Integrated Ocean Observing System

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The Business Case for Improving NOAA's Management and Integration of Ocean and Coastal Data

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Executive Summary

One of NOAA's most valuable assets is the data that it collects. Ocean and coastal data are critical to NOAA's ability to deliver the products and services that provide significant, tangible benefits to society. Because of this, it is vital that users are able to access the vast stores of physical, biological, and chemical ocean data. To respond to user needs, the NOAA Integrated Ocean Observing System (IOOS) Program proposes to facilitate access to ocean and coastal data by improving the way data are integrated and managed. NOAA directed the IOOS Program to deliver a business case to address the capability gaps and potential solutions identified by the IOOS Program.

This business case provides the rationale for improving NOAA ocean data management and integration, describes the demand for and value of ocean and coastal data, describes the current approach to supplying these data, and provides a detailed description of how an ocean data management solution can be achieved by evolving the current Data Integration Framework (DIF) efforts into a comprehensive Data Management and Communication (DMAC) capability.

While there are many existing NOAA data integration efforts that focus on supporting a few models and tools, there is no comprehensive data management approach. NOAA and end users are spending significant amounts of time, sometimes 25 to 50 percent of an FTE, to access, format, and ingest the data for every product or output delivered. Smaller scale investments have yielded benefits for some users, but these are not available to all potential users, due to the limited scope of the solution. Research in private industry has found that *quick fix* solutions are less likely to generate the level of sustained benefit that an enterprise-wide data management solution can provide.

This business case uses cost-benefit analysis to estimate the expected Net Present Value (NPV) to NOAA of an investment in DMAC. Using information collected from NOAA data users, the business case assesses the impacts of the current ocean data management structure, and estimates the potential benefits of a proposed new data management system. This business case also recognizes that there

are significant benefits to non-NOAA organizations and to society at large; however, these benefits cannot be fully quantified and, therefore, have not been included in the cost-benefit analysis.

The analysis indicates that an investment in DMAC would likely generate a NPV between $38 and $60 million dollars over a 15-year period. While this estimate does not include the benefits to non-NOAA users and the public, a significant body of literature estimates that societal benefits created by an integrated ocean observing system enabled by DMAC is likely to be in the hundreds of millions of dollars.

The DMAC solution offers NOAA a feasible approach to implementing a data management solution that responds to the needs of a broad user community. Overall, the costs of development are small relative to the societal benefits, and the large internal benefit to NOAA indicates that DMAC is a low-risk investment.

Contents

Figures

Tables

INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) is charged with understanding and predicting changes in Earth's environment, and with conserving and managing coastal and marine resources to meet our nation's economic, social, and environmental needs. NOAA's vision is an informed society that uses a comprehensive understanding of the role of the oceans, coasts, and atmosphere in the global ecosystem to make the best social and economic decisions. To fulfill its mission and realize its vision, NOAA—through its various programs and partnerships with its regional associations—collects myriad data on oceans and coastal waters. Those data come from NOAA's ocean observation platforms; including buoys, gauges, satellites, and reference stations**.** The data are used by NOAA, as well as by other federal agencies, state and local government organizations, academia and the private sector.

One of NOAA's most valuable assets is the data that it collects. Ocean and coastal data are critical to NOAA's ability to deliver the products and services that provide significant, tangible benefits to society. Ocean and coastal data drive the models, forecasts, and other decision-support tools that help to protect our nation's economy, public safety, and the environment, among other things. For example, NOAA's data inform an ecosystems approach to protecting, restoring, and managing the use of our ocean and coastal resources. NOAA's data also inform our understanding of climate variability—for example, changes in arctic surface temperatures and sea ice, ocean salinity, and frequency and intensity of extreme weather such as droughts and floods—thereby enhancing decision makers' ability to plan and respond. Similarly, NOAA's data inform weather forecasts, making it possible to alert the public about impending danger from hurricanes and other extreme weather events. Nearly one-third of the U.S. economy, about $4 trillion, is sensitive to climate and weather.[1] Another key area supported by NOAA's data is transportation; safe, efficient, and environmentally sound transportation systems are crucial to the nation's commerce and thus to the nation's economy.

Because of the critical role that data plays in the efforts of NOAA and others to manage and conserve marine and coastal resources, it is vital that users be able to access the vast stores of oceanographic data. However, there is currently no single point of access to ocean data. Instead, data users must obtain it from whatever sources they can identify, involving duplicated effort, redundant costs, and wasted time. Furthermore, because any data they find is not formatted in a standardized way, users must bear the additional costs of processing the data—normalizing and reformatting—before they can use the data in their analyses.

The NOAA Integrated Ocean Observing System (IOOS) Program proposes to facilitate access to ocean and coastal data by improving the way data are integrated and managed. This business case provides the rationale for pursuing this effort. It

[1] National Oceanic and Atmospheric Administration, *Strategic Plan FY2009-2014*, July 2008, p. 10.

describes the demand for and value of ocean and coastal data, the current approach to supplying these data, and the costs and benefits of improving the current approach by investing in data management and integration. The business case also describes several data management and integration options, recommends a preferred solution, and presents a concept of operations for the proposed solution.

Federal Foundation for Change

The foundation for IOOS, and its associated data management component, has developed over 17 years of international and national planning efforts. The implementation of a Global Ocean Observing System was proposed by the United Nations Intergovernmental Oceanographic Commission in 1991. The 1992 United Nations Conference on Environment and Development achieved an agreement by participating nations to develop this system.[2] In response to an August 1998 request from Representatives James Saxton and Curt Weldon to "propose a plan to achieve a truly integrated ocean observing system," the U.S. National Ocean Research Leadership Council (NORLC), the leadership arm of the National Oceanographic Partnership Program (NOPP), developed two reports that laid out a plan for creating a U.S. Integrated Ocean Observing System, concluding with *An Integrated Ocean Observing System: A Strategy for Implementing the First Steps of a U.S. Plan*.

This report recommended a comprehensive development strategy for IOOS, including an end-to-end systems engineering and development approach using a system integrator to develop a schedule and plan that ranges from concept design to operational implementation. The plan recommended multiple demonstration projects and specifically addressed data management, dissemination, and assimilation, noting that: "the two most important features that must be developed are 1) the distributed network of data and data archives, and 2) the development of standards and protocols for the data."[3] To further the implementation of the strategy, in 2002 the NOPP established Ocean.US as an interagency office to develop a national capability for integrating and sustaining ocean observations and predictions.

In 2004, the U.S. Commission on Ocean Policy noted that "the implementation of a sustained, national integrated Ocean Observation System (IOOS) is overdue and should begin immediately."[4] Its report identifies the need for a national governance structure, a regional structure that provides observations, data management and value-added products, and broad-based product development (not just for federal applications or research). The commission identified "two major challenges facing data managers today: the exponentially growing volume of data,

[2] U.S. Commission on Ocean Policy, *An Ocean Blueprint for the 21st Century*, Final Report, (Washington, DC, 2004), pp. 396-397, http://oceancommission.gov/documents/welcome.html, accessed July 2008.

[3] Ocean Observations Task Team, *An Integrated Ocean Observing System: A Strategy for Implementing the First Steps of a U.S. Plan*, December, 1999, http://www.nopp.org/Dev2Go.web?id=220672&rnd=19264, accessed July 2008.

[4] Commission on Ocean Policy, *Ocean Blueprint*.

which continually strains ingestion, storage, and assimilation capabilities; and the need for timely accessibility of these data to the user community in a variety of useful formats." To address these challenges, the commission recommended establishing "an interagency task force to plan for the modernizing of the national environmental data archiving, assimilation, modeling, and distribution system with the goal of creating an integrated earth environmental data and information system."

Perhaps most significantly for NOAA's IOOS leadership responsibilities, the commission recommended funding all aspects of IOOS, including federal and nonfederal partners, as a line item in the NOAA budget, subject to interagency direction (under the National Ocean Council). The commission presents IOOS as a multi-billion-dollar endeavor with estimated first-year startup costs of $138 million, including $18 million for data management and communications (based on Ocean.US estimates from 2002).[5]

The U.S. Ocean Action Plan (subtitled "The Bush Administration's Response to the U.S. Commission on Ocean Policy") of 2004 identified interagency collaboration as essential to achieving ocean science and technology priorities, and particularly for planning and coordinating an ocean observation system. At the same time the report was issued, President Bush signed Executive Order 13366, which established the Committee on Ocean Policy. The Ocean Action Plan and Executive Order 13366 established a coordinated ocean governance structure to enhance leadership and coordination among the many federal agencies with ocean-related responsibilities and activities. The Committee on Ocean Policy manages its efforts through subordinate committees including the Interagency Committee on Ocean Science and Resource Management Integration (ICOSRMI) and the Joint Subcommittee on Ocean Science and Technology (JSOST), which reports to the National Science and Technology Council (NSTC) Committee on Environment and Natural Resources (CENR) as well as the ICOSRMI.[6]

In 2006 the NORLC and ICOSRMI issued the *First U.S. Integrated Ocean Observing System (IOOS) Development Plan.* This IOOS Development Plan (IDP) included the recommendation to implement a comprehensive Data Management and Communications (DMAC) Plan developed in 2005 by the DMAC Steering Committee appointed by Ocean.US.

NOAA's Role

NOAA's leadership role in IOOS development is established in the interagency process. The Interagency Working Group on Ocean Observations (IWGOO) was established in 2006 by the JSOST. The IWGOO manages the interagency coordination of IOOS. The IWGOO charter designates NOAA as the lead federal agency for the administering and implementing an integrated ocean observation

[5] Commission on Ocean Policy, *Ocean Blueprint*, Chapters 26 and 28.
[6] Committee on Ocean Policy, http://ocean.ceq.gov/, accessed July 2008.

system.[7] Additionally, NOAA's role as the lead agency for coordinating the development of the regional component of IOOS was confirmed by the IWGOO in May 2008.

The FY2006–2011 NOAA Strategic Plan (2005) identifies an IOOS as a key capability with significant linkages to NOAA mission goals:

> NOAA will continue to work with local, national, and international partners to develop an integrated global-to-local environmental and ecological observation and data management system that will continually monitor the complex, symbiotic systems of the ocean, atmosphere, and land. This coordinating activity will maximize the mutual benefits of national and international exchange of data.[8]

The FY2011-2015 Annual Guidance Memorandum states that management and integration of observation data is a key cross-cutting priority:

> NOAA's mission increasingly demands advanced data management processes, including standards based data integration and assimilation, to achieve archived, interoperable, accessible, and readily usable observations data. These management and integration functions are essential for NOAA to maximize the utility of NOAA's observing systems infrastructure, and to leverage the capabilities of international, federal, regional, state, local and private sector partners.[9]

NOAA must, therefore, invest in efforts to improve the data systems that drive the products and services that it creates. Several NOAA goal teams continue to express a need for improvements to and integration of NOAA data systems.

The stand-up of the NOAA IOOS Program, as defined by the NOAA Decision Memorandum of December 15, 2006, demonstrates NOAA's commitment to address the significant ocean data management issues identified in administration and NOAA guidance.[10] These requirements, in combination with the expressed needs put forward by data users, call for NOAA to take the lead in identifying and implementing a solution to the existing data management challenges.

The NOAA IOOS Program's initial effort in a comprehensive ocean data management solution is the Data Integration Framework (DIF). The DIF will establish technical framework, identify standards, and provide guidelines to improve delivery of at least 7 (initially 5) of the 20 IOOS core oceanographic variables defined in the First U.S. IOOS Development Plan. In addition to providing a foundation for further ocean data management efforts, the DIF is being viewed by leaders in

[7] Charter of the Interagency Working Group on Ocean Observations, December 2006.

[8] NOAA, *New Priorities for the 21st Century – NOAA's Strategic Plan Updated for FY 2006-FY 2011*, April 2005.

[9] NOAA, *Annual Guidance Memorandum for FY2011–2015*, June 2008 .

[10] Conrad C. Lautenbacher, Jr., Chair, NOAA Executive Council and John J. Kelly Jr., Chair, NOAA Executive Panel, "NOAA Decision Memorandum," December 15, 2006.

the NOAA data management community as an essential first step to developing the U.S. contribution to the Global Earth Observation–Integrated Data Environment. The DIF and eventual Data Management and Communication (DMAC) solution will also provide standards, techniques, and procedures that will inform NOAA's many other data management efforts, and should provide opportunities for some consolidation of these efforts.

CURRENT OCEAN DATA ENVIRONMENT

The ocean—all open ocean, coasts, coastal watersheds, and the Great Lakes—plays such an obvious, yet crucial role in human life and commerce that it is easy to overlook its importance. Today, the oceans provide:

- *Primary residential locations.* More than half of the U.S. population—153 million people—live in the 673 coastal counties, a share that is expected to reach approximately 75 percent by 2025.[11] This trend is placing greater demand on coastal ecosystems and heightening the urgency of storm warnings and forecasts.

- *Vital elements of commerce.* Almost half of the national economy comes from coastal watershed counties. Coastal states earn 85 percent of all U.S. tourism revenues, with approximately 89.3 million people vacationing and recreating along U.S. coasts every year. More than 78 percent of U.S. overseas trade by volume, and 38 percent by value, is waterborne—contributing $742 billion annually to the gross domestic product, while employing 13 million Americans.[12] Healthy coasts and estuaries are essential for protecting more than $800 billion of trade each year, tens of billions of dollars in recreational activities annually, and more than 45 percent of the nation's petroleum refining capability.[13]

- *Critical energy resources.* Offshore oil and gas development currently generates 22 percent of all domestically produced oil and 27 percent of natural gas.[14]

- *Ecological importance.* Oceans are the home of most of the world's living organisms, and over the past two decades, thousands of potentially valuable marine biochemicals have been identified.

The ocean provides food, recreation, and other opportunities for human enrichment, but at the same time it presents risks that, if not understood and respected, pose serious threats to lives and livelihoods.[15] It is a primary indicator of the

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[11] NOAA, National Ocean Service, *Population Growth Trends Along the Coastal United States: 1980-2008*, September 2004. Accessible at https://oceanservice.noaa.gov/programs/mb/pdfs/coastal_pop_trends_complete.pdf.

[12] National Oceanic and Atmospheric Administration, *Economic Statistics for NOAA*, Fifth Edition, April 2006.

[13] Linwood Pendleton ed., *The Economic and Market Value of Coasts and Estuaries*, http://www.estuaries.org/assets/documents/FINAL%20ECON%20WITH%20COVER%20PDF%205-20-2008.pdf, accessed June 20, 2008.

[14] NOAA, Office of the Chief NOAA Economist, *Economic Statistics for NOAA*, 5th ed., April 2006.

[15] National Science and Technology Council, Joint Subcommittee on Ocean Science and Technology, *Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy*, January 26, 2007.

conditions that have profound effects on our society—from rising sea levels and coastal flooding to climate change, harmful algal blooms, dead zones, and fish kills. Our ability to measure, understand, and predict such conditions depends on our ability to collect, distribute, and use ocean data.

Demand for Ocean Data

According to the U.S. Ocean Action Plan (OAP), hundreds of federal, state and local organizations collect information about U.S. oceans and coasts and administer more than 140 federal laws.[16] The administration of these laws at federal, state, and local levels occurs through independently funded and operated offices. For example, NOAA has offices to comply with legal requirements for fisheries management, marine transportation, marine mammal protection, the Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA), and more. The Environmental Protection Agency (EPA) has programs to meet mandatory requirements for water quality and public health. The U.S. Army Corps of Engineers (USACE) has programs to meet permitting requirements for coastal zone public works. The OAP has pointed out that "these activities would benefit substantially from more systematic collaboration and better integration of effort."[17] Many of these organizations collect, distribute, and archive the very same data (such as temperature and salinity), but in different ways. For example, the IOOS Program found that 10 NOAA organizations collect sea temperature data, but each one does so using a different system. NOAA's Consolidated Observations Requirements List (CORL) shows 25 different systems that deliver sea surface temperature data.[18]

NOAA Demand

Several NOAA Goal Teams have expressed a need for integrated ocean data to support efforts to improve existing models and decision support tools. One Goal Team has indicated that there is a growing demand for much better information and more variables, especially at finer spatial scales, and believes that achieving a better match between supply and demand of information will require increased scientific understanding along with enhanced observation and computational resources. Integrating observations is a potential remedy for data and information shortcomings, and supports measurement and monitoring of environmental changes through an integrated system of quality observations and data management techniques to improve predictions, projections and decision support.

Across the programmatic spectrum, NOAA customers and partners have repeatedly called for additional research, data, information, tools, methods and training to aid their contingency planning and recovery efforts. More specifically, they have expressed a need for products and services that integrate a variety of data and in-

[16] U.S White House, *U.S. Ocean Action Plan*, p. 4, December 2004.

[17] *U.S. Ocean Action Plan*, p. 4.

[18] NOAA, *Consolidated Observations Requirements List* database, accessed July 2008.

formation into decision support tools, and associated training and outreach on using these tools. A second Goal Team believes that serving multiple missions with an observing capacity and the data and/or products derived from it is a basic Integrated Ocean Observing System/Integrated Ocean and Coastal Mapping principle and increases the economic benefits realized from investments in these systems.

