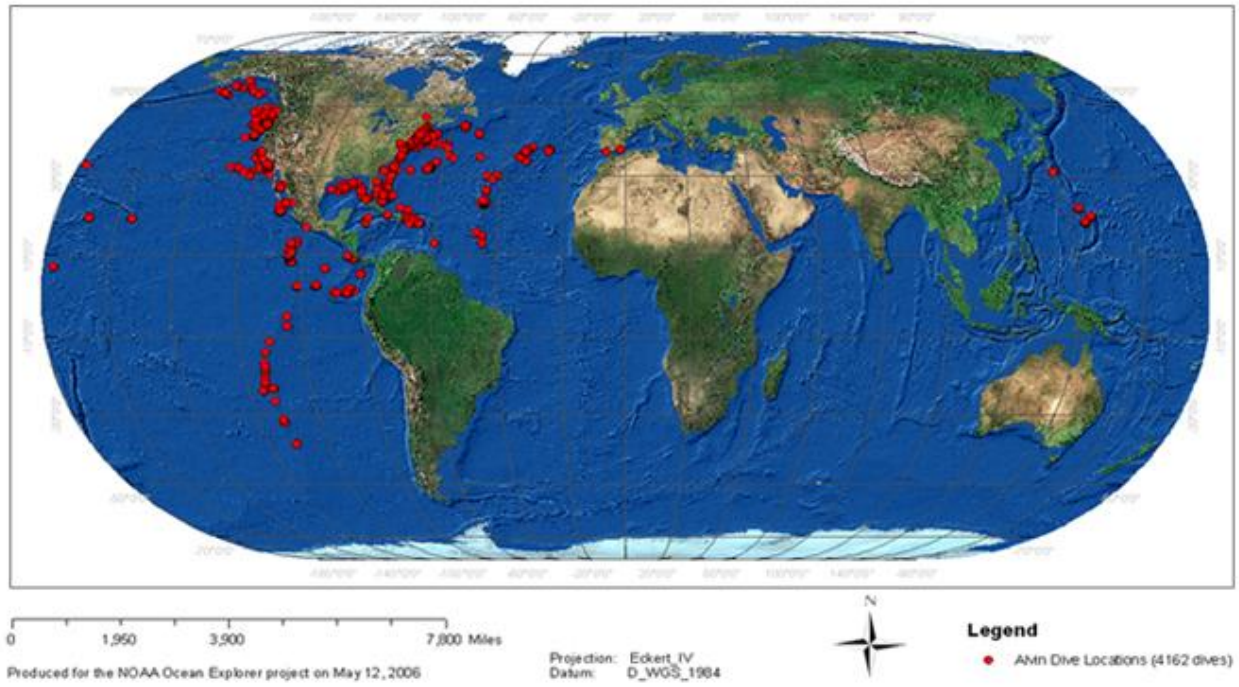
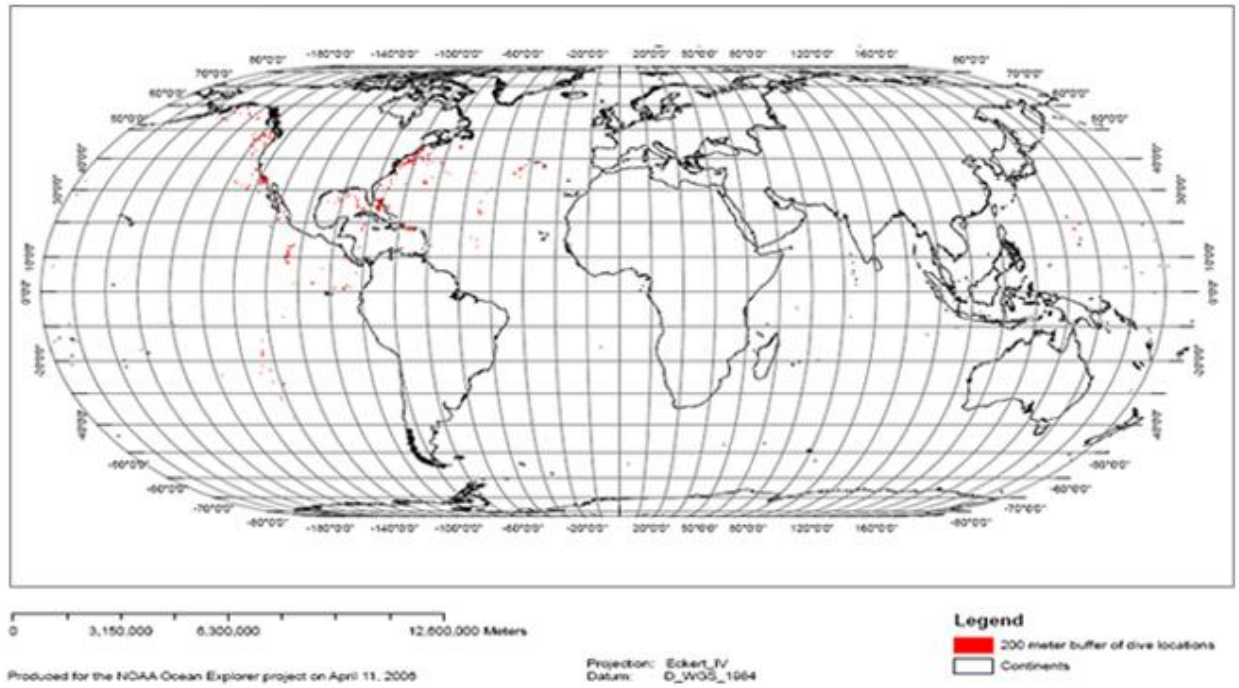
United States Department of Commerce
National Oceanic and Atmospheric Administration

