THE REPORT OF

OCEAN EXPLORATION 2020

A NATIONAL FORUM

AQUARIUM OF THE PACIFIC®

A non-profit institution

JULY 19-21 · 2013

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Ocean Exploration 2020: A National Forum.

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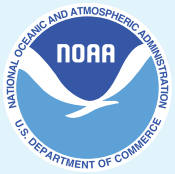

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“ Given the importance of the ocean in human history and in regulating climate change, guaranteeing food security, providing energy resources, and enabling worldwide commerce, it is astounding that we still know so little about it. This is due primarily to the lack of a long-term, large-scale national commitment to ocean exploration. The ocean and its depths need to be systematically explored to serve the interests of the nation and humankind.”

U.S. Commission on Ocean Policy:
An Ocean Blueprint for the 21st Century (2004)

EXECUTIVE SUMMARY

Attendees of Ocean Exploration 2020: A National Forum.

In July 2013, more than 110 ocean explorers gathered at the Aquarium of the Pacific in Long Beach, California, for Ocean Exploration 2020: A National Forum. Ocean Exploration 2020 was the first-ever gathering of a significant segment of the U.S. ocean exploration community, making it distinctly different from the several reviews and commission reports done earlier. Participants in the Forum were challenged to identify key characteristics of a national program of ocean exploration in 2020—the kind of national program called for in the President's Panel on Ocean Exploration (2000); a National Academy of Sciences study (Exploration of the Seas, 2003); and the Ocean Exploration Act of 2009 (PL 111-11).

The forum examined the future of ocean exploration through the lens of a coordinated federal effort involving multiple agencies led by NOAA in collaboration with the private sector. It is a vision that captures many of the nation's ocean exploration activities, but not all. Some will be excluded because of national security, others because of constraints by funders. The proposed framework for Ocean Exploration 2020 captures more of the nation's existing ocean exploration enterprise than ever before and offers ways of expanding and enhancing it.

This report is a record of Ocean Exploration 2020. Ocean Exploration 2020 participants described ocean exploration as a great opportunity, an urgent necessity, and an issue of national security. They agreed that a national program in 2020 should include the following attributes.

OCEAN EXPLORATION PRIORITIES In 2020, clear priorities are identified by the exploration community and revisited on a regular basis.

Having a clear, focused set of ocean exploration priorities is a critical element in developing and sustaining a national program of ocean exploration. No group is better qualified to identify these priorities than the community of ocean explorers. The community identified the polar regions, particularly the Arctic; ocean acidification; and the water column (noting that exploration extends from the sub-seafloor to the surface) as important exploration priorities. The Indo-Pacific and Central Pacific regions are also important for further exploration. Participants agreed that a clear mission statement for national ocean exploration is critical as is a process to engage ocean exploration stakeholders on a recurrent basis in determining priorities.

Image courtesy of the NOAA office of Ocean Exploration and Research.

Photos taken under the Arctic ice surface show the complexity of the ice structure and stunning shades of blue. When ice floes push together, they form pressure ridges that are visible both above and below the surface, forming a complex habitat that supports an abundant and diverse assemblage of organisms.

PARTNERSHIPS In 2020, there is an extensive and dynamic network of partnerships that link public agencies, private sector organizations, and academic institutions.

There was near unanimity that in 2020 and beyond, most dedicated ocean exploration expeditions and programs will be partnerships—public and private, national and international. NOAA has been assigned a leadership role in developing and sustaining a national program of ocean exploration under the Ocean Exploration Act of 2009, one that "promotes collaboration with other federal ocean and undersea research and exploration programs."

PLATFORMS In 2020, a greater number of ships, submersibles, and other platforms are dedicated to ocean exploration.