A third Goal Team has indicated that access to information is a key stakeholder concern and has identified integration as the preferred solution to the data/information access problem. Many stakeholders have urged that NOAA provide greater access to its data by using new technologies/web-based solutions to share results, foster communication, and collaborate. Equally accentuated was the idea that NOAA should get information out in a timely and user-friendly manner. Many suggested that NOAA provide stakeholders with web-based access to a repository for raw data, synthesized data (at different levels of synthesis for various user needs), as well as information about NOAA research, best practices, management tools, accomplishments, and abilities.

Clearly, many NOAA operations depend on ocean data to support the models and forecast tools that generate NOAA products and services. Forecasters and meteorologists use ocean data to better understand ambient conditions, and better predict how conditions might change. Ocean data enhances the predictive capabilities of decision support tools by providing the current conditions used to “preset” model parameters. Discussions with users of ocean data, including modelers and meteorologists, revealed that users spend an average of 25–50 percent of their time searching for, accessing, formatting, and ingesting data into their various models, forecasting tools, and other products. Taken across the entire NOAA organization, significant resources are being expended performing data management activities that might otherwise be used to perform forecasting and research activities.

NON-NOAA DEMAND

There is equally high demand for ocean data outside of NOAA, within other federal entities, in the private-sector, and in academia. Numerous federal, state, local, and non-governmental entities rely on ocean data for development of region-specific products and services, and to inform critical decision-making. Federal data users typically leverage NOAA’s data to complement their existing data sets and enable them to better perform their missions. For example, the U.S. Coast Guard (USCG) uses ocean data, particularly surface current, and meteorological data when conducting search and rescue operations and presently has a 22 percent success rate where the environmental conditions are highly uncertain—for example, where currents and other oceanographic conditions are not known. Reliable access to surface current data has the potential to more consistently support

USCG activities, improve search and rescue success rate across the board, and provide the capability to save an additional 26–46 people every year.[19]

In another example, the U.S. Army Corps of Engineers uses ocean data to establish a historical baseline of ocean conditions to enable development of construction requirements.[20] When data are not available or are inaccessible, which is often the case, USACE must estimate the severity of weather that its projects must withstand, which could lead to over- or under-engineering.

State governments, as well as regional and private concerns, also generate demand for ocean data. Wave, wind, current, and water quality measurements are used to help local officials determine when beaches and other coastal recreation areas must be closed for safety or to protect human health. Other ocean data, including physical oceanography, chemical, and biological parameters, help fishery managers assess the size and movement of fish stocks to determine if and when fishing should be prohibited to protect fish populations.

Regional and academic entities use ocean data to develop the products and services to address the most pressing local needs. One example of this is the cooperative arrangement between the Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA), an IOOS-funded Regional Association (RA) based in the mid-Atlantic states, and Public Service Gas and Electric (PSG&E), a New Jersey based utility company. MACOORA integrates data from NOAA and its own observing systems and delivers valuable services to PSG&E, including:

- Operational weather forecasts tailored to PSG&E, which are delivered daily via protected website;
- Issuance of severe weather alerts and transmission of them to PSG&E personnel via email and a protected website;
- Experimental plant damage forecasts transmitted to PSG&E personnel via email at the initiation of severe weather alerts.

Findings from PSG&E analysis of MACOORA's severe weather alert verification statistics between October 2004 and December 2006 indicate an accuracy level of 82.9 percent.[21] These services allow PSG&E to preposition trucks and personnel to respond better to severe weather threats. PSG&E says that the MACOORA forecasts, in addition to other public and private forecast services, allow the company to use their expensive emergency response resources more efficiently, and

[19] Corey Wisneski and Thomas Gulbransen, *Integrated Ocean Observing System (IOOS) Mission Analysis and Related Case Summaries for the United States Coast Guard*, (Arlington, VA: Battelle, 2007).

[20] Telephone Interview with USACE, April 10, 2008.

[21] Scott Glen, Wayne Wittman et al, *Storm Modeling,* briefing to Electric Power Research Institute Power Delivery and Markets Distribution Advisory Council, February 13, 2007, http://marcoos.us/presentations.htm (EPRI Distribution Program.ppt) accessed on July 18, 2008.

help them to restore power more quickly, limiting the impact to millions of businesses and residents.[22]

Although private sector organizations are often end-users of ocean-related products and services, they are sometimes developers of products and services as well. For example, Weatherflow Inc., a company that combines NOAA ocean data with its own network of observation stations, creates tailored marine weather forecasts for recreational sailors. Weatherflow estimates that demand for these types of services is larger than its ability to provide information because of the challenges of accessing and using currently available ocean data.[23]

Our research indicates a broad array of economic sectors make use of ocean data in one form or another. Table 1 provides a sample of the economic sectors that could likely benefit from further development of products and services that use ocean data.

Table 1. Economic Sectors Demanding Ocean Data

Impact Areas Identified			
Energy	Environment	Safety and Health	Commercial
◆ Wind energy ◆ Hydroelectric generation, transmission, and distribution ◆ Electricity power generation ◆ Offshore power generation ◆ Energy forecasting	◆ CO2 emission policy ◆ Climate prediction ◆ Meteorological services ◆ Hydrological services ◆ Environmental education ◆ Management of endangered species ◆ Scientific research ◆ Coastal protection and management	◆ Storm forecasts ◆ Search and rescue operations ◆ Oil spill response ◆ Water quality ◆ Famine prevention ◆ National defense	◆ Weather forecasts ◆ Tourism ◆ Recreation ◆ Oil and gas production ◆ Maritime operations ◆ Vessel management operations ◆ Fisheries ◆ Trade ◆ Development ◆ Land management ◆ Transportation

Creating Value from Ocean Data

In 2008, the federal government, through at least 15 agencies, will fund roughly $9.5 billion for oceans and coastal activities. The National Ocean Service alone spent approximately $85 million on ocean-related operations and research.[24] Federal, state, and local agencies fund hundreds of organizations that use ocean and coastal data to fulfill their missions. However, these raw observation data have

[22] Telephone Interview with PSG&E. Conducted July 18, 2008.

[23] Telephone Interview with Weatherflow, April 18, 2008.

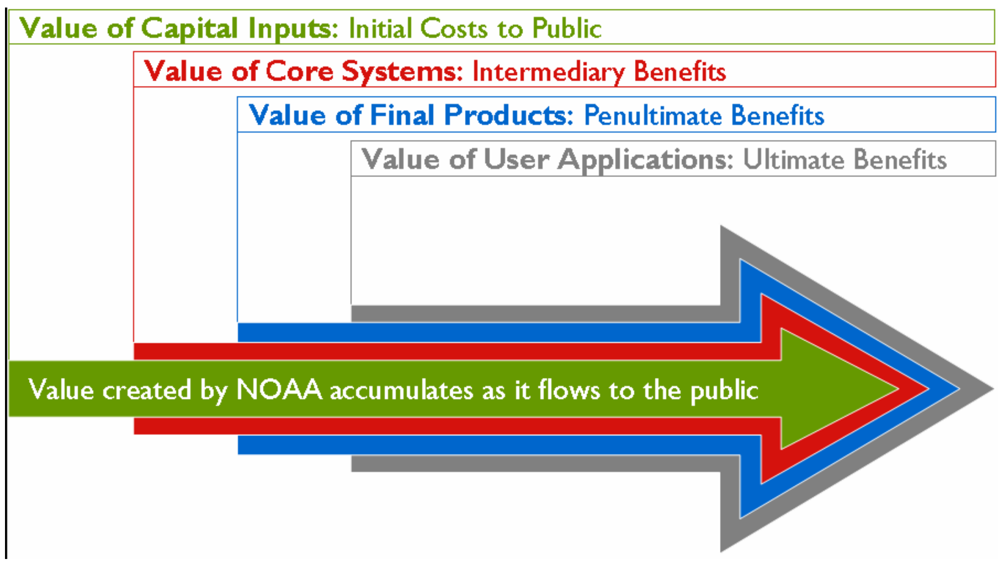
[24] U.S. Interagency Committee on Ocean Science and Resource Management Integration, *Federal Ocean and Coastal Activities Report*, 2007.

little value until they are processed and put into a useful context. As the FY2011–2015 Annual Guidance Memorandum states,

> Once a data point is created by a sensing device, there is still a long chain of processes that must occur before it is available for use by a NOAA modeler or an external consumer. These processes of data transmission, storage, quality control and validation, integration, and assimilation, as well as sensor calibration, are often not fully considered in the cost of the observing system and thus tend to be under-funded, limiting the availability of system data to a wide range of models and products developed by NOAA and its partners.[25]

NOAA's Business Operations Manual provides a graphical illustration of how NOAA processes deliver value from operations like ocean data collection.[26] As Figure 1 illustrates, the value of NOAA activities is enhanced as they progress toward public use. At the back end of the arrows are activities like ocean observations and research and development. At the front of the arrow are activities like weather and water forecasts and ecosystem management.

Figure 1. NOAA Functions Adding Value



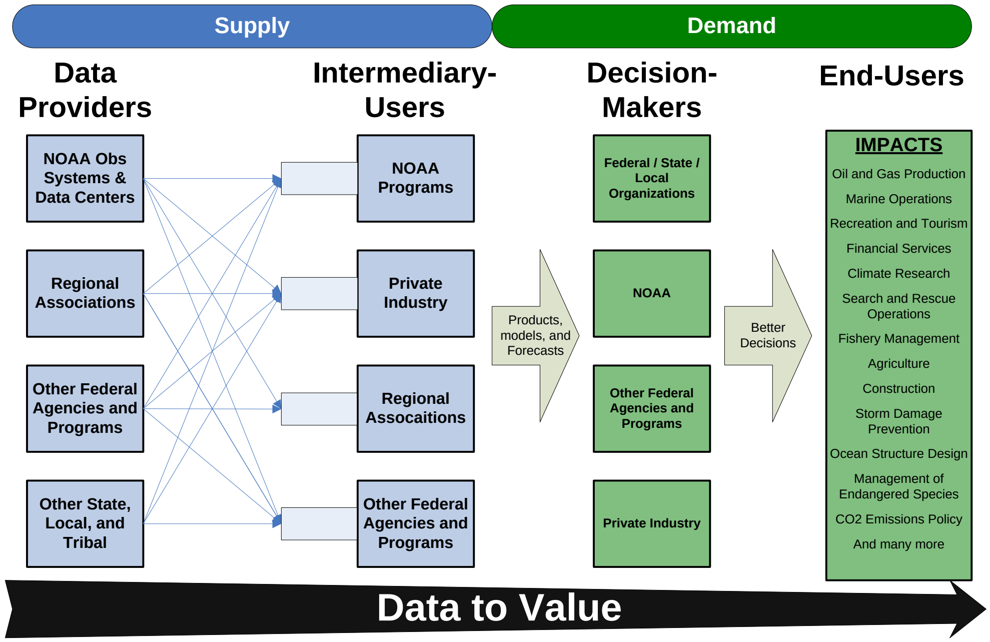
Similarly, the concept of value creation can be applied to data. Specifically, a data value chain describes how an organization creates business intelligence, which is "an organization's core information with relevant context to detect significant events and [enable] illumination [of] cloudy issues."[27] A depiction of how the activities of data users and providers interact is presented in Figure 2—the ocean data value chain.

[25] NOAA, *Annual Guidance Memorandum for FY2011–2015*, June 2008.

[26] NOAA, *Business Operations Manual,* Version 3.3, May 2007.

[27] Michael Brackett, "Business Intelligence Value Chain," *DM Review Magazine*, March 1999.

Figure 2. Ocean Data Value Chain



Note: NOAA Obs Systems and Data Centers refers to providers of ocean data, data centers and centers of data, including National Data Buoy Center (NDBC), National Oceanographic Data Center (NODC), National Climatic Data Center (NCDC), National Geophysical Data Center (NGDC), CO-OPS, CoastWatch, and NOAA Fisheries Science Centers (NFSC).

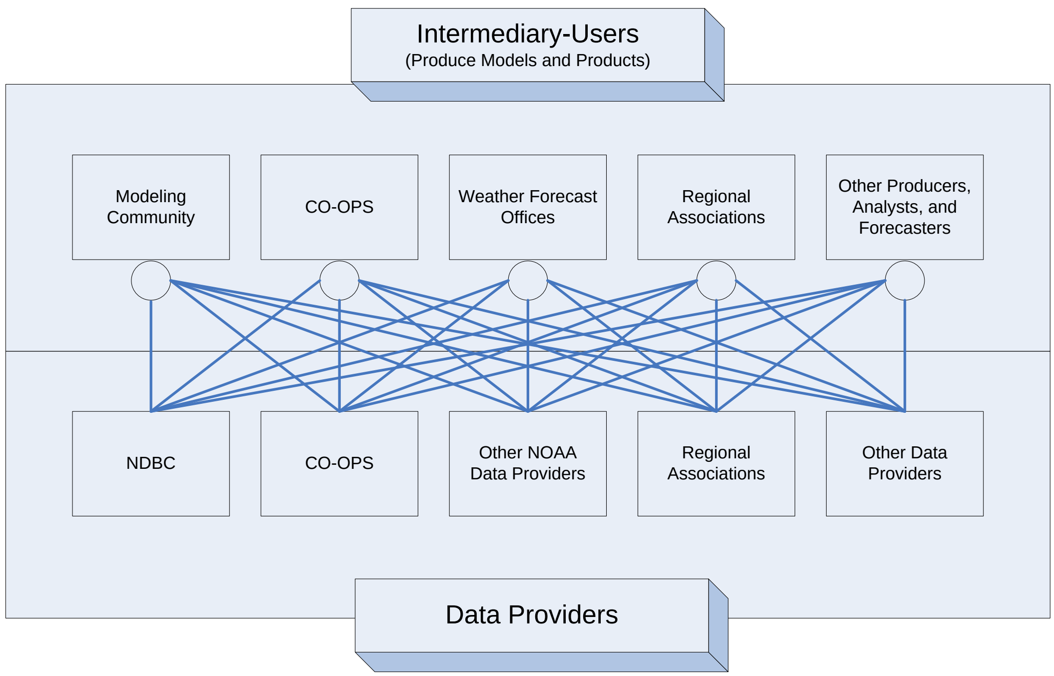
The value chain has been divided into *upstream* (supply) and *downstream* (demand) components to better illustrate the roles played within NOAA, versus those played by other participants in the value chain. At the upstream end of the value chain, data providers deliver relevant *in situ* and remote data observations. At this point, data have no specific relevance to a product or service. They are "individual raw facts that are out of context, have no meaning and are difficult to understand."[28] However, as the data are delivered to and used by NOAA users, other federal agencies, state, local and regional organizations, and private industry—the intermediary users—and as NOAA and other users assimilate the data into forecast models and decision support tools, the data are transformed into usable information with enhanced relevance and increased value for end users. The products delivered following this transformation are more valuable to users than individual sensor data because they deliver the insights needed to enable them to quickly and easily produce value-added products and services, and are easier to understand and use. Yet, the ultimate societal benefits are derived from the downstream segment of the value chain, where local and regional decision making occurs, and end user products and services are delivered.

[28] Brackett, "Business Intelligence Value Chain."

Current Data Management Approach

As previously described, the current NOAA ocean data management structure is primarily facilitated by the data users. There are few commonly accepted and applied standards for data format and transport across NOAA organizations and systems. While many efforts are underway to integrate data and systems, these efforts focus primarily on integrating data specific for a single system, model or forecast tool, and therefore, makes delivering the resulting benefit to the larger NOAA or ocean community difficult. Figure 3 illustrates the current data management approach.

Figure 3. NOAA's Current Data Management Approach



In the status quo environment, thousands of data collection and management systems—from satellites orbiting above the Earth to sensors on the surface of the land and ocean to sensors deployed in and on the bottom of the ocean—are gathering data. Many of these systems collect, distribute, and archive the *same* data (temperature, salinity, and so on) but in *different* ways. This disparity results in data that cannot be combined or analyzed together, reside in multiple systems and databases, and are not easily identifiable, accessible or useable. Consequently, time and resources are wasted converting disparate data and potentially duplicating data collections.

The current value chain has many concurrent activities within NOAA that support the transformation of data into valuable products and services. However, for users to make use of the vast stores of information stored within NOAA databases, the data management activities must be robust enough to provide access to all of the data needed to drive NOAA models and decision-support tools. The blue lines in the value chain, depicted in Figure 3, represent the many interactions between the users who need ocean observation data, and the providers that deliver it. There is no clear coordinating system or process to manage requests for data access. Therefore, users are forced to expend resources to establish their own individual data management processes and distribution arrangements to gain access to the data they need. Users unable to establish such an arrangement might resort to pulling data from any number of available data websites. While the Internet offers broader distribution of ocean data, there is no generally accepted reporting standard for ocean data, so any retrieved data that does not match a user's system or product specifications must be re-formatted to suit those specific needs.

The uncoordinated data management activities essentially limit the supply of ocean data to users, resulting in a set of potentially redundant systems and processes that are not integrated and may not recognize each other. The ad hoc data management environment also limits the ability of resource and emergency managers, forecasters and modelers, researchers and private industry to know what data are available, and how to access and use the data cost effectively. The nature of the data management structure has, thereby, created barriers for the average data user, and consequently high costs of data retrieval and use. In order for NOAA to deliver the full benefits from the wealth of data it collects, data management activities must be coordinated to enable easy access to all available data.