NOAA Office of Ocean Exploration and Research: Strategic Plan FY 2011-FY 2015

May 2011



The Human-Occupied Vehicle (HOV) *Alvin* made 4,162 dives from 1964-2005 or about 100 per year. Dive locations are indicated by red dots (dots not to scale: the dots are about the size/area of the state of Massachusetts, approximately 27,000km^2).



The same 4,162 Alvin dive locations from the upper panel, shown to scale. Here, the dot-size is 0.125 km^2, approximating the actual area studied during a dive. Alvin is used to study in detail areas discovered during exploration. Assuming the same rate of exploration and detailed study over the next 40 years, the global ocean will still remain mostly unknown in 2050. To complement HOV research, OER is investing in new tools, probes, sensors, and unmanned systems to greatly increase the pace, scope, and efficiency of characterizing and accessing the global ocean.

INTRODUCTION

"The oceans are our common global heritage. They cover 70% of the Earth's surface, regulate our weather and climate, and connect the people of many nations. Despite our intimate connection with the sea, much of the world's oceans and ocean floor remain unexplored. This is the last frontier on Earth – and the potential for discovery is largely untapped."[1]

"The basic necessities for protecting lives, enhancing livelihoods, and improving quality of life depend, in no small measure, on properly functioning and healthy ocean ecosystems, the availability of ocean resources, and on a safe and secure maritime domain and associated marine-based economic sectors. The ocean provides food, recreation, and other forms of enrichment, but at the same time, presents risks that, if not understood and respected, pose serious threats to lives and livelihoods. Informed management of the ocean environment will prevent or minimize the risks of illness and disease; bolster the resilience of coastal communities and regions to hazards that arise from the marine environment; enhance national, homeland, and economic security of the nation; ensure the economic productivity of the open ocean, coasts, coastal watersheds, and the Great Lakes; and improve the health of ecosystems within them."[2]

> "Exploration advances the breadth of knowledge and basic research advances the depth of knowledge. Exploration and basic research share:
>
> 1) the goal of discovery and expanding our base of knowledge;
>
> 2) technology and infrastructure needs; and
>
> 3) the opportunity for integrating science and education."
>
> *- J. Yoder, 2003, National Research Council* [1]
>
> **OER combines all three of these aspects in its program.**

The ocean is a significant source of benefits for humanity and is central to the Earth system functioning. Yet, considering the ocean's vastness, there is much more to learn. The National Oceanic and Atmospheric Administration (NOAA) created the Office of Ocean Exploration and Research (OER) specifically to lead the Nation's first program dedicated to expanding our understanding of the ocean via exploration, targeted research, and the use and advancement of undersea technologies.

OER strives to:

- Increase our scientific knowledge and understanding about the whole ocean including its Earth and atmospheric boundaries, its poorly known or unknown marine life, features, non-living resources as well as oceanic processes, phenomena, and interactions;
- Generate new lines of scientific inquiry and research that will help identify how the ocean is changing in response to natural and anthropogenic changes in our planet;
- Develop and use advanced technologies that will enable increased access to the sea and facilitate scientific investigations; and
- Disseminate widely the results of its work to increase ocean literacy and awareness of the importance of the ocean in our lives.

