access protocol.	DMAC	15. DMAC Plan p. 77, No. 3.4
	The core semantic data model shall include the set of translational use metadata.	DMAC	15. DMAC Plan p. 77, No. 3.4.1
3.6.58	The DMAC shall provide the capability for the collection and transmission of data from sensor subsystems at entry points where the data become available using DMAC standards and protocols.	DMAC	15. DMAC Plan p. 66, No. 2.1
	The DMAC shall provide oversight mechanisms, including fault detection and correction, to ensure the proper functioning and smooth evolution of IOOS.	DMAC	15. DMAC Plan p. 67, No. 2.9
3.4.23	The Data Discovery System shall provide the capability for the system administrator to ensure that links between metadata records and points of data access remain valid over time.	DMAC	15. DMAC Plan p. 33, second paragraph
A.1.2	The DMAC will provide a minimal level product-generation capability, only–the guarantee of a uniform, interactive, geo-time- referenced browse capability suitable for quick evaluation of data by IOOS scientists.	DMAC	15. DMAC Plan p. 66, No. 2.4

Appendix B
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Appendix C
Sample Use Case Template

The following is Sample Use Case Template from the IBM Rational Unified Process.

<Project Name>

Use Case Specification: <Use-Case Name>

Version <1.0>

[Note: The following template is provided for use with the Rational Unified Process. Text enclosed in square brackets and displayed in blue italics (style=InfoBlue) is included to provide guidance to the author and should be deleted before publishing the document. A paragraph entered following this style will automatically be set to normal (style=Body Text).]

[To customize automatic fields (which display a gray background when selected), select File>Properties and replace the Title, Subject and Company fields with the appropriate information for this document. After closing the dialog, automatic fields may be updated throughout the document by selecting Edit>Select All (or Ctrl-A) and pressing F9, or simply click on the field and press F9. This must be done separately for Headers and Footers. Alt-F9 will toggle between displaying the field names and the field contents. See Word help for more information on working with fields.]

Revision History

Date	Version	Description	Author
<dd/mmm/yy>	<x.x>	<details>	<name>

Table of Contents

Use Case Specification: <Use-Case Name>

1. Use Case Name

1.1 Brief Description

[The description should briefly convey the role and purpose of the use case. A single paragraph should suffice for this description.]

2. Flow of Events

2.1 Basic Flow

[This use case starts when the actor does something. An actor always initiates use Cases. The use case should describe what the actor does and what the system does in response. It should be phrased in the form of a dialog between the actor and the system.

The use case should describe what happens inside the system, but not how or why. If information is exchanged, be specific about what is passed back and forth. For example, it is not very illuminating to say that the Actor enters customer information; it is better to say the Actor enters the customer's name and address. A Glossary of Terms is often useful to keep the complexity of the use case manageable; you may want to define things like customer information there, to keep the use case from drowning in details.

Simple alternatives may be presented within the text of the use case. If it only takes a few sentences to describe what happens when there is an alternative, do it directly within the flow of events section. If the alternative flows are more complex, use a separate section to describe it. For example An Alternative Flow describes how to describe more complex alternatives.

A picture is sometimes worth a thousand words (though there is no substitute for clean, clear prose). If it improves clarity, feel free to paste graphical depictions of user interfaces, process flows, or other figures into the use case to improve its clarity. If a flow chart is useful to present a complex decision process, by all means use it! Similarly for state-dependent behavior, a state-transition diagram often clarifies the behavior of a system better than pages upon pages of text. Use the right presentation medium for your problem, but be wary of using terminology, notation or figures that your audience may not understand. Remember that your purpose is to clarify, not obscure.]

2.2 Alternative Flows

2.2.1 < First Alternative Flow >

[More complex alternatives should be described in a separate section, which is referred to in the basic flow of events section. Think of the alternative flow sections like alternative behavior–each alternative flow represents alternative behavior (many times, because of exceptions that occur in the main flow). They may be as long as necessary to describe the events associated with the alternative behavior. When an alternative flow ends, the events of the main flow of events are resumed unless otherwise stated.]

2.2.1.1 < An alternative sub-flow >

[Alternative flows may in turn be broken down into sub-sections if it improves clarity.]

2.2.2 < Second Alternative Flow >

[There may be, and most likely will be, a number of alternative flows in a use case. Keep each alternative separate to improve clarity. Using alternative flows improves the readability of the use case, as well as preventing use cases from being decomposed into hierarchies of use cases. Keep in mind that use cases are just textual descriptions, and their main purpose is to document the behavior of a system in a clear, concise and understandable way.]