There is a critical need for new ships and other platforms. The need for autonomous underwater vehicles and remotely operated vehicles is greater than for human occupied vehicles. A national program requires a mix of dedicated and shared ocean exploration assets. Participants agreed that ocean exploration should take advantage of all sources of available and relevant data. For example, cabled observatories, recoverable observatories, the various ocean observation networks, and satellites are all important in a national program of ocean exploration.

TECHNOLOGY DEVELOPMENT By 2020, private sector investments in exploration technology development specifically for the dedicated national program of exploration exceed the federal investment, but federal partners play a key role in testing and refining new technologies.

Forum participants agreed that a top priority for a national ocean exploration program of distinction is the development of mechanisms to fund emerging and creatively disruptive technologies to enhance and expand exploration capabilities. In addition to the significant federal government investment in ocean exploration technology development—whether by the U.S. Navy, NASA, NOAA, or other civilian agencies—many felt strongly that increased investment would come from the private sector to achieve the kind of program they envisioned. Participants also felt that national program partners should continue to play a key role in testing and refining these technologies as well as working to adapt existing and proven technologies for exploration.

CITIZEN SCIENCE In 2020, citizen scientists play an increasingly important role in ocean exploration.

There was a consensus among Forum participants that citizen explorers will play an increasing role in ocean exploration by 2020. These citizen explorers may follow and contribute to national expeditions online, analyze data from past expeditions and submit their work to national and international data bases, or they may use their own tools, such as small, inexpensive remotely operated vehicles equipped with cameras or measuring devices to collect data that are then quality controlled and included in national databases. Opportunities for citizen explorers to participate in shipboard experiences should also be expanded.

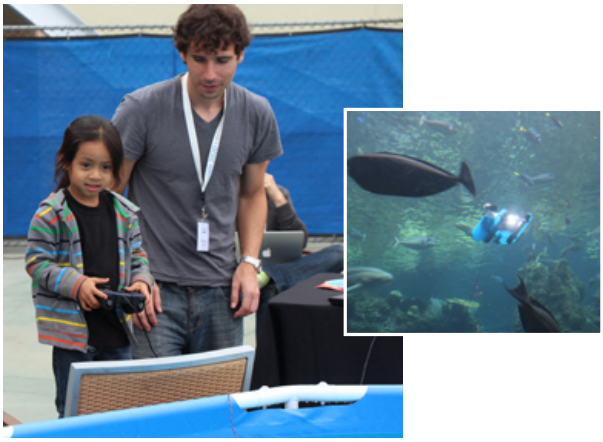
DATA SHARING In 2020, all data obtained through publicly funded, dedicated civilian ocean exploration projects are available quickly and widely at little or no additional cost to the user.

There was a strong consensus among Ocean Exploration 2020 participants that all data, including images and access to samples resulting from publicly supported,

dedicated civilian exploration expeditions, be made widely available at little or no additional cost in real time or as soon as appropriate quality assurances have been completed. Ocean exploration data should reside within established data repositories and their existence be made widely known.

PUBLIC ENGAGEMENT In 2020, ocean explorers are part of a coordinated communication network and have the tools they need to engage the public.

Participants were in strong agreement that we need to enhance and expand existing efforts and find new ways to communicate with the public about ocean exploration. We can provide better interaction between scientists and the public during expeditions, especially increasing the use of telepresence for active engagement.



Eric Stackpole, co-founder of OpenROV, helps a future ocean explorer navigate a remotely operated vehicle. *Image courtesy of Jim Trezzo, OpenROV.*

Ocean Exploration 2020 participants also agreed that a shared strategy is needed to communicate effectively and engage with the public about ocean exploration. Many ocean exploration scientists need more experience and better resources, tools, and partnerships to implement this communication strategy and to build public support for the national program.

Toward a National Program of Ocean Exploration
Ocean Exploration 2020 participants agreed that there is a critical need for effective coordination among the federal agencies in all aspects of ocean exploration and research. Likely federal budget ocean exploration allocations for these agencies are too small for independent approaches.