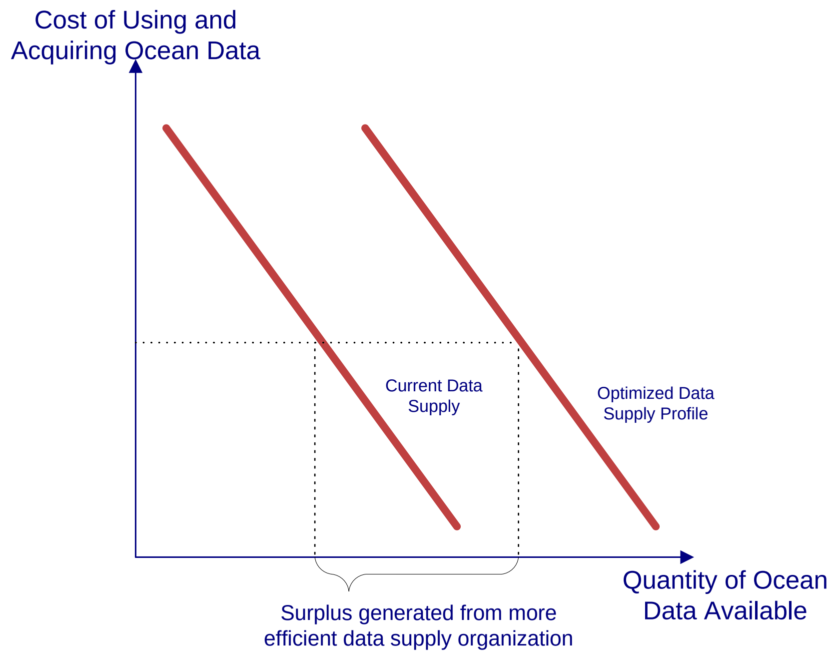
Analogues to the barriers illustrated by NOAA's data value chain can be found in other research areas also performing data collection and delivery. For example, many different federal organizations collect economic data series, such as gross domestic product, price levels, business activity, employment, and the like. In the past, researchers and private-sector users of these data would have to search for these economic and trade data that were captured and stored by different sources. To resolve this problem, the Department of Commerce created a service called STAT-USA, which provides authoritative business, trade, and economic information from across the federal government.[29] Now, users can go to the website to download the data they need. Although the data originate from different sources, they are easy to access and available in a consistent format. Moreover, this centralized source provides a valued service not only to researchers, but also the private-sector as well, including both Fortune 500 companies and small businesses. In 2007, STAT-USA generated over $1.6 million in revenue from subscriptions.[30] While IOOS does not intend to follow the STAT-USA model which charges the public for access to its data, this example illustrates that integrated, easy to access data does have economic value.

The current data management processes also generate costs, in the form of opportunity costs, which are higher than optimized data management processes. Figure 4 provides a graphical representation of the relationship between the quantity of data available and the relative costs of using it. An opportunity cost is an implicit

[29] STAT-USA, http://home.stat-usa.gov/homestat.nsf/ref/About_Us, accessed July 2008.
[30] Telephone Interview with STAT-USA, May 2008.

cost which is not obvious, because no monies are exchanged between parties. The opportunity costs represent an input or resource forgone (or opportunity lost) by not employing it in its best alternative use.[31] In the case of the current data supply chain, resources are applied to performing data management functions, thereby, reducing the opportunity to use them to perform other value-generating activities.

Figure 4. Ocean Data Supply vs. Costs



The duplicative nature of overlapping data management and coordination activities and their recurring costs generate opportunity costs inside and outside NOAA. These opportunity costs accrue because data users and/or decision makers are burdened with performing data management activities, which reduces their ability to focus resources on the knowledge-generating activities that produce value for society. Therefore, the total cost of delivering data becomes much larger than just the cost of collection and distribution—it includes the opportunity costs that come with an uncoordinated approach to data management. Based on our interviews, we believe that such costs represent at least 25 percent of the cost of using ocean data to generate products and services.[32]

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[31] Miltiades Chacholiades, *Microeconomics* (New York, NY: Macmillan Publishing Company, 1986), p. 206.

[32] The estimate of opportunity costs was developed based on interviews with data users and is discussed in more detail under *Defining a Solution*.

WHY INVEST IN DATA MANAGEMENT AND INTEGRATION?

Given the significant demand for ocean data, it is clear that without them, many NOAA data users will be continually challenged to deliver the full value of their respective products and services. Ocean data hold many of the keys to unlocking nature's mysteries, and safeguarding our well-being and our livelihoods. But is a federal investment in an ocean data management system appropriate? The following sections outline the rationale for a NOAA investment in data management and integration.

Investment in Public Good

Although there is a strong need for a more efficient ocean observing system, the private sector (market), left unto itself, would not invest to create it. As envisioned, a system of this type would not provide a competitive advantage to any one user or business because the resulting information would be available for public consumption; any interested user could easily access and use it. Also, the level of investment required by any one interest to create a fully functional system would be so large that it would not be justified by the resulting level of benefit. Stated in economic terms, this type of investment is a *public good*, meaning that investments of this type must be undertaken by a government entity if they are to develop.[33]

The justification for investing in enhanced data management and integration is similar to that of many federal technology investments. Many public good investments have been leveraged by the public to create value-added products and services. For example, public good investments framed the development of the Internet. In 1973, the Defense Advanced Research Projects Agency (DARPA) initiated a research program to investigate techniques and technologies for interlinking packet networks of various kinds. The objective was to develop communication protocols that would allow networked computers to communicate transparently across multiple, linked packet networks. This was called the Internetting project and the system of networks that emerged from the research was known as the Internet. In 1986, the U.S. National Science Foundation (NSF) initiated the development of the NSFNET which, today, provides a major backbone communication service for the Internet. The National Aeronautics and Space Administration (NASA) and the Department of Energy contributed additional backbone facilities in the form of the NSINET and ESNET respectively. A great deal of support for the Internet community has come from the federal government,

[33] In economics, a public good is one that is non-rival and non-excludable. This means, respectively, that consumption of the good by one individual does not reduce the amount of the good available for consumption by others; and no one can be effectively excluded from using that good.

since the Internet was originally part of a federally-funded research program and, subsequently, has become a major part of the U.S. technology infrastructure.[34]

Enables Product and Service Improvement

Much of NOAA's work is characterized by highly visible efforts whose merit is unquestionable and highly valued, and for which user demand is self-evident. In contrast, data management and integration are among the unseen, yet essential elements that enable many of these organizations to work better and deliver better products and services. While it does not directly respond to the end-users needs, it enables other NOAA organizations to be more effective at doing so.

At its core, data management provides an enabling technology—it enhances the ability of NOAA organizations and external users to access the information they need to deliver their products and services. Data management focuses primarily on making data accessible to users; benefits will also accrue to NOAA data users, which in turn will enhance the value of their respective outputs. An investment in data management represents a commitment to improve availability of and access to data, to enhance the types and quality of data, to reduce the data management burden currently borne by every NOAA data user and end user, and to free data users to focus on creating products and services to respond to the nation's most challenging issues.

Benefits for NOAA and Other Federal Agencies

There is significant opportunity to deliver benefits to NOAA, and other federal agencies that make use of ocean data, by improving data management and integration capabilities. While there been little research done to date to estimate the potential agency benefits, these would generally accrue to NOAA and other federal agencies via the following outcomes:

- *Customer benefits*—improved customer satisfaction levels and tangible impacts to customers;
- *Service coverage*—improvement in the extent to which the desired customer population is being served and customers are using data, products and services;
- *Timeliness and responsiveness*—enhanced responsiveness to customer requirements;

[34] For a detailed discussion and analysis of how such public technology investments lead to high added value for both the public and private sectors, see National Research Council, Computer Science and Telecommunications Board Commission on Physical Sciences, Mathematics, and Applications, *Funding a Revolution: Government Support for Computing Research*, *Committee on Innovations in Computing and Communications: Lessons from History (*Washington, D.C). National Academy Press, 1999.

- *Service quality*—improved quality from the customer's perspective;
- *Service accessibility*—improved availability of data products and services to customers, and self-service options and automation, where appropriate.[35]

According to Gartner, a leading IT research organization, a trend is developing in the area of information-centric infrastructure implementation, where IT leaders believe that this new system architecture will better support application-driven organizations. Gartner believes that this trend is being "driven by three primary drivers:

- *[Industry] Ecosystems*: An accepted practice within [industries] to share and exchange all types of content.
- *Info-glut*: The need to extract meaning from ever-increasing amounts of information and to find ways for 'normalizing the chaos' across diverse applications, standards, formats and protocols.
- *Convergence*: The need to find ways of unifying structures, semi-structures and less structured information across the content continuum to address a variety of information and access needs."[36]

Gartner believes that one of the reasons organizations cannot respond quickly to customer needs is that much of the available information is isolated within applications—each fulfilling requirements driven by a single-process. Although NOAA is not profit-driven, it can learn from the data management challenges and solutions that are emerging in the private sector. Private-sector research has identified numerous instances where companies that were burdened with overly complex, de-facto data architectures achieved substantial cost-savings and improved outcomes through data management and integration.

Gartner also found that "many attempts at information management are cut short by what seem to be more urgent 'quick fixes' designed to avoid costs." Some of the 'quick fixes' have taken the form of "data marts and specialized databases because they had silo funding, because of political factors, or because of data management barriers and sourcing issues." Gartner believes that in siloed data marts, as much as 50 percent of the cost required to support each data mart is redundant (because of duplicate resources across data marts in terms of infrastructure, storage and database administration).[37] Organizations can, therefore, reduce the costs

[35] Executive Office of the President of the United States, *Federal Enterprise Architecture Consolidated Reference Model Document*, Version 2.3, October 2007.

[36] David Newman, Rita Knox, and Mark Beyer, *Gartner Defines the Information-Centric Infrastructure*, May 25, 2007, Gartner Research (ID number: G00147664).

[37] Eric Thoo and Mark Beyer, *Tactical Guideline: How Data Mart Consolidation Can Improve Information Management and Reduce Costs*, March 28, 2008, Gartner Research (ID number G00156097).

of their data management activities by reorganizing their approach to data management and integration.

Additionally, a more centralized data management approach would enable NOAA to facilitate the establishment and enforcement of standards for how data is modeled, stored, accessed and delivered. Enforcing corporate standards for the use of tools, schema design, naming conventions and various other dimensions of data management would allow the entire organization to "speak the same language." Currently, data standards and integration are occurring within NOAA at the individual application level, which greatly reduces the savings generated from standardization. In the course of this analysis, we spoke to representatives of numerous NOAA offices that had adopted data standards for one application, but used a different set of standards for another application that used the same data. A common set of data standards would help NOAA—and other federal organizations—to fully leverage the wealth of collected data.

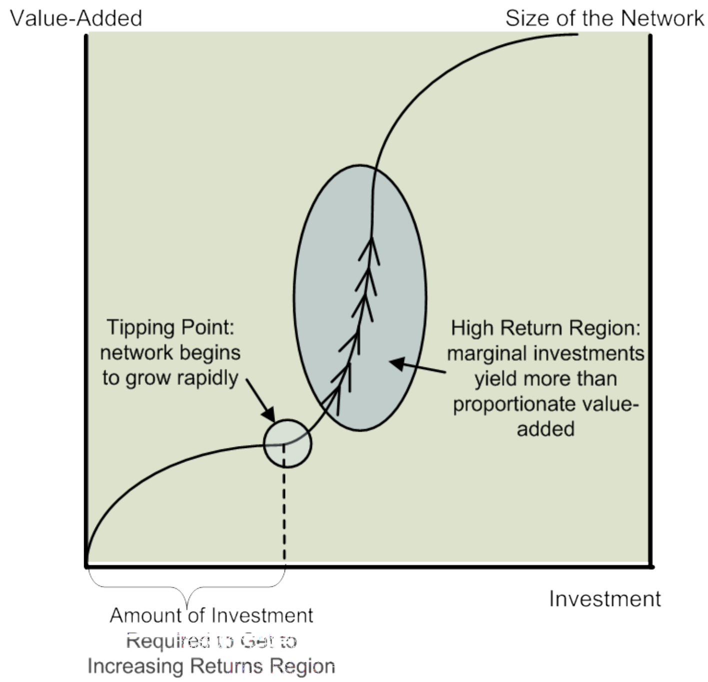
BENEFITS FOR DATA USERS

Improved data management and integration offers significant benefits for users over individually stored and accessed data or data sets. It reduces the opportunity cost of acquiring the data needed to initiate models and decision support tools. Reducing the data management burden that users bear would make more resources available for the critical tasks of analyzing data and evaluating model output.

Improved data management and integration is also likely to produce a phenomenon known as network externality. A positive network externality exists "in products for which the utility that a user derives from consumption of that good increases with the number of other agents consuming that good."[38] In this scenario, as the number of users on the network grows, the value of the network to each individual user also grows, because users have access to a growing array of data and tools, as new providers and users connect to the new data network. Figure 5 illustrates this investment value-added phenomenon.

[38] Michael L. Katz and Carl Shapiro, "Network Externalities, Competition, and Compatibility," *The American Economic Review*, Vol. 75, No. 3 (June 1985), p. 424.

Figure 5. Positive Network Effects Can Yield Disproportionately Large Returns



This illustration highlights the relationship between the level of investment and the resulting size of network and the added value that results. At first, small investments in integration would yield some small-scale benefits to users, since the network is small and not likely to attract all potential users. However, there is a point beyond which an additional marginal investment produces disproportionately larger returns as the size of the network grows. For investment in integration to achieve these exponential benefits, the network of observation data and users must reach a critical mass to attract users—too little investment would keep the technology below the level at which it would begin to yield significant returns.

The existence of network externalities creates a paradox. Although the value of the system is many times that of its individual parts, there is no real incentive for any one individual (or company) to pay for creating the system.[39] This is because it is difficult for any one individual to obtain compensation for the external benefits that result from creating the system. Collecting ocean observation data on the scale necessary for a functioning IOOS will benefit so many different users that it will be nearly impossible to figure out what any individual should be willing to pay as an equitable share of the costs. Moreover, once the system is in place,

[39] Rich Adams, *et al*., The Economics of Sustained Ocean Observations: *Benefits and Rationale for Public Funding*, National Oceanic and Atmospheric Administration and Office of Naval Research, August 2000.

individual users will have a strong incentive not to pay their share of the costs but to "free ride" on the fact that the system already exists.[40]

The phenomenon of network externality has been seen many times in the deployment of many new technologies, including the Internet and cellular phone service. During the initial offering of public cellular service, the costs of gaining access to the network were high and few saw the value of having access to a portable phone. As the number of cell phone users increased, costs to access the network began to fall, and the perceived value of having a phone rose, since people outside the network could not stay connected to those within the network.

Supports Creation of Economic Value

Economic value is created when ocean-related products and services are used by federal, state, local and private-sector entities to perform the missions that save lives, protect and preserve natural resources, and generally help to improve our everyday lives. Some economic value estimates are more easily quantified, like estimated impact of a beach closure, or the benefit of avoiding a closure. Other economic values are more difficult to quantify, like the value of a reduction in fish mortality.

ESTIMATED ECONOMIC VALUE IMPACTS

Many efforts have contributed toward identifying both the economic sectors affected and the intensity of that impact. Nonetheless, inherent difficulties in predicting the economic impacts of public sector technology investments, coupled with a dearth of information about future economic decision-making, have prevented moving beyond rough order of magnitude estimates. While many users would benefit from an investment in data management technology, the products and services of other potential future users have yet to be developed. The delayed impact of these products, along with the complexity of the current value chain, makes it difficult to attribute value to the original investment. Despite these challenges, it is reasonable to believe that some portion of the economic value can be attributed to the availability of ocean data.

A full accounting of all the likely benefits generated from an investment in ocean observing systems has not been done. With this in mind, the majority of the studies completed to date estimate that a value-added impact of 1.0 percent (relative to gross domestic product from each industry sector) would generate an economic benefit on the order of about $1 billion. Even an extremely conservative value-added increase of 0.1 percent of GDP from this sector would yield benefits in the hundreds of millions. In fact, the most rigorous research to date supports this magnitude of economic impact. Kite-Powell *et al*. (2004) noted that the overall range of economic impacts from implementing IOOS would be in the "multiple

[40] Rich Adams, *et al*., The Economics of Sustained Ocean Observations: *Benefits and Rationale for Public Funding*, National Oceanic and Atmospheric Administration and Office of Naval Research, August 2000.

100s of millions of dollars per year."[41] This estimate does not include the impact of new products or services that would arise due to investing in ocean observing. Although the value of public good products and services is difficult to estimate for any type of investment, history has shown that value is typically created by unforeseen products or services.

In general, benefits to the public that might be attributable to a data management system will accrue through primary and secondary impacts. A primary impact directly originates from using the output from a system or service (for example, ocean temperature data) to create value (such as the value derived from making a more informed decision). A secondary impact is a product or service developed by virtue of the existence of a product or service, and whose output is then used by an economic actor to generate value. For example, an enhanced data management system might enable improved accuracy in short- and long-term weather forecasting which may allow more informed decisions. Thus an improvement in model forecast accuracy, enabled by the availability of more accessible ocean data, might then be used by members of the agriculture sector to make more informed planting decisions. Research has asserted that a moderate degree of El Niño Southern Oscillation (ENSO) forecasting accuracy could yield benefits to the agricultural sector on the order of $240 million annually.[42] The following discussion summarizes the efforts to date to estimate the value generated by investing in ocean observations.

