EXPLORE

NOAA Office of Ocean Exploration and Research

Independent Review of the Ocean Exploration Program 10 Year Review 2001 - 2011

Draft: May 21, 2012

This document was prepared for the external panel which reviewed the NOAA Ocean Exploration Program on May 7-8, 2012. As such, it provides a succinct and objective overview of the first 10 years of the program. The NOAA Ocean Exploration Program considers this a 'living document' and will be updating specific sections and adding material in response to the discussions that took place during the review.

Acknowledgements

April 26, 2012

Dear Review Team Member,

Thank you for participating in the program review of the National Oceanic and Atmospheric Administration's (NOAA) Ocean Exploration Program. I appreciate your willingness to participate in this important effort to review the relevance, performance and quality of this critical program.

In 2000, the President's Panel on Ocean Exploration issued its seminal report, which called for a "national program in ocean exploration in which discovery and the spirit of challenge are the cornerstones." The Panel also called for the designation of a lead agency to be in charge of the program and accountable for its success, and thus was born the NOAA Ocean Exploration Program. The Program was codified in 2009 under Public Law 111-11 with the responsibility of coordinating a national ocean exploration program to promote collaboration with other Federal ocean and undersea research and exploration programs.

And so, it is fitting at this time to review the Program after a decade of ocean exploration. We ask that you consider past performance, but more importantly, advise NOAA on the future of the Ocean Exploration Program and recommend steps to strengthen the Program and its leadership of the U.S. ocean exploration enterprise over the next decade.

I cannot overemphasize the critical importance of this review—to focus on how we can move towards a truly national ocean exploration program across Federal agencies and the increasingly important stakeholders outside of the government.

Again, thank you for participating in this review. I look forward to meeting you and working with you on this initiative.

Sincerely,

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Director, NOAA Office of Ocean Exploration and Research

Independent Review of the Ocean Exploration Program
10 Year Review: 2001 - 2011

May 2012

National Oceanic and Atmospheric Administration
Ocean and Atmospheric Research

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May 7–8, 2012

1. Introduction

This document describes the National Oceanic and Atmospheric Administration (NOAA) Ocean Exploration Program—how it was formed, how it has evolved and how it functions. It provides detailed descriptions of the Cornerstones and Foundational Elements of the NOAA Ocean Exploration Program, as well as examples of how key investments and activities have addressed the recommendations made in the Report of the President's Panel on Ocean Exploration (President's Panel Report [2000]). Strengths, weaknesses, opportunities, and challenges are presented and discussed. Finally, recent and ongoing efforts to continue to evolve the NOAA Ocean Exploration Program in order to renew interest in establishing a national strategy and capability for ocean exploration are described.

This document provides critical information to a panel of experts that will convene in Silver Spring, Maryland, on May 7–8, 2012, to conduct the first formal, independent review of the NOAA Ocean Exploration Program. The panel is charged with reviewing the relevance, performance and quality of the program with regard to the President's Panel Report, as well as Public Law 111-11, Title XII (Oceans), Subtitle A (Ocean Exploration), Part I (Exploration), which authorized a NOAA Ocean Exploration Program (2009).

2. NOAA Ocean Exploration Program Overview

2.1 What is Exploration?

As described in the President's Panel Report, ocean exploration is defined as "discovery through disciplined diverse observations and the recording of the findings. An explorer is distinguished from a researcher by virtue of the fact that an explorer has not narrowly designed the observing strategy to test a specific hypothesis. A successful explorer leaves a legacy of new knowledge that can be used by those not yet born to answer questions not yet posed at the time of the exploration." Above all, the overarching purpose of ocean exploration is to increase our knowledge of the ocean environment; its features, habitats, and species; and how it functions as part of the global ecosystem.

In practice, the NOAA Ocean Exploration Program adopted and continues to promote an approach to engage teams of scientists representing multiple disciplines to explore unknown and poorly known ocean areas and phenomena. This approach also includes recruiting natural resource managers, educators, journalists, documentary filmmakers, and others to join expeditions and provide a unique perspective on the areas being investigated. The objective is to generate a comprehensive characterization of the area and phenomena explored, providing a rich foundation to stimulate follow-on research, as well as new lines of scientific inquiry.

2.2 Organization

2.2.1 Mission

The mission of the NOAA Ocean Exploration Program is to evolve and sustain a national program and multifaceted capability to explore the world's ocean, and to provide cutting-edge products and services that provide an accessible legacy of information—information that others can build upon. By investigating new areas and phenomena and catalyzing key research to transform discoveries to useful knowledge, the NOAA Ocean Exploration Program provides a foundation of information to help the Nation respond to new and emerging issues.

2.2.2 Position within NOAA

The NOAA Ocean Exploration Program is part of the NOAA Office of Oceanic and Atmospheric Research (OAR), which provides NOAA and the Nation with a focused capability for enhancing our knowledge of complex Earth systems. The NOAA Ocean Exploration Program aligns with the NOAA Next Generation Strategic Plan as part of the Science and Technology Enterprise, and provides critical baseline information to help NOAA meet long-term goals for sustaining healthy and productive marine ecosystems. In essence, the NOAA Ocean Exploration Program is a critical part of the NOAA community, which serves the Nation by helping to ensure wise ocean environmental stewardship and appropriate utilization of marine resources.

The NOAA Ocean Exploration Program was established in 2001 and is part of the NOAA Office of Ocean Exploration and Research (OER), which includes the National Undersea Research Program (NURP). Created in 2007, OER was designed to provide NOAA and the Nation with a unique capability to explore new ocean areas and phenomena, as well as a means to align purposeful and focused research with important discoveries—in essence, catalyzing research (Fig. 1).

Today, the NOAA Ocean Exploration Program is organized into discrete product lines,

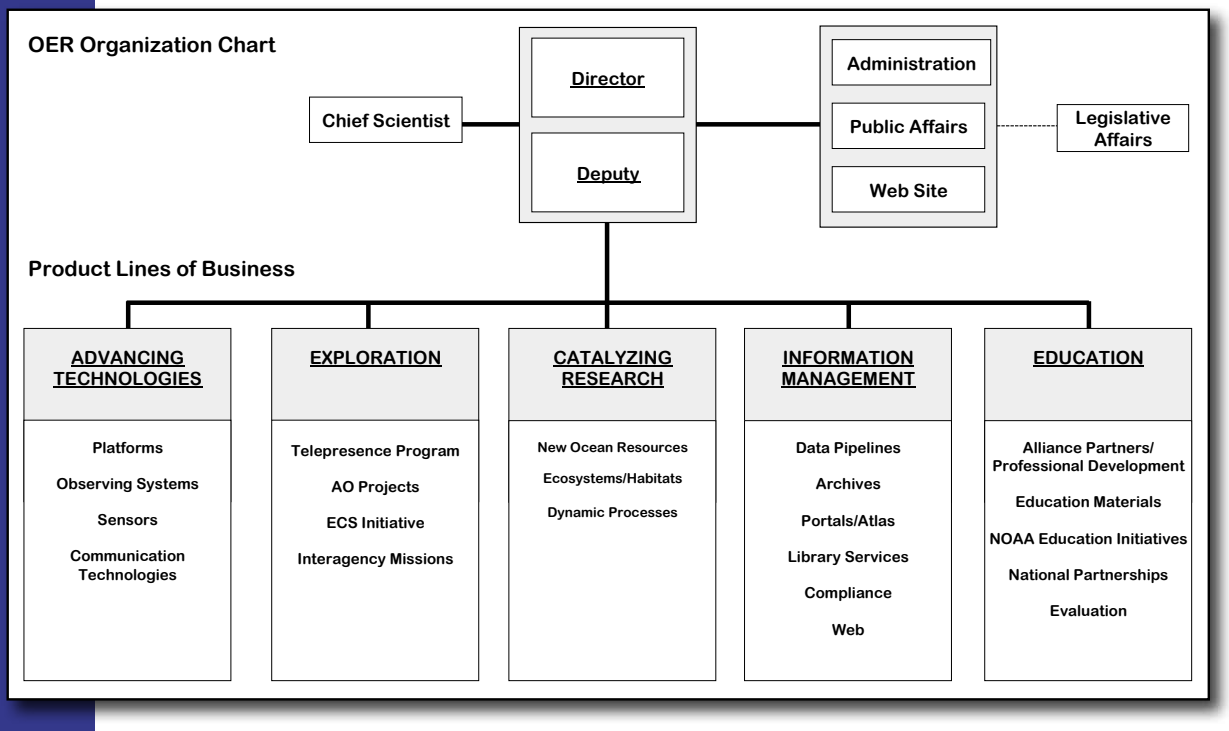


Figure 1. NOAA Ocean Exploration and Research Program Organization Chart.

including:

- Exploration: revealing the unknown;
- Advancing Technologies: increasing the pace, efficiency, and ability to explore;
- Catalyzing Research: building on and expanding the value of discoveries;
- Information Management: archiving and disseminating information and results; and
- Education and Outreach: engaging a broad spectrum of audiences and users.

To ensure the vessels, submersibles, tools and technologies required to support expeditions are available, OER also supports an operations team to work with the NOAA Fleet, UNOLS, and other providers. This team developed procedures and guidelines tailored to working directly with the multidisciplinary teams to plan and execute expeditions, and to develop and disseminate summary results. Furthermore, this team has evolved to meet the program's operational responsibilities for the mission systems integrated on the NOAA Ship *Okeanos Explorer*.

2.2.3 Partnerships

The NOAA Ocean Exploration Program is the only Federal program focused on and funded to explore unknown and poorly known ocean areas and phenomena—an inherently high-risk venture. The NOAA Ocean Exploration Program recognizes and embraces ocean exploration as a process requiring the involvement of multiple scientific disciplines and the capabilities and expertise of multiple institutions to fully meet the objective of improving our understanding of the ocean. As such, the NOAA Ocean Exploration Program has nurtured and evolved both formal and informal partnerships over the years with other NOAA programs, Federal agencies, academic institutions, non-governmental organizations, business, industry and others that share similar objectives.

These partnerships reflect every face of the program. For example, through a formal partnership with the Naval Undersea Warfare Center (NUWC) the program has invested in several efforts focused on new undersea technologies and sensors. Likewise, through a mosaic of formal and informal arrangements with institutions, such as the Sea Research Foundation's Institute for Exploration (IFE), the University of Rhode Island (URI), and the University of New Hampshire (UNH), the NOAA Ocean Exploration Program is collaboratively breaking new ground in developing a new model for systematically exploring remote ocean areas through telepresence, described in detail below.

2.2.4 History and Evolution of the NOAA Ocean Exploration Program

Over the past 11 years, using the recommendations in the President's Panel Report and other guiding documents, the NOAA Ocean Exploration Program has evolved to focus on four Cornerstones, or major areas of investment:

- targeted exploration;
- systematic telepresence-enabled exploration;
- Extended Continental Shelf (ECS) mapping; and
- baseline characterization through interagency partnerships.

The following provides an overview of how the program has evolved and the major

attributes of each Cornerstone. It is important to note that each of these exploration Cornerstones reflect all aspects of the NOAA Ocean Exploration Program, including activities related to advancing technologies, catalyzing research, informing resource management, information management, and education and outreach. In addition to the Cornerstones, the NOAA Ocean Exploration Program has always invested in two Foundational Elements: information management and product development; and engagement. Each of these is described in more detail later in this report.

2.2.5 Cornerstone 1: 2001–Present, Targeted Exploration

The NOAA Ocean Exploration Program was established in 2001 in response to the recommendations and challenges set forth in the President's Panel Report, and in recognition of the value such a program could provide to NOAA and the Nation. Adopting the key recommendations in the report, NOAA created a program to map and characterize unknown and poorly known areas, and to investigate new phenomena, dynamic ocean properties and processes at multiple spatial and temporal scales.

Guiding Documents

- President's Panel Report
- NRC Report on Exploration of the Seas
- U.S. Commission on Ocean Policy Report
- Public Law 111-11
- NOAA Strategic Plan
- National Ocean Priorities Plan

A series of workshops was held during the first year of the NOAA Ocean Exploration Program to engage the science community and other interested users in identifying priority areas to explore within specific geographic regions. These included poorly known areas suspected to be of interest in terms of geology, biology, ecology, and maritime history, as well as areas thought to exhibit unique oceanographic characteristics. The results of these workshops were used to develop annual Announcements of Opportunity (AO), encouraging teams of scientists to submit ocean exploration proposals for review.

Following the guidelines in the President's Panel Report, the results of the regional workshops and NOAA priorities for areas to be explored, applicants to the AO are encouraged to submit proposals related to general exploration and maritime archaeology. Proposals focused on new and innovative use of undersea technologies for exploration also have been entertained. Using the National Science Foundation (NSF) process as a model, proposals are peer reviewed and recommendations made for funding. Final funding recommendations by the Program Director are based on rank order from the peer-review panel unless justified using the following criteria that are listed in the Federal Register Notice each year:

- Availability of funding;
- Balance/distribution of funds;
- Geographically—includes ship availability;
- Type of institutions;
- Type of partners;
- Research areas;
- Project types;
- Whether the proposal duplicates other proposals funded or considered for funding by NOAA or other Federal agencies;
- Program priorities and policy factors;
- Applicant's prior award performance;
- Partnerships and/or participation of targeted groups; and
- Adequacy of information necessary for NOAA staff to make a NEPA determination.

A key component of the NOAA Ocean Exploration Program Targeted Exploration

approach is that all proposals—those developed by the external science community and those developed by NOAA scientists—are vetted through the same peer-review process.

Outputs from the NOAA Ocean Exploration Program Targeted Exploration effort are the peer-reviewed journal articles prepared by the applicant and the science team. A bibliographic–citation analysis based on articles available through the Web of Science is presented in Appendix 1. Worth noting is the analysis discovered 362 publications with a total of 3,442 citations and an average of 9.45 citations per publication. The H-Index for this analysis was 27. Other important outputs include metadata and data derived from the expeditions and projects, which are available through the NOAA National Archive Centers and the NOAA Central Library.

2.2.5.1 Status

Although the NOAA Ocean Exploration Program has funded 330 expeditions and projects over the past 11 years, there has not been an Announcement of Opportunity since 2010. Reduced budgets, growing responsibilities related to other investment areas, and unanticipated costs to secure access to NOAA-owned ships that were previously available at no cost to the program have contributed to deferring investments in this area. However, targeted exploration continues to occur at a much-reduced level as the program funds a small number of multi-year exploration grants that were awarded through this process. The NOAA Ocean Exploration Program intends to renew this effort in 2013, but at a reduced level of approximately $1M.

Targeted Exploration addresses all four of the exploration priorities recommended in the President's Panel Report:

(1) to map and characterize new ocean areas;
(2) to explore ocean dynamics and interactions;
(3) to develop new technologies; and
(4) to reach out in new ways to stakeholders.

2.2.6 Cornerstone 2: 2005–Present, Systematic Telepresence-enabled Exploration

As the NOAA Ocean Exploration Program grew between 2001 and 2005, attention was given to acquiring a NOAA ship dedicated to ocean exploration. The program engaged the NOAA Fleet, UNOLS community, internal and external scientists, and others to determine base requirements for an exploration vessel and to identify available platforms. At the same time, the program entered into a formal Joint Project Agreement with the Institute for Exploration to bring such a vessel online, and to use it to implement a new paradigm for ocean exploration and research based on cutting-edge telepresence technology—specifically, allowing teams of shore-based scientists and other stakeholders to guide expeditions from shore-based "Exploration Command Centers" as opposed to being confined to a ship. This new model for ocean exploration was designed to collect information in a systematic standard manner, and to disseminate the results as widely as possible in real- and near-real time.

In 2005 at the direction of Congress, NOAA received a USN T-AGOS vessel and $17M to convert it to a dedicated exploration vessel. Working with the NOAA Office of Marine and Aviation Operations (OMAO), the program engaged scientists,

engineers, technicians, ship operators and other knowledgeable experts to define the requirements for the vessel, focusing on three key mission capabilities: (1) multibeam mapping and the ability to insonify the water column; (2) deepwater dual-body ROV (remotely operated vehicle) operations; and (3) telepresence communications to enable broad-band transmission of information including high-definition video from the ROV and ship to shore. In 2008 after undergoing conversion, the vessel was dedicated the NOAA Ship *Okeanos Explorer*, and is now engaged in its third full field season.

Concurrently, through Congressional earmarks and other public and private investments, the shore-based infrastructure, including the Inner Space Center at the University of Rhode Island Graduate School of Oceanography, was created, providing the network capabilities for engaging shore-based scientists and other stakeholders. In addition, the Ocean Exploration Trust has brought a similarly equipped exploration vessel online, the E/V *Nautilus*, which also conducts telepresence-enabled expeditions using the Institute for Exploration network. Through the Joint Project Agreement with the Institute for Exploration, the NOAA Ocean Exploration Program has been making investments in the shore-based infrastructure and network, as well as exploratory missions conducted by the *Nautilus*.

Unlike the NOAA Ocean Exploration Program Targeted Exploration effort, the *Okeanos Explorer* and *Nautilus* do not operate in support of individual peer-review projects with a specific set of objectives. In contrast, the systematic telepresence-enabled approach enables the vessels to explore unknown and poorly known areas with communities of scientists and other stakeholders contributing in real-time. In essence, the ships conduct expeditions that establish a comprehensive foundation of data, information, observations, reports and publications that support a wide variety of projects, and catalyze follow-on exploration and research focusing on specific discoveries and attributes of the area explored.

Target areas to be explored are identified by the science community and others in open and participatory workshops, which allow participants to share ideas and provide recommendations on areas that should be explored using this approach, and for the express purpose of benefiting the science community at large as opposed to individual scientists. Appendix 2 describes the workshop process.

The primary outputs from this effort include all of the data and information collected: high-definition video and still images; multibeam bathymetry, backscatter, and water column data; oceanographic data sets collected from sensors on and deployed from the ship and ROV; and the event logs generated in a blog environment. The NOAA Ocean Exploration Program is also in the process of working with the core team of scientists assembled to guide each mission to design a summary report similar to a USGS "open file report." Of course the most unique aspect of this effort is the outputs are available in real- or near-real time.

2.2.6.1 Status

The NOAA Ship *Okeanos Explorer* is fully operational. A dedicated ROV system is in the final stages of development and is anticipated to engage in operations in 2013. Meanwhile, the NOAA Ocean Exploration Program continues to use the Little Hercules ROV, which is on loan from IFE. The NOAA Ocean Exploration Program is responsible for operating and maintaining the mission systems and has engaged a core team of professionals to conduct multibeam mapping, ROV, and telepresence operations, as well as to oversee the planning and execution of each mission. This includes engaging teams of scientists to work on the ship and at the shore-based Exploration Command Centers.

The Ocean Exploration Trust vessel *Nautilus* is fully operational, and has been focusing on missions in the Black and Mediterranean Seas over the past three years. The *Nautilus* is currently equipped for sidescan sonar surveys, deepwater dual-body ROV operations, and telepresence, and is scheduled to have a multibeam mapping system installed in the next year. Through the Joint Project Agreement, the NOAA Ocean Exploration Program invests in approximately three months of missions focused on exploring undersea habitats and submerged cultural resources.

Systematic Telepresence-enabled Exploration addresses all four of the exploration priorities recommended in the President's Panel Report:
(1) to map and characterize new ocean areas;
(2) to explore ocean dynamics and interactions;
(3) to develop new technologies; and
(4) to reach out in new ways to stakeholders.
It also meets the objective of dedicating a ship to ocean exploration.

2.2.7 Cornerstone 3: 2006–Present, Interagency Baseline Characterization

In 2005, the NOAA Ocean Exploration Program partnered with the Bureau of Ocean Energy Management (BOEM) under the auspices of the National Oceanographic Partnership Program (NOPP) to explore and characterize deepwater biological communities and submerged cultural resources in the Gulf of Mexico beginning in 2006. The objective is to provide BOEM with critical information to manage oil and gas activities, as well as to provide information to NOAA required to meet ecosystem-based management responsibilities. Through this partnership, BOEM conducts a peer-review process to select and fund scientists, while the NOAA Ocean Exploration Program provides the ships and submersibles to conduct the work. The effort has been very successful and the partnership has been extended to conduct similar operations in the Mid-Atlantic Bight.

Priority areas to be explored are established by BOEM with input from the NOAA Ocean Exploration Program, and the NOAA Ocean Exploration Program participates in drafting the request for proposals, as well as the peer-review and selection process. As the science is funded through BOEM, the primary output is a detailed report of the investigations and results, which is available to both agencies.

2.2.7.1 Status

Since 2006, the NOAA Ocean Exploration Program and BOEM have conducted five major expeditions in the Gulf of Mexico locating and investigating deepwater chemosynthetic and coral communities, as well as shipwrecks. A final mission is planned for 2012 to explore deepwater biological communities associated with oil and gas platforms. In 2011, a 3-year effort to investigate the system of canyons intersecting the continental shelf along the Mid-Atlantic Bight was initiated, using the same model developed for this work in the Gulf of Mexico.

The Interagency Baseline Characterization missions meet the President's Panel Report recommendation to map and characterize new ocean areas. The NOAA Ocean Exploration Program also has successfully used these missions to reach out in new ways to stakeholders.

2.2.8 Cornerstone 4: 2008–Present, Extended Continental Shelf Mapping

In 2008, the NOAA Ocean Exploration Program received an increase in funding to lead an interagency effort to map the potential extension of the U.S. continental shelf using the criteria outlined in the UN Convention on the Law of the Sea (UNCLOS), Article 76. The objective of the Extended Continental Shelf (ECS) effort is to establish the fullest extent of the U.S. continental shelf over which we may exercise sovereign rights, consistent with international law, and signifies the largest and potentially most significant interagency marine survey ever undertaken by the U.S. Although the U.S. is not yet a signatory to UNCLOS, the Bush and the Obama Administrations, as well as Congress, recognized the value of mapping this area and improving our understanding of its living and non-living marine resources. The effort also is a priority for NOAA and the NOAA Ocean Exploration Program as exploring and mapping this area enhances our overall knowledge of the seafloor and ocean processes, and provides a foundation and framework for targeting future exploration and research.