The community noted that a national program must be flexible, responsive, and inclusive, and called for NOAA to act as a coordinator and facilitator of all exploration activities. The program must have the means to grow partnerships of all kinds to seize the opportunity—and respond to the urgent need to understand the global ocean.

Finally, Ocean Exploration 2020 participants noted the value of this National Forum and the need for regular opportunities for the community of ocean explorers to come together. Maintaining the momentum from Ocean Exploration 2020 is critical, and NOAA and its partners need to take advantage of all opportunities to capture the energy and maintain the commitment of the ocean exploration community.

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ACCELERATING OCEAN EXPLORATION

An editorial by Marcia McNutt, Ocean Exploration 2020 Executive Chair and editor-in-chief of *Science.*

Last month, a distinguished group of ocean researchers and explorers convened in Long Beach, California, at the Aquarium of the Pacific to assess progress and future prospects in ocean exploration. Thirteen years ago, U.S. President Clinton challenged a similar group to provide a blueprint for ocean exploration and discovery. Since then, the fundamental rationale has not changed: to collect high-quality data on the physics, chemistry biology, and geology of the oceans that can be used to answer known questions as well as those we do not yet know enough to pose, to develop new instruments and systems to explore the ocean in new dimensions, and to engage a new generation of youth in science and technology. Recently, however, exploration has taken on a more urgent imperative: to record the substantial changes occurring in largely undocumented regions of the ocean. With half of the ocean more than 10 kilometers from the nearest depth surrounding, ecosystem function in the deep sea still a mystery an no first-order baseline for many globally important ocean processes, the current pace of exploration is woefully inadequate to address this daunting task, especially as the planet responds to changes in climate. To meet this challenge, future ocean exploration must depart dramatically from the classical ship-based expeditions of the past devoted to mapping and sampling.

As a first step, future exploration should make better use of autonomous platforms that are equipped with a broader array of in situ sensors, for lower-cost data gathering. Fortunately, new, more nimble, and easily deployed platforms are available, ranging from $200 kits for build-your-own remotely operated vehicles to long-range autonomous underwater vehicles (AUVs), solar-powered autonomous platforms, autonomous boats, AUVs that operate cooperatively in swarming behavior through the use of artificial intelligence, and gliders that can cross entire oceans. New in situ chemical and biological sensors allow the probing of ocean processes in real time in ways not possible if samples are processed later in laboratories.

Exploration also would greatly benefit from improvements in telepresence. For expeditions that require ships (very distant from shore and requiring the return of complex samples), experts on shore can now "join" through satellite links, enlarging the pool of talent available to comment on the importance of discoveries as they happen and to participate in real-time decisions that affect expedition planning. This type of communication can enrich the critical human interactions that guide the discovery process on such expeditions.

Words such as "crowd sourcing," "crowd funded," and "citizen scientist" are nowhere to be found in the President's Ocean Exploration Panel report of 2000, but at the Long Beach meeting, intense excitement revolved around growing public engage-

ment in many aspects of ocean exploration through mechanisms that did not exist 13 years ago. However, there is not yet a body of experience on how to take advantage of this new paradigm on the scale of a problem as large as ocean exploration. For example, what tasks are most suitable for citizen scientists, and how can they be trained efficiently? Can the quality control of their work be automated? Can crowd-sources tasks be scheduled to avoid duplication and gaps?

Should any region of the ocean receive priority? Although the southern oceans are still largely unexplored, and coral reef hot spots for biodiversity are gravely imperiled by ocean warming and acidification, there was much support by Long Beach participants for prioritizing the Arctic, a region likely to experience some of the most extreme climate change impacts. An ice-free ocean could affect weather patterns, sea conditions, and ecosystem dynamics and invite increases in shipping, tourism, energy extraction, and mining. Good decisions by Arctic nations on Arctic stewardship, emergency preparedness, economic development, and climate change adaptation will need to be informed by good science. Exploration of this frontier needs to happen now to provide a useful informational baseline for future decisions.