Previous Ocean Economic Studies

Many efforts have contributed toward estimating IOOS economic impacts, most specifically those for end-user products and services. As previously mentioned, it is difficult to determine what portion of this value might be directly attributable to an enhanced data management system. However, these studies provide a reasonable baseline for estimating the value of an investment in enhanced data management capability. Table 2 summarizes some of the studies that have been completed to date. A complete list of references is provided at the end of the report.

[41] The Kite-Powell study indicates that the "information needed to develop detailed estimates of the economic benefits of ocean observing systems is, for the most part, unavailable at this time."

[42] Andrew R. Solow, *et al.*, "The Value of Improved ENSO Prediction to U.S. Agriculture," *Climate Change*, Vol. 39, 1998, pp 47-60.

Table 2. Summary of Ocean Economic Studies

Study Title	Author(s)	Summary
Quantitative Value Estimates		
Potential Benefit of Coastal Ocean Observing System to Alaskan Commercial Fisheries	K.F. Wellman and M. Hartley	The authors use a case study approach to show that an enhanced AOOS could contribute over $600 million in additional revenue to Alaska's ground fish industry. They also find that, had AOOS been available in the 1970s and 1980s, the Kodiak king crab stock collapse could have been avoided, saving $60 million. The results of this study are far beyond Kite-Powell's estimates.
Estimating the Economic Benefits of Regional Ocean Observing Systems	Hauke Kite-Powell et al.	As a general order of magnitude estimate, the authors note that "the annual benefits to users from the deployment of ocean observing systems are likely to run in the multiple $100s of millions of dollars." The authors examined 10 regions in the United States across 5 broad impact areas, including recreational activities, transportation, health and safety, energy, and commercial fishing. See Table 4 for breakdown of specific regional economic benefits.
The Potential Economic Benefits of Integrated and Sustainable Ocean Observation Systems: The Southeast Atlantic Region	Christopher F. Dumas and John C. Whitehead	The authors focus on the benefits of a South East Atlantic Coastal Ocean Observing System (SEACOOS). The authors note that the total annual benefits of SEACOOS information are difficult to quantify, however they estimate that the total annual benefits of SEACOOS information across all states in the region are $170 million (in 2003 dollars). The state of Florida would receive two-thirds of the benefits.
A Bayesian Methodology for Estimating the Impacts of Improved Coastal Ocean Information on the Marine Recreational Fishing Industry	Kenneth Wieand	The study develops a model of recreational fish catch probabilities, based on angler fishing strategies, that is conditional on uncertain information about the coastal ocean environment. It estimates that the annual value to boat-based anglers of an increase in the expected catch from the use of IOOS data is $91,198,023.
The Economics of Sustained Marine Measurements	UK Inter-Agency Committee on Marine Science and Technology (IACMST)	The study found that sustained marine measurements in the United Kingdom. add, on average, between 840,000 and 84,000,000 British pounds per year in revenue.
Qualitative Value Estimates		
The Economics of Sustained Ocean Observations: Benefits and Rationale for Public Funding	Adams et al. (joint publication of NOAA and the Office of Naval Research, 2000)	The authors identify potential areas that would benefit from integrated ocean observing, including seasonal weather forecasting; agriculture; hydro electric generation; coastal management, including sewage outflows and beach closure decisions; storm forecasts; electric power generation; oil and gas for space heating; construction; storm damage forecasts; commercial fisheries; outdoor recreation; famine and health; marine forecasts; marine transportation; offshore power generation; national defense; search and rescue operations; oil spill containment and clean-up; ocean structure design; global climate; and scientific research.

Table 2. Summary of Ocean Economic Studies

Study Title	Author(s)	Summary
The Business Case for the Global Observing System	Mary G. Altalo et al.	The authors identify potential areas that would benefit from integrated ocean observing, including government (meteorological and hydrological services, ocean services, agricultural services, housing and social services, natural resource management services, trade and development services, and defense services) and the private sector (energy, recreation and tourism, financial services, and health services).
IOOS Stakeholder Communication Plan	Vince Brown, et al.	The authors identify potential areas that would benefit from integrated ocean observing, including electricity generation, transmission, and distribution; oil and gas production; wind energy; environmental education; marine operations; water quality; climate research; oil spill response; search and recue operations; vessel management operations; and fisheries.
Dividends from Investing in Ocean Observations: A European Perspective	Nicholas C. Flemming	The author identifies potential areas that would benefit from integrated ocean observing, including CO_2 emissions policy; climate prediction; energy forecasts; coastal projection; facilities planning; agricultural projects; fisheries utilization; energy management; transportation planning; land management; safety warnings and hazard prevention; fishing operations; ship routing; offshore oil and gas operations; SAR; environmental protection; and others.
Ocean Observing Systems, Public Health, and Harmful Algal Blooms: A Florida Approach	Kirkpatrick et al.	The authors identify potential areas that would benefit from integrated ocean observing, including tourism; public health and safety; fishing and agriculture; and endangered species management.
Potential Economic Benefits of Coastal Ocean Observing Systems: The Gulf of Maine	Kite-Powell and Colgan (2001) (joint publication of NOAA, the Office of Naval Research, and Woods Hole Oceanographic Institution, 2001)	The authors discuss an alternative approach to estimating the value of marine measurements. Instead of looking at cost savings, this approach looks at the value that better marine measurements adds for commercial fisheries. Better information allows fishermen to locate fish stocks more easily and allows regulators to design harvest seasons and allowable catch quotas more sustainably. Better information could also allow fishermen to plan which days to go out to sea. This could increase revenues by reducing the number of days spent at sea without a catch and therefore reduce the cost of the catch. (Cited in *The Economics of Sustained Marine Measurements*, a publication of IACMST.)

Table 3 summarizes the benefits of improved information in specific application areas, particularly meteorological forecasting, hurricane prediction, and disaster relief. The application areas presented in this table span only a portion of the full universe of areas that might benefit from an investment in ocean observation.

Table 3. Summary of Value Estimates in Specific Application Areas

Title	Author(s)	Summary
Quantitative Value Estimates		
The Value of Improved ENSO Prediction to U.S. Agriculture	Andrew R. Solow, et al.	The authors estimate a range of values for three different levels of ENSO prediction skill. A modest prediction accuracy would generate an economic value to the farm sector of $240 million; a high level of accuracy generates an estimated $266 million; a perfect forecast would generate economic value of $323 million.
Value of Improved Long-Range Weather Information	R. M. Adams, et al.	The study presents research that focuses on the value to the U.S. agricultural sector of improved ENSO forecasting. The authors focus their study on a limited set of crops and note several critical assumptions, they assert that the value of improved ENSO forecasting is about $100 million/year or greater.
One Million Dollars a Mile? The Opportunity Costs of Hurricane Evacuation	John C. Whitehead	The primary purpose of this research is to estimate the opportunity costs of hurricane evacuations. The author finds that hurricane evacuation costs for ocean counties in North Carolina range from about $1 million to $50 million. This cost depends on storm intensity and emergency management policy.
The Value of Hurricane Forecasts to Oil and Gas Producers in the Gulf of Mexico	Considine et al.	The authors estimate the value of improved accuracy in hurricane forecasts to offshore drilling rigs. They currently estimate the value of 48-hour hurricane forecasts to offshore drilling at an average of about $8 million per year throughout the 1990s. They simulate the value of increased hurricane forecast accuracy and find that the value of an assumed 50 percent improvement in accuracy of 48-hour forecasts can lead to a rise in value by more than $15 million per year.
Economic Implications of Potential ENSO Frequency and Strength Shifts	Chi-Chung Chen, Bruce A. McCarl, and Richard M. Adams	The authors examine the economic impact of increased frequency and strength of the ENSO. They note that increases in the strength of the ENSO will yield much larger economic damages (on the order of $1 billion) than increases in frequency. They further note that the economic damages perpetuated by an ENSO phase shift can be somewhat mitigated (by about $10 million) by using forecasting in producer decision making. This study indirectly points to the value generated via improved forecasting in the face of global climate shifts, meaning how forecasts can help mitigate economic loss across changes in global climate patterns.
Qualitative Value Estimates		
The Economic Value of Hurricane Forecasts: An Overview and Research Needs	Letson et al.	This paper reviews research that has estimated the value of hurricane forecasts and warning systems and the value of improving forecast quality. The authors want to identify what they believe should be the priorities for social science research related to hurricane forecasts and warning systems. The authors address three main issues: the difference between “forecast value” and “impact mitigation”; why public provision of hurricane forecasts is rational; and how to estimate forecast value.
The Socio-Economic Value of Improved Weather and Climate Information	Williamson et al.	The authors review many studies of the economic value of weather forecasts, and conclude that while “savings and benefits are real,” they “are extremely difficult to measure on a national or global scale.”

A number of regional studies have attempted to estimate the economic benefits of ocean observing that accrue directly to regional and coastal areas. Table 4 summarizes estimated regional economic impacts.

Table 4. Estimated Economic Benefits of Regional Ocean Observing Systems

Region	Industry or Field	Low Estimate[a]	High Estimate[a]	Measure	Benefit Source	IOOS Information
Alaska	Commercial fishing	$504.00	$504.00	Wholesale value	Increased groundfish catch	Reduced risk in management decisions
Alaska	Commercial fishing	$62.50	$62.50	Wholesale value	Increased crab catch	Reduced risk in management decisions
Bristol Bay, Alaska	Commercial fishing	$77.00	$77.00	Producer surplus	Improved capital/labor investments	Salmon run forecasts
Florida	Recreation	$91.20	$91.20	Consumer surplus	Improved spatial/temporal accuracy	Recreational fishing conditions forecasts
Great Lakes	Recreation	$20.70	$103.50	Total expenditures	Improved spatial/temporal accuracy	Recreational boating conditions forecasts
Gulf of Maine/Mid Atlantic	Transportation	$0.50	$1.00	Producer surplus	Improved spatial/temporal accuracy	Seastate & visibility forecasts and nowcasts
Gulf of Maine/Mid Atlantic	Search and Rescue	$10.00	$15.00	Producer surplus	Improved spatial/temporal accuracy	Surface currents & winds
Gulf of Maine/Mid Atlantic	Search and Rescue	$2.30	$4.70	Producer surplus	Improved spatial/temporal accuracy	Surface currents & winds
Gulf of Mexico	Energy	$3.80	$7.50	Cost savings	Avoided false positives	Improved hurricane forecasts
Gulf of Mexico	Health and Safety	$0.60	$1.00	Social Cost savings	Improved spatial/temporal accuracy	Oil Spill dispersion models
Southeast US Atlantic Coast	Storm Prediction	$35.60	$35.60	Cost savings	Improved spatial/temporal accuracy	Improved tropical storm track and intensity forecasts
Southeast US Atlantic Coast	Storm Prediction	$4.00	$4.00	Tourism revenue	Improved spatial/temporal accuracy	Improved tropical storm track and intensity forecasts
Southern California	Recreation	$2.30	$3.50	Consumer surplus	Decrease false negatives	Beach closure forecasts
Southern California	Recreation	$4.20	$9.30	Total expenditures	Decrease false negatives	Beach closure forecasts
Southern California	Recreation	$1.10	$1.10	Total expenditures	Decrease false positives	Beach closure forecasts

[a] Millions of dollars.

Source: Kite-Powell, Hauke, *et al.*, "Estimating the Economic Benefits of Regional Ocean Observing Systems," August 2004.

Taken collectively, these studies validate the assertion that investing in a comprehensive ocean observation system would generate considerable socioeconomic value. This benefit cannot be achieved without implementation of a comprehensive data management solution.

DEFINING A SOLUTION

Any solution for resolving the challenges associated with the current data management processes should be tied to issues and concerns expressed by those who use it. These concerns, articulated in discussions with NOAA and non-NOAA constituents and documented in many IOOS development documents, form the foundation for building a solution to fill many of the existing capability gaps. As part of this analysis, the IOOS Program held discussions with current users, and reviewed existing requirements and design documents to further define gaps in current processes, and identify potential options for resolving them.

User Discussions

To better understand the types of improvements that would be most desirable to data users, and to estimate their potential impacts, the IOOS Program interviewed stakeholders from across NOAA and the regions, including some private sector organizations. A diverse set of participants was selected to provide a broad view of the ways that data are used. The following organizations participated in these discussions:

- National Weather Service, Weather Forecast Offices
- Environmental Modeling Program
- Center for Operational Oceanographic Products and Services (COOPS)
- National Centers for Coastal Ocean Science
- NOAA Fisheries
- Regional Associations
- Weatherflow, Inc.
- Public Service Gas and Electric (PSG&E).

We held 29 discussions with stakeholders and asked them to describe the methods they used to identify and access the data they need to perform their daily activities. Most respondents identified the following three data activities as the primary data functions performed.

- Data discovery & formatting—time spent looking for desired data sets and making format changes to assimilate into products and services;
- QA/QC—intermediary user time engaged in quality assurance and/or quality control

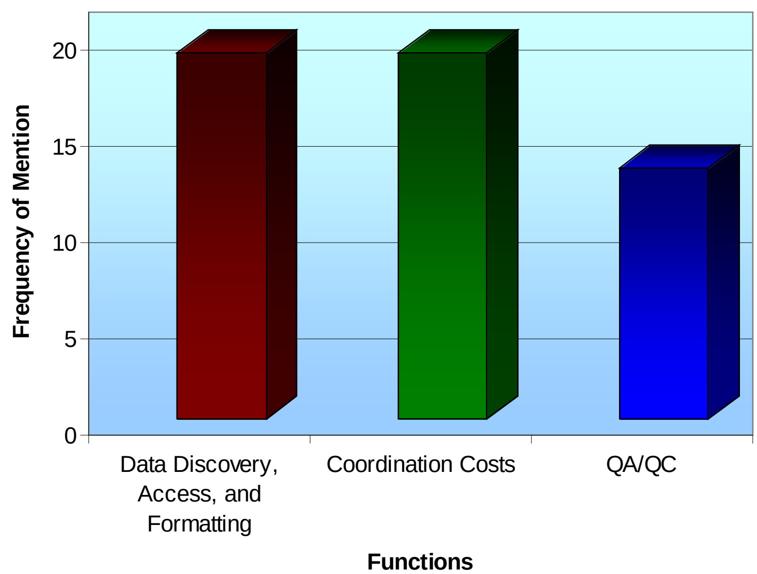
- Coordination costs—intermediary user time spent contacting or coordinating with data providers

These activities were used to assess the impact of the proposed data management options on the data user community.

Discussion Findings

Discussions with data users revealed the extent to which data users struggle with the same data management issues. Currently, many users are challenged in their ability to gain sufficient access to the data they need to deliver products and services. Participants indicated that data management activities consume a large portion of the resources used to deliver a product. These findings are highlighted in Figure 6 below, which shows the number of participants who indicated that they perform these data management functions. While the scope of this analysis limited the number of participants that could be included in this survey, we believe that these responses are indicative of a larger data management issue within the ocean data user community. Therefore, we used these findings to provide a baseline measure of the types of changes that users would most like to see made to the existing data management structure.

Figure 6. Number of Users Performing Data Management Functions



The Same Data Management Functions Are Required Throughout NOAA

Almost every participant indicated that they perform similar data management activities. Many times, the data users perform similar data management functions on the same types of data. For instance, all three ingest the same core ocean variables, but each one has spent considerable energy building unique programming code to access and use the data.

Data Management Functions Consume a Significant Amount of Time and Energy

During the course of our discussions, NOAA and non-NOAA users explained how they spend significant time finding, accessing, formatting, and ingesting ocean data. A number of intermediary users said that they spend roughly 50 percent of their total full-time equivalent (FTE) hours on the three basic data management functions identified above.

In addition to performing those formal data management functions, the participants we spoke to spend considerable time negotiating terms for data access, coordinating with data providers, and fixing glitches as they occur. For instance, many times, intermediary-users said that to obtain access to data they needed to contact data providers multiple times to see what data are available and how to access them.

It is important to note that these projects were established to provide services and conduct analysis on functional areas, such as coastal inundation. Many of the discussion participants expressed sentiments such as "[data] formats are the bane of my existence," or "we spent more time worrying about data, than doing the analysis we spent decades in school learning to do." In general, participants want to focus more energy on the products, services, forecasts, and models that allow end-users to create environmental and socio-economic impacts. However, they are bogged down with data discovery and formatting, QA/QC and coordination.

High-level Requirements Review

Within the broader IOOS Program, the mission of the proposed DMAC subsystem is to manage services, standards, and facilities that integrate ocean, coastal, and Great Lakes observation data collected by a variety of systems and entities. A number of *foundational* documents outline the tenets for an IOOS system, including the U.S. Integrated Ocean Observing System (IOOS) Development Plan and the Data Management and Communication Implementation Plan. These tenets provide the guiding parameters around which to develop a system to improve access to and usability of ocean data. The foundational documents also confirm the need to coordinate the large numbers of existing and emerging monitoring and observing systems operated by federal and state agencies, academia, and the private-sector to better meet the needs of user communities.

KEY IOOS TENETS

The key IOOS development tenets are as follows:

- *IOOS will integrate existing (legacy) and new observing systems, data, organizations, and products.* IOOS will (1) efficiently link environmental observations, data management and communications, data analyses, and models; (2) provide rapid access to multidisciplinary data from many sources; (3) supply data and information required to achieve multiple goals that historically have been the domain of separate agencies, offices, or programs; and (4) involve crosscutting partnerships among federal and state agencies, private-sector entities, and academic institutions.