An interagency task force led by the Department of State, NOAA and the Department of Interior enabled partners to develop a strategy and plan for acquiring the critical data and information, design the required databases and repositories, engage knowledgeable experts in interpreting information and conducting analyses for determining potential extensions, and to increase the pace and efficiency of the entire process. Furthermore, since most of the data has been collected, the NOAA Ocean Exploration Program and partners are now poised to use future ECS funds to initiate follow-on efforts to further explore and investigate high-priority targets that can be identified in the data.

Priority areas for this effort have been identified in a continuing series of reports developed by the Center for Coastal and Ocean Mapping Joint Hydrographic Center (CCOM/JHC) at the UNH—a partnership between NOAA and the university. These reports, as well as a project plan developed by the ECS Task Force, have continued to guide data acquisition efforts. Having a detailed list of priority areas has enabled the NOAA Ocean Exploration Program to leverage opportunities to meet multiple ocean exploration objectives. For example, while field-testing the EM-302 multibeam mapping system on the *Okeanos Explorer*, the program mapped much of the Mendocino Ridge off California, simultaneously meeting objectives for telepresence-enabled exploration, as well as ECS. Furthermore, this effort proved to meet the

objectives of other programs and Federal agencies, such as the NOAA Pacific Marine Environmental Laboratory's (PMEL's) Vents Program.

The primary outputs from the ECS effort transcend digital bathymetric maps and the preliminary regional analyses now taking shape. They include a rich series of descriptive reports summarizing the findings from each expedition, as well as compilation reports describing each region. Many of these products are available at the CCOM/JHC Law of the Sea website: http://ccom.unh.edu/theme/law-sea.

2.2.8.1 Status

Since 2008, the NOAA Ocean Exploration Program has supported eight expeditions as part of the ECS effort in the Atlantic, Pacific, and Arctic oceans, mapping approximately 700,000 square kilometers of ocean bottom in high resolution. Close to 200,000 square kilometers have been mapped in the Arctic alone during a series of four cruises in collaboration with Canada, using the USCG icebreaker *Healy* to acquire multibeam data, and the Canadian vessel *Louis S. St-Laurent* to collect multichannel seismic data. Another Arctic cruise is scheduled in 2012, which should complete most of the bathymetric work required in the Arctic, and a cruise is also scheduled for the U.S. east coast.

The NOAA Ocean Exploration Program has also supported the development of an interactive database system at the NOAA National Geophysical Data Center, designed to provide teams of scientists with the capabilities to perform the necessary analyses for each region to determine the maximum potential extension using the formula outlined in Article 76. A preliminary analysis has been completed for each region, which will help guide any additional mapping missions that may be required to fill in key gaps, as well as to begin the preparation of formal materials that could be used for a submission to the UN.

The ECS mapping effort meets the President's Panel Report recommendation to map and characterize new ocean areas.

2.2.9 Foundational Elements

In addition to the Cornerstones discussed above, the NOAA Ocean Exploration Program has always invested in two Foundational Elements: information management and product development; and engagement through education and outreach.

Since the inception of the program, the NOAA Ocean Exploration Program has engaged a cross-NOAA Line and program office team comprised of resident experts in data and information management and dissemination, as well as staff from the NOAA National Data Archives. This team developed the innovative tools and techniques required for ensuring information collected under each cornerstone activity meets national standards, is archived appropriately, and is made available to catalyze further exploration, research, natural resource management, and education and outreach. The team's efforts have always been designed to ensure transferability to other endeavors, and they now play a lead role in NOAA and interagency 'rolling deck to repository' (R2R) efforts. Furthermore, their expertise has been instrumental to meeting the new challenges presented by telepresence-enable exploration.

Also from the very start of the program, NOAA Ocean Exploration Program developed

a dedicated education and outreach program and capability to meet the President's Panel recommendation to engage learners of all ages and backgrounds in new and innovative ways in order to improve ocean literacy. This team has developed key internal and external partnerships focused on formal education and public engagement through professional education communities, museums and aquaria, and relationships with media outlets such as the National Geographic Society, the Discovery Channel, and Google. This team has also designed and developed the award winning NOAA Ocean Explorer website. Like the data and information management team, this team continues to evolve its activities and products in new and innovative ways in response to the NOAA Ocean Exploration Program Cornerstones.

2.3 Budget

2.3.1 Overview

Over the past 10 years, the NOAA Ocean Exploration Program budget has ranged from a low of $13.1M to a high of $23.6M, with an average of $16.8M. However, the budget has varied significantly from year-to-year. As depicted in Figure 2, in 2005 the program received an unexpected one-time increase, which was used to support a signature expedition in the Arctic, building on a successful expedition in 2002, as well as to make initial investments in a dedicated ROV and telepresence technology for the NOAA Ship *Okeanos Explorer*. In 2008, the NOAA Ocean Exploration Program received an adjustment to base of $3.4M to lead the interagency ECS Mapping initiative, and in 2010 the program received a one-time increase to support telepresence-enabled expeditions using the *Okeanos Explorer* and the *Nautilus*. Efforts to establish an increase to base to support telepresence-enabled exploration have not been successful to date.

In summary, between 2002 and 2004 the program focused exclusively on targeted

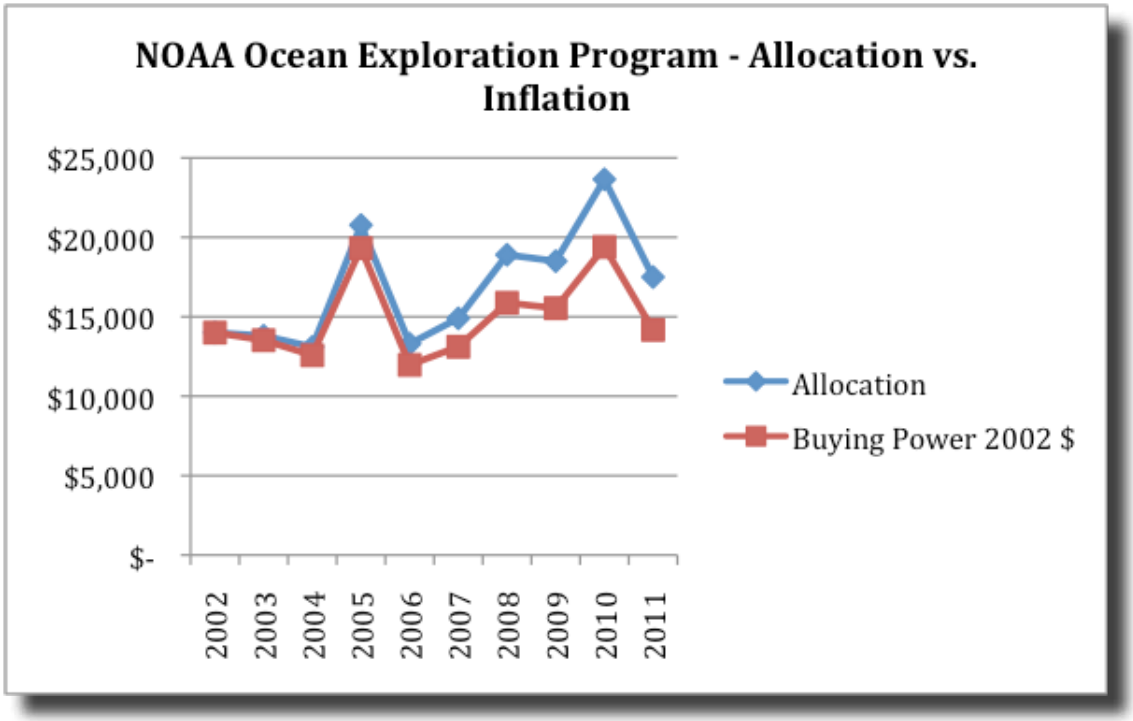


Figure 2. Allocation vs. Inflation (value of 2002 dollar), 2002-2011.

exploration through the annual announcement of opportunity and peer-review proposal process, and has since evolved to engage in the other three Cornerstone activities. The combination of a vacillating budget and one-time increases has made it challenging to achieve stability and to meet the program's responsibilities for each Cornerstone, and over time, investments in targeted exploration, including investments in UNOLS and charter vessels, have decreased substantially.

2.3.1.1 Key Investments

Figure 3 provides more detail on the distribution of investments in the Cornerstones and Foundational Elements of the program between 2002 and 2011. The shift in investments in targeted exploration (89% of the budget in 2002) to the combination of investments in telepresence-enabled exploration, ECS, and the interagency expeditions with BOEM (83% of the budget in 2011) is apparent. While each of the Cornerstones results in similar outputs and outcomes, note the investment in the *Okeanos Explorer* between 2005 and 2008 (average of 28% of the budget per year) was primarily dedicated to capital-cost investments in ship conversion and the mission systems required for conducting telepresence-enabled exploration. Over time, the NOAA Ocean Exploration Program investments in education and outreach, as well as information management and dissemination, have remained fairly constant between 5% and 7% of the overall budget.

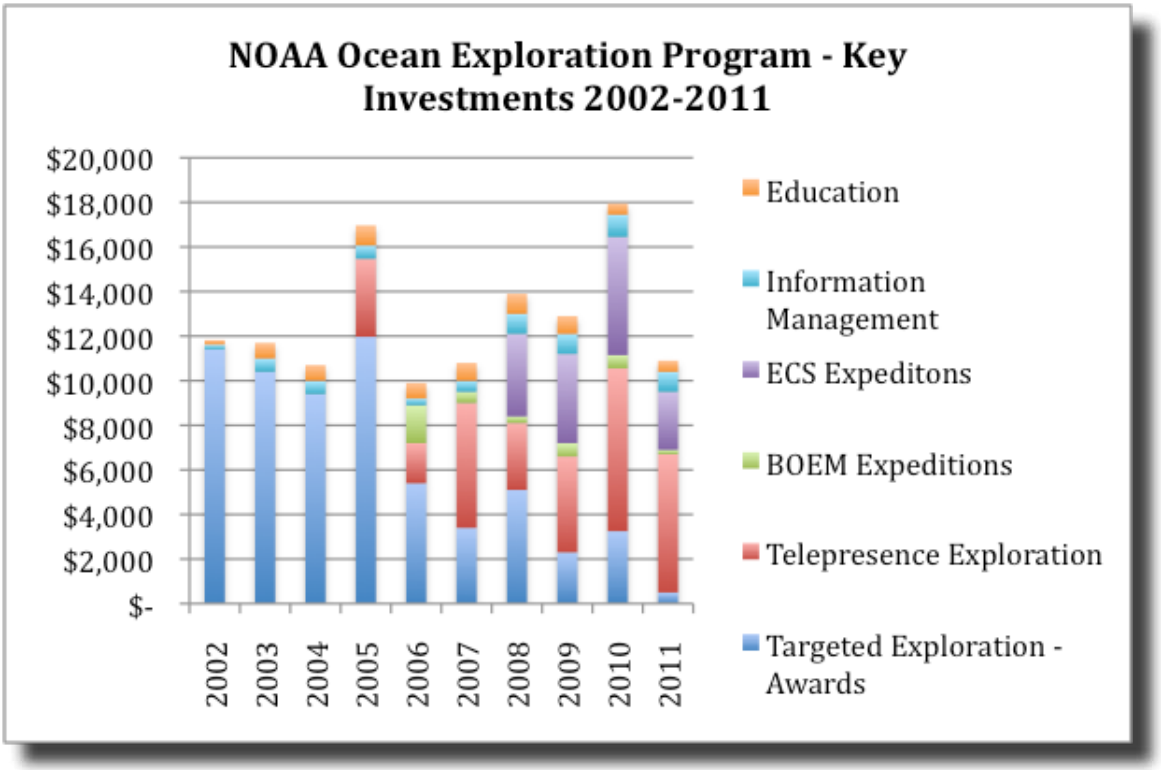


Figure 3. Distribution of Key Investments, 2002–2011.

2.3.1.2 Investment in Peer-Reviewed Proposals

Since the inception of the program, the NOAA Ocean Exploration Program implemented a process that required NOAA and non-NOAA scientists to prepare proposals for peer-review to make informed decisions on which proposals should be awarded funds. Not only did this establish a common framework for evaluating all

proposals, it encouraged scientists from many different institutions and disciplines to team together in drafting proposals. Figure 4 depicts the NOAA Ocean Exploration Program investment in external and internal (NOAA) awards in terms of the institution receiving the funding. It is important to note that regardless of whether the award was made externally or internally, in many cases the team involved in the project included both NOAA and non-NOAA scientists.

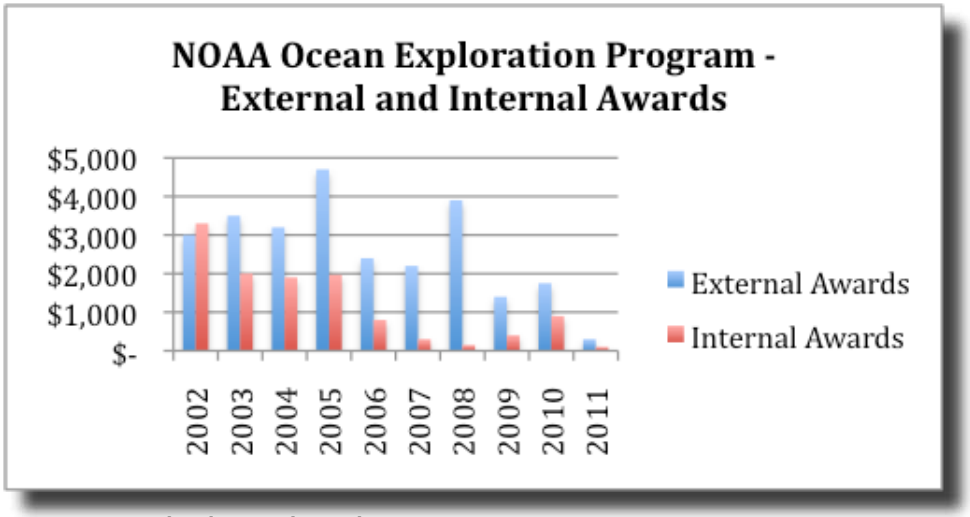


Figure 4. External and Internal Awards, 2002-2011.

2.3.1.3 Noncompetitive Awards

In terms of noncompetitive awards related to targeted exploration (awards or investments not related to telepresence-enabled exploration, ECS, or the interagency partnership with BOEM), the NOAA Ocean Exploration Program has made some minimal, but important investments in a variety of activities over the years (Fig. 5). For example, in 2002 the NOAA Ocean Exploration Program partnered with the U.S. Navy and the NOAA National Marine Sanctuary Program on an effort focused on advanced diving technologies and techniques required for assessing the condition

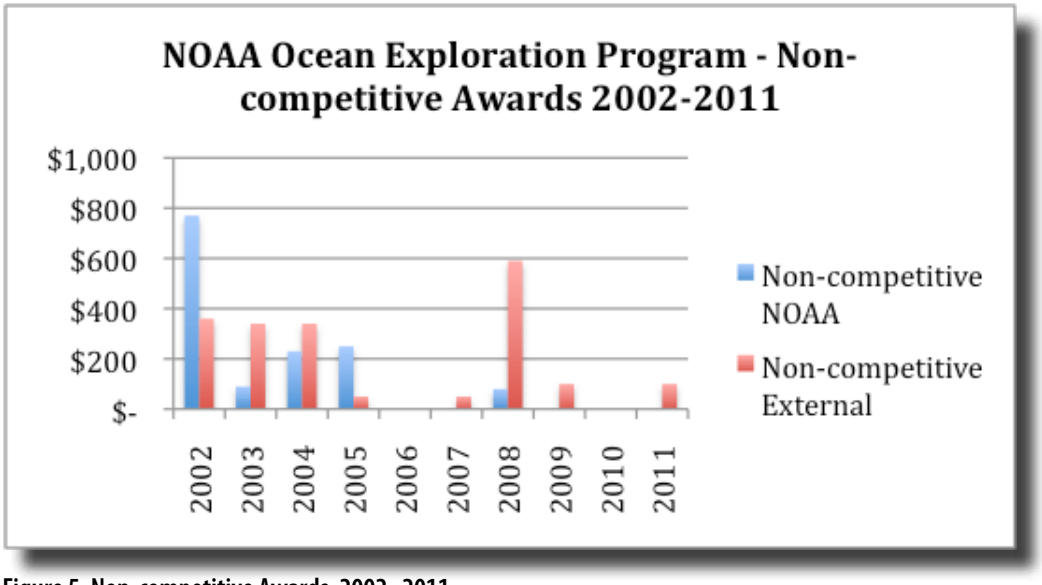


Figure 5. Non-competitive Awards, 2002–2011.

of and raising the turret of the USS Monitor. Other examples include investments leveraging funds from other partners, such as the Naval Undersea Warfare Center (NUWC) for efforts focused on advanced undersea technologies, support for activities and conferences related to the Census of Marine Life (CoML), and in 2008, an AUV Festival in collaboration with NUWC and the NSF that brought together experts in undersea warfare and maritime archaeology to test AUVs and sensors for imaging submerged shipwrecks. Finally, the NOAA Ocean Exploration Program has contributed non-competitive funds in support of the Alvin submersible, as well as the development of the *Nereus* hybrid ROV.

2.3.1.4 Okeanos Explorer

In 2004, Congress directed the U.S. Navy to provide NOAA a T-AGOS vessel and $17M to convert the ship to the first NOAA vessel dedicated to ocean exploration. The conversion process and investment of these funds were managed by OMAO with significant input from the NOAA Ocean Exploration Program and external experts and partners the program engaged (Fig. 6). Between 2005 and 2007, the NOAA Ocean Exploration Program made further investments of base funds in developing and integrating the mission systems required for telepresence-enabled exploration, and made additional investments in ship infrastructure and upgrades to make up OMAO budget shortfalls.

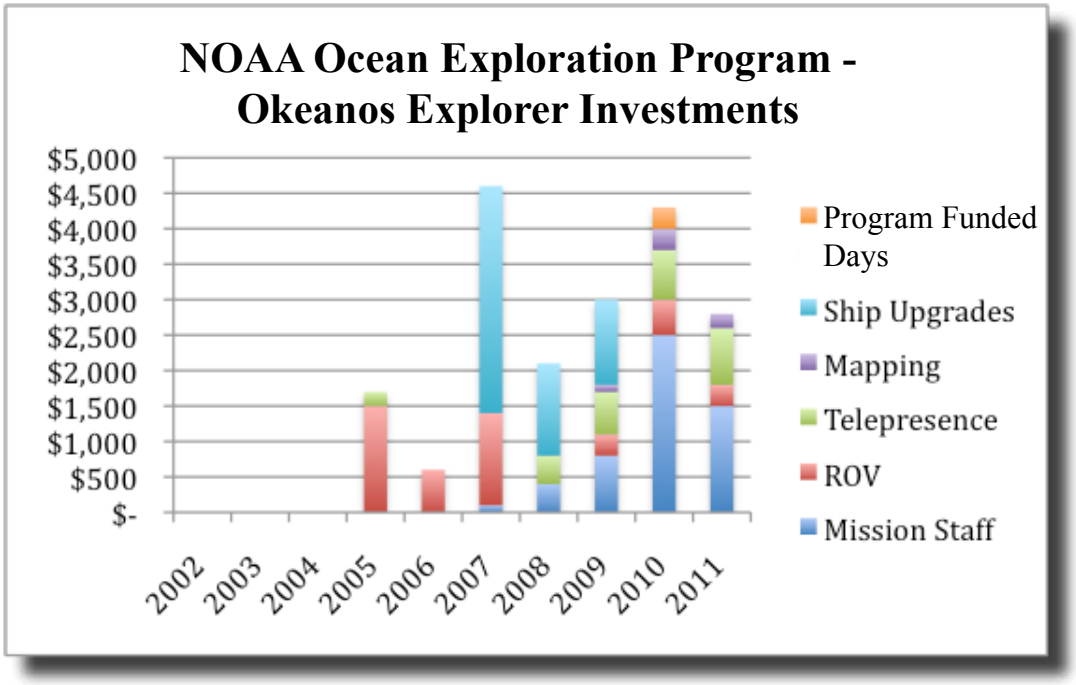


Figure 6. Okeanos Explorer Investments, 2005–2011.

In 2008, investments were made in completing upgrades to the ship and ensuring ABS (American Bureau of Shipping) compliance, completing the integration of the mission systems, and field testing the multibeam mapping and telepresence systems for delivering information and products in support of ECS and other exploration objectives. Investments in 2009 focused on continuing to field test the ship and mission systems through a series of exploration missions, and since 2010 the *Okeanos Explorer* has been fully operational conducting successful expeditions

off Indonesia, off the U.S. east and west coasts, in the vicinity of the Galapagos spreading center, on the Cayman Rise, and in the Gulf of Mexico.

Starting in 2005, the NOAA Ocean Exploration Program also made complementary investments in collaboration with the Institute for Exploration (IFE) to continue to build the shore-based infrastructure required for telepresence-enabled exploration, as well as in conducting these types of expeditions using the IFE fly-away systems on ships of opportunity (Fig. 6). This allowed the NOAA Ocean Exploration Program, IFE and the science community to develop procedures and protocols for these types of missions while exploring unknown and poorly known ocean areas. The NOAA Ocean Exploration Program continues to invest in telepresence-enabled expeditions off the *Nautilus*, further refining and evolving the telepresence model. This is a highly leveraged activity whereby IFE matches the NOAA Ocean Exploration Program investment dollar-to-dollar.

2.4 NOAA Ocean Exploration Program Challenges

Although the NOAA Ocean Exploration Program has been quite successful in evolving an ocean exploration program focused on the recommendations in the President's Panel Report, the budget environment continues to be challenging. Vacillating budgets, a series of continuing resolutions, and receiving a budget late in the fiscal year (late June in the case of 2011) have made it extremely difficult to achieve the stability required to run a successful and evolving program, and to fully meet growing responsibilities related to operating and maintaining the mission systems on the *Okeanos Explorer*. However, the NOAA Ocean Exploration Program continues to leverage partnerships to advance each facet of the program, with the exception of targeted exploration through peer-reviewed proposals.