Marcia McNutt
www.sciencemag.org

Editorial by Marcia McNutt, "Accelerating Ocean Exploration" SCIENCE 341:937 (30 August 2013). Reprinted with permission from AAAS. Dr. McNutt served as Executive Chair of the Ocean Exploration 2020 Forum.

Image courtesy of Andy David/Schmidt Ocean Institute.

"How fully and wisely the United States uses the sea in the decades ahead will affect profoundly its security, its economy, its ability to meet increasing demands for food and raw materials, its position and influence in the world community, and the quality of the environment in which its people live."

Stratton Commission Report, 1969, p. 1

Image courtesy of Susan Poulton/Ocean Exploration Trust.

Image courtesy of The Schmidt Ocean Institute/Deep Sea Systems International, Inc.

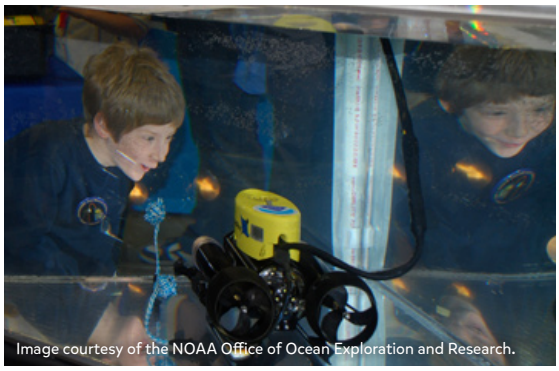
Image courtesy of the NOAA Office of Ocean Exploration and Research.

INTRODUCTION

We've only explored five to ten percent of the World Ocean… just imagine what we'd find if we could explore even more of Earth's final frontier.

We have an unprecedented opportunity to increase the pace and efficiency of exploring the unknown ocean in all of its dimensions in space and time. The past 20 years have seen a dramatic increase in attempts by the U.S. government, academic institutions, private industry and entrepreneurs, and others to explore unknown ocean areas and phenomena. The results of these expeditions establish a foundation that inspires others to follow: to build on the discoveries and apply the knowledge gained to address some of the most pressing challenges we face as a nation and an interconnected world, in addition to the ultimate challenge—our human survival.

Ocean Exploration: An Opportunity and A Necessity

A strong commitment to ocean exploration and research is an opportunity, an urgent necessity, and an issue of national security.

Every ocean exploration expedition yields new data and information, often new species, and sometimes entirely new ecosystems. Scientists from different disciplines, resource managers, and the public working together, unfettered by preconceived notions or constrained by narrowly defined hypotheses, are empowered by the exploratory process.

Exploration:

- **demands integration** of observations, concepts, thoughts, and ideas.
- **leads to discovery of new resources**—food, medicines, minerals, and new sources of energy.
- **leads to new connections** among diverse observations that allow us to quickly provide information critical for establishing or refining marine policy, as well as making important decisions concerning the conservation and sustained use of marine resources.
- **is a critical early phase of research.** It guides research to areas and topics of promise and helps generate and refine research hypotheses, thus increasing the return on the nation's investment in research. As we saw with the discovery of hydrothermal vents and chemosynthetic communities in the 1970s, exploration sometimes requires us to rethink long-held and well-established scientific paradigms, exposing our ignorance and dramatically expanding our knowledge as a result.
- **pushes technology development.** As we seek to explore new depths, in new time horizons, and understand new details of the ocean, new technologies and tools are

developed, from sensors to telecommunications.

- **inspires and moves us** as humans to action, forever changing our perspectives and daily lives, and leaves us with a legacy of knowledge and renewed passion to ensure humanity's survival on the ocean planet—Earth.