- *IOOS will provide data to modelers for assimilation*. IOOS data will be provided to modelers for comparison with expected data to determine whether data fall within expectations or require additional review.

- *IOOS will provide mechanisms for aggregating (and buffering) data streams over useful spans of time and space.* Data aggregation is any process in which a data set is generated by joining in some manner data held in more than one data set, possibly in more than one file, possibly at more than one site. In this manner data are replicated, not restructured.[43]

DMAC Principles

The principles for DMAC are built on the IOOS tenets, and designed to enable development of the data management structure to support an IOOS system. To meet the goals outlined in these documents and others, the IOOS Program established the following fundamental principles for data management and communications:

- 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 produced at the public expense in a timely manner

- Ensure data quality and interoperability by meeting federally approved standards and protocols for observations, data telemetry, DMAC, and modeling

[43] 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.

- 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.

Achieving these goals will depend on having a robust network of operational observing activities that routinely, reliably, and continuously provides data and information on oceans and coasts, in forms and at rates specified by groups that use, depend on, manage, and study marine systems; provides multidisciplinary data and information from *in situ* and remote sensing; 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. A data management and communications system would link existing efforts together with emerging systems into a seamless, interoperable data-sharing network.

REQUIREMENTS REVIEW FINDINGS

A comparison of user discussion findings and high level functional requirements reveals that a data management system solution would align with user needs, and provide the types of capabilities that would support their ability to develop or improve end user products and services. NOAA’s ability to fully respond to these needs will depend on the ability to secure resources to develop a solution, which in turn depends on a clear understanding of costs and benefits that address some or all of the areas of need. Deciding whether to pursue this approach would also depend in part upon NOAA priorities, capability requirements and organizational readiness.

Proposed Data Management and Integration Approach

The proposed data management and integration solution responds most fully to the identified system and user-identified functional requirements, and would significantly enhance the value of ocean data. The improved data management and integration approach would enable NOAA to reduce information-sharing barriers imposed by a siloed approach to data management, and enable users to make better use of available information resources. The proposed approach includes the Data Management and Communications (DMAC) system and a Data Integration

Framework (DIF). The DMAC system represents the desired end-state with the DIF being an initial implementation which continues to evolve and contributes to the DMAC.

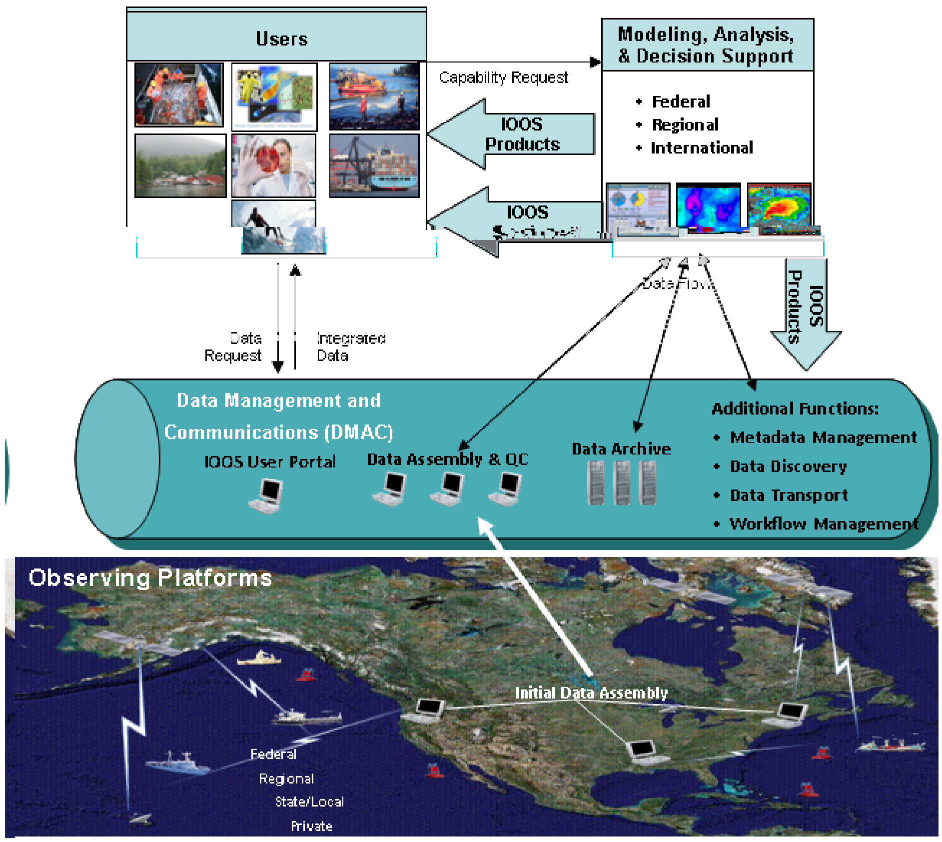
Data Management and Communications System

The DMAC system will aggregate and integrate data from thousands of independently owned and operated collection sensors and make the data available to hundreds of equally diverse users who use the data for modeling and analysis, as well as for decision support. This exchange of data requires that data collectors and users "speak the same language" in terms of data definition, structure, and transmission both within and across components. Therefore, the DMAC cannot consist solely of hardware, software, and communications infrastructure. To ensure that the data are interoperable across a national and global community, DMAC and all IOOS partners must also incorporate standards for data collection and management and for metadata. In addition, the DMAC will comply with both the Federal Enterprise Architecture, the NOAA common infrastructure, federal information security requirements, and other applicable federal standards.

For simplicity purposes, the DMAC concept of operations described here would deliver the national DMAC as a single system operating at a single location. However, the NOAA IOOS Program recognizes that most observing programs have some level of data assembly and quality control capabilities, and many also have data transport and modeling capabilities. This will become increasingly the case as NOAA supports the efforts of regional associations to develop regional DMACs over the next several years. In addition, initiatives such National Science Foundation's Ocean Observatories Initiative (OOI) and NOAA's NDBC are supplying or may supply various levels of the infrastructure. The national DMAC must leverage these capabilities. Therefore, in the long term, rather than being a single system operating at a single location, the national DMAC may be a single system operating in multiple locations, or it may be an interoperable family of systems operating in multiple locations. In some or all cases, regional DMACs may also serve either as separate but integrated partners or as integral components of the national DMAC.

The proposed DMAC system will collect data from participating observing organizations. The DMAC will work with the observing organizations to ensure that the data are presented in a unified manner, based on agreed-upon standards, similar to the Data Integration Framework (DIF). Figure 7 illustrates a notional DMAC implementation approach, highlighting key participants and interactions.

Figure 7. Notional DMAC Implementation Approach



Generally, the observing organization would be responsible for forwarding the data in accordance with identified standards, although in some cases the DMAC may modify the data to meet the standards. The DMAC would provide data to modeling and analysis centers in accordance with the approved standards. DMAC's specific functions would be as follows:[44]

- Data transport
- Data assembly, quality control, transformation (standardization), and workflow management
- Data access
  - Data Discovery and Metadata Management

[44] The list of identified functions draws heavily upon previous IOOS studies. The principal studies are National Office for Integrated and Sustained Ocean Observations, *Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems*, Ocean.US Publication 6, 2005; Lockheed Martin, *Integrated Ocean Observing System (IOOS): Conceptual Design*, 2006; and Raytheon, *IOOS Conceptual Design*, Volume 1, 2006.

    - Data Access Operations
        - Access by major partners
        - Access by external users via portal (online browsing)
- Data storage
- Data archiving
- Information assurance
- Support services
    - Data standards and governance
    - Service level agreements (SLAs)
    - User support
    - System administration and monitoring.

Given NOAA's current level of investment in existing observation and data management systems and platforms, the IOOS Program expects that the DMAC system will focus on integrating established systems and hardware, where appropriate. The full implementation of DMAC will rely on the contributions of multiple organizations across NOAA, including observation systems, models, decision-support tools, and certain data management activities. While these organizations are not directly managed or organizationally housed under the IOOS Program, it is responsible for understanding, managing, and coordinating these distributed capabilities to maximize NOAA's contributions to IOOS. The objective is to take advantage of existing technical capacity, rather than duplicate capabilities, and to objectively identify opportunities without being constrained by the agency's financial or programmatic ties to existing structures, systems, or approaches.

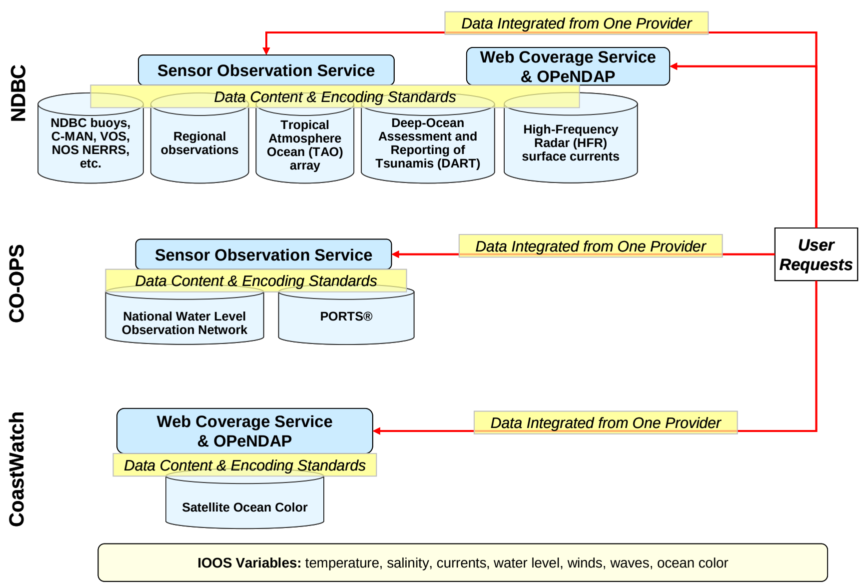
DATA INTEGRATION FRAMEWORK

Because of the scope and complexity of the DMAC capability, NOAA is developing a DIF as a precursor to DMAC. The DIF is specifically designed as a limited-scope, risk-reduction project to develop and implement a repeatable, extensible approach to data integration. The DIF is a set of systems and standards that will support the interoperability of data products delivered by data providers.[45]

[45] Interoperability refers to the ability of two or more systems to exchange and mutually use data, metadata, information, or system parameters using established protocols or standards.

The DIF is intended to improve management and delivery of an initial subset of ocean observations, and to provide customers with uniformly accepted and applied standards for data format and transport to facilitate their ability to assemble data from diverse sources. The DIF will not define how data providers' data holdings should be managed, but rather will define interfaces and specifications for how data should be delivered.[46] Implementation of standards would improve the usability of data products and significantly reduce the data formatting burden currently experienced by both intermediate and end users. In conjunction with the establishment of DIF infrastructure, the IOOS Program will identify data standards via an interagency review process and provide guidelines to improve delivery of IOOS variables by standardizing the content of data records, quality control, data documentation (metadata), and transport procedures. The DIF implementation approach is illustrated in Figure 8 and Figure 9 below.

Figure 8. FY2009 DIF Implementation



The DIF will establish a web service layer atop key NOAA data providers, including the National Data Buoy Center (NDBC), the Center for Operational Oceanographic Products and Services (CO-OPS), and the Center for Satellite Applications and Research (STAR) CoastWatch, using existing consensus or international standards where possible. The DIF services will provide integrated access to both NOAA and regional partner data. Since no single web service type or data format will satisfy all users, the DIF project has broadly identified three general classes of scientific information—*in situ* data, gridded data, and images of data—and has selected web services and encoding conventions to be used in each case. These selections are intended to standardize a small number of data access methods and thereby to enable additional providers, users and variables to join the network more easily. While the standards and protocols identified are broadly

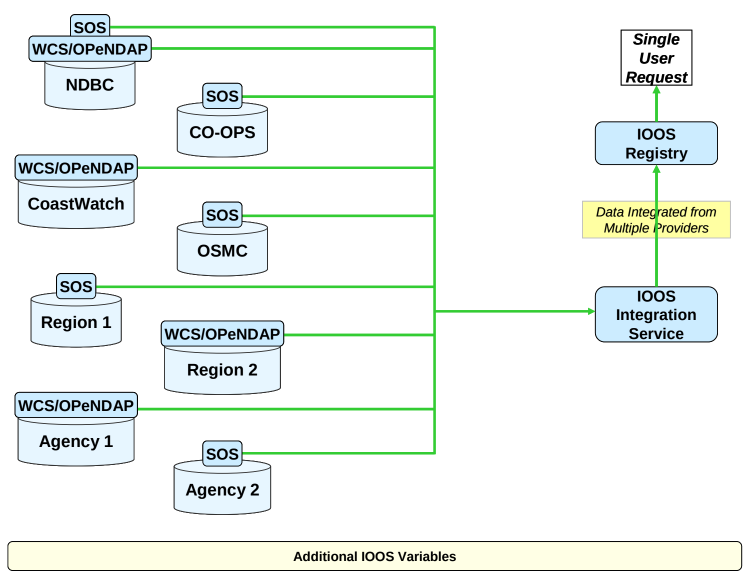
[46] NOAA IOOS Data Integration Framework (DIF) Functional Requirements Document, November 2007.

applicable, decision-support tools and models relevant to harmful algal blooms, integrated ecosystem assessments, hurricane intensity, and coastal inundation have been targeted as initial customer focus areas for the DIF.

Data standardization will establish a common data language—structure and content—that helps to improve the usability of the data by a larger segment of the stakeholder population. With more uniform data, users are better able to combine available data sets to support their individual needs, giving them a more complete representation of ocean dynamics. Standardization also reduces the level of effort required to use the available data, as interim users will no longer have to build multiple interfaces, or re-format multiple data sets from each data provider to get the information that they need. This will reduce the time and opportunity costs to deliver products and services, and create a more stable foundation upon which to build operational-quality value-added products and services that meet the needs of local and regional concerns.

By the end of FY2008, the initial web service implementations at NDBC and CO-OPS should be complete, with the CoastWatch implementation to be completed in early FY2009. Expected follow-on steps include IOOS registry implementation, metadata management, data integration service and the expansion of DIF to include additional variables. Figure 9 shows the notional DIF structure expected by FY2012.

Figure 9. Notional FY2012 DIF Implementation



In FY2012, data from additional providers, such as the Office of Climate Observation (OCO) Observing Monitoring Center (OSMC), Regional Associations, and other federal agencies, will be available through the IOOS Integration Service and the web services layers implemented at each data provider. The IOOS Integration Service will enable data conversion to other formats that might be preferred by a data user, and will support the aggregation of data from multiple data providers in response to a single request. Because of funding limitations, DIF development is not expected to include significant administrative, security, or life-cycle support services that will be necessary for a DMAC solution.

The DIF was originally intended to be a risk-reduction project with the objective of validating that the performance of select predictive models could be improved by providing access to input data in a more integrated and homogeneous way. By establishing technical protocols, enhancing data standardization, establishing partnerships and formalizing IOOS distributed implementation; the DIF also provides a transition path to DMAC. The DIF should also reduce total implementation costs below the initial industry concept design estimates developed in 2006.

ANALYSIS OF DMAC COSTS AND BENEFITS

NOAA user discussions, ocean community studies and reports, and ocean economic literature all identify a need for, and identify benefits from a comprehensive ocean data management solution. While it is challenging to quantify the specific value of the significant societal benefits identified with this solution, it is feasible to estimate the benefits to the NOAA ocean data management and data user community.

Based on findings from user discussions, we believe that an enterprise-wide data management solution would enhance NOAA's data management efficiency by streamlining data functions. Using an enterprise data management construct, data would be processed once but used many times, allowing users to shift efforts away from managing data and toward delivering the analyses, forecasts, and models that generate socioeconomic benefits.

Our analysis weighs potential productivity gains against the costs of developing proposed DMAC functionalities. To estimate the potential productivity gains, we asked NOAA intermediary users to estimate the time they spend performing data management functions, and to predict the reduction in effort that a DMAC-type solution might provide. These estimates, along with DMAC cost estimates provided by previous industry studies, were used to develop a model to predict expected returns over a 15-year period.

The model uses net present value (NPV) to estimate the expected internal benefits that NOAA is likely to generate with the implementation of DMAC. NPV is the standard criterion for deciding whether a government investment can be justified on economic principles, and measures the sum total of discounted costs and benefits. The NPV of a project represents the value, in current dollars, of all anticipated cash flows expected over the project's life. Discounting of out-year benefits and costs adjusts values to recognize the different years of incurrence, and converts them to a common unit of measure.[47] An NPV of zero would mean that, over the life of the option, total productivity gain equals total cost. In other words, for an NPV = $0, all operations and start-up costs are covered by the total productivity gains generated, when both are adjusted by the discount rate.

While our analysis was constructed according to Office of Management and Budget (OMB) Circular A-94 guidelines, the model is not intended to provide precise cost and benefit calculations. It is intended to provide a most-likely range of NOAA benefit, and describe the level of uncertainty associated with that range. The model does not attempt to capture the potential non-NOAA benefits that are likely to be generated by DMAC, nor does it attempt to capture the incremental benefits to NOAA made possible by the resources available as a result of DMAC

[47] Office of Management and Budget, Circular A-94: *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*.

productivity enhancements. A full description of the model is provided in the Appendix A.