The NOAA Ocean Exploration Program continues to be challenged by difficulties in acquiring the personnel required to meet growing responsibilities. Since 2004, the NOAA Ocean Exploration Program has evolved from a program focused only on managing targeted exploration projects based on peer-review, to a program engaged in telepresence-enabled exploration, ECS, and interagency partnerships, but has not experienced a commensurate growth in staff. This is primarily due to an unstable and now shrinking budget. However, the program continues to leverage partnerships both internally and externally to address this issue as best possible.

Given the state of the economy and shrinking Federal budgets across the board, the NOAA Ocean Exploration Program is challenged by over-reliance on partners whose own decisions may negatively impact the program. For example, in the case of the *Okeanos Explorer*, the NOAA Ocean Exploration Program has fiscal responsibility for operating and maintaining the mission systems, while OMAO has fiscal responsibility for operating the ship. Recent serious shortfalls in the OMAO budget have forced the NOAA Ocean Exploration Program to make up these shortfalls to enable the ship to operate. These unforeseen and thus, unplanned investments are ones that the NOAA Ocean Exploration Program is often unaware of until very late in the fiscal year. This becomes even more challenging as decisions concerning the fate of the ship are often debated and made by NOAA senior leadership in the context of the entire NOAA fleet, with no input from the NOAA Ocean Exploration Program.

Finally, the merger with NURP to form OER has proven challenging, especially with regard to the potential termination of NURP in 2013. There are requirements to safely and effectively secure and shut down infrastructure while meeting environmental compliance requirements when program terminations occur, and currently there is no dedicated funding provided for the NURP termination. It is possible these costs will be incurred by the NOAA Ocean Exploration Program.

3. Toward a National Ocean Exploration Program

The vision and objectives established in the 2000 President's Panel report are as good today as they were a decade ago. Our nation needs tangible and compelling targets to focus, align and unify interagency and nongovernmental efforts towards a systematic national ocean exploration program. While the NOAA Ocean Exploration Program has been working toward fulfilling the vision and recommendations expressed in the President's Panel Report and has deliberately tailored the Cornerstones and Foundational Elements to address this, there is an opportunity now to transform our existing partnerships, create new and innovative partnerships, and to collaborate deliberately on developing a National Ocean Exploration Program.

3.1 Partnerships in Support of a National Ocean Exploration Program

A hallmark of the Ocean Exploration Program over the past decade has been the successful partnerships it has nurtured and strengthened to progress the state-of-knowledge of the ocean through exploration. The resulting outcomes have been beneficial to NOAA, the Nation, and the international community and have built effective and enduring, partnerships in ocean exploration. The benefits and strengths of partnerships—leveraging limited resources and capitalizing on the unique capabilities and strengths of various partners in ocean exploration—have resulted in far more than any one entity or agency might have been able to achieve.

For example, the aforementioned partnership with BOEM has leveraged the resources of both institutions while delivering baseline information that benefits the Nation. This was proven during the Deepwater Horizon oil spill when the information and characterizations produced by this partnership represented the most comprehensive record of deepwater habitats in the Gulf of Mexico, and which continue to be used to conduct research on the long-term impacts of this unprecedented event.

Likewise, the partnerships between federal agencies, academic institutions, and non-profit organizations that continue to form and grow around telepresence-enabled exploration represent a profound shift in how partnerships enable paradigm shifts to the benefit of ocean exploration and research. The partners involved in this effort continue to break new ground in exploring unknown areas, adapting and evaluating new technologies and using rapidly evolving social media tools and technologies in new and innovative ways as part of a broad engagement strategy. The NOAA Ocean Exploration Program has benefited greatly from formal partnerships with the Institute for Exploration, the University of Rhode Island, and the University of New Hampshire in this regard, as well as through the counsel of the Ocean Exploration Advisory Working Group that recognized the potential of this effort for increasing the pace and efficiency of ocean exploration, as well as functioning as a training ground for future generations of ocean explorers and scientists.

Another fruitful area for expanding future partnerships is internationally as was proven by a collaborative expedition between the NOAA Ocean Exploration Program and the government of Indonesia, which is described in detail later in this document. This effort brought together a host of partners including other NOAA programs, Federal agencies, and academic institutions to explore one of the most unknown and biologically rich ocean areas on the planet, and was a success in terms of exploration, the use of advanced technologies, education and outreach, and most importantly—diplomacy as an effective form of soft power.

3.2 Transformation Initiatives in Support of a National Ocean Exploration Program

In January 2012, the NOAA Ocean Exploration Program identified several transformation initiatives to further align with national and NOAA priorities and to promote effectiveness and efficiency in the NOAA Ocean Exploration and Research Program. These initiatives support a national ocean exploration program and include:

- Working with the ocean science community to explore new tools and technologies that will increase the pace and efficiency of ocean exploration, including using existing technologies in new and innovative ways. While the NOAA Ocean Exploration Program has achieved some success in this area in partnership with other agencies and institutions, the time is right to engage others in developing a long-term strategy and plan to ensure such efforts are sustained.
- Reengaging the ocean science community in developing and sustaining an interagency effort focused on targeted exploration. This will enable Federal agencies to better leverage investments to meet complementary objectives, as well as establish strong connections where the results of exploration will catalyze further research, as well as natural resource management.
- Working with the ocean science community to develop meaningful performance measures and metrics that demonstrate a return on investment and a disciplined scientific evaluation process, and enabling others to capitalize on results.

3.3 Public Law 111-11 in Support of a National Ocean Exploration Program

Public Law 111-11 provides a solid framework for a national ocean exploration program. Specifically, it calls for and authorizes NOAA to rise to this opportunity through collaboration with other Federal ocean and undersea research and exploration agencies, academic institutions, non-profit organizations, and private business and industry in such efforts as:

- Conducting interdisciplinary voyages to explore and survey little known areas of the marine environment, inventory, observe, and assess living and nonliving marine resources, and report such findings;
- Focusing attention on deep ocean regions, the most unexplored realm on the planet;
- Enhancing the technical capability of the U.S. marine science community by promoting the development of improved oceanographic research, communication, navigation and data collection systems, as well as underwater platforms and sensor and autonomous vehicles;
- Establishing an ocean exploration forum to encourage partnerships and promote communication among experts and other stakeholders to enhance the scientific and technical expertise and relevance of the national program; and
- Coordinating data and information management systems, outreach and education

programs to improve public understanding of ocean and coastal resources and development and transfer of technologies to facilitate ocean and undersea research and exploration.

Finally, Public Law 111-11 calls for NOAA, in coordination with the National Science Foundation (NSF), the National Aeronautics and Space Administration, the United States Geological Survey (USGS), the Department of the Navy, the Bureau of Ocean Energy Management, and relevant governmental, nongovernmental, academic, industry and other experts to convene an ocean exploration and undersea research technology and infrastructure task force to develop and implement a strategy to:

- Facilitate transfer of new exploration and undersea research technology to the programs authorized;
- Improve availability of communications infrastructure, including satellite capabilities, to such programs;
- Develop an integrated, workable, and comprehensive data management information processing system that will make information on unique and significant features obtained by such programs available for research and management purposes;
- Conduct public outreach activities that improve the public understanding of ocean science, resources, and processes, in conjunction with relevant programs of NOAA, the NSF, and other agencies; and
- Encourage cost-sharing partnerships with governmental and nongovernmental entities that will assist in transferring exploration and undersea research technology and technical expertise to the programs.

3.4 National Ocean Policy Implementation Plan in Support of a National Ocean Exploration Program

The current draft of the National Ocean Policy Implementation Plan emphasizes the importance of ocean exploration and partnerships in global-scale ocean exploration. It lays out the initial steps required to achieve the vision and charge of the National Ocean Policy. To support the National Priority Objective to *Inform Decisions and Improve Understanding*, Action 1 is to *Advance fundamental scientific knowledge through exploration and research*. Through international and Federal–nongovernmental partnerships, this action promotes scientific exploration, particularly of the 95 percent of the ocean that remains poorly known.

3.5 A Public in Support of a National Ocean Exploration Program

The time is right to fully embrace and implement the key provisions of the President's Panel Report and PL 111-11. Given the current high-visibility of ocean exploration through recent events including James Cameron's recent dive to Challenger Deep; the remembrance of the 100th anniversary of the sinking of RMS *Titanic*; Dr. Robert Ballard's exploration in the Mediterranean and Black Seas; and the NOAA Ocean Exploration Program's recent expeditions and efforts in Indonesia, the Gulf of Mexico, and in the Arctic; there is an opportunity to establish momentum and gain stability for investments in this important endeavor.

The timing of the Ocean Exploration Program Review is ideal. Review Panel recommendations could reinforce the importance of ocean exploration at a time when

it is more visible than ever before. Review recommendations will certainly guide the NOAA Ocean Exploration Program and NOAA, and should inform the Administration and Congress. From the NOAA Ocean Exploration Program's perspective, national plans for advancing technology, operational exploration, catalyzing research, information and data management, education and outreach and partnerships are needed to reinforce and advance a national ocean exploration program.

4. Conclusions

4.1 The Value of Ocean Exploration

Ocean exploration *writ large* has provided tremendous value in serving vital national interests and shows potential to provide an increasing amount of value in the future. Exploration of new ocean areas and phenomena, and the development of comprehensive descriptions form an essential baseline framework critical to:

- ensure continued advances in basic scientific understanding and to support informed policy;
- identify natural resources and understand how to best develop and conserve them;
- focus research efforts on priority areas and phenomena;
- make informed decisions regarding how we interact with the ocean environment;
- make new ocean discoveries to establish a baseline knowledge and understanding of ocean biodiversity and ecological health; and
- further explore our sovereign territories with potential for vast natural resources.

4.2 Significant Steps Have Been Taken by the NOAA Ocean Exploration Program in Advancing Ocean Exploration

The NOAA Office of Ocean Exploration has been working toward a coordinated national ocean exploration program as envisioned by the President's Panel Report (2000), the U.S. Ocean Commission Report (2004) and in Public Law 111-11 (2009). The NOAA Ocean Exploration Program continues to collaborate by co-sponsoring ocean exploration projects to leverage limited funding, including:

- National initiatives: Extended Continental Shelf mapping with the Department of State, involving 10 other Federal agencies and Canada;
- Interagency initiatives: Multiyear cooperative explorations of deep-water lease blocks with the Department of the Interior/BOEM; and
- Other expeditions that advance science, technology, education, and international relations.

The NOAA Ocean Exploration Program is also engaging the ocean science community, educators and the American public through telepresence-enabled systematic ocean exploration, and providing mapping and other data products in unprecedented timely ways, especially to support resource management policy and decision makers. Telepresence is breaking the mold in terms of how we engage people in ocean exploration. It is a force multiplier, accelerating how information can be used to inform decisions, often immediately while it is being collected.

The NOAA Ocean Exploration Program has invested in cutting-edge research-targeted exploration, including investing in ocean "pioneers" who engage in high-risk, high-return exploration. We are also making great strides in ocean-inspired STEM education and outreach, as well as setting the pace in information management, sharing, and dissemination.

4.3 Much Work Lies Ahead

Much has been done in exploring our oceans. However, many times more exploration remains to be done as human knowledge of the oceans is extremely limited, including the ocean's myriad of habitats, resources, and functions. Even when we investigate areas we think we know well, we are often surprised by what we discover!

If we are ever to establish a baseline of knowledge regarding our oceans somewhat equivalent to our knowledge of the land surface, which is only about 25 percent of the earth's surface, we will need to pursue a systematic, multi-disciplinary approach for exploring the oceans. This would entail the development of foundational products including:

- Inventories of what exists, and where;
- Informative maps of habitats and ecosystems at meaningful scales; and
- Accurate descriptions of ecological functions and how habitats and ecosystems change over time.

4.4 There is Much More We Can Accomplish

The Ocean Exploration Program has been firmly established as a valued NOAA activity. Over the past ten-years we have made progress towards establishing a National ocean exploration program. We have made progress toward creating systematic approaches and meaningful products. We have also been increasing the scope, pace and efficiency of exploring the world's oceans. However, we have made only marginal progress relative to the work that lies before us.

Significant actions are needed if the NOAA Office of Ocean Exploration is to fully meet its role as envisioned by Public Law 111-11 to coordinate a national ocean exploration program that promotes collaboration with other Federal ocean and undersea research and exploration programs. Such actions might include NOAA:

- Establishing an enduring commitment to a national ocean exploration program and engaging relevant agencies, foundations, and the private sector in defining the national ocean exploration endeavor.
- Serving as an ombudsman for ocean exploration, promoting opportunities for collaboration and participation in ocean exploration expeditions whether public or private.
- Establishing the Ocean Exploration Advisory Board which can provide advice and to ensure transparency from a perspective external to NOAA. Consultations with other ocean exploration stakeholders would also help to set the Ocean Exploration program's priorities.
- Establishing an ocean exploration forum as called for by Public Law 111-11.
- Maintaining a dynamic list of high priority ocean exploration needs.
- Along with other relevant Federal agencies, convening an ocean exploration and undersea research technology and infrastructure task force.
- Endorsing creative external partnerships that leverage expertise and funding from outside of NOAA. Such partnerships could be beneficial as regards:
  - technology development;
  - scientific and technical expertise;
  - operational capacity and expertise;
  - access to ocean exploration platforms and vehicles;

- data management and distribution;
- public engagement through education and outreach; and
- assisting NOAA in meeting its ocean exploration staffing needs, including unique skill sets.

• Taking full-advantage of what the NOAA Ocean Exploration Program brings to the agency for meeting its national ocean responsibilities, including:
- technology and discovery incubation;
- public engagement in ocean issues;
- information for policy and management; and
- science and information relevant to other NOAA programs to most efficiently and effectively execute NOAA's mission.

5. Ocean Exploration Cornerstones and Foundational Elements

This section describes the key thematic areas of the NOAA Ocean Exploration Program Review and presents them as either Ocean Exploration Cornerstones or Foundational Elements. Cornerstones are defined as baseline characterizations of little-known and unknown ocean areas and phenomena, and are derived from the recommendations made in the President's Panel Report. The Foundational Areas are critical programmatic "foundations" that cross-cut and support the Programmatic Cornerstones. A final thematic area, presented as Other Key Activities, includes descriptions of significant NOAA Ocean Exploration Program investments over the past 10 years in Technology Development and Innovation, Catalyzing Research and Informing Resource Management.

The Cornerstone descriptions include:
- Targeted Exploration;
- Systematic Telepresence-enabled Exploration;
- Extended Continental Shelf Mapping Initiative; and
- Interagency Baseline Characterization.

The Foundational Elements include:
- Information and Data Management and Product Development and
- Engagement.

Each description includes (1) an overview of the key thematic area; (2) a list of Strengths, Weaknesses, Opportunities, and Challenges (SWOC); and (3) one or more Case Studies to provide the Review Panel with an understanding of the evolution, construct and interconnectedness of each Cornerstone and Foundational Element within the NOAA Ocean Exploration Program as a whole.

5.1 Ocean Exploration Cornerstones

5.1.1 Cornerstone 1: Targeted Exploration

5.1.1.1 Overview

The NOAA Ocean Exploration Program's targeted exploration program is implemented through an Announcement of Opportunity (AO) in support of NOAA's Mission. Exploration and discovery of the ocean's unknown and poorly known areas and phenomena supports NOAA's goal to "Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management."

The results of deepwater ocean science are cornerstones upon which ecosystems are discovered, defined, and understood. This enables NOAA to protect, restore, and manage these areas, and contributes to improving our holistic understanding of the ocean environment, how it functions, and how it is interconnected with other Earth systems.

Initiated in 2002, the AO provides an opportunity for the ocean sciences community to present innovative exploration proposals to the NOAA Ocean Exploration Program that have the potential to catalyze ocean and Great Lakes discovery and understanding through baseline characterization of little known or unknown ocean areas. These proposals would typically not be funded elsewhere within the Federal government system.

In the program's early years, the AOs were designed to focus on General Exploration and Marine Archaeology and as such, successfully competed proposals reflected a wide range of ocean exploration topics and geographic coverage. Technology Development and/or Education categories were also introduced into the AO process early on to encourage the use of innovative technologies and education and outreach efforts associated with the successfully competed exploration portfolios. Ship time for successful proposals was supported with pre-purchased ship time on UNOLS vessels or ship time acquired by leveraging project efforts led by the NOAA Ocean Exploration Program staff and/or funded Principle Investigators (PIs).

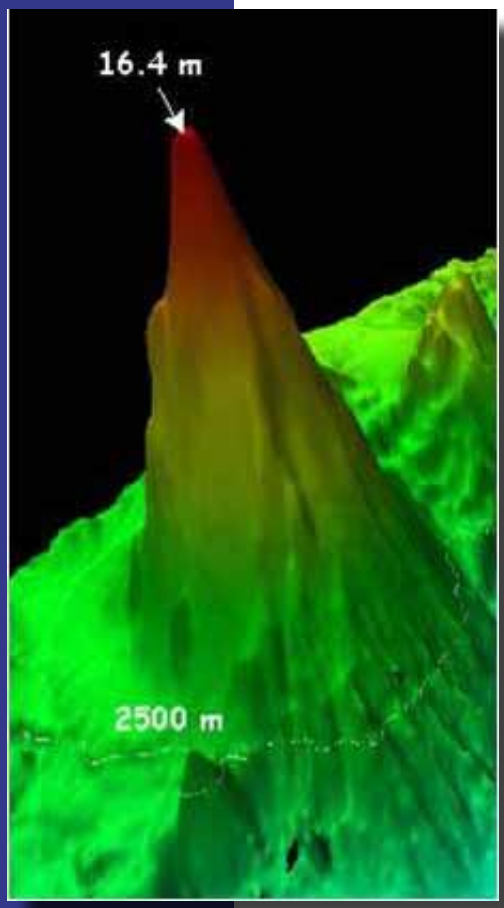
With continued input from the ocean science community, the AO process evolved to focus on geographical areas of interest, or geographic exploration targets, and included pre-arranged ship, ROV or AUV time. The Maritime Archaeology component of the AO was initially funded at lower levels since activities typically occurred in coastal or Great Lakes waters. Over time, funding levels for individual awards were increased to support larger, more intensive efforts using advanced technologies which required larger vessels and an innovative portfolio of shipboard expertise and operations not typically available to the marine archaeological community. Until 2012, the NOAA Ocean Exploration Program provided one of the largest sources of Federal competitive grant funding for maritime archaeological explorations in the U.S. Between 2006 and 2011, the NOAA Ocean Exploration Program allocated an average of $400,000 a year for the Maritime Archaeology AO.

A General Ocean Exploration AO has not been offered since 2010 and the Marine Archaeology AO has not been supported since 2011 due to budget constraints on the program. In 2011, in an effort to support emerging new ideas, the NOAA Ocean Exploration Program created a Small Grants for Maritime Archaeological Exploration Announcement funded at $25,000 per award in FY2011. The goal was to fund smaller efforts that have a high potential to evolve into larger marine archaeological exploration missions. It also served as a mechanism to fund promising smaller proposals that do not compete well with larger, more cost-intensive proposals submitted to the Maritime Archaeology AO.

a. How are Geographic Targets Selected?

The President's Panel Report discusses the importance of interdisciplinary partnerships in the development of a national ocean exploration program—partnerships in planning, use of exploration platforms and other assets, information sharing and education. Decisions on which topical areas to support through the AO process since the inception of the program have been and continue to be informed by many stakeholder groups.

Initially, eight National Ocean Exploration Regional Workshops were held throughout the country to present the recommendations made by the President's Panel and provide an opportunity for regional stakeholders to help shape the construct of a national ocean exploration program within a Federal agency. Workshop locations included the Caribbean, Gulf of Mexico, Hawaii, Alaska, West Coast, North Atlantic, South Atlantic, and Great Lakes regions. In addition to stakeholders attending the National Ocean Exploration Regional Workshops, other stakeholders include, but are not limited to, the Ocean Exploration Advisory Working Group (OEAWG) and Interagency Partners, such as the Bureau of Ocean Energy Management, the National Science Foundation (NSF), the Office of Naval Research (ONR), the Smithsonian Institution, the U.S. Navy, and U. S. Geological Survey (USGS).



Multibeam image of submarine volcano. ***Image courtesy NOAA.***

b. The AO Process

The NOAA Ocean Exploration Program AO procedures are modeled after the National Science Foundation's peer-review process. The AOs are published in the Federal Register and online at Grants.Gov, and describe the topical and geographic area of focus, characteristic elements of exploration, interdisciplinary exploration, and innovative use of technologies. Links to all past AOs can be accessed via Grantsonline.gov or Grants.gov. In addition, a Constituent E-mail Listserv with over 700 subscribers is also used to notify potential interested parties

Principal Investigators from academia, the private sector, NOAA and other agencies can submit proposals. The process, involves a pre-proposal or letter of intent and a full proposal submission. In the first phase, pre-proposals are evaluated using criteria where the NOAA Ocean Exploration Program Director, in consultation with the program staff, makes the decision to encourage or discourage full proposal submissions based on one or more of the Pre-proposal Evaluation criteria. The final decision to submit a full proposal is up to the applicant. See Appendix 3 for an example AO.

Accepted proposals are subjected to peer review. The peer reviewers rate the individual proposals using evaluation criteria provided in the AO under Full Proposal Evaluation Criteria and provide summary comment. Both Federal and non-Federal experts in the field may be used in the peer-review process, which may include external mail reviews and/or a peer-review panel. The peer reviewers are subject matter experts in the ocean-related sciences and are screened to

ensure they have no conflict of interest with regard to the proposals undergoing review. Peer-review panelists do not reach consensus on individual proposals. Based on the individual scores, summary comments, summaries and scores by the panelists, the NOAA Ocean Exploration Program Senior Scientist, in consultation with appropriate staff, makes funding recommendations to the NOAA Ocean Exploration Program Director. In making the final selections, the Director will award in rank order, unless the proposal is justified to be selected out of rank order based upon one or more of the selection factors described in the AO. All proposals must be approved by the NOAA Grants Management Division.