We depend on the ocean more now than ever before—as a nation and as a global community. As new technologies and new partnerships allow us to explore and exploit more of the ocean, more quickly, and at a higher resolution and rate than could even be imagined a decade ago, the pressures and impacts on the ocean systems and resources on which we depend also increase. Nations around the world understand the political and economic importance of exploring the ocean, whether in the Arctic or in the South China Sea. Ocean Exploration 2020 is a timely reminder of what we can achieve if we seize our opportunities to act—and the consequences if we do not.

A National Ocean Exploration Program

The President's Panel on Ocean Exploration (2000) and a National Academy of Sciences study (*Exploration of the Seas*, 2003) called for the U.S. to develop a national program of ocean exploration, one that includes the public and private sectors.

The Ocean Exploration Act of 2009 (PL 111-11) requires NOAA to work collaboratively with other federal agencies to develop a coordinated national program of ocean exploration. The statute also calls for NOAA to organize an "ocean exploration forum to encourage partnerships and encourage communications among stakeholders." In 2012, the NOAA Science Advisory Board conducted an independent review of the NOAA Ocean Exploration and Research Program. The review report, *Ocean Exploration's Second Decade*, reminded NOAA of the Ocean Exploration Act's requirements and recommended that a national forum on ocean exploration be held that included representatives of all stakeholders in ocean exploration.

In July 2013, more than 110 ocean explorers met at the Aquarium of the Pacific in Long Beach, California, for Ocean Exploration 2020: A National Forum. Their task: to define the attributes that a successful national program would have in 2020 and establish the framework for the national program of ocean exploration that the Ocean Exploration Act described. This report summarizes Ocean Exploration 2020 findings and recommendations.

Jerry R. Schubel
Aquarium of the Pacific

David McKinnie
NOAA, Office of Ocean Exploration and Research

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OCEAN EXPLORATION 2020 STRATEGY

Individual programs of ocean exploration—whether managed by NOAA, an academic institution, or a not-for-profit organization—focus on priorities that fit their own organizational goals. While some organizational priorities may be national in scope, in aggregate, they fall short of defining a coherent national program. A national program of ocean exploration must include a diversity of voices in setting priorities, a diversity of approaches to exploration, a wide array of disciplines, and involvement of many different stakeholders. The results of such a national program of ocean exploration must be widely and readily available to all. Identifying the framework for this program was a primary goal of Ocean Exploration 2020: A National Forum, held July 19-21, 2013, at the Aquarium of the Pacific in Long Beach, California.

We recognized at the outset that the success of the first National Forum on Ocean Exploration would determine whether there would be a second. Acting on advice and assistance from the Ocean Exploration Advisory Working Group (OEAWG), we designed Ocean Exploration 2020 to be of manageable size—no more than 120 participants—and to focus on the United States. We wanted results and recommendations that could lead to immediate action and help build a diverse community of ocean explorers and a demand for a second National Forum of Ocean Exploration. This section describes our strategy for achieving these results.

INVITATIONS

We invited approximately 160 of the nation's leading ocean explorers to Long Beach. We relied heavily on advice and suggestions from NOAA and other federal agency partners, from key academic and not-for-profit organizations, and from a number of for-profit organizations involved in ocean exploration. This process led to a list of invitees with expertise that ranged from art to zoology. One hundred and twelve ocean explorers accepted the invitation and participated.

VIRTUAL PARTICIPATION

The organizers provided a virtual breakout session for invitees who could not attend the forum in person. In addition, all plenary sessions were streamed live online for the public. Onsite correspondents provided commentary via social media and monitored comments in real-time from the online community, so in-person participants could benefit from the online dialogue.

SURVEYS

To encourage an informed and active dialogue, we designed seven short surveys—one for each of the seven forum themes:

- Exploration Priorities
- Exploration Platforms

- Technology
- Partnerships and Funding
- Data and Information Sharing
- Public Engagement
- Citizen Science

We depended heavily on members of the OEAWG for their advice in developing the surveys. All invitees were asked to take the surveys so that those who could attend in person or virtually could benefit from the views of the larger community of ocean explorers. We compiled the results into graphic form and evaluated additional comments we received to identify the most salient points and elements of convergence. All forum participants received these survey results in advance in order to establish a baseline of common information at the outset of the short, one and one-half day forum event. Graphical summaries of survey results and recurrent comments are included in an appendix to this report.