Critical investments with critical results

OER sponsored baseline biodiversity surveys in the Gulf of Mexico years prior to the Deep Water Horizon (DWH) oil platform sinking. The information gathered informed NOAA and was used in the Nation's response to the oil spill. OER technology development investments in an underwater mass-spectrometer allowed for detailed mapping of the subsurface DWH oil. Several months after the spill, OER revisited sites near the well and found dead and degraded coral habitat.

Photo Credit: C. Fisher *Photo Credit: US Coast Guard* *Photo Credit: C. Fisher*

Left to right: Healthy deep sea coral from the Gulf of Mexico; Deepwater Horizon Platform fire; Impacted deep sea coral a few miles from the site of DWH's blown-out wellhead.

PAST AND PRESENT MEET TO BUILD THE FUTURE

NOAA created OER in 2007 by integrating two established programs: the National Undersea Research Program (NURP) and the Office of Ocean Exploration (OE). NURP, which has a nearly 30-year history in NOAA, was created in 1982 as a network of regional undersea science and technology centers at major universities and other facilities to focus its research on NOAA's mission responsibilities and to advance underwater technologies. In 2000, the President's Panel on "Ocean Exploration, Discovering Earths Final Frontier: A U.S. Strategy for Ocean Exploration"[3] recommended establishing a national program in which the cornerstones would be discovery and the spirit of challenge. Given that mankind cannot protect what it does not know and that attaining accurate and complete knowledge of the oceans is essential, NOAA created OE in 2001 to champion a broad spirit of ocean exploration that would involve stakeholders and establish effective partnerships among commercial, academic, private, non-governmental, and government entities.

OER represents much more than a simple merger for administrative efficiency between two historically successful programs. It recognizes and emphasizes that exploration and research are a scientific continuum that are most productive when linked by common objectives and supported by targeted technology development. As an organization, OER is unique in this regard and strongly positioned to advance NOAA and national goals of generating new knowledge and understanding of oceans so critical to human existence. OER is a NOAA foundation program, facilitating NOAA's ability to respond across disciplines with advanced technologies to new and emerging scientific issues and transforming discoveries into useful knowledge and applications.

OER develops and utilizes cutting-edge technology and sensors to explore and study poorly known and unknown areas and phenomena in the ocean. It makes and transitions ocean discoveries and research results to new products, processes, and policies that benefit society; and it manages the information acquired and generates the scientific knowledge necessary to educate the public and inform management and policy makers on the use and preservation of

ocean resources. OER contributes significantly to important NOAA focus areas – such as the Arctic, global climate change, ocean acidification, biodiversity, new ocean resources, coastal and marine spatial planning, as well as technology development and demonstration. OER is critical to the NOAA's mission, which serves the Nation by helping ensure wise ocean environmental stewardship and appropriate utilization of marine resources.

"Risk has several dimensions: lack of knowledge regarding the phenomena or concept itself; lack of knowledge about the applications that might result if the phenomena or concept were understood; inability to gauge the cost of arriving at answers regarding either of these; and difficulty of determining broader operational and cost impacts of adopting the concept."

- R. Van Atta, 2008, DARPA [4]

By learning via exploration and observations and then refining via research, OER can greatly reduce risk associated with adoption or consideration of management actions based on new concepts, phenomena, or technologies by NOAA.

OER IN SUPPORT OF AGENCY GOALS

OER's core capabilities support the overall NOAA science, service and stewardship mission as highlighted in the current version of NOAA's *Next Generation Strategic Plan*, 2010 (NGSP).[5] OER aligns especially with NOAA's dedication to maintain a vibrant research enterprise as expressed within the NGSP [5]---one that provides an expansive grasp on how climate, ocean, and coastal systems are inextricably interconnected. Through discovery, innovation, and the systematic exploration and scientific study of unknown and poorly known ocean areas and phenomena, OER helps NOAA meet its Healthy Ocean objective for "an Improved Understanding of Ecosystems to Inform Resource Management Decisions."[5] The results of OER activities are cornerstones upon which ecosystems will be discovered, defined, and understood. These results will enable NOAA to protect, restore, and manage those ecosystems. The multidisciplinary and interdisciplinary nature of OER activities also are relevant to the NGSP Science & Technology enterprise objectives for "Holistic Understanding"[5] and serve NOAA's Climate Adaptation and Mitigation Goal objective for "Improved Scientific Understanding of the Changing Climate System and its Impacts."[5] OER's activities collect basic ocean data, as well as detect, discover, and characterize ocean phenomena, dynamic processes, and trends that provide essential information for understanding ocean-atmosphere connections and their influence on the climate. In addition, OER catalogues and tracks biodiversity, to provide an indicator of changing natural or human-made ocean conditions, including those driven by climate change. OER also serves as a lead on the NOAA Engagement Enterprise with its main thrust to engage and educate stakeholders with an improved capacity to make environmentally informed decisions.