As evidenced by the annual exploration portfolio (Appendix 4), the NOAA Ocean Exploration Program supports Signature Expeditions representing high-level partnerships that have the potential to result in a large return on investment (Arctic, interagency), are multi-disciplinary and/or multiproject, present novel concepts in exploration, and employ advanced technologies. The NOAA Ocean Exploration Program invests its own resources in Signature Expeditions to support Data Management, Education, Outreach and Media efforts associated with the mission. Signature Expeditions receive coverage on the award-winning Ocean Explorer website (http://oceanexplorer.noaa.gov/), and include daily logs from sea, content essays produced by PIs, compelling imagery, lessons for educators, and an "Ask an Explorer" feature.

5.1.1.2 Strengths

The AO process is ocean science community-informed, enabling the NOAA Ocean Exploration Program to support baseline characterization exploration efforts in topical and geographic areas that have high potential to generate novel and innovative research endeavors that should be at the forefront of the ocean science research enterprise. As such, the NOAA Ocean Exploration Program serves as an "incubator" for the ocean science research community, helping to catalyze the next generation of newly informed ocean science research questions to be presented for funding to other partner agencies.

Community-informed exploration guidance has served to enhance scientific understanding within a broad range of ocean science disciplines, as scientists have worked collaboratively on multiple platforms using advance tools and technologies. The outcomes have been contributions to our basic understanding of the deep ocean environment in national and international waters. See Appendix 5 for a list of publications resulting from the NOAA Ocean Exploration Program-supported projects.

The NOAA Ocean Exploration Program has been able to respond quickly to unexpected opportunities when they present themselves. Collaborating with NSF and Pacific Marine Environmental Laboratory (PMEL) to support the Northeast Lau Response Cruise in 2009 in the Central Pacific is just one example. Scientists arrived at the erupting volcano just six months after its discovery and observed for the first time, active lava flow in the deep ocean.

http://oceanexplorer.noaa.gov/explorations/09laubasin/welcome.html

Significant discoveries and baseline characterizations inform critical NOAA management decisions, an integral part of the Agency's mission. An example is multiple NOAA Ocean Exploration Program-supported explorations of deep-sea corals in the Southeast Atlantic Bight. These expeditions served to define five areas designated as deepwater Coral Habitat Areas of Particular Concern (HAPC).

5.1.1.3 Weaknesses

The NOAA Ocean Exploration Program operates the AO program with a small staff; roughly four people who have other duties and several others who assist during periods of high activity. This has led to delays in preparing grant packages when a high volume of proposals are funded. Among the grant staff there is not enough cross training to provide redundancy in critical roles. This leads to a single point of failure in processing proposals. Limited staff also presents difficulties when following-up with PIs to ensure they have properly archived data and data products, and to maintain a list of publications resulting from NOAA Ocean Exploration Program funding.

Disbursement of funds is always a challenge within the structure of the Federal government. Because the NOAA Ocean Exploration Program's AO has always been open to academia, private sector, interagency and NOAA scientists, program personnel must be knowledgeable and adept with regulations and procedures for disbursement of funds through a variety of mechanisms. Whether a funding transaction associated with a proposal is a grant, an internal Budget Operating Plan transfer to another NOAA office, an interagency transfer, or contract depends on any number of circumstances. It is not uncommon that funding one proposal results in multiple funding transactions through multiple mechanisms. Administrative personnel must be knowledgeable about the process and constraints for every mechanism.

5.1.1.4 Opportunities

With reinstatement of the AO grant program on a two-year award processing cycle. The NOAA Ocean Exploration Program can better capitalize on expedition planning to take advantage of available platform time, including ship time, ROVs and AUVs. This would alleviate the issues inherent with the timing of budget allocations, such as schedule delays and spending at risk. The NOAA Ocean Exploration Program could develop a small flexible grant program for general exploration similar to the one developed for maritime archaeology, to take advantage of unexpected opportunities as they arise.

Data and products collected by the *Okeanos Explorer's* mapping and ROV systems could be used to inform topical and geographic foci in the AO process. While discoveries lead to research, they also lead to new areas or topics to explore. Significant discoveries can warrant further exploration using new tools and methods to support baseline characterization.

Since partnerships offer opportunities to expand our limited resources and increase the efficiency of exploration, leveraging our current partnerships with agencies, such as BOEM and the Office of Naval Research (ONR) would add benefits.

5.1.1.5 Challenges

The NOAA Ocean Exploration Program works with many groups that do not have a full understanding of how the program approaches ocean exploration through targeted exploration. The NOAA Ocean Exploration Program continues to reach out to the ocean science community by participating in major scientific conferences, such as the American Geophysical Union (AGU) annual conference and The Oceans Conference, to increase understanding of this approach outside of the stakeholder community. Leadership within NOAA and the Federal government is another important group we seek to inform.

Unpredictable and unstable budget scenarios make it challenging to achieve stability and meet program responsibilities with an annual AO.

Identifying areas of exploration and prioritizing them is a challenge when working across the broad spectrum of ocean science. Recent workshops (2007 and 2011) to refine exploration targets for the NOAA Ship *Okeanos Explorer* demonstrate the range of targets and highlight the great potential for discovery throughout the ocean. Aligning AO priorities with NOAA and National ocean priorities is a further challenge.

Processing grants within NOAA is a special challenge. Regulations administered by NOAA's Grant Management Division provide the structure for the award process. The processing timeline works best when NOAA receives its annual fiscal allocation early in the fiscal year. Delays caused by continuing resolutions, which often happen, cause a corresponding shift in grant awards to later in the fiscal year. The NOAA Ocean Exploration Program cannot commit grant funds to successful proposals before receipt of the annual allocation. This often impinges on a PI's planned schedule, delaying the start of an expedition. The downstream impact can include the loss of ship time or other assets and loss of a weather window. To circumvent this, some PIs spend "at risk" before they receive their award. Spending "at risk" can alleviate some of these issues, but has its own inherent issues and some institutions will not allow it.

Shifting and uncertain budgets are a liability for the program. With the timing of budget allocations varying from year to year, it is difficult to plan ahead, coordinate budgets for grants with UNOLS and NOAA ship time, and schedule assets, such as ROVs. In addition, bringing the NOAA Ship *Okeanos Explorer* through a two-year, multiple-phased conversion to successful execution of the maiden voyage in international waters resulted in a significant impact in funding levels, affecting all aspects of the NOAA Ocean Exploration Program, including the AO process.

5.1.1.6 Case Studies for Targeted Exploration

Case Study 1. Strengthening the Foundation of High Arctic Science to Understand Ecosystem Change: The 2005 Hidden Ocean Expeditions

Overview. Even before environmental change in the Arctic garnered media headlines, NOAA Ocean Exploration Program-sponsored scientists were collecting base-line data and information about sea ice, water column and the seafloor in the ice-covered high Arctic. Working with inter-agency, academic, and international partners as part of the Hidden Ocean Expeditions, the NOAA

Scientists on the Hidden Ocean 2005 Expedition are lowered down onto Arctic ice in a "man lift." *Image courtesy NOAA-OE.*

Divers collect and image organisms living in and under the Arctic pack ice during Hidden Ocean 2002. *Image courtesy Deep Sea Systems International, NOAA-OE.*

This jellyfish (*Corssota norvegico*) was found floating in the chilly depths during the Hidden Ocean 2005 Expedition. *Image courtesy Kevin Roskoff, Monterey Peninsula College; NOAA-OE.*

Ocean Exploration Program sponsored more than 10 major expeditions and projects north of the Bering Strait. Since 2007, The NOAA Ocean Exploration Program's Arctic efforts have largely been through support of the ECS initiative.

As the first-ever scientific expedition focused on under-ice deepwater ROV operations and a particularly intense mobilization on the icebreaker U.S. Coast Guard Cutter *Healy* via helicopter, the month-long Hidden Ocean 2005 expedition was perhaps the NOAA Ocean Exploration Program's highest risk venture ever. It was also the most expensive expedition funded through the NOAA Ocean Exploration Program AO. In advance of media and public attention on the high Arctic, it is one of the biggest successes of the NOAA Ocean Exploration Program.

The goal was to assess the diversity of life and the environment in all three major realms (i.e., sea ice, water column, and benthic) of the deep Canada Basin.

For one month, the science party and the Coast Guard crewmembers on the US Coast Guard Cutter *Healy* conducted round-the-clock science operations. Core science operations included measuring sea ice properties, primary productivity, and pelagic (water column) and benthic (seafloor) community composition. The combined work of all 35 participating scientists helped to create a more complete understanding of the Arctic food web from the sea-ice surface

to the benthic realm. The expedition represented the first comprehensive, multidisciplinary effort toward understanding and characterizing the diversity of life in all three realms of the ice-covered Arctic Ocean.

NOAA Ocean Exploration Program Arctic Highlights

2002

- Partnered with Canada, Japan, and China to conduct pilot project focused on census of life in the Canada Basin from the sea ice down to the seafloor
- Funded initial engineering, development and testing of under-ice capable, deepwater science-class ROV.
- Demonstrated that ROV operations could be conducted successfully in the pack ice.
- NOAA Ocean Exploration Program-sponsored academic scientists leveraged the 2002 Arctic expedition to lead the Census of Marine Life (CoML) Arctic Ocean Diversity project.

2003

- In conjunction with NOAA's Office of Coast Survey and the University of New Hampshire (UNH), conducted the first U.S. Arctic ECS-related mapping expedition in 2003.

2004

- The NOAA Arctic Research Office and the NOAA Ocean Exploration Program co-sponsored the first joint Russian-American Long-term Census of the Arctic (RUSALCA) expedition.

2005

- First high Arctic icebreaker expedition dedicated to under ice ROV operations.
- Special issue of *Polar Biology* focused on 2002 expedition results published.
- Special issue of *Deep Sea Research* focused on 2005 expedition results published.

5.1.2 Cornerstone 2: Systematic Telepresence-enabled Exploration

5.1.2.1 Summary

The NOAA Ocean Exploration Program's Systematic Telepresence Enabled Exploration Cornerstone encompasses innovative interdisciplinary exploration, technology development, education and outreach conducted by the *Okeanos Explorer* and E/V *Nautilus* programs. Activities provide habitat, species or ecosystem characterizations for previously poorly known or unknown areas or phenomena, baseline data and information for follow-on research for holistic understanding of the ecosystems and biodiversity; inform management decisions and policies; and engage scientists, students and the public in the expeditions in real-time using telepresence technology.

Systematic Telepresence-enabled Exploration

- Explores unknown areas of the world ocean leaving a legacy of data and products to catalyze others
- Fosters testing and advancement of new exploration technologies, tools and methods to increase the pace and efficiency of exploration
- Educates, trains and engages educators and learners of all ages in the excitement, methods and benefits of exploration to increase ocean literacy and train the scientific and engineering workforce.
- Stimulates and capitalizes on domestic and international partnerships to leverage expertise, assets and resources, complementing existing efforts to explore the vast unknown.

5.1.2.2 About the Program

In 2000 the President's Panel Report issued recommendations for a national ocean exploration strategy in which discovery and the spirit of challenge were the cornerstones. Underlying much of the Panel's recommendations was the understanding that today we have "new technological eyes" with which to explore the ocean. From the use of human-occupied submersibles, to remotely or autonomously operated vehicles and genetic sensors to measure bacteria, these "new technological eyes" are fundamentally changing how scientists explore, observe, study, document, and communicate about the oceanic realm.

Twelve years later and after eight years of development and testing by the NOAA Ocean Exploration Program and its partners, a new paradigm of systematic telepresence-enabled exploration is taking hold providing a new set of technological eyes that engages an unlimited number of human eyes in real-time ocean exploration. Telepresence-enabled exploration is the *Okeanos Explorer* and Ocean Exploration Trust *Nautilus* exploration programs' operational paradigm. These programs operate worldwide, fully involving scientists and the public who participate from shore via telepresence. Telepresence increases the pace and efficiency of global exploration, catalyzing research and technology development, engaging people in innovative ways to inspire and educate the next generation of explorers and stimulating innovative partnerships domestically and abroad.

Using telepresence-enabled vessels equipped with high speed satellite connections, high resolution mapping, oceanographic sensors and remotely operated vehicle systems, both programs engage in expeditions to characterize new ocean areas and phenomena. Scientists at Internet 2-linked shore-based Exploration Command Centers and Remote Consoles participate in real time, providing observations, data processing and operational recommendations to at-sea scientists and technicians bringing a global and interdisciplinary breadth of expertise to every expedition. Through live broadcasts on commodity internet and links to the Inner Space Center (ISC) at University of Rhode Island (URI), scientists and technicians interact with teachers, students and the public bringing the excitement of exploration live into newsrooms, homes, classrooms and other learning centers reaching millions of people around the globe every year.

The NOAA Ocean Exploration Program recognized the benefits of the new model and committed to developing it with base funds and no supporting budget increase for the last eight years. Since both the *Okeanos* and *Nautilus* programs achieve higher level NOAA Ocean Exploration Program goals, they integrate across all major and supporting elements of the NOAA Ocean Exploration Program and its partnerships and require ongoing operations and programming support in administration, finance, communications, exploration, research, technology, education and information management.

Systematic Telepresence-enabled Exploration Informs and Supports

- Nautical charting
- Deep-sea corals studies
- Sanctuary boundary deliberations habitat characterizations
- Hazards modeling (tsunami inundation models) and identification (undersea volcanoes, faults, etc)
- Extended continental shelf initiative
- Climate adaptation and mitigation research
- Underwater cultural heritage monitoring and identification
- Natural resources damage assessment
- New ocean resource identification
- Research proposals and cruises
- Graduate level dissertations
- U.S. diplomatic relations and publications
- U.S. and foreign documentary films and television shows
- Educator professional development workshops and lesson plans
- Exhibits and interactions at public aquaria and science centers and others
- Non-disclosed naval research and development

Diagram showing telepresence systems onboard a ship of exploration and the pathways connecting live video from undersea vehicles to the Inner Space Center and on to the internet. ***Credit: K. Cantner.***

With three years of full operations completed, return on investment is being realized in follow-on research, management uses of data, public access and use of data and products by third parties, participation from the science community and professional development for educators and training new explorers. As a proven model, it is gaining interest from other vessel operators and field programs. In a few years time, this model could result in an evolutionary paradigm shift in how we explore, understand and value the world ocean.

However, significant challenges, such as budget instability, government business processes, and ability for others to fund follow-on research, may limit the potential for growing this model beyond the two current vessels. Strategic partnership opportunities actively being pursued to improve business process, products and exploration priority setting may offset these challenges by providing additional capabilities and constituent support.

5.1.2.3 Relevance

This new model of exploration achieves many of the recommendations of the President's Panel report and aligns with and supports NOAA's Next Generation Strategic Plan Goals for Climate Adaptation and Mitigation, Healthy Oceans, and

Resilient Coastal Communities and Economies. Exploration also is a critical element of the U.S. National Ocean Policy and Implementation Plan Goal to Inform Decisions and Improve Understanding. Data and products resulting from telepresence-enabled exploration will inform and support a variety of societally relevant and critical functions.

5.1.2.4 History

Telepresence is not new, as it has been applied in myriad ways for decades by government agencies and private industry. The vision of adapting this technology for oceanographic work was first conceived by Dr. Robert Ballard more than 25 years ago. He envisioned the use of telepresence to connect scientists, teachers and students on shore to live images and real-time data from ships at sea, providing a portal into the excitement of oceanographic discovery, and demonstrating to a broad audience the importance of exploring and protecting our largely unknown ocean.

Since 2004, the NOAA Ocean Exploration Program, Institute for Exploration (IFE), URI and other partners worked to determine the most effective and efficient application of this rapidly developing technology for ocean science and exploration, and for education and outreach. The partners developed and refined complex ship-and-shore-based operating protocols, brought new shipboard and shore-based telepresence systems online, and built the hub for this technology, the ISC, at URI. The ISC includes a production studio for live and post-produced education and outreach efforts and a 'Mission Control Center' for ship-to-shore connectivity to support telepresence-enabled expeditions. Simultaneously, *Okeanos Explorer* and E/V *Nautilus* underwent extensive refitting to become the first two platforms customized for telepresence-enabled systematic ocean exploration.

Other critical partners in the development of this new model include every line office of NOAA, the UNH Center for Coastal and Ocean Mapping Joint Hydrographic Center (CCOM), the NOAA Science Advisory Board's Ocean Exploration Advisory Working Group (OEAWG), the *Nautilus* Advisory Board (NAB), and the dozens of representatives from science, management and education communities through various collaborative activities and workshops.

5.1.2.5 Strengths

Implementation and Efficiency. The application of telepresence technology for ship-based work provides unlimited access to personnel on shore, transcending berthing limitations, schedules, expertise, skills, and abilities of traditional shipboard teams. It enables partnerships between geographically dispersed groups and allows for the most efficient use of all resources sharing information across the globe in real time.

Stakeholder Engagement. Beginning with the definition of Okeanos conversion requirements, community participation and input into telepresence-enabled exploration are critical components of making the model a successful endeavor. OEAWG and the NOAA Ocean Exploration Program hosted workshops with science, education and management representatives. The NOAA Ocean Exploration Program

incorporates this input, balancing community identified and national agency priorities with available ship time and program budgets, and actively engages the community in detailed cruise planning and execution.

Public Access to a Legacy of Data. Significant investment by the NOAA Ocean Exploration Program in video broadcast, data collection, processing, distribution, metadata development, iconographic product standardization, archive standards, and access technology and portals resulted in *Okeanos Explorer*'s data pipeline being identified as NOAA's gold standard for end-to-end data management. It integrates high quality metadata, standard bathymetry, sensor, video and image products, which are moved in real- or near real-time from acquisition to archive in 60-90 days for public access. The NOAA Ocean Exploration Program is collaborating with the *Nautilus* team to apply this proven model to *Nautilus*.

Catalyzing Others. Targets identified by the community are usually high-risk, potential high-value areas. Explorations in these areas can yield valuable data to support ongoing research, proposals for further exploration and research, and management deliberations.

Diplomacy and Partnerships. The white government hull of the Okeanos makes it an effective tool for soft-power diplomacy. Explorations by *Nautilus* in the Black Sea and Mediterranean also result in scientific and technical collaborations between U.S. and regional scientists, catalyze partner nation agency collaborations and stimulate education and outreach activities that add value to domestic and international diplomatic goals.

5.1.2.6 Challenges

Multiple challenges may prevent the systematic telepresence-enabled exploration model from planting firm roots and growing beyond the two programs.

Demonstrating Return on Investment. The most common metric for scientific merit of data is the number of peer reviewed publications and citations. Tracking data value is challenging for uses in which data is used to write proposals, plan activities, inform management decisions, produce video or media products and educate others. Number of ecosystems characterized is a common metric—but each discipline defines "ecosystem" and "characterization" differently. Quantifying the number of hours of high quality video, terabytes of mapping and sensor data, number of video views, and other metrics also do not necessarily reflect actual usage or net return on investment, including follow-on research catalyzed by this exploration. NOAA and the NOAA Ocean Exploration Program need to define useful metrics to illustrate the return on investment to NOAA and the Nation. Working with social scientists and economists, metrics could also be developed to highlight net economic benefit per capita to make the economic case for exploration.

Sampling, Characterization and Advancing Technology. Early discussions with the community and Ocean Exploration Advisory Working Group (OEAWG) highlighted the need for advanced technologies to increase the pace and efficiency of systematic exploration. The NOAA Ocean Exploration Program currently invests

very little to catalyze new technologies. The scientific community continues to emphasize sampling until new technologies emerge. Greater collaboration, investment, borrowing or developing technology is needed to harness the power of telepresence. Until then, additional community discussions are needed to: define standard base level "characterizations" for specific sample types, secure funding to ensure these characterizations are routinely completed and publicly available; and develop relationships with appropriate repositories to ensure public access to samples.

Business Process and Resource Constraints. The telepresence program suffers from deficiencies in staffing, business process and financial support. Critical gaps exist in Chief Scientist, Data Steward and Communications roles and subject matter expertise is "one-deep" with "single points of failure." NOAA funding and budget cycles and processes differ from partners making collaborations difficult. Competition for ship time on the *Okeanos* and working collaboratively with a different organizations within NOAA to operate the vessel make planning and scheduling sometimes erratic and unpredictable. New acquisition processes increase net costs by slowing down critical functions.

Video Storage and Access. Across institutions there is a lack of adequate video storage and online access. The Inner Space Center (ISC) is beginning to develop an online repository of compressed video clips from *Okeanos* and *Nautilus* operations. Capacity is limited, however. NOAA should consider leveraging the Google Cooperative Research and Development Agreement (CRADA) or the URI ISC partnership to develop a national ocean video infrastructure to provide capture, cataloging, archiving and distribution of video on demand for all ocean video collectors and users.

5.1.2.7 Opportunities

Always Exploring, Always Live! With only two telepresence-enabled vessels, live exploration and remote participation is only possible six months of the year resulting in an ebb and flow of attention from scientists, managers and the public. Enabling other vessels in NOAA, UNOLS and other nations and institutions with telepresence capabilities, partnering with others to create economies of scale in technology and contracted bandwidth services, and providing year-round or even 24/7 online presence from the ocean will achieve the vision of Always Exploring, Always Live! and accelerate this paradigm shift.

Catalyzing Others. Catalyzing follow-on research and additional product development is critical for program success. This requires stewardship of the data and continually connecting with stakeholders, to involve them in planning and execution. A dedicated Data Steward and Chief Scientist can strengthen these linkages reaching deeper into NOAA, NASA, NSF and others. Creating places for communities to develop around data, including crowd-sourcing further analyses, will enable collaborations, data synthesis and other uses. Forums, such as PLoSONE can be developed.

Creative Partnerships. Lean budgets require creative collaborations and partnerships. The NOAA Ocean Exploration Program actively engages third parties to bring additional resources to ocean exploration endeavors. Engaging in unique partnerships with communications, media and film schools can also result in innovative communications products and greater reach to diverse audiences. Potential collaborations should be explored with the high visibility endeavors of Virgin Oceanic, Deep Ocean Exploration Research (DOER) and others.