MARKETPLACE OF IDEAS

The forum began with a "Marketplace of Ideas." Five experts, representing different areas of expertise important to ocean exploration, presented their visions of what a national program of ocean exploration should look like in 2020. These were short dynamic talks intended to stimulate creativity and provoke thoughtful dialogue about the future of ocean exploration. The Marketplace also provided an opportunity for all participants to offer their own ideas for the future, and the moderator shared ideas received in real-time from the online community.

KEYNOTE TALKS

The first full day of the forum began with three keynote talks. Each added a personal perspective on the qualities a national ocean exploration program should have in 2020 and issued a challenge to participants to think creatively about getting ocean exploration on the national agenda by 2020.

RESPONSE PANEL

A response panel of three experienced ocean explorers was charged with reacting to the ideas presented during the Marketplace of Ideas and by the Keynote Speakers. These four program elements—the surveys of the community of ocean explorers, the Marketplace of Ideas, the keynote addresses, and the reaction panel—were intended to set the stage for a vigorous discussion and debate of national program opportunities, requirements, and program elements in the breakout sessions that followed.

BREAKOUT SESSIONS

The executive chair charged each of the four physical breakout sessions and one virtual breakout session participants with defining ten to fifteen elements that should characterize a national program of ocean exploration in 2020. Participants were asked to focus on seven initial themes, but not to be constrained by them. The

rationale for giving each of the breakout groups the same assignment was to attempt to identify the most robust elements a national program of ocean exploration should include. Over the course of two hours, participants debated requirements, priorities, and mechanisms for ocean exploration in 2020, and then reconvened in plenary during which each group reported out their results. The executive chair orchestrated the search for recurrent and well-developed elements and charged that, in their next breakout session, participants should focus their attention on other elements that had support, but not a clear consensus.

The virtual breakout session, hosted on Google+ Hangout, enabled engagement of key members of the ocean exploration community and for the public to monitor and comment on the discussion. The virtual breakout session moderator relayed comments from the online community to the virtual breakout session participants.

In plenary, breakout sessions reported their results with a focus on those important qualities for which there was a strong consensus. The executive chair then reconvened the breakout groups with the task of resolving areas of disagreement.

A final plenary session provided a venue for discussion of results and a summary of consensus elements to include in a draft framework of a national program of ocean exploration—the primary goal of the forum.

EXPLORERS DAY

An important benefit of NOAA's partnership with the Aquarium of the Pacific was the ability to use the Aquarium to showcase ocean explorers and ocean exploration to the public. Aquarium visitors had the opportunity to have breakfast and lunch with explorers, to hear short talks, to operate small remotely operated vehicles, and to interact with several ships of exploration. The Ocean Symposium (www.onlineoceansymposium.com) hosted a Google+ Hangout featuring Ocean Exploration 2020 participants and other ocean explorers to discuss Forum results with a much broader audience than was able to participate in person.

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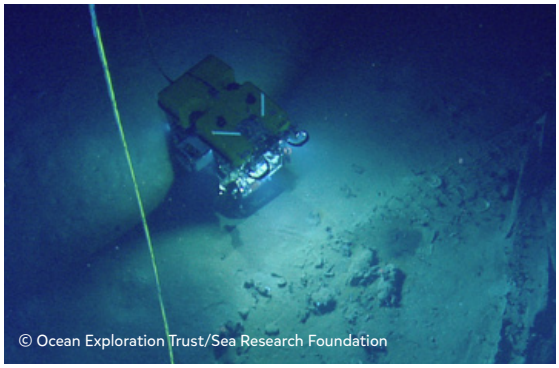

© Ocean Exploration Trust/Sea Research Foundation

"We are growing in the awareness that the ocean influences our daily lives in hundreds of ways. From providing fisheries resources or cures for disease, to unlocking the secrets of long-term climate, we are constantly reminded of the ocean's importance in sustaining life. Truly, our economic, environmental, and national security depend on our ability to understand the ocean frontier, as well as balancing the competing interests of conservation and economics."