3. Special Requirements

[A Special Requirement is typically a non-functional requirement that is specific to a use case but is not easily or naturally specified in the text of the use case’s event flow. Examples of special requirements include legal and regulatory requirements, application standards, and quality attributes of the system to be built, including usability, reliability, performance or supportability requirements. Additionally, other requirements such as operating systems and environments, compatibility requirements, and design constraints should be captured in this section.]

3.1 < First special requirement >

4. Pre-Conditions

[A pre-condition (of a use case) is the state of the system that must be present prior to a use case being performed.]

4.1 < Pre-condition One >

5. Post-Conditions

[A post-condition (of a use case) is a list of possible states the system can be in immediately after a use case has finished.]

5.1 < Post-condition One >

6. Extension Points

[Extension points of the use case.]

6.1 <name of extension point>

[Definition of the location of the extension point in the flow of events.]

Appendix D
Abbreviations

AA	Archiving and Access
AOOS	Alaska Ocean Observing System
API	Application Programmer Interface
CaRA	Caribbean Regional Association
CCB	Configuration Control Board
CeNCOOS	Central and Northern California Ocean Observing System
CMAN	Coastal Marine Automated Network
CONOPS	Concept of Operations
COTS	Commercial Off-the-Shelf
DIF	Data Integration Framework
DMAC	Data Management and Communications
DMAC-ST	Data Management and Communications Steering Team
DT	Data Transport
EEZ	Exclusive Economic Zone
FGDC	Federal Geographic Data Committee
FIPS PUB	Federal Information Processing Standards Publications
FISMA	Federal Information Security Management Act
FRD	Functional Requirements Document
FTP	File Transfer Protocol
FY	Fiscal Year
GCOOS	Global Coastal Ocean Observing System
GCOS	Global Climate Observing System
GEO-IDE	Global Earth Observation–Integrated Data Environment
GEOSS	Global Earth Observation System of Systems
GIS	Geographic Information System
GLOBEC	Global Ocean Ecosystem Dynamics
GLOS	Great Lakes Observing System
GODAE	Global Ocean Data Assimilation

GOES	Geostationary Operational Environmental Satellite
GOOS	Global Ocean Observing System
GOTS	Government Off-the-Shelf
GrADS	Grid Analysis and Display System
GUI	Graphical User Interface
HAB	Harmful Algal Bloom
HOTO	Health of the Ocean
HTTP	Hypertext Transfer Protocol
IEA	Integrated Ecosystem Assessment
IEOS	Integrated Earth Observation System
IOC	Initial Operational Capability
IOOS	Integrated Ocean Observing System
IPT	Integrated Product Team
JAFOOS	Joint Australian Facility for Ocean Observing Systems
JCOMM	Joint Intergovernmental Oceanographic and Marine Meteorology
LMR-ES	Living Marine Resources–Ecosystems Survey
MACOORA	Mid-Atlantic Coastal Ocean Observing Regional Association
MAS	Modeling and Analysis Systems
MMS	Metadata Management System
NARA	National Archives and Records Administration
NANOOS	Networked Coastal Ocean Observing System
NDBC	National Data Buoy Center
NERACOOS	Northeastern Regional Association of Coastal Ocean Observing Systems
NERRS	National Estuarine Research Reserve System
NGO	Nongovernmental Organizations
NOAA	National Oceanic and Atmospheric Administration
NSIP	National Streamflow Information Program
NSQAN	National Stream Quality Accounting Network
NWLON	National Water Level Observation Network
OOI	Ocean Observatories Initiative
OOPC	Ocean Observations Panel for Climate
OPeNDAP	Open Source Project for a Network Data Access Protocol

ORION	Ocean Research Interactive Observatory Networks
PacIOOS	Pacific Islands Integrated Ocean Observing System
POES	Polar Operational Environmental Satellite
PORTS	Physical Oceanographic Real-Time System
RA	Regional Association
RCOOS	Regional Coastal Ocean Observing Systems
RTM	Requirements Traceability Matrix
RUP	Rational Unified Process
SCCOOS	Southern California Coastal Ocean Observing System
SDI	Spatial Data Infrastructure
SECOORA	Southeast Coastal Ocean Observing Regional Association
TBD	To Be Determined
WOCE	World Ocean Circulation Experiment