Analysis Results

The NPV analysis was conducted using a form of Monte Carlo simulation[48], called Latin Hypercube, to generate a distribution of most likely benefit outcomes.[49] To ensure that a broad range of uncertainty was captured in the model, we performed simulations using both triangular and uniform distributions to evaluate how much impact user responses had on the NPV estimates.[50] The results of these simulation runs were used to define the range of most-likely benefit outcomes for NOAA.

Triangular Distributions

By applying triangular distributions to the data collected from user interviews, the model estimated an average NPV between $56.4 and $59.9 million.[51] Figure 10 shows the range of potential NPV outcomes estimated by the model using triangular distributions. The analysis also indicates that there is roughly a 73 percent probability that an investment in DMAC will return a NPV of zero or greater. At the far ends of the distribution outcomes of $ -194 million and $472 million both have a 0.25 percent probability of occurrence.

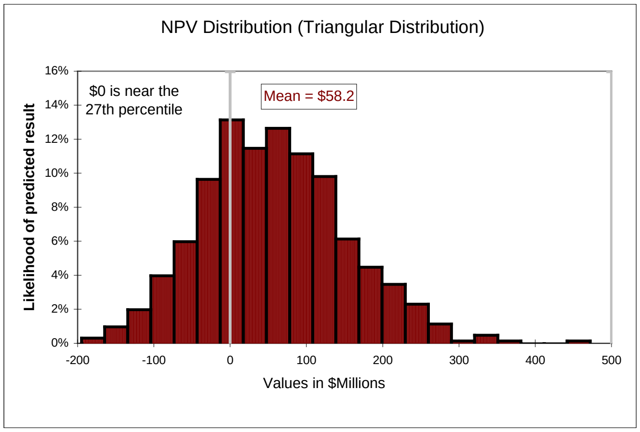
[48] Monte Carlo simulation is a method of iteratively evaluating a deterministic model which varies the model inputs within identified parameter ranges to test the variability in model output.

[49] Latin Hypercube simulation uses a more efficient and systematic sampling approach than Monte Carlo, and provides a reliable sample of the whole parameter space more quickly and with less iteration than purely random sampling, improving convergence rates and speeding up model execution.

[50] See Appendix A for a detailed discussion of the model and analytical approach.

[51] Distributions were applied to user data. Since users provided a range estimate of how much benefit could be expected from DMAC implementation, these could easily be applied to a distribution. DMAC cost estimates are point estimates. In order to apply a distribution to cost estimates, further definition of DMAC requirements is necessary to enable the identification of the most-likely range of DMAC costs.

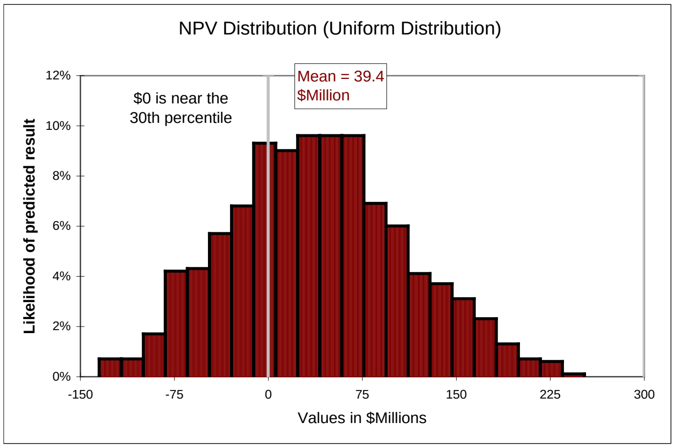
Figure 10. DMAC NPV Distribution using Triangular Distributions



UNIFORM DISTRIBUTIONS

Using uniform distributions, the model estimated an average NPV between $38.2 and $40.6 million. Figure 11 shows the range of potential NPV outcomes estimated by the model using uniform distributions. With uniform distributions, the model indicates that there is roughly a 70 percent probability that an investment in DMAC will return a NPV of zero or greater. At the far ends of the distribution, outcomes of $ -134 million and $252 million both have a 0.25 percent probability of occurrence.

Figure 11. DMAC NPV Distribution using Uniform Distributions



Results in Context

While it is not the goal of the model to deliver exact estimates of benefit to NOAA, it is clear that significant benefits, ranging from about $38 million to $60 million, are likely to accrue to NOAA from an investment in DMAC, regardless of the distribution-type used. In addition, it is imperative to remember that this is not an analysis of the full benefits associated with DMAC development. Thus, our results should not be understood to be the full NPV associated with DMAC. This model captures only the productivity benefits for intermediary users within NOAA. This analysis excludes both the benefits accrued to non-NOAA intermediary users and to the economy in general. Moreover, it does not estimate the potential benefits associated with the full range of DMAC functionalities. For example, this analysis does not capture the benefits associated with planned DMAC security features, although DMAC costs include delivery of security capabilities.

Additionally, this analysis only considers the impact of the DMAC on user productivity, excluding other savings that might be available by integrating other NOAA data management systems. Finally, the 15-year planning horizon, gave the DMAC a relatively short timeframe in which to accrue benefits. Even within this study's limited scope, this analysis results in a positive NPV for NOAA.

IMPLEMENTATION PLAN

The IOOS Program plan for DMAC capability development is based on NOAA's requirements for major program acquisition, refined through insights obtained from National Aeronautics and Space Administration and Department of Defense acquisition guidance. Conceptually, this plan follows the framework of Government Accountability Office (GAO) knowledge-based acquisition best practices. GAO identified these practices from studying many organizations that have begun to adopt practices to better enable their projects to successfully meet customer expectations when delivering large-scale technology solutions. Collectively, these practices ensure that a high level of knowledge exists about critical facets of the product at key points during its development.[52]

Reviews by the GAO identify three critical junctures at which organizations must have sufficient knowledge to make large investment decisions.

- First, and most importantly, before product development is started, organizations must be able to match customers' needs with the available development resources—technical and engineering knowledge, time, and funding.
- Second, a product's design must demonstrate its ability to meet performance requirements and be stable about midway through development.
- Third, the developer must show that the product can be developed within cost, schedule, and quality targets and is demonstrated to be reliable before production begins.

If the knowledge available at each of these points in the development process does not confirm the business case that originally justified the acquisition, the program does not go forward.

One approach that enables organizations to achieve a match between customer needs and resources is evolutionary product development. Under this approach, basic requirements are achieved first, with additional capabilities planned for future generations of the product. Commercial companies have found that trying to capture the knowledge needed to stabilize the design of a product with considerable new technical development can be an unwieldy task. With incremental product development, the task of achieving the required knowledge to complete system development becomes more manageable.[53]

[52] Government Accountability Office, *Using a Knowledge-based Approach to Improve Weapon Acquisition*, GAO-04-386SP, Washington, DC. January 2004.

[53] Ibid.

The IOOS Program implementation plan uses an evolutionary design approach to plan for, design, and implement data management capabilities. This approach delivers increased levels of design specificity with each design phase, and improves NOAA's ability to determine how best to respond to the identified capability gaps. The following discussion outlines the IOOS Program approach to delivering the proposed data management and integration functionality.

Goals and Objectives

NOAA's contributions to the U.S. Integrated Ocean Observing System (IOOS) are distributed across the agency and around the country, presenting significant programmatic and technical integration challenges. Therefore, the IOOS Program, in collaboration with partners from all NOAA Line Offices, the Office of Program Planning and Integration, and the Budget Office, initiated a strategic planning process in May 2007 to establish a long-term vision and mission for the program, as well as a clear set of goals and objectives to advance NOAA's contributions to the U.S. IOOS. The goals and objectives for DMAC development stem from the first goal of the NOAA IOOS Program Strategic Plan: improve access to high-quality, integrated data.[54]

Efforts to improve access to data will include integrating oceanographic variables, including temperature, salinity, sea level, currents, and ocean color, and will require a planned transition from DIF development to a more comprehensive DMAC development approach. With DMAC development, data will be compiled from a variety of sources, including NOAA observing systems, Regional Coastal Ocean Observing Systems (RCOOSs), and other federal agencies and partners assisting in the development of DMAC capabilities. The IOOS Program will also continue to evaluate conceptual design studies prepared by industry and the Regional Associations to support identification of the most appropriate and cost-effective solution to the identified data access issues. To help ensure that development efforts remain consistent with the larger NOAA and user community goals, the IOOS Program plans to pursue the following objectives in developing a DMAC capability. These objectives are drawn from the NOAA IOOS Program Strategic Plan.[55]

- **Objective 1.1.** Advance NOAA IOOS efforts to deliver ocean observations in NOAA IOOS DMAC-compatible, standards-compliant form.
  - Increase NOAA's participation in open source standards activities, such as the Federal Geographic Data Committee (FGDC), International Organization for Standardization (ISO), Open-source Project for a Network Data Access Protocol (OPeNDAP), and Open GIS Consortium (OGC).

[54] NOAA, *Integrated Ocean Observing Program (IOOS) Strategic Plan, 2008–2014*, October 2007. Accessible at http://ioos.noaa.gov/pdfs/IOOS_Prog_StratPlan.pdf.

[55] Ibid.

- Support implementation of data standards through coordination with national and international standards bodies within the U.S. IOOS, Global Ocean Observing System (GOOS), GEOSS, and data management communities.

- Work with the larger U.S. IOOS community to identify, evaluate, and implement additional or emerging standards needed to maintain data management system performance.

- **Objective 1.2.** Integrate NOAA data across multiple systems, platforms, and structures.

  - Prioritize IOOS core variables for integration based on NOAA's model and data product requirements.

  - Identify sources, conditions, formats, and transfer protocols for IOOS variables across NOAA and establish functional and quality requirements to achieve system interoperability and access to distributed data.

- **Objective 1.3.** Utilize systems engineering planning to establish an operational data management capability.

  - Build upon industry conceptual designs and internal NOAA efforts to initiate integrated system engineering planning for data management across NOAA and regional partners, including timelines, projected costs, and phased implementation.

  - Develop transition plan to advance from DIF Initial Operating Capability to achieve a more comprehensive NOAA contribution to IOOS DMAC.

- **Objective 1.4.** Integrate non-NOAA data into the DMAC capability.

  - Support development and implementation of regional DMAC plans.

  - Work through existing regional management structures to identify and enable collection of high-priority, quality-controlled data from sub-regional and regional systems into the NOAA IOOS DMAC.

  - Establish data sharing agreements with other federal and international partners to advance development of the U.S. IOOS.

- **Objective 1.5.** Adopt a service-oriented architecture and Web services-based approach for access to data by NOAA IOOS partners and the public.

  - Define user interface requirements (such as search and discovery functionality) to ensure rapid, efficient extraction of subset information from various IOOS data sources.

- Establish a service-oriented architecture that allows seamless integration of various data sources.

- Develop system interfaces to support the needs of NOAA and its partners for integrated data and information.

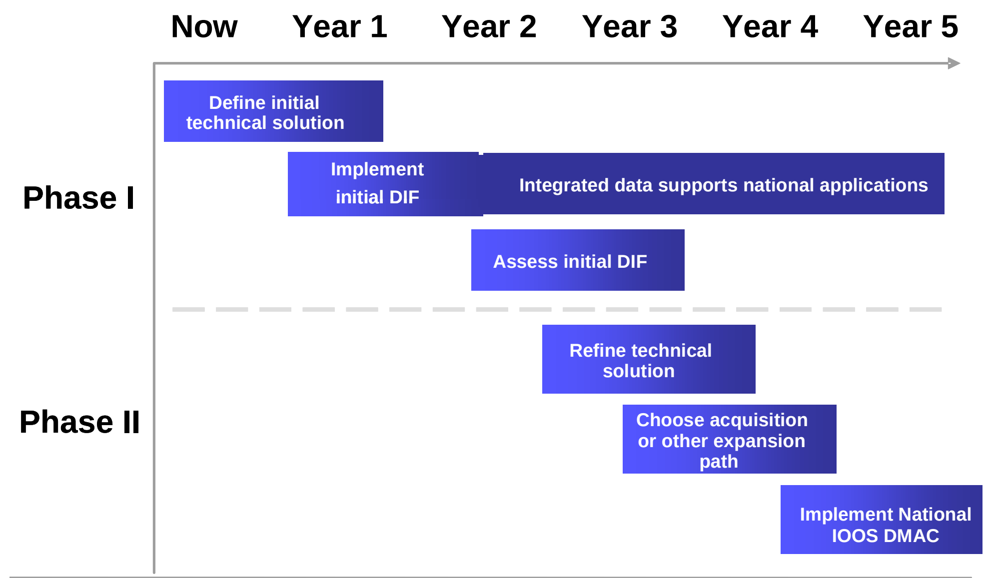
- Coordinate with the NOAA Observing Systems Council (NOSC) Data Management Committee to maximize consistency between DIF and implementable GEO-IDE features.

By pursuing these objectives, the IOOS Program will be able to address the most prominent data management concerns expressed by users, and will better enable NOAA data users, as well as non-NOAA users, to take full advantage of the wealth of data available on NOAA and regional systems.

DIF to DMAC Transition

The IOOS Program intends to evolve the DIF effort into a National IOOS DMAC capability. The DIF development effort is described in detail in the section on "Defining a Solution." Figure 12 provides a high-level view of the intended DIF–DMAC transition sequence.

Figure 12. Schedule for IOOS Data Integration Efforts



IOOS Data Integration

Current State Where We Are Now	Future State Where We Plan to Be in Year 5
• Interoperability challenges faced by IOOS • DMAC standards collection process underway • Determination and integration of at least 5 IOOS core variables of key importance to ocean science and modeling	• Implementation of initial IOOS DMAC and National IOOS that meets end users ' needs • Integration of data from diverse sources • Requirements met for geographic coverage, resolution, accuracy, and timeliness of multiple NOAA ocean models, assessments, or product owners • Integrated data incorporated into national applications: HAB forecasting, IEA development, total water level inundation prediction, and national surface current capability (high frequency radar) • Improved performance of models and decision support tools

This process is well underway and the IOOS Program anticipated delivering on the initial capability of 5 variables (anticipated to actually achieve 7 variables) integrated and supporting specified models or services by FY2010. An additional increment of DIF should deliver registry services that will greatly enhance data discovery and access by FY2012.

While developing early DIF capabilities, the IOOS Program has begun the capability development process for a National DMAC system. This process is described in the following paragraphs.

High-level DMAC Capability Development Activity Descriptions

The activities included in this section constitute the primary activities associated with developing DMAC. These activities span the system development life-cycle, including identifying stakeholders and partners, selecting a preferred system implementation path, and implementing the desired system alternative to provide required capabilities. These activities are in line with the aforementioned GAO best practices and will help to ensure that the final product addresses the expectations of NOAA and others.

DEFINE AND DOCUMENT FUNCTIONAL REQUIREMENTS

This activity entails providing a description of the required system behavior, which must be clear and unambiguous to enable development of useable software products and tools. The IOOS Program has begun this effort by collecting IOOS and DMAC requirements from a variety of previously documented sources and compiling into a High-Level Functional Requirements Document (HLFRD).

The HLFRD is currently being socialized throughout the IOOS stakeholder community. From this effort, it is expected that a community consensus will develop as to what the DMAC functions should be, without yet identifying the technical aspects of how it will perform the identified functions. Once consensus is achieved, the IOOS Program will begin developing use cases to document specific scenarios under which the system will be expected to perform.[56] Use cases will be developed through community involvement and are the cornerstone of a detailed functional requirements document.

ANALYSIS OF ALTERNATIVES

The detailed functional requirements will provide the basis for developing an analysis of alternatives (AoA), which describes various ways to attain the DMAC capability. The analysis of alternatives does not deliver a technical design, but does identify possible strategies for implementation. Each alternative will typically present a different set of risks and benefits, which should be weighed against project goals, existing architecture, organization readiness, and any other factors that impact the final selection of an alternative. The list below includes a few representative alternatives that will likely be considered during the analysis:

- Commercial development of services to provide an initial DMAC capability to process a large portion of existing observation data, which will then be expanded to provide data management services, including public access, for all IOOS-related systems. [Referred to as a “buy” approach]

[56] The program will use the IBM Rational tool suite to document requirements.

- Expand existing DIF capability through a series of incremental steps with NOAA and partner resources, but without significant commercial participation. [Referred to as a "build" approach]

- Integrate DIF and other existing NOAA, regional, and commercial components to form an initial capability, and incrementally increase both the level of standardization and capability. [Referred to as a "blend" approach]

The AoA will consider how capabilities will be developed and implemented, as well as how they will be organized and evolved. The AoA will strive to avoid unnecessary overlaps in function and data, as well as ensure that initial steps support the target end state. Initial efforts and data collection for the AoA began in the summer of 2008 with a preliminary analysis of approaches, which surveys the IOOS landscape to identify current capabilities that can contribute to a DMAC solution. The formal AoA will be conducted in 2009 after NOAA and interagency consensus has been reached on the DMAC high-level requirements and concept of operations.[57]

More detailed estimates of cost will be developed to support the AoA, particularly if cost is a criterion in determining the preferred alternative. Following the completion of the AoA, a more detailed economic analysis is conducted to support NOAA, Department of Commerce, and Office of Management and Budget (OMB) approval of the preferred alternative.