OER's ocean exploration and research pursuits are highlighted as a priority in NOAA's 20-year Research Vision[6] because they provide a foundation for understanding complex relationships between ocean and terrestrial ecosystems.

Finally, this priority is cited in NOAA's current 5-year Research Plan[7] which acknowledges the need for new ocean technologies including new sensors and platforms and enhanced information and telecommunications technologies.

New methods of sea access and exploration

Unmanned Systems, including Autonomous Underwater Vehicles (AUV), gliders and animal-borne sensors (using elephant seals, narwhals, fish and other animals) are some of the new technologies being used to explore the ocean. (*Photo Credits: D .Costa*)

OER's core activities directly address the challenge associated with expanding the scientific frontier and the need for fundamental science highlighted in the *National Ocean Research Priorities Plan and Implementation Strategy*[2], which states:

> *"It is essential that the Nation cultivate and investigate new ideas about the ocean and new approaches for exploring the marine environment that may challenge existing interpretations. In doing so, society should recognize and even encourage risk-taking in supporting the most exciting and promising ideas for making progress in understanding the ocean."*[2]

OER provides a foundation for all six themes in the *Ocean Research Priorities Plan*[2] through exploration, discoveries, and research. To help the Nation address these themes, OER explores and observes the ocean and its environments, tests new ideas, utilizes new approaches, and develops new technologies. As envisioned in the Report of the President's Panel on Ocean Exploration[3], OER also engages in partnerships with other agencies and programs such as the National Science Foundation (NSF), the Office of Naval Research (ONR), the National Aeronautic and Space Administration (NASA), the Department of the Interior Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE), the Census of Marine Life (CoML), and the National Oceanographic Partnership Program (NOPP) to leverage its pursuit and achievement of NOAA and national goals.

Image Copyright: Emory Kristof, National Geographic
A view of the bow & railing of R.M.S. *Titanic.*

OER VISION

A society that understands the importance of a healthy ocean to all life on Earth and is informed and inspired by discoveries that reveal the wonders, mysteries, and workings of the ocean.

OER MISSION

Develop and use state-of-the-art technology to increase our scientific knowledge of the Earth's largely unknown ocean, in all its dimensions, to support NOAA and national objectives.

OER STRATEGIC GOALS

GOAL 1:	**Conduct scientific baseline characterizations of unknown or poorly-known ocean* basin boundaries, processes, and resources**
GOAL 2:	**Transition ocean exploration discoveries to new research areas (E2R) and research results to new applications (R2A) to benefit society**
GOAL 3:	**Increase the pace, scope, and efficiency of exploration and research through advancement of underwater technologies**
GOAL 4:	**Engage audiences through innovative means by integrating science, education, and outreach**

* "Ocean" includes coastal marine areas and the Great Lakes.

GOAL 1: Conduct scientific baseline characterization of unknown or poorly known ocean basin boundaries, processes, and resources

> "Discovery is the prelude to new paradigms; it jolts us out of the ruts of incremental scientific progress and fuels the great leap forward."
>
> - *President's Panel Report on Ocean Exploration, 2000* [3]

OER conducts interdisciplinary (geological, biological, physical, and chemical) ocean science investigations of unknown and poorly known ocean areas and seeks to catalyze discovery, description, and better understanding of our ocean frontiers through bold and innovative exploration. OER maps, observes, detects, and characterizes ocean basin boundaries, processes, and resources in space and over time. As unknown and poorly known areas or aspects are emphasized (e.g., areas or aspects that are distant, deep, harsh, hazardous, overlooked), these baseline characterizations result in new scientific frontiers, discoveries, insights, and knowledge, and oftentimes, when followed by rigorous research, lead to new or revised understandings of the ocean.