Opening Career Paths. The NOAA Ocean Exploration Program-funded Lau Basin cruise aboard the R/V *Revelle* in 2012 requires funding to implement telepresence to enable participation from scientists who cannot sail. Similar endeavors to allow participation of individuals with disabilities can lead to new collaborative tools, provide funding and incentives for technology developments, and open opportunities for other scientists, engineers and students in marine-related fields. Additional efforts to reach underrepresented and underserved communities have equally significant potential to open career paths and build a workforce that reflects society's diversity.

Consistent Branding and Communications. A consistent branding and suite of communications products, events and tools should be developed so when either vessel is underway or in port, the public knows what to expect and how to get involved. Creative communications tools, such as competitions for "embedded blogger" positions, should be implemented to raise awareness and reach new audiences.

5.1.2.8 Case Studies

Case Study 1: INDEX/SATAL 2010—The Power of Two

Overview. The 2010 Indonesia-USA Deep-Sea Exploration of the Sangihe Talaud Region (INDEX/SATAL 2010) expedition was *Okeanos Explorer*'s maiden voyage to explore unknown deep ocean areas in the planet's most biologically diverse shallow ocean area. The expedition took place in the center of the Coral Triangle, home to an estimated one fifth of the planet's corals where data is needed to understand and measure change in ocean acidification, flow-through currents, sea level rise, climate change, volcanic and tectonic plate activity, seafood sustainability, and the abundance, distribution, and diversity of ocean life. This was a high priority area identified by the U.S. science community during a 2008 Ocean Exploration Advisory Working Group (OEAWG) workshop on the Maiden Voyage of the *Okeanos Explorer*.

The expedition kicked off a new era of scientific cooperation between the U.S. and Indonesia and built relationships at many levels, catalyzing ongoing collaborations. President Yudhoyono of Indonesia encouraged the joint expedition and was strongly supported by the former U.S. Ambassador to Indonesia Cameron Hume. The joint expedition also aligned with President Obama's landmark June 2009 speech at Cairo University when he spoke of building partnerships to support science and technological development in Muslim-majority nations.

The expedition was a result of two years of collaborative operational and science planning resulting in a two-ship exploration expedition and an extensive portfolio of education and outreach collaborations. The Indonesian vessel *Baruna Jaya IV* used its multibeam sonar, nets and other equipment to explore areas down to 2500 meters and obtain samples for post-expedition study while the *Okeanos Explorer* used its capabilities to explore areas deeper than 2500 meters using a Doctor's on Duty or Doctor's on Watch model with scientists participating via telepresence ashore in the U.S., Canada and Indonesia. U.S. and Indonesian scientists worked together on each vessel.

Scientific Value. Deep-sea biological diversity was observed to be abundant and different from shallow waters. Scientists observed perhaps 40 new potential coral species and 50 potential new species of other animals (NOAA Press Release, December 2010). One remotely participating scientist wrote, "As we are looking at the imagery now (compared to similar depths off this [British Columbia] coast), I remain stunned by the diversity of form and function in the organisms." (15 November 2010). Initial results indicate that the deep-water diversity of this region, in the heart of the Coral Triangle, may be as significant as the well-known shallow water diversity of the region.

U.S. and Indonesian scientists presented seven abstracts to the 2010 American Geophysical Union Fall Meeting. We know that of one follow-on research proposal based on data collected during INDEX/SATAL 2010 was submitted to NSF in 2012. We know of several undergraduate and graduate theses in both the U.S. and Indonesia based on INDEX/SATAL results. Additionally, imagery was used as was live video in labs and classrooms at University of Victoria, Woods Hole Oceanographic Institution and others.

Building Relationships and Collaborations. This was the *Okeanos'* first full use of telepresence-enabled exploration with 20 scientists participating from three countries, five time zones, and distributed across thousands of miles, witnessing, discussing and documenting the expedition from shore in Exploration Command Centers (ECCs) and other locations. A live event log allowed scientists around the world to seamlessly and synchronously log and discuss observations of video and data. Exploration Command Centers provided additional scientific collaborations between

At SeaWorld Indonesia, more than a thousand students signed pledges that, as Ocean Ambassadors, they would learn more about the ocean, protect the ocean, and teach others to do so. ***Image courtesy of NOAA Okeanos Explorer Program, INDEX/SATAL 2010.***

U.S. and Indonesian scientists, and across disciplines. One NOAA geologist stated after his experience working in an ECC for two weeks, "I learned more about microbiology in the last two weeks from a graduate student here than in my 25 years going to sea." Graduate students also praised the increase in cross-discipline learning possible in ECCs compared to typical interactions onboard a vessel.

Public Access to Data. Data management collaborations allowed the *Okeanos* data team to manage and transfer data from both vessels for quick public access. Both Nations exchanged copies of each other's data in a closing ceremony. All data was made publicly available at NOAA's National Geophysical and Ocean Data Centers (NGDC and NODC) and NOAA Central Library. *Baruna Jaya* samples were retained by Indonesian scientists for future analysis with U.S. scientists. *Okeanos* water samples were shared between the two Nations. One hundred hours of high definition video and 100,000 photos were obtained from ROV dives, with 21,000 square miles of seafloor mapped.

Education and Outreach. Despite being over-taken by the Deepwater Horizon spill, an extensive education and outreach program was implemented with great success. Six interns participated as mapping and ROV technicians. A live media interaction between the Jakarta ECC and the *Okeanos* welcomed the ship to Indonesian waters. Three live interactions between the *Okeanos* and an ECC were conducted with NOAA partner The Exploratorium in San Francisco bringing live exploration to the public on the exhibit floor. Mystic Aquarium also displayed the live video feeds for public viewing. One live Indonesian television interview was conducted during a morning news show. Several science seminars in Indonesia with U.S. scientists engaged Indonesian graduate students. Partnering with SeaWorld Indonesia, more than 1,000 Indonesian students were sworn in as Ocean Ambassadors to learn, protect and teach others about the ocean. Standards-based lesson plans in English and Bahasa Indonesia were developed and posted online. NOAA's Ocean Explorer Web site chronicled the expedition in English and Bahasa Indonesia, including live updates and imagery from sea from both vessels. Embassy Jakarta tweeted and posted on Facebook about expedition and collaboration activities.

Major print media including *The Economist*, *Washington Post*, *New York Times*, *International Herald Tribune* and *The Jakarta Post*, and dozens of online media including MSNBC covered the expedition for a total of some 190 articles. Coverage includes ongoing extensive use of imagery in ocean exploration articles. Through NOAA's CRADA with Google, Google product training was hosted in Indonesia and an interactive KML (Keyhole Markup Language) and flythrough highlighting data and imagery collected were produced and shared online in Google Earth Ocean Expeditions layer. Three live interactions between the ship and ECCs were held with targeted VIPs, media and students. Five nationally-distributed Ocean Today Kiosk videos and one student's video were produced. Finally, the people of Indonesia responded positively, thanking U.S. explorers wherever they went for showing them their national underwater resources.

Soft-Power Diplomacy. The American Embassy was an active and critical partner in the expedition. The North Sulawesi Governor hosted the INDEX team for a closing gala and cultural event strengthening relationships between U.S. and Indonesian teams. The Embassy selected ocean exploration as the opening theme for its innovative, award-winning outreach center "@america," which hosted several INDEX/SATAL events for students, officials, and Indonesia scientists. Even the Embassy's 2010 Fourth of July gala focused on the INDEX/SATAL collaboration under the theme "The Power of Two"—two great maritime nations working together to explore the center of marine biodiversity. The U.S. Department of State hosted a live webcast on INDEX/SATAL 2010 and the U.S.-Indonesia science and technology partnership with NOAA's Dr. Jane Lubchenco, Indonesian Ambassador Dino Jalal and U.S. Science Envoy Bruce Alberts that linked with students at the @America outreach center.

A letter from U.S. Ambassador Cameron R. Hume congratulating the crew of *Okeanos Explorer* highlighted the success and importance of the expedition: "Much has been learned about the world's most diverse marine environment, and the stage has been set to learn even more in the future… The *Okeanos Explorer* voyage of discovery to the Sangihe Talaud region vividly illustrates how a science partnership can become a powerful tool for diplomacy and result in closer ties between our countries." His Excellency Dino Djalal, Indonesia Ambassador to the U.S. and former senior advisor to President Yudhoyono, remarked, "I cannot find a better example of how the Indonesia-US Comprehensive Partnership is being executed in terms of the soft power relationship than the present scientific cooperation of INDEX/SATAL 2010…."

Case Study 2: *Nautilus* 2011 Field Season

Over the past three years, *Nautilus* has engaged hundreds of people from all over the world to explore the deep sea, and used telepresence technology to bring the excitement of expeditions to millions of viewers worldwide. The four-month field season in 2011 built upon years of previous work in the Mediterranean and Black Sea regions, strengthening relationships with many partners, and building new ones for investigating unexplored areas. The successful collaboration with 186 participants from 19 countries illustrates the diplomatic power of *Nautilus* and the common goal of exploring the world's ocean.

Explorations. The 2011 season commenced in July off the Turkish Black Sea coast, engaging local geologists, biologists, and archaeologists to acoustically map the continental shelf and document evidence of internal wave dynamics and trawling activity, particularly as they affect the preservation of ancient shipwrecks. During this project, nine shipwrecks with varying degrees of preservation were discovered, the oldest dating to ca. 500 BCE. Additional exploration in Turkish waters off the coast of Knidos in the southeastern Aegean Sea investigated marine geological features and 10 previously undiscovered shipwrecks. These discoveries, in combination with extensive seafloor mapping, are catalyzing research on the effect of trawling on the destruction of shipwreck sites in deep water.

Exploration of volcanic centers in Greek and Italian waters led to exciting discoveries in geology, chemistry, and biology that will lead to a better understanding of past and present volcanic and hydrothermal systems in these areas. Collaboration with Greek scientists included geologists, water chemists and microbiologists to explore the Santorini and Kolumbo volcanoes, as well as the nearby Christiana group of four small islets and the deep Cretan Basin. New exploration in the Italian Aeolian Arc and Straits of Sicily offered a glimpse into vast hydrothermal systems, along with the vent site of a recent underwater volcanic eruption and the discovery of a World War II Italian airplane. The passive margins of Spain and Israel proved to be amazingly dynamic targets of exploration, revealing extensive deposits of ancient volcanic rocks, including pillow basalts, as well as deepwater coral reefs and an abundance of other biology. Continued exploration off the Israeli coast resulted in the discovery of seafloor vents, possibly releasing methane, and associated megafauna, including colonies of small tubeworms.

The 2011 season was the first time that *Nautilus* worked in the Atlantic Ocean. Due west of the Strait of Gibraltar lies Gorringe Bank, a ridge composed of two uplifted blocks of oceanic crust and mantle. As its geological origin is similar to that of the Atlantic Massif on the Mid- Atlantic Ridge, it was thought that it could have similar hydrothermal systems to those found at Lost City. Although there was no evidence of active venting, samples of serpentinite and gabbro similar to those documented at Lost City were recovered. Many species of coral, fish, and other benthic organisms, which were abundant at this intersection between the North Atlantic Ocean and the Mediterranean Sea were documented.

Technology Development. The *Nautilus* Mapping and Imaging Team continues to break new ground by developing techniques to map not only the seafloor, but also active seafloor venting, using stereo imagery, structured light, and high-frequency multibeam sonar. The initial results and the broad range of potential applications of these new techniques are encouraging. Two student projects were also developed, one to collect water samples under pressure, and the other to build a rock chipper to collect samples from outcrops.

Platform for Lifelong Learning. *Nautilus* provides a platform for developing education and outreach programs to engage people of all ages encompassing broad-scale outreach, K-12 science, technology, engineering and mathematics (STEM) programs, undergraduate and graduate internships, and on the job training. Partners including National Geographic Society (NGS), Sea Research Foundation, and the JASON project present live feeds and results to the public using numerous types of media including Internet, film, television, magazines and books. The *Nautilus* live website hosted 97,696 unique visitors from 173 countries between July 20 to November 16 thanks in part to the NGS partnership to reach new global audiences. A popular feature on the *Nautilus* Live was "Send a Question" which viewers submitted over 13,000 questions online for a response by an expedition team member. The *Nautilus* at Mystic Aquarium hosted 486 live presentations for over 29,000 guests.

Live Exploration Command Centers at schools, boys and girls clubs, libraries, informal education sites, and science centers across the country displayed the live feeds and provided exclusive interactions with *Nautilus* Live Theatre. Approximately 55 live interactions between educators, students, and scientists on the ship with schools and informal education sites reached 70,000 people.

Live media events and press releases in the US and partner countries and ship visits by press and dignitaries in Turkey, Greece and Israel elevated the profile of the program and its ability to reach additional viewers. Nineteen educators at sea from museums, aquariums and schools across the US participated onboard and ashore posting 65 blogs and participating in 482 shows with *Nautilus* Live Theatre and working with their own students. The JASON project continued reaching middle and high school levels engaging students in transit operations, digital labs, curricular materials and live webcasts reaching more than 400,000 teachers and students worldwide. Immersion Learning focused on inspirational career role models supporting 55 youth serving organizations and held professional development workshops for 376 program leaders. A total of 50 high school, undergraduate and graduate students were also engaged as interns aboard and onshore conducting research and training in science and engineering.

Catalyzing Research. Over 20 peer-reviewed publications and graduate dissertations on research that has been conducted on *Nautilus* are currently in progress or have been published. Several countries that we have worked with have expressed interest in follow-on research. Scientists from the Hellenic Center of Marine Research and University of Athens are conducting a research cruise to Santorini and Kolumbo in July 2012 to follow up on the preliminary results of two *Nautilus* cruises. Israel, Spain, and Italy have expressed interest in using *Nautilus* in the future, as they lack the infrastructure to conduct telepresence-enabled exploration cruises themselves.

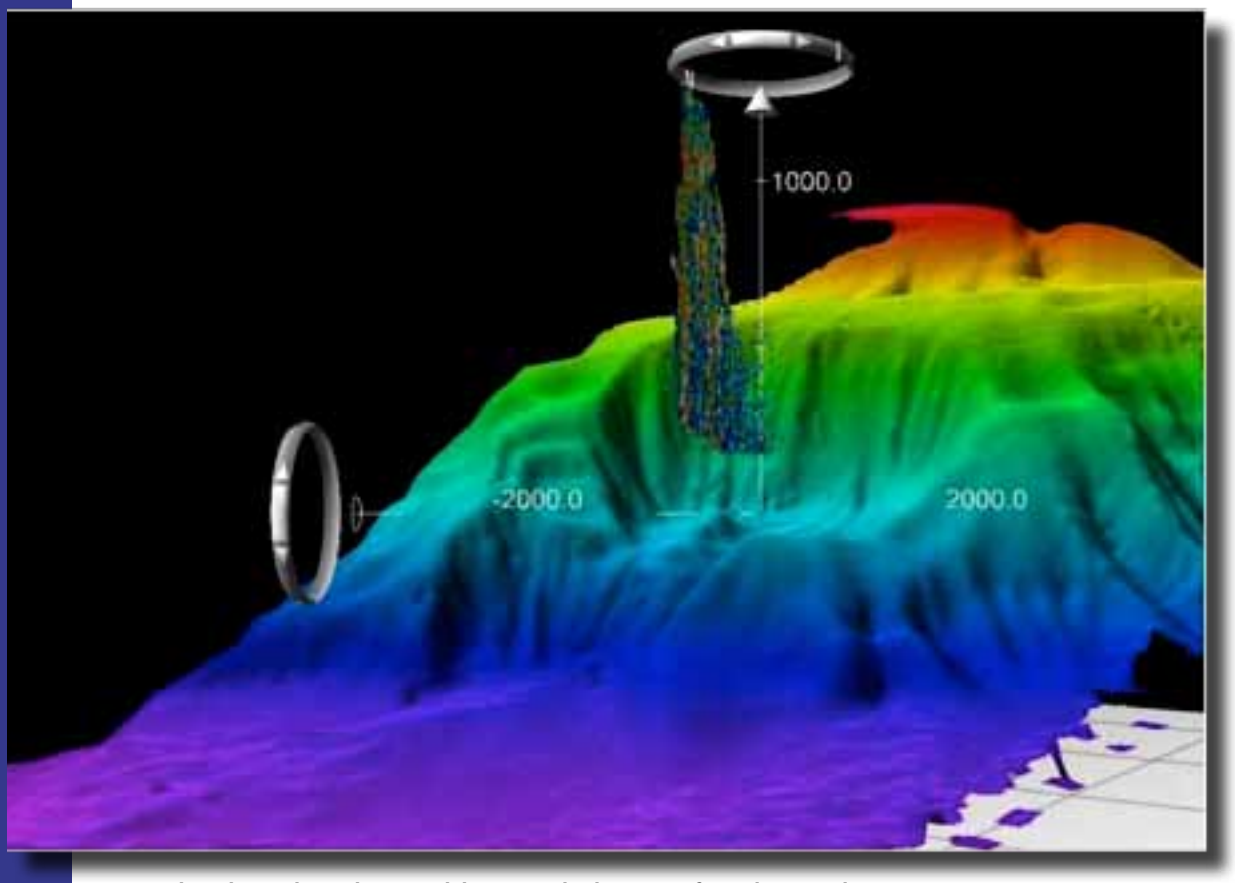
5.1.3 Cornerstone 3: The U.S. Extended Continental Shelf Mapping Initiative

5.1.3.1 Overview

As defined in the Law of the Sea Convention (UNCLOS), every coastal country has a continental shelf that extends out to 200 nmi from its coastline, or to a maritime boundary with another country. If a country meets the criteria outlined in UNCLOS Article 76 (Article 76), it can have a continental shelf extending beyond 200 nmi, i.e., an "extended continental shelf." The mission of the U.S. Extended Continental Shelf (ECS) Project is to establish the fullest extent of the U.S. continental shelf over which the U.S. may exercise sovereign rights, consistent with international law. The Project signifies the largest, and potentially most significant, interagency marine survey ever undertaken by the U.S.

Why Do It?

The U.S., like other countries, has an inherent interest in knowing, and declaring to others, the exact extent of our sovereign rights in the ocean. The continental shelf is an important maritime zone, one that holds many resources and vital habitats for marine life. In this maritime zone, a nation may exercise sovereign rights over



Suspected methane plume discovered during ECS bathymetry of Mendocino Ridge. ***Image courtesy NOAA.***

the resources on and under the seabed, including petroleum resources (oil, gas, gas hydrates); "sedentary" organisms, such as clams, crabs and corals; and mineral resources, such as manganese nodules, ferromanganese crusts and polymetallic sulfides.

Defining these rights in concrete geographical terms provides the specificity and certainty necessary to protect, manage and/or use those areas and resources. Ultimately, these determinations also provide a rich foundation for setting priorities for future exploration, research and management, and at times, for national security and navigational safety. International recognition is important as well in establishing the necessary stability for development, conservation and protection of these areas.

It is important to note that with the potential to add at least 1 million square kilometers of seafloor over which the U.S. would have authority, the ECS Project rivals the addition of the Exclusive Economic Zone in terms of its importance to governance and sovereign land rights; implications for various industry sectors also are likely to be profound.

In terms of the NOAA Ocean Exploration Program, the President's Panel recognized mapping unknown areas as a critical cornerstone of a National Ocean Exploration Program. In essence, maps are one of the most critical products an explorer can prepare based on their observations, allowing other explorers and researchers to build on this foundation over time.

Evolution of the Initiative

Expeditions to help define the limits of the U.S. continental shelf, areas beyond 200 nautical miles (nm) of U.S. coastlines, have been the focus of high-resolution bathymetric mapping and seismic reflection profiling for over nine years. The process to determine the continental shelf outermost limits requires the collection and analysis of data that describe the depth, shape, and geophysical characteristics of the seabed and sub-seafloor. Article 76 specifies the formulae, constraints, and other requirements to delineate an ECS. Delineation requires understanding and mapping of the geology and morphology of the continental margin out to and beyond 200 nm, as well as documenting sediment thickness where the sediment thickness formula may apply.

Since 2008, the NOAA Ocean Exploration Program has formally supported the ECS Project, providing leadership, funding on the order of $3.4 to $4M annually, and communications coordination. In addition to establishing a website (continentalshelf.gov) on behalf of the ECS Project and its 13 participating agencies, the NOAA Ocean Exploration Program has contributed to the collection of more than 1.6 million square kilometers of bathymetric data (along the continental shelf and slope, *i.e.*, 0.4% of the ocean). The NOAA Ocean Exploration Program also supports efforts to archive, inventory, and deliver marine mapping data in a coordinated, consistent manner. Management and stewardship of ocean mapping data will improve our ability to obtain, use, and share data, thus enabling better science, promoting collaboration and supporting regional ocean management efforts. Providing discovery of, description and access to past data via modern inventories, web services and map viewers enables informed decision-making when planning and prioritizing new data collection efforts.

Future of the Program

The program's evolution, particularly since the ECS Task Force was established in 2007, is an indicator of growing momentum and support for the project. Five years ago, NOAA did not have the resources required to accelerate ECS field efforts (or information management efforts), but given the importance of the project, NOAA argued successfully for ECS-specific resources. As a result, over 250,000 square kilometers have since been mapped in the Arctic Basin alone. Additionally, an ECS information management system was developed to ensure the utility of data and products at all stages of the ECS Project, archive, from ship to eventual submission of the U.S. ECS determination to the Commission on the Limit of the Continental Shelf (CLCS).

5.1.3.2 Strengths

The mapping efforts signify what may be the largest marine mapping survey of the 21st century. The ECS Project represents a significant series of mapping surveys that aim to reveal information to confirm, enhance or even significantly alter accepted knowledge about the United States' maritime boundaries, as well as resources within those maritime boundaries.

In addition to their direct benefit to the Project, ECS survey data collected in poorly known and unknown parts of the ocean will shed light on habitats and resources,

e.g., mineral, oil and gas, within those maritime boundaries, serving as the baseline for future exploration and research.