Define the Capability Development/Acquisition Strategy

Following identification of the requirements, the preferred alternative to meet the requirements and the cost and economic analysis, the program office will formalize and seek approval of an acquisition strategy.[58] The acquisition strategy will guide the development of the preferred alternative—build, buy, or blend—and designate the capability development approach. Regardless of the development approach, the acquisition strategy should specify threshold and objective capabilities for capability increments.

The acquisition strategy will determine whether system integration engineering efforts to determine the detailed technical requirements should be conducted as part of the development effort or as a stand-alone activity, and whether these efforts should be conducted by the same or different organizations. For example, if all or part of DMAC is determined to be appropriate for a commercial procurement, then the acquisition strategy would determine whether a systems integration contract would be separate from a development contract. If separate, then it would determine whether the systems integrator should be allowed to offer development services. If commercial development is pursued, the acquisition strategy would

[57] The cost-benefit analysis in this business case assumes a "blend" approach.

[58] The term Acquisition Strategy does not imply a major acquisition as the selected alternative.

also specify the recommended type of contract and incentive structure. Under a "build" or "blend" approach, the capability development/acquisition strategy will detail the roles and responsibilities of NOAA and other development partners for those portions of the system where commercial development is not recommended.

The acquisition strategy will also define the approach for testing and validation of the capability development effort and the life-cycle support process.

In addition, the acquisition strategy will address all NOAA specific requirements detailed by NAO 208-1, NOAA Acquisition Handbook, and NAO 208-3, Major System Acquisition, as appropriate.

Develop Detailed Technical Design

The purpose of this activity is to further refine the functional requirements into detailed technical specifications for the DMAC system. This planning effort will result in a series of documents (in size and scope proportional to the selected approach) that support the following:

- Technical design
- Data management
- Data and technical standards
- Testing and training
- Deployment (roll-out) planning
- User services and outreach
- Program governance including configuration and change management
- Program management including both near- and long-term planning.

Implementation, Deployment, and Operations

The steps that occur during this activity depend heavily on the selected alternative, but will be guided by the plans developed during the detailed design phase. Important high-level issues that must be considered include the following:

- The critical importance of employing standards in order to eliminate recurring and redundant data manipulation and/or incorrect understanding and use of data.
- Coordinated planning to eliminate unnecessary redundant processing of the same data. The result of this effort may result in changes in scope for some organizations.

- Coordinated planning to identify observation data and DMAC functions to be developed, including desired products and outcomes. This is critical to ensure intermediate steps contribute to the long-term goal.
- The need for long-term program management and governance, and continuous outreach and reassessment of efforts and results.

Technical and Organizational Risks

Implementing a project with the scope and scale of DMAC always involves risks. This effort requires the integration of many diverse systems and data streams involving a wide range of individuals and organizations. It will be both technically and organizationally complex.

The detailed design of DMAC is immature, which is to be expected at this stage in the development lifecycle. The IOOS Program has planned a comprehensive systems engineering and integration effort to refine the design before committing to development. Efforts to speed the fielding of DMAC without conducting these engineering and integration efforts increase technical and cost risk. A rigorous design effort may determine that current cost estimates are not executable, requiring re-scoping of the project. Conversely, the design effort may identify existing capabilities and technical approaches which can reduce the overall development effort, reducing the cost and development time.

The strategy of distributed implementation of the U.S. IOOS means that the organizations and systems for observing, modeling and analysis, and data management are only loosely coupled. As a result, successful implementation depends on the timely cooperation of multiple organizations. While the level of collaboration demonstrated in the IOOS Program's DIF Integrated Products Team (IPT) is encouraging, an inability to achieve this timely cooperation would extend development time and increase resource requirements.

The DMAC will integrate systems that have previously operated in a stand-alone or limited data sharing environment. Although this creates technical risk, there is a well developed industry that supports technology integration as well as an interested and involved community of data managers at NOAA with the experience to support the identification and development of technical solutions. Nevertheless, unforeseen technical challenges could extend the development time and increase resource requirements.

The DMAC will require significant resources. If resources are reduced once the development effort begins, the program will take longer to reach the desired capability and the total overall cost may increase. However, once design is complete and implementation has begun, most development applications will generate benefits, regardless of total systems completion.

The DMAC will require significant software development. In view of the diverse nature of the IOOS community of interest, it will be extremely important to follow software development and documentation best practices to ensure that the software can be maintained and upgraded systematically. Failure to follow such practices will likely increase the cost of maintaining the software and ensuring system stability.

The key to successful implementation is to identify, monitor, and control these risks for the duration of the project. To support this objective, the IOOS Program has developed a comprehensive risk management plan.

NEXT STEPS

This analysis presents a relatively conservative estimate of the costs and benefits related to DMAC development and implementation. Additional analysis will be required to develop a more detailed assessment of the full range of DMAC costs and benefits. While many of the technical development planning activities have begun, and will provide more detail on system specifications, further analysis will be necessary to more definitively evaluate the benefits that DMAC implementation will generate. Some of the data and analysis that would contribute to refining the benefit estimate include:

- *NOAA data management costs*. In this report, there is limited information on current NOAA data management costs, both direct and indirect. Data management costs are typically included in system costs, and were therefore difficult to separate from other program activities. Further examination of the data management cost structure would provide baseline for comparison to DMAC implementation. In addition, considerable data management efforts are performed by NOAA personnel assigned to science or operational duties. Their efforts are rarely captured as data management costs.

- *NOAA User needs assessment*. The scope of this business case effort did not allow for a survey of all current and potential users of ocean data. A broader and more detailed survey of users would provide a more accurate estimate of potential productivity gains related to implementing a data management solution. Such a survey could help identify data management efforts and functions at a more precise level of detail than the current analysis, allowing for refinement of the model and providing useful information for prioritizing data management capability development efforts. The results could also be useful in identifying personnel who are conducting data management functions whose labor costs (or a percentage thereof) are not currently being attributed to data management.

- *NOAA data management inventory*. NOAA has a number of systems designed and implemented, being developed, or being proposed to perform data management functions. In order to fully leverage these efforts, a comprehensive analysis of NOAA data management capabilities must be performed. A full NOAA data management inventory detailing both costs and capabilities would prove useful in ensuring that all NOAA systems are suitably integrated with the DMAC. This inventory might also identify operational or development efforts that could be considered for consolidation, providing system efficiencies and further reducing NOAA's data management costs. The NOAA CasaNOSA Information Management System (IMS) survey is a useful first step to such a comprehensive inventory but the program provided data is not complete in scope, cost, or capability information.

While there may be some overlap and disparity in the results of the IMS surveys, such a comprehensive approach would allow NOAA to capture its data management needs, costs, and potential benefits at a level of detail that would better support Department of Commerce and OMB approval of data management initiatives. These initiatives in turn would support repurposing of data and human capital toward science and operational functions.

In addition, as DIF and DMAC system capability descriptions and delivery estimates are further refined, this model can be updated to provide revised estimates of the net benefit or to provide comparative analysis of options.

CONCLUSION

This business case presents clear evidence of a need for NOAA to improve existing ocean data management systems and processes. NOAA and end users who depend on NOAA data to drive their models and decision-supports tools are spending significant amounts of time, sometimes 25 to 50 percent of the time of assigned personnel, to discover, access, format, and ingest the data for each product or output delivered. These data management activities deter resources away from the value-adding research and analysis activities that deliver benefits to society. User discussion, ocean community requirements documents, ocean economic community literature and NOAA's guidance and strategy documents, at the goal and agency level, confirm the demand for integrated ocean data.

This business case also illustrates that the implementation of a data management solution is likely to generate a NPV between $38.2 and $59.9 million dollars over a 15-year period within NOAA, based on data management productivity gains alone. The positive NPV indicates that a NOAA investment will provide substantial benefits to NOAA, without even considering the full range of benefits to the nation that can be expected from better products and services associated with improved data management. In addition, this NPV estimate represents a relatively short planning horizon against which to measure benefits generated. By extending the horizon to 25 or 30 years, it is clear that the total DMAC benefits are even larger than presented in this business case.

Finally, NOAA must remember that the benefits outlined in this business case are based on a long-term investment in data management. Private industry has found that *quick fix* solutions are less likely to generate the level of sustained benefit that an enterprise-wide data management solution can provide. In order to achieve the type of network impacts seen by other systems, like the Internet or cellular communication, NOAA must invest to a level that provides a comprehensive ocean data network with open access to attract users and providers alike to use the system. After achieving such a "critical mass," the system is likely to produce economic benefits beyond current reasonable expectations.

The DMAC solution offers NOAA a feasible approach to implementing a data management solution that responds to the needs of a broad user community. The costs are small relative to the societal benefits and the large internal return to NOAA indicates that DMAC is a low-risk investment.

Appendix A. DMAC Cost-Benefit Model

This appendix presents a description of the financial model used to evaluate costs and benefits related to the DMAC. The financial model provides a structured framework for estimating the expected value that NOAA is likely to generate with the implementation of DMAC. This model is not intended to produce an exact value for DMAC, but is intended to provide a most-likely range of values, and describe the level of uncertainty associated with those values. The model assesses the costs of developing the proposed DMAC capabilities, against the potential benefits generated for NOAA science and product developers. The model does not attempt to capture the potential non-NOAA benefits that are likely to be generated by DMAC, nor does it attempt to capture the benefits of NOAA products and services generated by the resources that are made available as a result of DMAC productivity enhancements.

Estimated Productivity Gains

To collect productivity gain inputs that would be used by the model, we held discussions with NOAA intermediary users to estimate how much time a data management system, like DMAC, could save them by executing certain data management tasks at an enterprise level. Our participant sample included representatives from four NOAA intermediary ocean data users:

- Weather Forecast Offices—Wakefield and Boston
- National Center for Coastal Ocean Science (NCCOS)–Coastal Oceans Project
- Center for Operational Oceanographic Products and Services (CO-OPS) Harmful Algal Bloom System (HABS) Project
- Coastal Services Center

Evaluation Parameters

When asked to identify their most burdensome data management activities performed when delivering their primary products and services, responses fell into three general categories:

- Data Discovery & Formatting—time spent looking for desired data sets and making format changes to assimilate into products and services;
- QA/QC—intermediary user time engaged in quality assurance and/or quality control
- Coordination Costs—intermediary user time spent contacting or coordinating with data providers

Typically, participants provided their feedback in terms of time spent by one or more FTEs. For example, one respondent stated that data discovery and formatting tasks consume 15 percent to 25 percent of 6 to 8 FTEs per year. Table A-1 presents the pessimistic (LOW) and optimistic (HIGH) estimates collected from our user discussions and grouped by data management function. We will further discuss the user estimates in the *Monetization and Scaling* section of this appendix.

Table A-1. Optimistic and Pessimistic Parameter Estimate Ranges

WFOs	**LOW**	**HIGH**
Data Discovery, Access, and Formatting	25.0%	50%
Coastal WFOs	70	70
National Centers for Coastal Ocean Science	**LOW**	**HIGH**
Data Discovery, Access, and Formatting	20%	35%
QA/QC	10%	25%
CO-OPS HABS Project	**LOW**	**HIGH**
Data Discovery, Access, and Formatting	50%	50%
FTEs	5	7
QA/QC	13%	20%
FTEs	5	7
CSC	**LOW**	**HIGH**
Data Discovery, Access, and Formatting	15%	25%
FTEs	6	8
QA/QC	15%	25%
FTEs	6	8
Coordination costs	30%	50%
FTEs	4	8
Number of CSC Development Efforts	10	15

Accounting for Uncertainty

To account for the uncertainty in the estimated parameter values, we applied distributions to each productivity gain estimate. Distributions offer a mechanism to apply a range of possible inputs to a model parameter. Since the data users we interviewed provided a range of possible productivity gain values which might result from DMAC, we used distributions to model the range of values associated with these inputs. Distributions were applied at the lowest possible input level—FTEs and time spent—to ensure that all likely uncertainty associated with these inputs was captured by the model. Applying risk at the lowest level also avoids the possibility that risk cancels itself out at high-levels in the analysis.

Two types of distributions were applied to the model, since precise probabilities of occurrence of the each estimated outcome were not known. The distribution types applied to the model were triangular and uniform. Triangular distributions, typically used in costs estimation, enable the creation of a three-point distribution around identified likely outcomes, using optimistic, pessimistic and most-likely estimates of subject matter expert (SME) estimates.[59] They also have intuitive arithmetic properties, such as bounds and a "visible" mode—the highest point of the triangle.[60] Uniform distributions, on the other hand, spread probabilities equally, assuming all points are equally likely to occur. This distribution is preferable when subject matter expertise is not available, or where estimates are less precise. However, uniform distributions do not easily account for values below the pessimistic, or above the optimistic values.

Triangular Distributions

To set the triangular distribution for each estimate, we used input from users and set their pessimistic estimates at the 10^{th} percentile, and their optimistic estimates at the 90^{th} percentile. Setting high and low estimates at the 10th and 90th percentiles, respectively, allows greater variability in our parameters to account for the fact that it is typically very difficult for SMEs to envision very rare states of the world. Survey participants tend to underestimate the likelihood of occurrence of the worst-case scenario. The model, therefore, does not set the distribution boundaries using survey participant input, but applies a 1 in 10 probability to both the worst-case scenario, and the best-case scenario.

The mode of the triangular distribution—the most-likely value—was set at a point 70 percent of the way between the pessimistic and optimistic estimates. The decision to place the most likely value at the 70^{th} percentile in a triangular distribution was based on a cost/risk analysis principle, developed by Dr. Stephen Book.[61] When data are limited, Book suggests that the analyst "[a]ssume that the total cost associated with your point estimate has a triangular distribution, and that "the confidence that [a] program could typically be delivered at [or below the most likely] cost [is] somewhere between 20 percent and 30 percent.[62]" In other words, Book suggests that there is a 70 to 80 percent probability that actual costs will exceed the "most likely" estimated cost.

We believe that Book's theory can reasonably be applied to benefit analysis by inverting the mostly likely point in the distribution, such that the lesser benefit

[59] Since SMEs typically provide parametric estimates of costs, based on previous project experience, the resulting estimates tend to be more realistic than not, and are, therefore, appropriate for use in a triangular distribution.

[60] See NASA cost estimating tenets: http://www.ceh.nasa.gov/webhelpfiles/The_12_Tenets_of_NASA_Cost-Risk_.htm.

[61] "How to Make Your Point Estimate Look like a Cost Risk Analysis." This paper was presented at the 2004 Society of Cost Estimating and Analysis (SCEA) Annual Conference in Manhattan Beach, CA, where it received an award for being the best paper in its track.

[62] Ibid, page 2.

values are more likely to occur than the higher benefit values. By placing the most-likely point at the 70th percentile, this analysis assumes that there is a 70 percent probability that actual benefits will be less than the "most likely" estimated cost savings. Figure A-1 illustrates a sample distribution of the FTE parameter data, with roughly 70 percent of the area under the triangle at the left of the mode. In this example, if the pessimistic estimate is 4 and the optimistic estimate is 8, then we assumed the 10th percentile to be at 4; the 90th percentile to be at 8, with the most-likely value—the mode—at 6.8. Table A-2 shows the triangular distribution points applied for each parameter.