OER's exploration endeavor embraces the U.S. and international ocean science communities and all disciplines of oceanography, including marine archaeology, and supports seagoing assets of the University-National Oceanographic Laboratory System as well as marine institutions and private industry. In 2010, OER initiated cruises using a dedicated exploration vessel, NOAA Ship *Okeanos Explorer,* in addition to other OER dedicated platforms. Goal 1 topical areas include:

Modern science recognizes the huge impact humanity has on Earth's biodiversity, which has changed more rapidly over the past 50 years than at any time in human history.

"It is hard to imagine a more important priority than protecting the ecosystem services underpinned by biodiversity. Biodiversity is fundamental to humans having food, fuel, clean water, and a habitable climate."

-Georgina Mace, 2010, Fellow of the Royal Society [8]

OER 's activities support the establishment of baseline biodiversity inventories and the understanding and implications of its changes.

- **Map and characterize ocean basin boundaries:** Ocean boundaries include those with the solid earth (e.g., the seafloor, ridges, canyons, faults, seamounts, and habitats), the atmosphere (e.g., ocean mixed layers, air-sea interface) and ice (e.g., different ice types and ages, keels, ridges, shelves, icebergs), which may have economic, hazardous, scientific, or cultural importance. OER will conduct these surveys using advanced technology/systems to include autonomous underwater vehicles, multi-beam sonar, side-scan sonar, and other seafloor and water column mapping technologies.

- **Discover and characterize new ocean resources:** Discover, observe, and describe new species, new communities of organisms, and new resources, both living and non-living, including those of economic importance and/or benefit to humanity (e.g., natural products for pharmaceutical or biotechnology applications; new hydrate, seep, or microbial environments; fish stocks and baseline biodiversity inventories; minerals and rare earth elements).

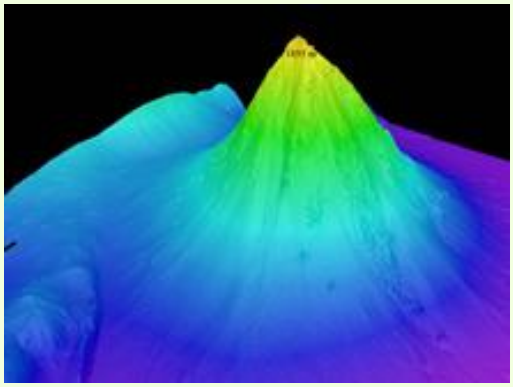


Image Credit: NOAA

Perspective view of the Kawio Barat seamount, in Indonesian waters.

- **Discover and characterize new geological, physical, chemical, and biological ocean processes and phenomena:** Discover, observe, and describe poorly known or unknown processes or phenomena with far-ranging implications for the study of the Earth's system (e.g., ocean currents; plumes or fronts of any origin; benthic-pelagic coupling; ocean-seabed, ocean-atmosphere, and ocean-ice interactions; and other significant ocean processes and phenomena).

- **Discover and characterize submerged cultural resources in the ocean:** Discover and characterize shipwrecks, aircraft, previously sub-aerial landscapes, and other submerged cultural resources. Foster the integration of new techniques and advanced technology in the discovery of underwater archaeology.

- **Define a new paradigm for the conduct of interdisciplinary systematic exploration of the oceans:** Using the NOAA Ship *Okeanos Explorer's* satellite-based, real-time

telepresence system, engage teams of shore-based scientists in the conduct and scientific decisions of the cruise; use and implement new data management practices to facilitate access to new data.

Transitioning Exploration to Research (E2R) and Research to Application (R2A): A Deep Sea Corals Example

In 2003, an OER workshop in Ireland recognized growing international consensus on the widespread distribution of deep-sea corals and their need for further study and protection. The workshop cultivated cross-NOAA line office collaboration. This further led to the establishment a NOAA-wide deep-sea coral working group to address all of NOAA's deep-sea coral activities.

OER-funded deep ocean science was instrumental in defining five areas recently designated as deepwater Coral Habitat Areas of Particular Concern (HAPC) off the U.S. east coast. Targeted research and proactive transition of discoveries through direct engagement with regional fishery management councils resulted in marine managed area designations of over 24,000 square miles.