Another strength is that this project represents a multiagency partnership. With responsibilities shared across multiple agencies, the available expertise for the various facets of the project is extensive. International collaborations are also a strength of this project. International partnering with the other Arctic States represents good diplomatic networking. International, as well as interagency collaboration, raises the potential for achieving economic efficiencies by sharing ships, data and samples and reducing duplicative efforts.

5.1.3.3 Challenges

Coordination among 12 agencies can be challenging, especially as the nature of agency contributions shift with vacillating budgets. In addition, quality of analysis and quantity of data collection can make a difference to the size of the ECS we delineate. There are a multitude of opinions about the ideal quality and quantity metrics.

Furthermore, scenarios under consideration now are likely to be different than those considered three to five years ago, if only because there have been more submissions from countries over the years that have influenced interpretations. Knowing this, a distinct challenge is to allow ourselves the flexibility to modify our interpretations/analyses, particularly if the CLCS changes their current reads on submissions. Likewise, if the CLCS commissioner changes, the "flavor"/approach/ balance of the CLCS review could change, and hence, force a change our approach with our scenarios.

Challenges also exist with propriety rights regarding data and samples across agencies and, in some cases, other nations, which may delay the use of this information for non-ECS purposes.

5.1.3.4 Opportunities

Near-term (1–2 years)

Promoting the value of ECS Project findings and establishing baselines necessary to define ecosystems at multiple and meaningful scales to understand change and to identify critical habitats is an opportunity.

Engaging potential partners to leverage ships of opportunity (using a "not to disturb" approach) and adding sensors and/or other monitoring capabilities to leveraging interests and data sharing would also benefit the initiative.

Long-term (2–10 years)

A long-term opportunity would be to strive to achieve the objectives of understanding ecosystem processes and ecosystem change, namely conducting baseline exploration and research necessary to define ecosystems at multiple meaningful scales and to identify key habitats and/or "sentinel sites"; identify funding to support additional work to further the value of baseline information being collected during the ECS surveys.

5.1.3.5 Case Studies for U.S. Extended Continental Shelf Project

Case Study 1: Joint US-Canada Arctic ECS

The NOAA Ocean Exploration Program-supported 2011 Arctic ECS cruise was the seventh in a series of U.S. cruises to the Arctic Ocean and the fourth in which U.S. and Canadian scientists worked together to collect ECS-relevant data of benefit to both countries. These cruises were notable examples of efficiencies of economy and effort. Of additional benefit were the ancillary field studies and "piggyback" projects aboard these cruises, such as the 2010 Arctic ocean-acidification study on the USCGC *Healy* that demonstrated promise in terms of amassing data that will impart scientific breakthroughs and serve a range of environmental, geologic engineering and resource management needs. Findings from the ancillary studies will open new windows on remote environments and provide better scientific understanding of the processes on U.S. continental margins; new insights are expected in understanding climate variability, marine ecosystems, undiscovered or unconventional energy, mineral resources and hazards resulting from extreme events, such as earthquakes and tsunamis.

Case Study 2: Leveraging ECS Project Data

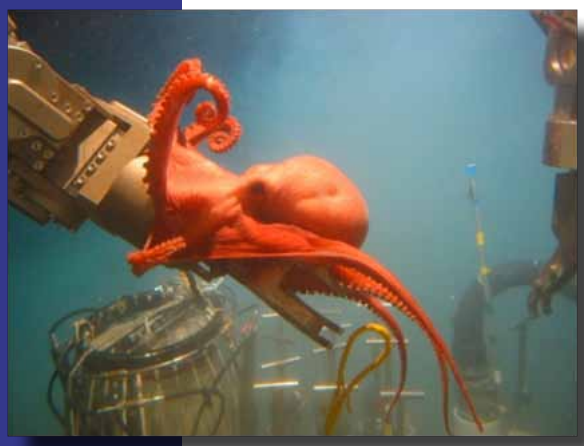
Although the primary goal of the ECS project is to delineate the ECS, a number of major scientific benefits have resulted. These include exploration of some of the most remote seafloor areas in the world, such as the Arctic, where new seamounts and previously unknown occurrences of critical minerals have been found. Data from the Bering Sea are being used to understand gas hydrates; data from the Gulf of Alaska can inform site surveys for ocean drilling in the future. Bathymetric data from the Atlantic margin have yielded new insights into submarine landslides and tsunami risks for the U.S. East Coast. Data management tools developed for the ECS project are being used across agencies to better manage scientific data. The data will also serve a range of environmental, engineering, and resource management needs. All data acquired with U.S. Federal dollars are publicly available within six months of acquisition. The U.S. ECS Project is yielding a legacy data set that will have value for understanding, exploring, and managing U.S. seafloor resources for decades to come.

5.1.4 Cornerstone 4: Interagency Baseline Characterization

5.1.4.1 Overview

The partnership between BOEM and the NOAA Ocean Exploration Program was initiated in 2004 to conduct a biological and archaeological investigation of six casualties of Hitler's U-boat war in the Gulf of Mexico. The project won Department of Interior's 2006 Cooperative Conservation Award in recognition of cooperative conservation achievements that involve collaborative activity among a diverse range of entities. Additionally it was awarded NOPP's 2007 Excellence in Partnership Award.

Buoyed by the initial success of this one-year project, BOEM and the NOAA Ocean Exploration Program have since partnered in a series of multiyear interdisciplinary projects:



This stunning octopod, *Benthoctopus sp.*, seemed quite interested in the DSV *Alvin's* port manipulator arm. Those inside the submersible were surprised by the octopod's inquisitive behavior. *Image courtesy of Bruce Strickrott, Expedition to the Deep Slope.*

- 2006 to 2007: Investigations of Chemosynthetic Communities on the Lower Continental Slope of the Gulf of Mexico (CHEMO III) was the first systematic exploration of hydrocarbon seep communities deeper than 1000 m in the Gulf of Mexico. The mission provided essential information on the ecology and biodiversity of these deep-sea communities to regulatory agencies and energy companies as the quest for oil moves into increasingly deeper waters. Department of Interior awarded it the 2007 Cooperative Conservation Award.
- 2008 to 2012: The Exploration and Research of Northern Gulf of Mexico Deepwater Natural and Artificial Hard Bottom Habitats (*Lophelia*-II) project sought to better define environmental conditions that result in significant high-density hard bottom communities that are sensitive to impacts from oil and gas development activities.
- 2011 to 2013: The ongoing Deep-water Mid-Atlantic Canyons project is a major systematic exploration of submarine canyons on the continental margin of the eastern United States.

The overarching objective throughout these projects is to characterize deepwater habitats and provide essential information to regulatory agencies on the ecology and biodiversity of deep-sea communities in advance of ongoing and future energy development. The NOAA Ocean Exploration Program's interest in the project is the discovery, exploration and characterization of these largely unknown and poorly known areas.

Through this partnership, BOEM develops the solicitation, reviews statements of work and selects proposals with input from the NOAA Ocean Exploration Program. BOEM awards the grant and is responsible for providing all direct science funding. The NOAA Ocean Exploration Program provides the ship and submersible time along with supporting outreach, education and information management activities.

Despite no written interagency agreement, both parties have upheld their commitments to the partnership.

5.1.4.2 Strengths

The partnership has been successful over the past nine years due to its well-defined process, which includes detailed cruise planning and understanding and management of expectations on the part of both major partners. Planning for these projects begins several years in advance and is closely monitored by both the NOAA Ocean Exploration Program and BOEM representatives. Using the NOAA Ocean Exploration Program's well-defined operational model, there are meetings with the science team, partners, the ship and undersea technology operators well in advance of the missions so that expectations are clearly defined and understood. While the

science teams, geographic locations, and specific study focus of these projects have shifted over the years, the consistency of the NOAA/BOEM partnership has remained the same.

The collaborative partnership also offers a large return on investment as it represents a significant cost-sharing effort in which BOEM and NOAA meet separate, yet aligned objectives. The NOAA Ocean Exploration Program accomplishes its objectives of exploring and characterizing poorly known areas and gains a baseline understanding of sensitive ecosystems, while BOEM gains access to critical data on these same ecosystems required for updating and revising notices to lessees. Additionally, the importance of having access to this type of baseline data was exemplified during the Deepwater Horizon event. The wellhead was located in proximity to several sites previously explored and characterized and as such, these observations represented some of the only pre-spill baseline observations of these deep-sea communities prior to the blowout event.

5.1.4.3 Challenges

The size and scope of these projects present challenges. While the national partners (BOEM, NOAA, USGS) and overarching objectives remain the same, the science complement and study areas have changed. This requires compromise and balancing of science needs with the needs of NOAA and BOEM. Over the years, there have also been challenges working around sensitive archaeological sites and most recently a major challenge has been working with oil platform operators to gain access to survey rig structures.

The gorgonian sea fan Collogoria: Americana and symbiotic brittle stars from a site at approximately 350-m depth in the Green Canyon area of the Gulf of Mexico. ***Image courtesy of Lophelia II 2010 Expedition, NOAA–OE/BOEM.***

5.1.4.4 Opportunities

The NOAA Ocean Exploration Program and BOEM are already taking advantage of an opportunity to apply this model to investigating deepwater hard-bottom biological communities and submerged cultural resources in the Mid-Atlantic Bight—an area of interest for potential oil and gas exploration and development, as well as sites for renewable energy activities. Preliminary mapping has been conducted and expeditions using ROVs are scheduled for 2012-2013. Additional opportunities include:

- Applying the systematic exploration operational model to areas off Alaska and the Arctic as there is increasing interest in exploring for offshore resources in these areas.
- Revisiting study sites to assess environmental impacts over time, where impacts of global climate change, anthropogenic influences and ocean acidification may be discovered. Without baseline characterizations, there would not be any data from which to gauge change or evaluate impacts, and in a rapidly changing environment, these types of explorations are crucial.

- Conducting similar baseline explorations with BOEM support on the NOAA Ship *Okeanos Explorer,* as the ship's mode of operations fits within the operational model of earlier baseline characterization studies.
- Using data collected during the NOAA Exploration Program-sponsored ECS Projects to potentially help launch more baseline investigations of newly mapped and discovered areas within U.S. waters.
- Learning from the importance of the baseline data in response to the Deepwater Horizon event, in the long-term future, data collected during these projects may be used for response to other events.

5.1.4.5 Case Studies for Baseline Characterization

Case Study 1: *Lophelia* II: Deepwater Reefs, Rigs, and Wrecks Project

September 20–October 2, 2008: NOAA Ship *Nancy Foster* and *Sea Eye Falcon* ROV
June 16–July 1, 2009: R/V *Brooks McCall* and *Sentry* AUV
August 19–September 12, 2009: NOAA Ship *Ronald H. Brown* and *Jason II* ROV
October 14–November 4, 2010: NOAA Ship *Ronald H. Brown* and *Jason II* ROV
June 2012 (Scheduled): R/V *Brooks McCall* and *Kraken 2* ROV

The *Lophelia* II Project was a multiyear effort starting in 2008 with its final cruise scheduled for June 2012. Building on the success of 2006-07's *Chemo* III project that investigated chemosynthetic communities in the deep (>1000 m) Gulf of Mexico, BOEM and The NOAA Ocean Exploration Program again partnered with support from USGS to explore deepwater coral communities in the northern Gulf of Mexico. The study focus for the *Lophelia* II project was on natural hard-bottom and man-made sites ranging from 300 meters to 3,000 meters depth. With human economic interests and impacts expanding into the deep-sea there was an urgent need for scientific investigations of these unknown and poorly known deepwater communities to provide baseline information before any potential extensive human impacts might occur. The value of these baseline investigations in the northern Gulf proved extremely relevant in the wake of the 2010 Deepwater Horizon incident, as data, knowledge and sampling procedures developed by the *Lophelia* II projects were used in event response.

5.2 Foundational Elements

Foundational Elements of the NOAA Ocean Exploration Program include Information and Data Management/Product Development and Engagement. These two Foundational Elements are both critical programmatic "foundations" that cross-cut and support the Ocean Exploration Cornerstones.

5.2.1 Foundational Element 1: Information, Data Management and Product Development

5.2.1.1 Overview

The President's Panel Report identified "data management and dissemination" as one of five strategic exploration priorities. The Panel recommended the establishment of ". . . a broad-based task force to design and implement an integrated, workable, and comprehensive data management information processing system . . ." and ongoing monitoring to ensure that such a system was established, implemented and monitored for effectiveness and reliability. The NOAA Ocean Exploration Program formed a collaborative partnership among the NOAA Ocean Exploration Program,

the NOAA Central Library, NOAA's Data Centers, and several extramural partners to form an Integrated Product Team (IPT) for Exploration Data Management and Dissemination to fulfill the President's Panel's recommendation. The IPT's broad range of collective experience was directed at defining specific requirements necessary to meet the key data management guidelines outlined in the President's Panel Report to accomplish the following goals:

- Carefully document exploration results;
- Facilitate ease of data archival and access to archived information;
- Ensure data and information interoperability through use of standard formats;
- Facilitate multidisciplinary data management for an Exploration Flagship;
- Integrate exploration information into a geographic Information system (GIS); and
- Widely disseminate exploration results via the Internet, ensuring maximum utilization.

The IPT partners invested in the development and implementation of strategic system components that were coupled with existing processes and systems to form the End-to End (E2E) System. In 2008, The Department of Commerce recognized the IPT's work with a Bronze Medal Award for *developing a unique, end-to-end data management system to organize, archive, and disseminate ocean exploration information for researchers and the public.*

With the 2008 commissioning of the *Okeanos Explorer*, the methods for E2E management began to rapidly evolve. IPT membership also grew to include many new collaborators engaged in collecting, processing and transporting information. This was not business as usual for the IPT. Viewed as an innovative IT platform, direct access to shipboard system data via telepresence information exchange methods enabled across the board process optimization. In addition to increased automation, benefits in enhanced standards validation, rapid transformation of data to open source formats for preservation, and faster throughput to end users have occurred. Aboard the *Okeanos Explorer*, E2E data management has evolved from a basic model where a data manager used a digital toolset to an optimized model that serves as a prototype for other vessels seeking to optimize information management.

The IPT approach to E2E information management; which emphasizes flexibility, adaptation and transparency; remains on course to meet future ocean exploration and information management needs. The cost savings and reliability made possible through standardization and optimization of data and information management and dissemination processes ensures that NOAA's investment in data collection is quickly and easily accessible to a broad range of end users and is preserved for perpetuity.

5.2.1.2 Strengths

The key strengths of this team are the expertise and resources the members bring with them, the support of NOAA Ocean Exploration Program senior management, and the mutual commitment to excellence the IPT shares. Team members are engaged in their communities of practice and therefore bring an element of give-and-take to the team that essentially extends the team boundaries beyond the formal team construct.

The IPT has proven to be both resilient and adaptable in meeting changing program requirements, as well as evolutions in standards and in technology. The IPT periodically reviews operational requirements and system status, and develops an Annual Operating Plan to prioritize and resource outstanding needs.

An important result of this robust effort has been the ability to show the return on investment in exploration. Sound scientific data and information products resulting from NOAA ocean exploration expeditions are broadly shared, as rapidly and as responsibly as possible. Data reuse in interagency programs and expedition-based education lesson plans, data access and archival metrics [e.g. web page hits, downloads and volume], along with the bibliographic collection and citation analysis of peer-reviewed publications, all combine to illustrate the value of managing information and, therefore, the Program's value.

5.2.1.3 Weaknesses

Some of the factors that offer the greatest programmatic strengths also represent programmatic weaknesses. The key strengths are in the interdisciplinary expertise and the framework of resources brought to bear by team members. The key weakness is that the E2E system relies on this expertise and on these framework components, which are threatened by delayed and reduced appropriations and which offer reduced effectiveness due to operating continually under a Continuing Resolution.

The IPT is a matrixed, collaborative organization with a complex resourcing model. In general, Federal staff time and government information technology resources (e.g. long term data center storage or information technology infrastructure) are provided 'in-kind' by partners. OER invests annually in a dedicated contract support team to operate the data management components.

The E2E model implemented by the IPT is successful in large part because duplication of effort is minimal or non-existent, and efficiency is increased. This model is built around a framework of pre-existing government-provided information technology resources. However in the face of Federal budget vagaries the continuance of in-kind support and the reliability of framework components are threatened, placing the operation at risk. While a certain amount of change is expected and perhaps desirable over the lifespan of a complex, multiyear program, the preference is for controlled or planned change. What is happening now is reactive change, where each partner organization is responding to economic pressures differently. The cohesiveness of OER's information management program could be impacted at a very fundamental level, and in fact the current E2E model may prove to be unsustainable in the near term.

Alternatives, such as investing in Non-Government Organization (NGO) owned information technology resources for solutions, are constrained both by resources and by policy. The government has limited ability to rapidly turn to NGOs for management of Federally-funded data collections. Requirements for external NGO compliance with government computer system Certification and Accreditation (C&A) standards are time consuming, expensive and not always cost effective. Even common-sense efforts toward utilization of cloud resources have been hindered

by C&A requirements. Information management resource issues are not limited to NOAA, and the IPT is closely monitoring ongoing government-wide efforts targeting these issues; however operational options at NGOs are limited at this time.

As a volunteer organization, the IPT is also limited in how it can respond to these collective pressures. Potentially a pre-eminent National or International exploration program could bring additional information management resources to bear and offer new opportunities to refresh and expand this data and information management model.

5.2.1.4 Challenges

An ongoing challenge to successful data management is achieving compliance with post-cruise submission agreements from scientists, some of whom reserve a two-year proprietary data use period to preserve intellectual property rights. Robust pre-cruise data management planning and engagement of principals in the planning process go a long way toward increasing awareness of data management objectives. IPT members offer data management as a service to scientists, which is also a big assist in encouraging compliance.

A second challenge relates to efficient and effective management of large volume data collections. As instrumentation advances, data management technologies often do not keep up with increased storage demands or, perhaps more importantly, with public user expectations for direct access to full resolution data. Commercial sector advancements in data storage and access methods are slow to translate to government applications due to IT security requirements, initial investment costs and other reasons. NOAA Ocean Exploration Program specific examples of challenging data sets include:

- Full resolution video: *Okeanos Explorer* and its remotely operated vehicles are equipped with eight high-definition and 21 standard-definition video cameras. Video is recorded digitally in full-resolution, and each expedition can require up to 25 terabytes of storage. Compressed versions of the videos are created for easy transmittal and web viewing, and these are shared with expedition participants and the public via Internet access points in near-real time. However the preservation requirements and access methods for the full resolution data, as well as for the streaming video and audio that accompany each dive, have yet to be determined.
- Water Column Data (WCD): The EM 302 multibeam echosounder onboard the *Okeanos Explorer* provides a unique opportunity to collect water column backscatter. The University of New Hampshire Center for Coastal and Oceanographic Mapping/Joint Hydrographic Center (UNH CCOM/JHC) partnership team leads the field in efforts to describe these water column capabilities, as demonstrated by the capability of imaging plumes of contrasting density within the water column.
  - On EX1201, WCD was collected for the entire expedition. The final volume was 63.46 GB of data in 105 files collected continuously for 8 days, 2 hours, 25 minutes (194.5 hours). This equates to approximately 0.326 GB an hour for EX1201. This data volume is variable, dependent upon the water depths encountered on any given expedition, and does not include EK60 water

column data. When multiplied over a full field season with varying depths, this data volume increases exponentially. The challenge is to develop a cost-effective, requirements-based stewardship model that can be broadly applied to meet the needs of both the data providers and the end user community.

5.2.1.5 Opportunities

International Standards (ISO) for geospatial metadata support a semantic web of knowledge that has the potential to link disparate data sets to the data products and publications that result over time. This is a multi-dimensional construct that has the potential to revolutionize the way scientific data are discovered, accessed and visualized. One can envision offering the "science data shopper" an Amazon-like data access and discovery experience.

To work toward this exciting future reality, the IPT is an early adopter of the ISO standards. Collaboration within this community provides an opportunity to influence implementation across NOAA and throughout the scientific community.

Similarly, extending the mutually beneficial relationship with the NSF-funded Academic Rolling Deck to Repository (R2R) Program, and serving as a "leader by example" to the NOAA R2R initiative offers an opportunity to promote community-wide standards compliance, again offering long-range benefits through enhanced data interoperability across the community.

This is an exciting time for data management—from cloud computing to tablet devices to the government's recently announced "big-data" initiative. Many positive IT advancements on the horizon hold the promise of increased access to scientific data, as well as potential cost efficiencies well beyond what a small NOAA Ocean Exploration Program team can accomplish independently.

Discovery, access, integration and visualization of oceanographic data will be enhanced when supported by cloud storage and computing. Pilot projects are underway within the government to evaluate security of such systems, along with best use. One key prototype currently developing across Federal agencies allows users to store geospatial information on the cloud (ESRI ArcGIS.com/Amazon cloud) for shared use by a designated user community. A similar prototype allows data manipulation with cloud-base software services. These examples and others demonstrate extended analysis capacity beyond traditional network boundaries, and offer potential cost savings. Other cost savings and increased access may be gained through consideration of cloud storage and exchange of large volume data sets.

Portable technology, such as tablet computers and smart phones, offer new opportunities for data collection and management. One key area for development is a simple application to bar code, document and track physical samples collected at sea.

Case Study 1: The *Okeanos Explorer*—An Optimized End-to-End Information Management Model

The vision of adapting telepresence technology for oceanographic work is now an operational reality aboard the *Okeanos Explorer* and the *Nautilus*. The IPT has extended this paradigm to investigate the concept of remote data

management. Innovative methods have been developed to leverage the unique capabilities at the ISC technology hub, couple these with IPT shore-side information management resources and efficient workflow management, and optimize data documentation and throughput aboard the *Okeanos Explorer* as a testbed system. This advanced methodology produces several benefits:

- Automation of standards-compliant metadata creation from shipboard event logs and shipboard sensor files optimizes the processes, providing efficiency and scalability.
- Selected sensor data are rapidly transformed to open-source, archive-ready formats, increasing accessibility, transparency, data reuse, and supporting long term preservation mandates.
- Expedition data collections and information products are completely documented, processed and submitted to NOAA's archives 60-90 days post cruise.
- The complete *Okeanos Explorer* data collection is readily discoverable and is available online in several formats.