Figure A-1. Sample Triangular Distribution

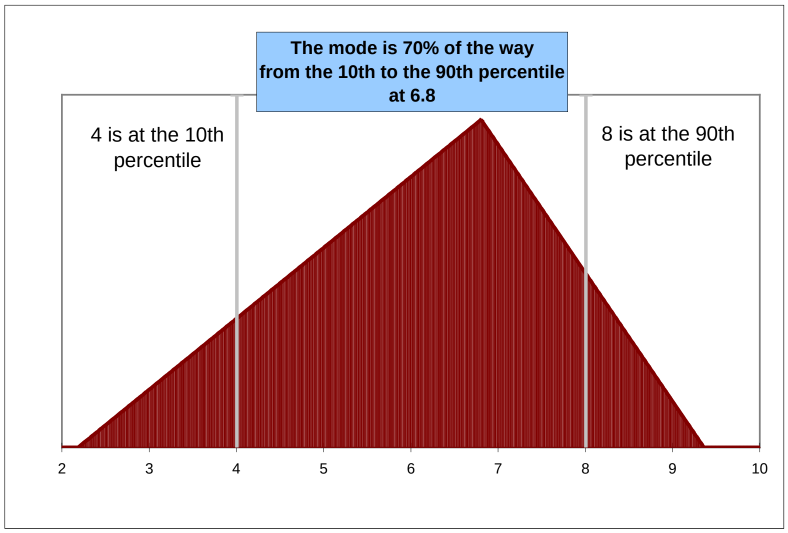


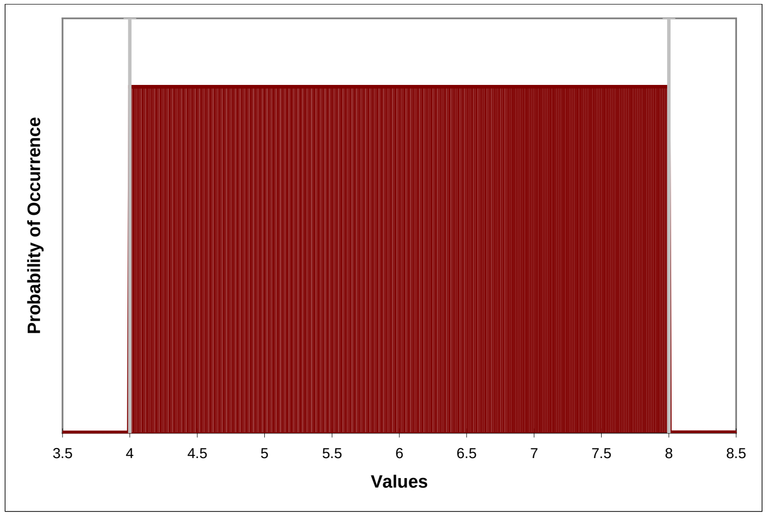
Table A-2. Parameter Values using Triangular Distributions

WFOs	LOW	HIGH	Mode
Data Discovery, Access, and Formatting	25.0%	50%	42.5%
Coastal WFOs	70	70	70.0
National Centers for Coastal Ocean Science	**LOW**	**HIGH**	**Mode**
Data Discovery, Access, and Formatting	20%	35%	30.5%
QA/QC	10%	25%	20.5%
Changing Standards (COST)	1%	2%	1.7%
CO-OPS HABS Project	**LOW**	**HIGH**	**Mode**
Data Discovery, Access, and Formatting	50%	50%	50.0%
FTEs	5	7	6
QA/QC	13%	20%	14.8%
FTEs	5	7	6
CSC	**LOW**	**HIGH**	**Mode**
Data Discovery, Access, and Formatting	15%	25%	22.0%
FTEs	6	8	7
QA/QC	15%	25%	22.0%
FTEs	6	8	7
Coordination costs	30%	50%	44.0%
FTEs	4	8	7
Number of CSC Development Efforts	10	15	14

Uniform Distributions

To test for variability in model results that might result from use of alternative distributions, we applied uniform distributions to data user inputs. Because uniform distributions assume that all values between the pessimistic and optimistic estimates are equally to occur, there is no most-likely value. The low and high parameter values of the uniform distribution are exactly the same as in the triangular distribution; however, the uniform distribution sets the pessimistic and optimistic estimates at the bounds, unlike the triangular distribution which uses the pessimistic and optimistic estimates at the 10^{th} and 90^{th} percentiles. Therefore, the uniform distribution does not consider occurrences above or below the estimates. Figure A-2 illustrates a sample uniform distribution using a pessimistic estimate of 4 and an optimistic estimate of 8.

Figure A-2. Sample Uniform Distribution



MONETIZATION

In order to normalize the input data, data management activity time estimates translated into cost estimates. To do this, a standard NOAA FTE rate of $150,000 per year was applied. Specific monetization approaches applied to each sample organization are listed below.

- WFOs—multiplied the data discovery, access, and formatting parameter by the NOAA FTE rate by 70. (We multiplied by 70 because there are roughly 70 WFOs that routinely use ocean data.[63]) This analysis assumed that our samples of 2 WFOs are representative of the remaining 68 WFOs.

- National Centers for Coastal Ocean Science—multiplied the parameter associated with each data management function by the NOAA FTE rate. For example, QA/QC savings for NCCOS are calculated by multiplying the QA/QC parameter by the NOAA FTE rate.

- CO-OPS HABS Project—multiplied each functional parameter by the accompanying FTE parameter and the NOAA FTE rate. For example, QA/QC savings for CO-OPS are calculated by multiplying the QA/QC parameter by the FTE parameter for QA/QC functions by the NOAA FTE rate.

- CSC—multiplied each functional parameter by the accompanying FTE parameter by the functional parameter that describes the number of CSC development efforts by the NOAA FTE rate. The parameter labeled *Number of CSC Development Efforts* was introduced because CSC provided their resource estimates in terms of a "typical" product development effort. The

[63] Telephone Interview with Aimee Devaris, National Weather Service, Office of the Chief Financial Officer, June 2008.

CSC participant estimated that the center undertakes 10 to 15 new product development efforts in an average year.

By summing these parameters by function, we obtained a point estimate of the time cost savings that DMAC can generate within our sample of NOAA intermediary users executing data discovery, access, and formatting; QA/QC; and coordination activities. We will call these *DMAC functional values*.

SCALING

This analysis uses a sample population of four organizational entities within NOAA as a basis to estimate the likely benefits from DMAC. However, analysis using only the sample population does not capture all of the benefits expected to accrue to NOAA. Additionally, three of the sample respondents provided estimates at a sub-program level. For example, the Coastal Ocean Project does not constitute the total ocean data usage in the Ecosystem Research Program. Although it is not known exactly how much of the data used by the ERP is used by the coastal ocean project, it is unlikely that the coastal ocean project is the only element in the ERP program that uses ocean data or would benefit from DMAC implementation. To estimate the total benefits of the DMAC to NOAA, we applied a scaling factor to the DMAC benefits projected to accrue to the sample population to reflect the benefits expected for all NOAA intermediary users.

To identify an appropriate scaling factor, we used the NOAA Consolidated Observational Requirements List (CORL) database, which identifies 22 NOAA programs as having ocean data requirements. Therefore, we applied a scaling factor of 5.5—22 divided by 4—to productivity benefits. This means that benefits to NOAA would be 5.5 times greater than the benefits estimated for the sample population, assuming that the four participant programs are representative of the larger ocean data user population.

Cost Inputs

The cost figures were derived from industry conceptual design studies commissioned by the IOOS Program in 2006, and provided point estimates of expected costs using bottom-up parametric estimation techniques.[64] Further analysis of NOAA functional capability needs, priorities and system development costs would be necessary to enable a three-point estimate—optimistic, pessimistic and most-likely—of expected DMAC costs. Therefore, this model does not apply distributions to the cost estimates. The cost estimates included in the model, shown in Table A-3, are best estimates for planned DIF and DMAC development activities.

[64] Parametric estimating techniques use historical project data to estimate project activity durations and costs to perform these activities, given the complexity of requirements, the uncertainty of requirements, and the personnel skill levels required to complete the activities.

Table A-3. DIF/DMAC Development Cost Estimate

DMAC Costs Estimates ($Millions)						
Development Functions	Year 1	Year 2	Year 3	Year 4	Year 5	Years 6 -15 (for each year)
DIF/DMAC Planning, Coordination, and execution support	$0.9	$1.0	$1.0	$1.0	$1.0	$1.0
Data Integration Framework Development	$1.2	$1.4	$1.4	$1.4	$2.6	$2.6
DIF/DMAC Standards ST Support	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3
Data Assembly Center (NDBC)	$0.5	$0.5	$0.8	$1.0	$1.0	$1.0
National Data Management and Communications	$0.8	$6.3	$11.3	$21.3	$41.3	$51.3
DIF/DMAC Development Totals	$3.6	$9.4	$14.7	$25.6	$45.6	$55.3

The key assumptions used to determine cost inputs are as follows:

- DIF/DMAC planning, coordination, and execution support. This support includes the portion of the IOOS office costs dedicated to DIF and DMAC development. The estimate is based on the DIF/DMAC share of labor, rent, travel, and general office costs.
- DIF development efforts. These efforts fund the initiatives of the DIF Integrated Product Team to develop DIF capabilities.
- DMAC data standards process. This process supports the interagency standards review process, established in October 2007 in accordance with the Ocean.US DMAC plan. This process will identify appropriate standards, best practices, and other protocols to establish a common foundation for integration.
- NDBC Data Assembly Center (DAC). IOOS funds a portion of the NDBC DAC to provide a common point of access to regional IOOS data and to serve as a test bed for DIF/DMAC integration efforts.

- National DMAC development efforts.
  - High-level cost estimates were initially developed from the DMAC segments of two industry concept designs sponsored by NOAA.
  - LMI created estimates for system engineering activities consistent with DMAC requirements to support a program of the size and scale detailed in the industry concept designs.
  - The cost estimate for Years 6 through 15 is assumed to be constant. This is because we anticipate that DMAC efforts will continue at Year 6 levels due to the evolving nature of data management activities, the need for technology refresh, and the transition from implementation to operations and maintenance.
  - Technical development of DMAC will be phased to help reduce NOAA's exposure to technical risk, and enable incremental delivery of DMAC capabilities.
  - We assume that the DIF–DMAC evolution will leverage DIF productivity enhancements, standards, and lessons learned–providing a solid technical foundation and proven distributed implementation approach and partners for DMAC, which will reduce the total DMAC cost below the industry concept designs.[65]

Model Design

DMAC is a data management solution that will be implemented over time. Consequently, we cannot attribute full functional population values to DMAC in its initial operating years. To determine when NOAA will realize functional savings, we analyzed DIF and DMAC functional requirements, preliminary design documents, and projected DIF initiative funding to see when productivity benefits could be attributed to DMAC. Table A-4 presents our assumptions about the productivity gains attributable to DIF and DMAC over the 15-year analysis period. The productivity gains shown in Years 1 through 6 are attributed to DIF development efforts. DMAC contributions begin in Year 7 and are assumed to reach maximum levels in Year 11, pending full operating capability certification.

[65] These assumptions will need to be reassessed in the economic analysis associated with the analysis of alternatives, which will be conducted following the establishment of detailed functional requirements.

Table A-4. DMAC Functional Value Attribution by Year

DMAC Functional Value by Implementation Year															
Implementation year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Data Discovery, Access, and Formatting Time Savings	10%	10%	25%	30%	35%	40%	60%	70%	80%	90%	100%	100%	100%	100%	100%
QA/QC Time Savings	0%	0%	0%	0%	0%	0%	50%	60%	70%	80%	100%	100%	100%	100%	100%
Coordination Costs Saved	10%	10%	25%	30%	35%	40%	60%	70%	80%	90%	100%	100%	100%	100%	100%

Note: Shaded years indicate productivity gains attributed to DIF.

To estimate the percent of functional value attributable to DMAC in each study year, we applied the following assumptions to our functional benefit categories:

- *Data Discovery, Access, and Formatting*: We assumed that early standards and observation registry efforts, as part of the DIF, would yield small, but increasing, benefits in the initial operating Years 1 through 6. In Year 7, the DMAC would become operational, which would further decrease the time that NOAA intermediary users need to spend on data discovery, access, and formatting issues. To be conservative, we assumed that the DMAC would take another four years after development to assume full capability for this functional category.
- *QA/QC*: We assumed that early development efforts would not reduce the time that NOAA intermediary users need to spend on QA/QC activities. Once the DMAC is fully implemented in Year 7, however, intermediary users would need to spend 50 percent less time on such activities. This savings would increase by 10 percent per year until Year 11, when the DMAC system assumes full capability for this functional category.
- *Coordination Costs*: We assumed that early development efforts would yield small, but increasing, savings for NOAA intermediary users in Years 1 through 6. Once the DMAC is fully implemented in Year 7, savings should increase to 60 percent and another 10 percent in each subsequent year. In Year 11, we assume that the DMAC will eliminate the need to conduct data coordination workshops, to resolve liability issues, and to communicate to providers how to connect to data streams.

GENERAL ASSUMPTIONS

This analysis is intended to provide decision-makers with an assessment of the risk associated with making a particular decision. While this analysis addresses the uncertainty associated with the collected data, it does not consider other uncertainties which were deemed to be of low risk. The following lists the assumptions included in the model which were not adjusted for risk.

- *Discount Rate*: model uses the OMB real discount rate of 2.7% to discount future costs and benefits over the 15-year capital investment lifecycle.
- *Study Period*: model assumes a 15-year planning horizon for evaluation of investment options. This allows investigation of the impacts of an operational solution.
- *Parameter Scaling*: applied parameter scaling rates at two points in the analysis. First, applied a risk adjusted scale rate to the productivity estimates from the WFOs. Second, applied a risk adjusted scale rate to CSC's productivity estimates. See the *Monetization and Scaling* section in this appendix for details.
- *Independence*: assumed productivity benefits are independent of each other; in other words, savings from one function does not necessarily lead to savings in another.
- *Resource Transfer*: assumed that DMAC implementation would enable transfer of resources from data management tasks to other equally or more important tasks. Under ideal circumstances, transfer tasks would include research or product development activities that enable NOAA to deliver increased societal benefits.
- *Accuracy of Productivity Inputs*: assumed participants had reasonable knowledge of level of effort required to perform data management activities.
- *Resource Costs*: assumed average cost of a fully loaded NOAA FTE is $150,000.

MONTE CARLO SIMULATION

In order to measure the uncertainty associated with model outputs, a form of Monte Carlo simulation was applied to the identified parameters. Monte Carlo simulation is a method of iteratively evaluating a deterministic model which varies the model inputs within identified parameter ranges to test the variability in model output.[66] This model uses Latin Hypercube simulation, which is similar to Monte Carlo, but selects the random inputs more efficiently. These simulation techniques are commonly used when the analysis involves multiple uncertain parameters.

[66] http://www.vertex42.com/ExcelArticles/mc/MonteCarloSimulation.html#ref.

Simulations were performed using the @RISK Excel add-in. @RISK provides a fast, repeatable method for performing thousands of iterations on a model of this type.[67] Simulations were run using the following settings:

Table A-5. @RISK Simulation Settings

Excel version	Microsoft Office 2003
@Risk version	4.5
Iterations	Auto
Auto-Stop Simulation Convergence Percentage	3.5
Sampling Type	Latin Hypercube
Standard Recalc	Expected value
Random Generator Seed	“Choose Randomly”
Collect Distribution Samples	All

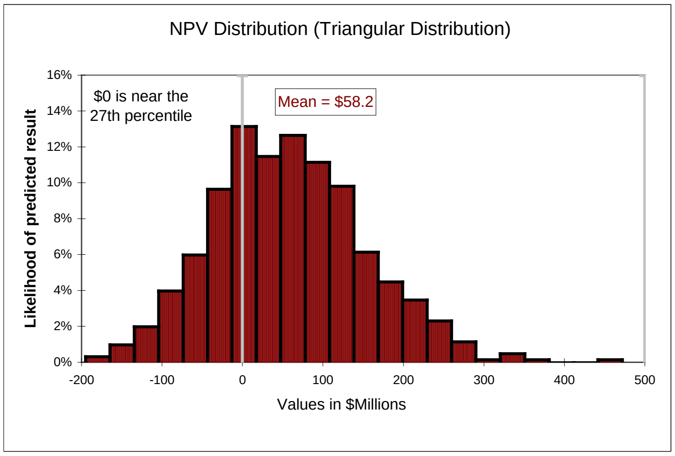
Model Outputs

The primary output from the model is Net Present Value (NPV). NPV is a yardstick that OMB and the private sector use to compare project options that involve cash flows—both benefits and costs—over multiple years. The NPV of a project is the present value of all anticipated cash flows expected over the project’s life. An NPV of zero means that, over the life of the option, total productivity gain equals total cost. In other words, for NPV = $0, all operations and start-up costs are covered by the total productivity gains generated, when both are adjusted by the discount rate.

The simulations run using triangular distributions estimated an average NPV between $56.4 and $59.9 million for DMAC implementation. Figure A-3 shows the range of potential NPV outcomes estimated by the model. The analysis also indicates that there is roughly a 73 percent probability that an investment in DMAC will return a NPV of zero or greater. At the far ends of the distribution, $ -194 million and $472 million both have a 0.25 percent probability of occurrence.

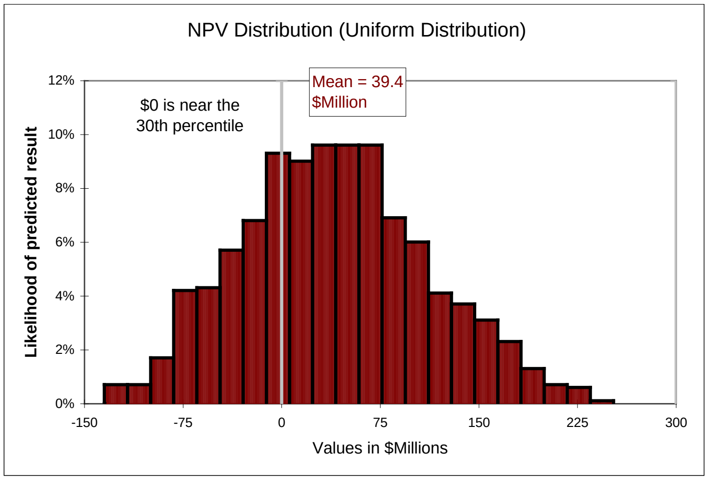
[67] Following completion of this business case, inconsistencies were identified between the results produced by Palisade @RISK version 4.5 and @RISK version 5.0. Specifically, the two versions did not produce similar convergence results. Research conducted with the software developer determined that version 5.0 has additional features not available in version 4.5 that impact the way simulations are performed. However, additional testing of the model confirmed that this design change does not significantly affect NPV estimates.

Figure A-3. DMAC NPV Distribution using Triangular Distributions



Using uniform distributions, the model estimated an average NPV between $38.2 and $40.6 million for DMAC implementation. Figure A-4 shows the range of potential NPV outcomes estimated by the model. The analysis also indicates that there is roughly a 70 percent probability that an investment in DMAC will return a NPV of zero or greater. At the far ends of the distribution, $ -134 million and $252 million both have a 0.25 percent probability of occurrence.

Figure A-4. DMAC NPV Distribution using Uniform Distributions



APPENDIX B. REFERENCES

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