GOAL 2: Transition ocean exploration discoveries to new research areas (E2R) and research results to new applications (R2A) to benefit society

Results from Goal 1 activities will highlight areas, resources, or processes that are new to ocean science or in need of further refinement. A portion of these new findings, those not directly applicable to NOAA's Mission, will transition to other ocean agencies (e.g., NSF, BOEMRE, ONR) for further research. The majority will have direct NOAA relevance and will need further study within NOAA programs and OER. NOAA-relevant findings are termed "Exploration to Research (E2R) transitions." Not all research conducted in OER will stem from exploration discoveries, but will be initiated on topics or needs arising from urgent events, findings from the broader scientific community, or are essential to move a scientific field forward. Finally, topics, where sufficient knowledge has been gained and which exhibit compelling NOAA-Mission relevance, will transition from Research to Application (R2A) within or outside NOAA. These stages, E2R and R2A, represent a scientific continuum. Examples of the process of getting from E2R and R2A for the topics first identified in Goal 1 are as follows:

- **Characterize ocean basin boundaries:** Baseline maps and characterizations obtained in Goal 1 will be screened to identify areas of intrinsic value or which merit further scientific investigation. These areas include extreme or unique environments, rare or sensitive habitats, and new ecosystems; areas of particular concern which are those that have been subjected to cumulative anthropogenic (e.g., overfishing) and/or natural (e.g., volcanic eruptions) impacts but that provide an important ecological function. These areas will be subjected to further research, mapping, or study to obtain advanced knowledge for consideration of protection from adverse impacts.

Photo Credit: K. Raskoff

Jellyfish in the order *Narcomedusae,* found beneath the frozen seas of the Arctic Ocean.

- **Characterize new ocean resources:** OER will give special attention to newly-discovered communities of organisms that display novel

relationships with their environments. Newly discovered living and non-living resources will be screened for their potential economic importance and/or benefit to humanity, e.g., marine natural products, pharmaceutical or biotechnology application, minerals, rare earth elements, or energy sources. Activities or further research both within and outside of NOAA will bring these resources to market or make them available to industry and academia. Research activities on submerged cultural resources with a significant role in American or world heritage will foster preservation and benefit society.

- **Understand poorly known or newly-discovered geological, physical, chemical, and biological ocean processes, phenomena, and their interactions:** Quantify the time, space, and dynamic variability of poorly known or newly-discovered ocean processes or phenomena with far ranging implications for the study of the Earth's system. These may be natural or human-made and are of particular interest if they result from an interaction across disciplines (e.g., climate change, ocean acidification, underwater volcanoes, seeps, venting, ice formation, or melting) or are, from an ecosystem perspective, important factors in the viability of living species and communities or play significant roles in the creation or destruction of habitats.

- **Understand ocean impacts of Earth's system changes:** Given an understanding of these poorly known or newly-discovered ocean processes, phenomena, and/or their interactions, monitor their status and trends to detect changes which may have far ranging implications for the Earth's system (e.g., changes in temperature, salinity, pH, biodiversity). Use this understanding and change detection ability to improve ecosystem management and ocean policies in order to maintain or restore ocean health.

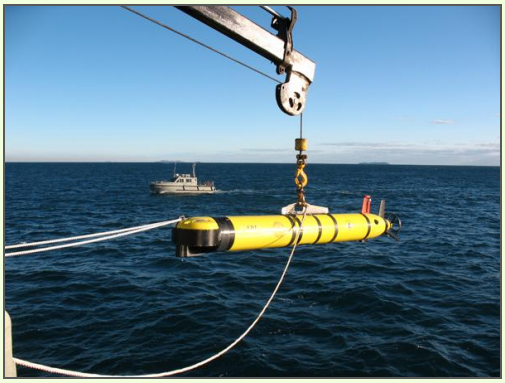


Photo Credit: NOAA

The ATLAS Autonomous Underwater Vehicle (AUV) explored a portion of Lake Huron searching for shipwrecks and mapping geological features with its unique forward looking sonar in an area now included within the expanded boundaries of Thunder Bay National Marine Sanctuary. This is one of several follow-on projects to *AUVfest 2008,* a NOAA OER and Office of Naval Research collaboration to demonstrate the dual-use capabilities of ONR unmanned undersea vehicles and sensors suites for mine hunting and maritime archaeology.

GOAL 3: Expansion of the pace, scope, and efficiency of exploration and research through the advancement of underwater technologies

OER strives to be a NOAA and national focal point for the design, development, deployment, testing, and evaluation of new marine technologies and tools including instrument systems, sensors, and platforms, as well as new technologies for data dissemination and access. New technologies and techniques developed by OER will propel science fields forward. Mission-enabling technologies and their application and transition to operations are focused investments of the program. Technology development efforts within OER will be conducted through long-term partnerships with industry, academia, and other government agencies.