Extended IPT partnerships with the ISC, have allowed the IPT to "explore" new frontiers in data management—well beyond business as usual. The telepresence information exchange system (Fig. 7) synchronizes information exchange between ship and shore.

Scientific data collection and ship-to-shore information flow commence when the *Okeanos Explorer* sets sail. Data products, reports and other mission information created by shipboard personnel are stored in the Ship-Board Repository Server (SBRS) in a standardized directory structure using specific file naming conventions.

The Shore-side Repository Server (SRS) is an information collection/ dissemination point that synchronizes hourly with the SBRS to provide

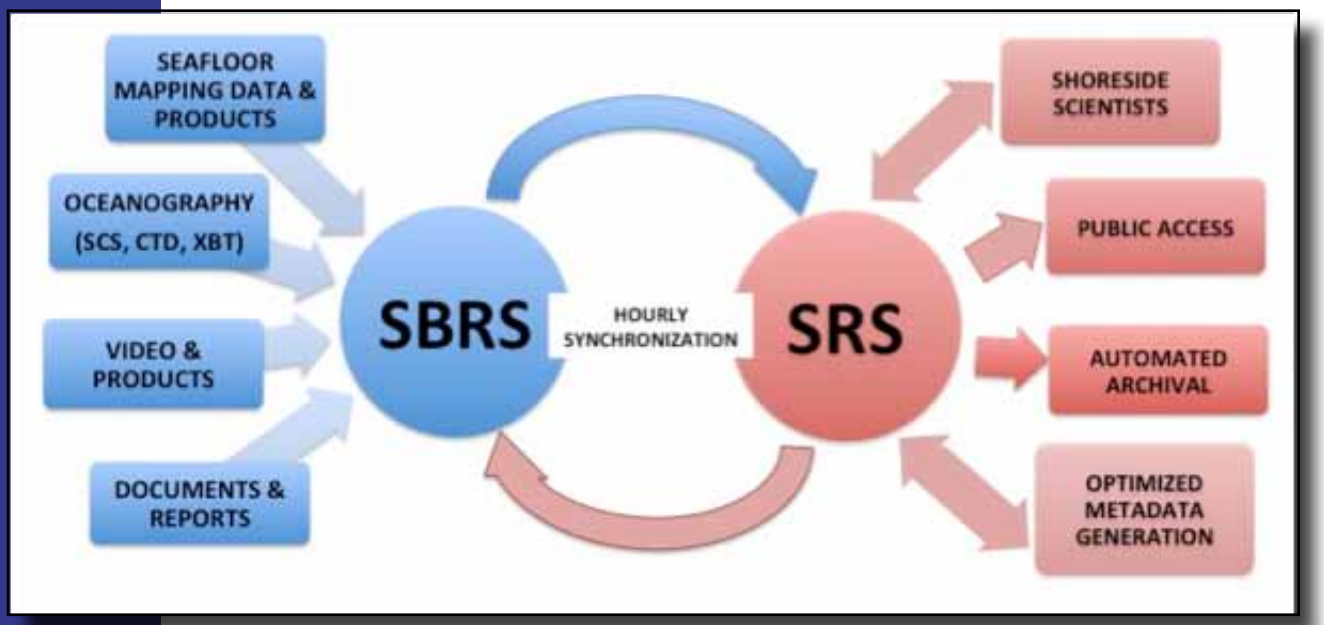


Figure 7. The telepresence information exchange system enables optimized management of shipboard sensor data.

near real-time access to cruise data and information products. Ship and shore-based personnel use the SRS as a data exchange location to facilitate remote exploration. The SRS is also an exchange location for remote data management. Specifically, the shipboard file system hierarchy and naming conventions are replicated shoreside, where automated software components routinely access and process information and return standard content.

The SRS system is also integral to maintaining public awareness of expedition progress. Near-real time information is presented to the public in the *Okeanos* Atlas, a Google™ map-based data visualization and analysis GIS that displays ship location and expedition information in mission-specific context. Frequent updates posted to the map include ship location and sea conditions, seafloor mapping imagery and other data products. The Atlas links educators to the Education Materials Collection, which incorporates data into classroom lesson plans.

Automated procedures are used to manage information movement between systems, to generate standards compliant metadata documentation, and to transform selected data to open source formats. These methods improve the reliability of information management outcomes for three primary categories of information:

- **Video and Still Imagery:** *Okeanos Explorer* and its remotely operated vehicles (ROVs) are equipped with several high-definition video cameras. Digital video is recorded in full-resolution, edited and compressed on board ship for still imagery creation, easy transmittal and web viewing. The compressed information is transmitted to the SRS where CIMS-nEXT modules gather select information to generate both geospatial and cataloging metadata in near-real time. At the end of the expedition, video data, imagery products and documentation are digitally transferred to the National Oceanographic Data Center (NODC) for tape backup, and to the NOAA Central Library for cataloging, discovery and access.

- **Seafloor Mapping:** *Okeanos Explorer* is equipped with an EM302 multibeam sonar system. Aboard ship, high resolution data are developed into a standard suite of quality-controlled mapping products by UNH/CCOM partners. These products are shared via SRS for dive planning and Internet mapping. Metadata creation is an automated process relying on standard file naming conventions. Unique records are created for the multibeam collection and for each raw and processed data file. Post cruise, mapping data undergo additional quality assurance and are submitted to the National Geophysical Data Center (NGDC) for long-term stewardship. Multibeam data are integrated into the NGDC databases and reused as part of the Integrated Ocean and Coastal Mapping program and for other uses.

- **Oceanography:** Data from ship sensors collecting navigational, meteorological, and oceanographic data are recorded in the NOAA Scientific Computing System (SCS). Daily SCS data transmissions to the SRS are collated into a single file post-cruise, and are converted to an Open Geospatial

Consortium-compliant NetCDF3 format for direct public access. Oceanographic data are stewarded at the NODC. Water profile data are integrated into the World Ocean Data Base.

This new approach has many short- and long-term benefits. In the remote exploration paradigm, ready access to highly structured, standardized information provides immediate benefit to the expedition while underway. In addition to short-term operational improvements, benefits from this data management approach accrue to all NOAA partners over the long-term. The data management strategy and practices used aboard the *Okeanos Explorer* serve as an example for R2R programs in both the academic and NOAA fleet, and provide a proof-of-concept for NOAA's environmental data management policies and procedures.

5.2.2 Foundational Element 2: Engagement

5.2.2.1 Overview

Education and Outreach Programs are conducted through the NOAA Ocean Exploration Program in direct response to the President's Panel report Key Recommendation: "Reaching out in new ways to stakeholders to improve the literacy of learners of all ages with respect to ocean issues." The NOAA Ocean Exploration Program Education and Outreach Programs also support NOAA's Education Mission to "advance environmental literacy and promote a diverse workforce in ocean, coast, Great Lakes, weather and climate science encouraging stewardship and increasing informed decision making for the Nation." The America COMPETES Act requires that "NOAA build on its role in stimulating excellence in the advancement of ocean and atmospheric science and engineering disciplines and provide opportunities and incentive for pursuit of academic studies in science, technology, engineering and mathematics (STEM) content areas." Education and Outreach Programs in the NOAA Ocean Exploration Program are not only in alignment with the America COMPETES Act mandate to NOAA, but also align to the NOAA Next Generation Strategic Plan, the NOAA Education Strategic Plan, the NOAA Ocean Exploration Program Strategic Plan, and recommendations that have come forward through the OEAWG.

The award-winning Ocean Explorer website (http://oceanexplorer.noaa.gov) is the single point of entry for the public to understand why we explore the ocean, how we explore the ocean, and learn more about the myriad of strange life forms and unique habitats in its deepest depths. Furthermore, it provides access to live streaming video and audio of missions as they happen in real time aboard the *Okeanos Explorer*. This section describes how the NOAA Ocean Exploration Program strives to engage the American public in ocean exploration through the Ocean Explorer website, the Outreach Program and the Education Program. These elements of the engagement strategy are connected, interwoven and dependant on one another and enable effective and seamless operations to occur.

Ocean Explorer Website

The Ocean Explorer website is an award-winning website established through a joint venture between the NOAA Ocean Exploration Program and the National Ocean Service (NOS), with the NOS providing expertise and resources

to create and maintain the robust offering and the NOAA Ocean Exploration Program providing oversight, content, and funding for staff. The Web Team collaborates with the NOAA Ocean Exploration Program leadership and staff, determining requirements for website offerings and translating this requirement into web-friendly content targeted to the public.

There are two levels of expedition-based support on the website: high-level (Signature) and summary-level (Nonsignature). Through online chronicling of missions, thousands of pages of content have been developed for the site. The majority of the content is developed by a large and diverse group of external contributing partners, all according to specific content development guidance. On Signature expeditions, NOAA staff serves as Web Coordinators and are responsible for working with the scientists to generate content.

Several years ago, the web team pioneered the use of social media in NOAA through the Ocean Explorer website. In 2011, the site saw 6,792,703 unique website visitors, over 18,000 Twitter followers, and over 4,000 YouTube subscribers. A Facebook page was recently created, and for the past five years, Apple iTunes Store has provided free downloads of NOAA Ocean Exploration Program podcasts, images, and more. The iTunes Channel content provided by the NOAA Ocean Exploration Program makes the NOAA Ocean Exploration Channel the most popular. The Web team is also working with iTunes University to join with other universities in offering education downloads.

Outreach Program

The Outreach Program within the NOAA Ocean Exploration Program engages the public in proven and novel ways to create and maintain open channels of communication with ocean stakeholders. The program also plays a large role in working with the public to raise the awareness of the importance of ocean exploration and the need for an informed constituency who will support the sustained investment that ocean exploration requires. Through hundreds of media relations, outreach materials, publications, exhibits, television documentaries, port events, IMAX movie productions and other highly visible projects, the Outreach Program has brought the importance of ocean exploration to new venues on both national and international levels. In addition to the inreach within NOAA across Line Offices and Operational Divisions, significant partnerships also exist with the NSF, National Geographic Society, Sea Research Foundation, Institute for Exploration (IFE) and other agencies, universities, and extramural organizations.

Education Program

Educators are essential to "Reaching out in new ways to stakeholders to improve the literacy of learners of all ages with respect to ocean issues." As such, major programmatic thrusts are to provide opportunities for educators to bring authentic ocean exploration science based on NOAA Ocean Exploration Program expeditions into classrooms throughout the country. Two significant community-based forums provided foundational programmatic recommendations at pivotal points during its evolution.

Education forum participants in front of the NOAA Ship *Okeanos Explorer* after a tour of the ship. *Image courtesy of S. Haynes.*

The first was a three-day National Ocean Exploration Education Workshop held in Charleston, South Carolina, in 2002, during which approximately 54 invited expert participants were asked to consider recommendations made at a recent National Science Foundation-funded workshop to inform the direction for Centers for Ocean Science Education Excellence (COSEE) and to advance these recommendations through the "lens" of ocean exploration education. This was significant and innovative since the NSF COSEE Workshop, which had recently been held at the University of Mississippi in 2000, convened over 70 invited scientists, ocean science educators, technology specialists, informal and formal classroom educators committed to forming partnerships between educators and ocean scientists to enhance ocean science literacy at the national level. See Appendix 6 for the programmatic outcomes based on The Charleston Ocean Exploration Education Workshop.

In 2008, a second opportunity presented itself for inviting expert community-based stakeholder input to inform the strategic development and direction of the Education Program. The *Okeanos Explorer* Education Forum (Forum), held for two days following the commissioning of the ship, convened over 30 invited participants at the NOAA Pacific Marine Environmental Laboratory Western Regional Center Campus in Seattle with the goal of developing the building blocks for a five–year education program for the ship. The Forum focused on how best to reach students, teachers and other audiences in novel ways with the excitement of ocean exploration in light of the new assets and capabilities brought to the NOAA Ocean Exploration Program by the *Okeanos Explorer.* This foundational workshop informed the development of the *Okeanos Explorer* Education Materials Collection and supporting materials found in Appendix 6.

Teacher studies the Ocean Literacy brochure.

NOAA Ocean Exploration Program Education seeks to provide a systemic approach to achieve equity in access to its education products/ programs. Through onsite and online professional development offerings, Short Courses at the National Science Teacher Association, Marine Technology Society and the National Marine Educators Association annual conferences, the NOAA Ocean Exploration Program reaches a wide variety of educators who teach in a wide range of environments with varying degrees of resources.

Online offerings have proven useful for engaging the international community. For example, segments of the *Learning Ocean Science through Ocean Exploration* curriculum were translated into Portuguese and components of NOAA Ocean Exploration Program's professional development model were transferred into a professional development for Portugal's educators. Additionally, a significant portion of the *Okeanos Explorer* website was translated, along with education materials, into Bahasa Indonesian for the INDEX/SATAL mission (and a new education partnership was established with SeaWorld Indonesia.

http://oceanexplorer.noaa.gov/okeanos/explorations/10index/media/bahasa_indonesian.html

Articles in peer-reviewed journals, newsletters, serving on boards and committees, collaborations through professional organizations and other partnerships, presentations to NOAA Leadership, to ocean leadership at the national level Ocean Research and Resources Advisory Panel (ORRAP), and to National Research Council (NRC) Review Committees are also venues through which the NOAA Ocean Exploration Program maximizes the return on investment in ocean exploration education. An external evaluation of the program enables the NOAA Ocean Exploration Program to continue to look forward to high-impact, highly leveraged innovative products and services while considering inputs, outputs, and outcome measures.

5.2.2.2 Strengths

Community-Informed. The Education Program is based on expert community-based informed recommendations that successfully transfer a proven state-level distributed model of professional development to a national level program. This enables NOAA to enhance engagement through partnering with 14 informal Education Alliance Partner sites nationwide to offer high-quality professional development to educators.

Design of Professional Development. The design of onsite professional development is based on the well-known and education research-based Bay Area Writing Project Model of professional development. This model forms the foundation for teaching and learning for professional educators using Learning Ocean Science through Ocean Exploration curriculum.

Engaging Scientists. Through NOAA Engagement, scientists have been provided with first-time opportunities to become engaged in ocean education; this has caused them to reflect on their roles in enhancing ocean science literacy.

Ocean Literacy. The NOAA Ocean Exploration Program introduced Ocean Literacy Essential Principle #7, "The ocean is largely unexplored," and the program has been instrumental in getting ocean literacy and ocean exploration addressed in the draft National Ocean Policy Implementation Plan.

Award-Winning Website. The strength and expertise of web team results in an excellent award-winning Ocean Explorer website. The work of the web team has resulted in a robust archive of information on website, much of which can be reused in a way that is fresh and compelling.

Live-Streaming Video. Live-streaming video and audio and other high definition imagery on Ocean Explorer website attract great interest, including having the site featured recently on The White House Blog. It opens new doors for additional opportunities to reach new audiences in novel ways.

Social Media. Cross-connected social media efforts result in enormous interests and web product usage and helps build and cross-connect audiences.

5.2.2.3 Weaknesses

Staff Limited in Number. Staff involved in Education, Outreach and the website are limited in number, and as new assets, such as the *Okeanos Explorer*, are realized, staff size has essentially remained the same.

Funding. An Education AO has not been offered in three years due to declines in Federal funding.

Higher Education. We need to extend into higher education and community colleges.

Data Acquisition. It is difficult to obtain detailed data on education user groups with website statistics; ability to do a third-level evaluation to determine use and impact over sustained time.

Scheduling. Unpredictable funding levels and resulting ship schedules makes it difficult to design, develop and implement certain education efforts with the *Okeanos Explorer* and other ships.

5.2.2.4 Challenges

STEM Reporting Requirements. The data calls related to America Competes Act, Office of Science, Technology and Policy (OSTP) and Government Accounting Office (GAO) STEM Inventories, development of Co-STEM Five-Year Strategic Plan for Federal STEM Investments are intensive program investments.

Media. The media needs to be persuaded that stories can be told from the Exploration Command Centers.

Web Compliance. Federal government web compliance requirements limit the ability to expand quickly into new communications technologies.

Funding. Funding decreases result in decreases in PI-generated science content on the Ocean Explorer website and the *Okeanos Explorer* website.

5.2.2.5 Opportunities

Social Media. With the NOAA Ocean Exploration Program investments in social media efforts, including the capability to stream live images to mobile devices (i.e., Smart Phones), there is increased potential to define and reach targeted audiences with key messages, including more diverse audiences and those less enthusiastic.

Ship Tours. With the recent development of a formal Education Tour Package for the *Okeanos Explorer* that includes pre- and post-visit information and activities, there is the potential to continue to build out education related to ship tours, both onsite and virtual, including career information and internship leads.

Education at ECC. There is tremendous education and outreach potential for the Exploration Command Centers, whether or not they are currently engaged in active missions. This potential could be easily leveraged across all aspects of the program, building on Education efforts in place through higher education collaborations.

Next-Generation Science Standards (NGSS). The NGSSs are under development and the NOAA Ocean Exploration Program is poised to begin to address them upon their release, as the program is currently correlating lessons with *A Framework for K-12 Science Education* to get educators involved in discussions of the NGSS and how ocean exploration can be used as a context through which to address practice and content.

Rich Content on Website. Online archived courses developed in partnership with The College of Exploration can easily be offered again, and leverage as springboards for content to support higher education courses online and onsite.

Case Study 1: The Ocean Explorer Website Coverage of the *Okeanos Explorer*

The Ocean Explorer website provides robust coverage of all aspects of the *Okeanos Explorer's* expeditions, including a mission plan, background essays describing the science conducted on the mission, frequent topical logs written by those on board, and near real-time daily updates written by the Expedition Coordinator. What sets the *Okeanos Explorer* web coverage apart, however, is its rich multimedia content. The Ocean Explorer website showcases hundreds of above- and undersea images from the ship's expeditions, many of which are available for download in high resolution. It also provides highlight videos of spectacular ROV footage, engaging the public in a rarely seen world of deep-sea ecosystems that they otherwise would never have the opportunity to see. Those wishing to track the ship's location and gain access to oceanographic data during the expedition are provided with a link to the *Okeanos Explorer* Digital Atlas.

Education activities on five reasons to explore Indonesia's deep sea.

One of the most compelling stories of the Ocean Explorer website was the coverage of the maiden voyage of the NOAA Ship *Okeanos Explorer*. The Web site (http://oceanexplorer.noaa.gov/okeanos/explorations/10index/

welcome.html) chronicled the Indonesia-USA Deep-Sea Exploration of the Sangihe Talaud Region (INDEX/SATAL) Expedition over a two-month period. In addition to the usual components of Signature coverage on the website, the majority of the Web site was presented not only in English, but also in Bahasa Indonesian. The site also offered robust media resources including stills, video, Fact Sheets, press releases and news feeds. A Why Do We Explore? Keynote Address featuring Drs. Shirley Pomponi, Charles Fisher, and Edie Widder was also translated into Bahasa Indonesian, and an Education Brochure and Fact Sheet, also translated into Bahasa Indonesian, were posted for students. Daily updates, the Digital Atlas, slideshows and a video playlist were also on the site. This was the first time that a dedicated effort had been made to reach out to the international community through the website.

The White House Blog featuring live streaming video from the NOAA Ship *Okeanos Explorer*.

Perhaps the most exciting multimedia product offered as part of the *Okeanos Explorer's* website is the live stream capability. When a dive is underway, the website broadcasts several video streams, directly from the ship, showing footage from the ROV, as well as sonar displays, navigation displays, and mapping data collection displays. The live feeds have been extremely popular with scientists and the general public alike, and The White House recently featured the coverage, including the feeds, on their blog.

Social media applications associated with the Ocean Explorer website.

Case Study 2: Using Social Media to Engage the Public

The use of social media to promote the Ocean Explorer website and the NOAA Ocean Exploration Program has had an immediate and profound impact on our ability to reach the public. The NOAA Ocean Explorer YouTube channel received over 733,000 video views in 2011 while also adding roughly 1,000 new channel members. This increased the cumulative total video views to 3,459,896 with 4,481 channel members for the year. The channel features 42 videos and attained coveted YouTube partner status in May 2007. More recently, we began featuring the *Okeanos Explorer*'s live video stream on YouTube as part of its "YouTube Live" application, which has been extremely successful.

The NOAA Ocean Exploration Program Twitter feed has nearly 20,000 followers, having doubled its number from last year. The Ocean Explorer Flickr image collection has received over 100,000 views (91,000 of

which were from the "Aliens of the Deep" set), despite a modest representation of about 50 photos.

We are in the process of providing access to our over 500 lesson plans through iTunes University, and are gaining a steady following on the NOAA Ocean Exploration Program Facebook page. Over 900,000 lessons were downloaded from the site last year and RSS feeds have made them even more accessible. The success of these social media ventures underscores the public's deep and abiding interest in ocean exploration, and the importance of the Ocean Explorer Web site in conveying our mission to others.

Sant Ocean Hall, Smithsonian's National Museum of Natural History. ***Image courtesy Chip Clark, Smithsonian Institution***

Case Study 3: The Smithsonian Institution's Sant Ocean Hall

The Office of Ocean Exploration led NOAA's five-year participation in design and development of the Sant Ocean Hall, a permanent national exhibition on the global ocean for the Smithsonian's National Museum of Natural History. The exhibit shows the ocean as a global system essential to all life, vast and largely unexplored. Since opening in 2008 to 42,000 visitors, the Sant Ocean Hall has received five million visitors annually. The exhibition is a cornerstone of the Smithsonian's Ocean Initiative (SOI), designed to increase ocean awareness and bring in a new wave of public ocean literacy. The Initiative is complemented by an online ocean education program via a web-based Ocean Portal with 14 million virtual visitors per year, and an enhanced marine science program at the museum.

The Ocean Exploration Program is involved in all elements of the SOI and ocean exploration content is found throughout the Sant Ocean Hall. As such, the complementary web-based Ocean Portal and associated public ocean programming opportunities are common points of leverage for NOAA Ocean Exploration Program and Smithsonian Institution goals and objectives. In calendar year 2011, the Portal had close to two million page views and the Ocean Exploration Program's contribution regarding the Arctic captured 10 percent of those views.