The Current Cost of Doing Business:

- **$50,000 per day:** ALVIN and its Mother Ship
- **$50,000 per day:** University-National Oceanographic Laboratory System (UNOLS) Global Class ship and Remotely Operated Vehicle (ROV)
- **$30,000-40,000 per day:** NOAA or UNOLS Ocean Class Ship and ROV
- **$80,000 per day:** the US Coast Guard Cutter polar icebreaker, HEALY

- **Increase the pace, efficiency, and scope of undersea discovery and understanding by using new technology:** Identify, prioritize, develop, and apply geological, physical, chemical, and biological oceanographic technologies in OER programs.
- **Stimulate and support creative development of new as well as improve existing advanced underwater technologies.**
- **Test and evaluate new advanced underwater technology.**
- **Transition new advanced underwater technologies to appropriate users within NOAA, the broader scientific community, and the private sector.**
- **Provide leadership and coordination throughout NOAA for developing, deploying and utilizing undersea technologies.**

GOAL 4: Engage diverse audiences through innovative means by integrating science, education, and outreach

OER endeavors to enhance literacy about ocean science through discovery and understanding of new ocean resources and ecosystem processes; mapping and characterizing key features and habitats; exploring for maritime heritage sites, and identifying, developing, and applying science tools to increase the pace, efficiency, and scope of discovery and understanding of the ocean.

- **Advance America's environmental literacy:** OER will engage key audiences in ocean exploration and research including near real-time engagement through the telepresence capabilities of NOAA Ship *Okeanos Explorer.* Educators in classrooms will have opportunities to use mathematics, science, and technology content associated with ocean exploration and associated research.
- **Enhance awareness, understanding, and stewardship of the complex ocean system and its importance to all life on Earth:** Through formal and informal education efforts, OER will encourage the fundamental human urge to explore and understand our ocean and to value a productive, robust ocean exploration and research program.

- **Ensure the vision, mission, goals, objectives, and achievements of OER are communicated effectively to audiences including NOAA and other federal agencies, Congress, the science community, educators and the general public:** Outreach efforts will communicate exciting findings on discoveries and missions through the Ocean Explorer website, web-based participation in scientific missions, media coverage, and other tools and techniques.

- **Expand participation of underserved and underrepresented groups:** To expand minority participation in science, technology, engineering, and mathematics (STEM) education and careers, and to assist with the development of the next generation of environmental leaders as diverse as the current and future U.S. population, OER will enhance efforts specifically focused on expanding environmental literacy and STEM education in underserved and underrepresented minority populations.

SUMMARY

The ocean is important to humanity and is still mostly unknown. Current methods of studying its interior, boundaries, processes, resources, and changes are slow and expensive, causing management decisions to be made from relatively uninformed and incomplete knowledge. NOAA formed OER to explicitly address these issues, accelerate the pace of discoveries, and increase our understanding of the ocean.

OER supports a continuum of ocean science that makes discoveries via exploration and research, and transitions the new knowledge and capabilities to the rest of NOAA, and the national and international science, technology, and ocean management communities. OER integrates science, education, and outreach to raise awareness and increase ocean science literacy.

OER discoveries and activities help address issues such as the causes and consequences of natural events and human activities (e.g., climate change, ocean acidification), establishing the baseline and assessing changes in biodiversity and other natural resources or habitats, understanding the dynamics of complex ecosystems, and improving the ability to model and predict future states of ocean and Great Lakes ecosystems.

OER Online Outreach & Education Annually by the Numbers

- 6.7 million visits to website (www.oceanexplorer.noaa.gov)
- 700,000 K-12 Education Module downloads
- 1 million YouTube downloads
- 8,000 Twitter followers (to date)

This plan is centered on four cornerstone goals: exploration, research, advanced undersea technology development, and education and outreach. OER enables discovery through the interdisciplinary efforts of ocean scientists. NOAA mission-related discoveries are transitioned to focused research (E2R) sponsored by OER and by other agencies and programs with ocean-related missions. Subsequent research-to-application and technology-to-application transitions (R2A) are the ultimate goal of OER activities and will strengthen science, education, and awareness, and result in improved societal understanding and management of the ocean.

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