The exhibit updates and public program opportunities are kept current through the efforts and imaginations of those at the Smithsonian, NOAA and other ocean organizations and the Ocean Exploration Program continues to this day to serve as a coordinating body for this dynamic and evolving partnership with the Smithsonian Institution.

When the museum's new Learning Center opens in 2013, live streaming video from the *Okeanos Explorer* will be a Learning Center highlight. Smithsonian scientists participate in Ocean Exploration Program expeditions through Exploration Command Centers, strengthening the partnership and furthering investments for both entities. The Ocean Exploration Program's Education Program works closely with the Director of Education for the Sant Ocean Hall and provides guidance in the direction of the Education Program's efforts. Formal lectures, informal education activities, Smithsonian Festivals, special

events, book publications and more provide ongoing opportunities to reach audiences broadly and carry the Ocean Exploration Program's message to the National Mall and beyond.

Case Study 4: Ocean Exploration Education Alliance Partnerships

Expert community-based recommendations provided at the National Ocean Exploration Education Workshop held in Charleston, SC in 2002, informed the development of *Learning Ocean Science through Ocean Exploration*, an Earth Science-based curriculum for teachers of Grades 6-12 that takes lesson plans that were developed for the NOAA Ocean Exploration Program's Voyages of Discovery and the Ocean Explorer Web Site and presents them in a comprehensive scope and sequence through subject area categories that cut across individual expeditions. Each lesson focuses on an inquiry-based approach to teaching and learning and is correlated to the National Science Education Standards. What is unique in this approach is the combination of the Ocean Explorer Web Site with each lesson. Through this approach, teachers and students have a direct connection to the scientists whose work they are modeling in the classroom and a direct connection to the exciting new discoveries through ocean exploration.

Location of Alliance Partner sites. Numbers in parentheses represent the number of participants at each partner site.

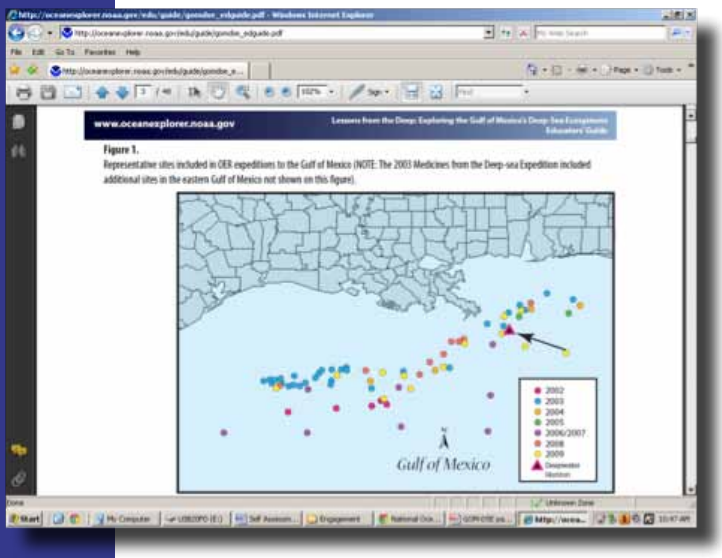
The design of the NOAA Ocean Exploration Program professional development is based on elements taken from the signature professional development program of the NSF-funded South Carolina Statewide Systemic Initiative – The Curriculum Leadership Institute (CLI). The CLI was modeled after the researched-based Bay Area Writing Project Model of Professional Development.

Since education efforts within the NOAA Ocean Exploration Program were not, by initial programmatic design, extended through regional or statewide networks, the NOAA Ocean Exploration Program elected to form novel partnerships with informal science centers and aquariums. Known as Exploration Education Alliance Partnerships (Alliance Partnerships), they were, in fact, novel for NOAA as they were solely dedicated to educator professional development and aimed at creating cadres of ocean exploration teacher leaders throughout the country. Essentially, a successful state model of "distributed" professional development was scaled to the national level within the NOAA Ocean Exploration Program, not only from "operations," but also in "execution."

The number of Alliance Partners has grown from two in 2004 to 14 in 2008 and remains at 14 to date. Seven facilitators are now supporting 14-hour long professional development at Alliance Partner sites to help build regional cadres of ocean exploration teacher leaders around the country. Pre- and post-workshop surveys are administered by the partners. BridgeWater Education Consultants conducted an external evaluation based on five years of survey data and is continuing to evaluate other program components.

Case Study 5: Lessons from the Deep: Exploring the Gulf of Mexico's Deep-Sea Ecosystems

Between 2001 and 2009, the NOAA Ocean Exploration Program sponsored 11 expeditions to explore deep-sea organisms and ecosystems in the Gulf of Mexico, with some of these sites within a few miles of the Deepwater Horizon well. Each of these expeditions was documented with an extensive Web site that included lesson plans for educators of Grade 5 through 12. Shortly after April 20, 2010, in response to the gas explosion that occurred on the mobile offshore drilling unit Deepwater Horizon, the NOAA Ocean Exploration Program began to assemble education materials from each of the 11 expeditions to make them easily accessible in one location on the Ocean Explorer website in anticipation of educator interests in the use of the materials.



Locations of expeditions sponsored by the NOAA Ocean Exploration Program from 2001 through 2009 in the Gulf of Mexico.

The NOAA Ocean Exploration Program developed the Gulf of Mexico Deep-Sea Ecosystem Education Materials Collection (http:// oceanexplorer.noaa.gov/edu/guide/gomdse_edguide.pdf), which includes a selection of expedition lesson plans together with new lessons and additional background information about the Deepwater Horizon blowout event. The purpose of this collection was to provide a foundation for student inquiries into deep-sea ecosystems, and to build capabilities for looking at observations from the NOAA Ocean Exploration Program expeditions with post-event information as more information became available.

Four months after the blowout event, the NOAA Ocean Exploration Program worked with The College of Exploration to offer *Lessons from the Deep Exploring the Gulf of Mexico's Deep-Sea Ecosystems* through an online course (http://www.coexploration.org/oe-dse/). The offering featured Keynote Addresses from renowned ocean explorers who have made significant contributions to scientific knowledge of deep-sea ecosystems in the Gulf of Mexico. Participants were formal and informal educators, as well as interested members of the public. Workshop components include online spaces for discussions to further professional development, a collection of resources, discussion rooms for

Keynote Speakers to interact with participants, and discussion rooms for teachers of different grade levels. A total of 693 participants representing 46 states and 21 countries participated in the offering.

These compiled education resources were also used in a Science Planning Workshop held in Silver Spring, Maryland, shortly after the blowout event to gather input from the science community to help identify exploration target areas for follow-on and baseline characterizations during future *Okeanos Explorer* and other potential exploration missions in the Gulf of Mexico.

5.2.3 Technology Development and Innovation

5.2.3.1 Overview

A startling fact is that in the 21st century, the ocean remains largely unexplored. The physical, chemical, and biological oceanographic processes that affect the planet's largest biome and that significantly influence both weather and climate are, for the most part, mysteries. Recognizing this, from its inception the NOAA Ocean Exploration Program has placed a high value on doing whatever it could, albeit with modest budgetary resources, to engage in marine technology development as well as utilizing existing technologies in innovative ways to increase the scope and pace of ocean exploration.

Because the NOAA Ocean Exploration Program has never been able allocate a robust budget for marine technology development or been able to engage in an aggressive program of innovative technological applications, the Program's successes have been correspondingly modest in terms of scope. The NOAA Ocean Exploration Program's marine technology accomplishments have, however, been of high quality and, while accomplishing exploration at impressive geographic scales, the program has simultaneously been innovative and effective in involving segments of the oceanographic science community, teachers and students and the general public in the excitement and value of ocean exploration.

5.2.3.2 Strengths

Advancing marine technology underpins the NOAA Ocean Exploration Program's entire ocean exploration mission. Because the ocean is vast, mostly unexplored, and the national budget for ocean exploration is relatively small, using purposely designed state-of-the-art marine technology offers the only practical means for effectively exploring the ocean within the, arguably critical, next several decades. Even though NOAA's marine technology budget is small, the program's mission will enable the NOAA Ocean Exploration Program to tackle major technological challenges and sustain the effort necessary to bring them into use.

Another strength available to the NOAA Ocean Exploration Program is that, by having a sustained, long-term approach to development and utilization of advanced marine technology, the program will attract partners whose ocean-related goals will benefit from shared resources and objectives. In particular, this includes being able to leverage the NOAA Ocean Exploration Program funding by taking advantage of NOAA's technological engineering expertise and experience, as well as that of other agencies and institutions.

A key factor in the development and use of marine technology, the NOAA Ocean Exploration Program has reliable access to seagoing assets, especially the NOAA Ship *Okeanos Explorer*. And, as ship time becomes less available over the next several years, reliable access to the *Okeanos Explorer* will be an effective means for securing valuable partnerships.

5.2.3.3 Weaknesses

The principal weakness obstructing the NOAA Ocean Exploration Program's marine technology goals is the lack of sufficient funding to enable advancement of the technology at a pace commensurate with the need. In particular, the program's inability to maintain an annual call for innovative technological proposals from the marine engineering community deprives the NOAA Ocean Exploration Program of a rich source of innovative ideas.

A secondary, less critical, weakness is the lack of dedicated engineering expertise within the NOAA Ocean Exploration Program staff. If the program manages to reinvigorate its marine technology activities (e.g., by reestablishing an annual call for marine technology proposals), having such a person on staff would become more desirable. In the interim, the NOAA Ocean Exploration Program can effectively rely on other NOAA and non-NOAA expertise.

5.2.3.4 Opportunities

Opportunities for advancing the NOAA Ocean Exploration Program's marine technology innovation and development include the following:

- Enhance utilization of the *Okeanos Explorer* as a platform to test and develop new sensors and systems both to enhance the ship's permanent exploration capabilities, as well as for testing new technology for deployment on vehicles including gliders, wave riders, drifters and moorings.
- Establish, maintain, and enhance partnerships with other U.S. ocean-mission agencies, such as BOEM, NSF, and the URI/ISC.
- Maintain/enhance the partnership with the Republic of Indonesia and actively seek other potential international partners with existing ocean exploration activities, *e.g.*, Japan, France, Germany, and New Zealand.
- Leverage the expertise, experience, and technological resources of ocean engineering organizations within NOAA, including the PMEL.

5.2.3.5 Challenges

Challenges faced by the NOAA Ocean Exploration Program's maritime technology enterprise include the following:

- Though NOAA budgets may decrease in economically-challenging times, certain operational capabilities and responsibilities—especially those required by law—will see priority funding. While NOAA's Ocean Exploration Program is often on the leading edge of marine science in the agency, the Ocean Exploration Program must demonstrate its value if it is to receive adequate funding in times of reduced budgets. The most obvious way to counter any action to reduce, or even eliminate, the NOAA Ocean Exploration Program's budget will be to ensure that the program's goals and objectives are as closely linked to NOAA high-priority missions and goals as they possibly can be. The fact that the ocean is under-explored and the

NOAA Ocean Exploration Program missions are strongly interdisciplinary mitigates in favor of the program being able to align its science and marine technology objectives to contribute to NOAA's high-priority objectives.

- The NOAA Ocean Exploration Program is unique among OAR programs in that it has primary financial and management responsibilities for current critical exploration systems and sensors on the *Okeanos Explorer*. A major challenge for the program will be to have adequate resources to not only maintain these capabilities but to refresh them in order to keep the ship on the leading edge of surveying and sampling technologies.

Case Study 1: A New Paradigm for Ocean Exploration: Development and Application of Systematic, Telepresence-enabled Exploration

Telepresence provides an individual or group of individuals with the data and information necessary for participation in an event or effort live when not physically present. Via telepresence, live images from the seafloor and other science data flow over satellite and high-speed Internet pathways to scientists who are standing watches at shore-side Exploration Command Centers around the world. Using Internet 2 connections and the Exploration Command Centers, explorers can remain on shore and lead or be part of the exploration operations, communicating real-time with the shipboard operators. Through standard Internet connections, anyone with a computer and web access can watch and listen in on operations aboard the ship, bringing real-time exploration into living rooms, offices, schools and businesses across the globe.

Through many years of extensive collaborative efforts, IFE), OER, and URI worked to determine the most effective and efficient application of this rapidly developing technology for ocean science, exploration, education and outreach. Each subsequent year brought new challenges and innovations. Over the years, we have developed and refined complex ship- and shore-based operating protocols, brought new ship- and shore-based telepresence systems online, and built the ISC as the hub for this technology at URI.

NOAA Ship *Okeanos Explorer* and IFE's E/V *Nautilus* are the only two vessels in the world that operate under the new paradigm of "telepresence-enabled" ocean exploration. The mission of these two ships is to explore the most unknown areas of the world's ocean, while engaging the interest of scientists, educators, students and the general public in undersea exploration and discovery through active participation in real time.

Case Study 2: Gulf of Mexico Mapping

NOAA Ship *Okeanos Explorer* is outfitted with one of the very few deep water multibeam sonars capable of providing water column backscatter data. In 2009, the ship unexpectedly imaged a large plume of methane gas seeping into the water column at Mendocino Ridge off the coast of California, using her multibeam sonar. Partnering with BOEM and UNH CCOM, a 2011 expedition in the Gulf of Mexico was conducted to follow-up on this capability, with the primary purpose of studying the feasibility of using this capability to map gases in the water column. With its increased swath width, the multibeam sonar offers the possibility of greatly increasing the seep survey efficiency.

In addition to detection and localization, the sonars on the *Okeanos Explorer* were examined for their ability to provide information regarding the seep morphologies, general makeup, and relative densities.

5.2.4 Other Notable Examples of NOAA Ocean Exploration Program-supported Innovative Technology Development

- Development of the TETHYS in situ mass spectrometer. TETHYS is a small, self-contained mass spectrometer capable of operation to 5,000 meters depth. The TETHYS instrument can quantitatively identify a wide range of hydrocarbons at trace concentrations (minimum limits of detection typically 500 parts-per-trillion) in the subsurface environment. TETHYS has been successfully deployed on AUVs, ROVs, towfish, manned submersibles and with divers for a variety of purposes, including deep ocean scientific exploration and mapping missions, as well as commercial offshore oil and gas leak detection and cleanup.
- Support for the *Nereus* Hybrid Remotely Operated Vehicle (HROV), which has reached an 11-km depth and displayed a new concept of operations. Primarily funded by NSF and ONR, and some NOAA Ocean Exploration Program contribution, *Nereus*, an unmanned vehicle, operates in two complementary modes. It can swim freely as an autonomous underwater vehicle (AUV) to survey large areas of the depths, map the seafloor, and give scientists a broad overview. When *Nereus* locates something interesting, the vehicle's support team can bring the vehicle back onboard the ship and transform it into a remotely operated vehicle tethered to the ship via a micro-thin, fiber-optic cable. Through this tether, *Nereus* can transmit high-quality, real-time video images and receive commands from skilled pilots on the ship to collect samples or conduct experiments with a manipulator arm.

5.2.4.1 Catalyzing Research and Informing Resource Management

Since 2002, NOAA Ocean Exploration Program-sponsored expeditions directly and indirectly spurred substantive research and management initiatives. Baseline information from expeditions led to the designation of protected ocean areas. Discoveries have also fueled research into emerging ocean concerns, such ocean acidification and biodiversity. While external personnel were the champions for most examples, the NOAA Ocean Exploration Program has become increasingly proactive at organizing and leveraging activities for broader impact. The following case studies provide a few examples of initiatives that had significant implications for research and management.

Case Study 1. Early Deep Coral Efforts and the Southeastern U.S. Deep Sea Coral (SEADESC) Initiative

Overview: A number of early NOAA Ocean Exploration Program expeditions focused on deep-sea coral habitats in the northeast, the South Atlantic Bight, the Northwestern Hawaiian, Islands, the Gulf of Alaska and the Gulf of Mexico. Information from these early expeditions was crucial to the emergent NOAA focus on important deep-sea coral habitats. The 2006 Magnuson-Stevens Fishery Conservation and Management Act re-authorization included a provision on deep-sea corals. In 2009, NOAA established the NOAA's Deep Sea Coral Research and Technology Program.

Inside the sphere of the Johnson Sea-Link submersible. *Image courtesy of Art Howard, Life on the Edge Expedition, NOAA-OE.*

Within the South Atlantic Bight alone, the NOAA Ocean Exploration Program funded 10 major expeditions from 2002 to 2007 with a focus on deep-sea coral habitats. They corresponded to a total of about 140 days at sea, including more than 100 days at sea on the R/V *Seward Johnson* with the *Johnson Sea Link* submersible. The NOAA Ocean Exploration Program base funding to cover direct science, ship/submersible time, and data analysis exceeded $3M.

Based on requests from the South Atlantic Fisheries Management Council (SAFMC) for fundamental information about deep-sea coral habitats in the region, the NOAA Ocean Exploration Program began working with the Council, project Principal Investigators, and collaborators at the National Undersea Research Center at UNC-Wilmington on a regional synopsis of habitat information from previous NOAA Ocean Exploration Program expeditions.

Marcha Nizinski, NMFS scientist, inspects a deep-water coral for associated fauna. *Image courtesy of Art Howard, Life on the Edge Expedition, NOAA–OE were critical to their designation.*

SEADESC Report: In 2008, the NOAA Ocean Exploration Program published the "Southeastern United States Deep-Sea Corals (SEADESC) Report" as a means of rapidly delivering general, small-scale habitat composition data from deep-sea (>200 m) habitats in the region. The purpose was to provide the scientific community with a means of sharing data from ongoing studies without jeopardizing future publication capabilities. Management and education groups needed information more rapidly than normally provided through the scientific publication process.

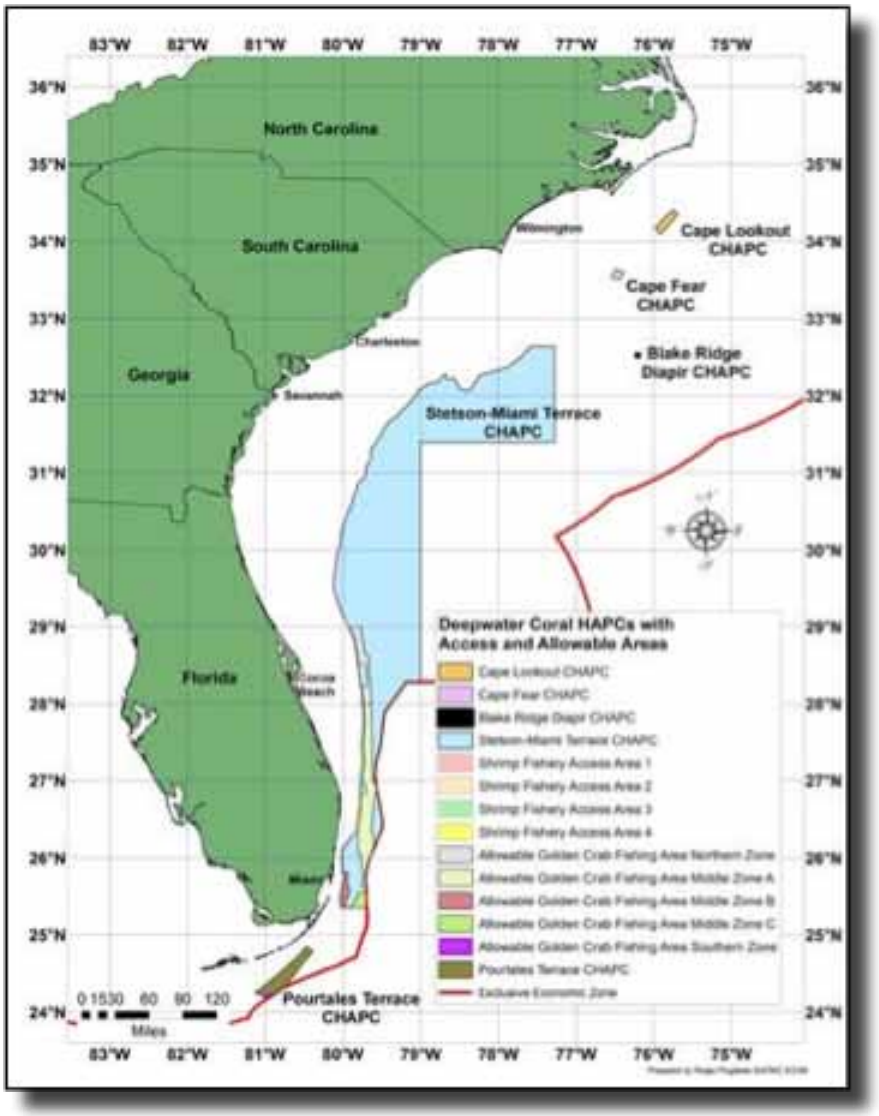
http://explore.noaa.gov/media/http/pubs/SEADESC_Report.pdf

Management Outcomes: The report provides data from eight expeditions over four years and describes areas of deep-sea corals and the habitats they support off the Southeastern United States. The information supported Council decisions to propose designation of four deepwater coral areas for higher levels of protection as new Habitat Areas of Particular Concern.

Myra Brouwer, a SAFMC scientist, said, "Resource managers may sometimes find themselves in the unenviable position of having to make decisions with incomplete information or data. The SEADESC initiative was a good first example of meeting information needs in a timeframe that is relevant

for management. Because the SAFMC received the data early on, rather than waiting a year or more for its appearance in a professional publication, the Council was able to act quickly to propose protection to vast areas of deepwater coral habitat in the South Atlantic region."

On July 22, 2010, the National Marine Fisheries Service and the Secretary of Commerce approved the SAFMC's proposed management measures to help protect these sensitive habitats. In total, five areas, encompassing more than 23,000 square miles (about the size of the State of West Virginia) were designated Coral Habitat Areas of Particular Concern (Coral HAPCs).



Map of the Coral HAPCs proposed by the SAFMC and approved by the Department of Commerce. Data and information from multiple OE expeditions were critical to their design. ***Map courtesy of SAFMC.***