Report of the President's Panel on Ocean Exploration. 2000

A FRAMEWORK FOR A NATIONAL OCEAN EXPLORATION PROGRAM IN 2020

Ocean Exploration 2020: A National Forum was the first gathering of a significant segment of the U.S. ocean exploration community, making it distinctly different from the several reviews and commission reports done earlier. Participants in the Forum were challenged to identify key characteristics of a national program of ocean exploration in 2020. These elements could serve as a blueprint for a program that is effective, collaborative, and sustainable.

This report is a record of Ocean Exploration 2020. Ocean Exploration 2020 participants described ocean exploration as a great opportunity, an urgent necessity, and an issue of national security. Based on results of a survey provided to invitees prior to Ocean Exploration 2020 (see appendix) and breakout sessions and discussions during the Forum, we have outlined below a draft framework for a national ocean exploration program that captures those qualities for which there was a strong and unequivocal consensus of the participants in Ocean Exploration 2020.

• • •

Image courtesy of Kevin Raskoff, California State University, Monterey Bay

"Our planet is a big, complex, intricate system and the ocean is the most poorly understood part of it. That system is under stress and we need to improve our understanding of how it works so that we can help preserve our home."

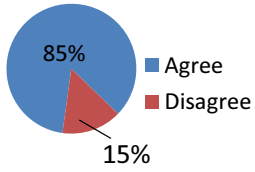
Testimony of James Cameron; Hearing on "Deepsea Challenge: Innovative Partnerships in Ocean Observing" Committee on Commerce, Science, and Transportation, U.S. Senate. June 11, 2013.

OCEAN EXPLORATION PRIORITIES

In 2020, clear priorities are identified by the exploration community and revisited on a regular basis.

Having a clear, focused set of ocean exploration priorities is a critical element in developing and sustaining a national program of ocean exploration. While the national interest, including national security, should drive publicly funded ocean exploration, the interests of the funder will drive privately funded expeditions. However, if both public and private sector institutions shared a core set of priorities, it would increase the probability that all expeditions would be complementary and well integrated with the work of others. No group is better qualified to identify these priorities than the community of ocean explorers.

Agree or Disagree: **Priorities for exploring geographic areas of the global ocean are driven by the ocean exploration community.**



Ocean Exploration 2020 participants came to strong consensus in terms of initial priorities for a national program of ocean exploration. These priorities are divided into geographic area, ocean feature, and oceanic processes and phenomena.

Geographic Areas (in rank order):

- The Arctic
- The Antarctic
- The Indo-Pacific
- The Central Pacific
- The U.S. EEZ and Extended Continental Shelf

Participants noted that "ocean exploration" includes everything from the sub-sea floor to the ocean surface. In all of these geographic areas, participants agreed that a greater emphasis should be placed on exploring the water column than often has been the case in the past.

Ocean Features (in rank order):

- Water column
- Trenches
- Coral ecosystems
- Methane seeps
- Marine life
- Seamounts

Oceanic Processes and Phenomena (in rank order):

- Ocean acidification
- Under-ice communities

As we move ahead in setting national priorities, we need a clear national mission statement that has been vetted widely and endorsed by the extended community of ocean explorers. This mission statement should be revisited every few years and revised as appropriate to reflect changing national priorities, new areas of promising potential for discovery, and new funding opportunities. Such a mission statement should also acknowledge that exploration includes the concept of "serendipitous discovery:" exciting, unexpected results from mission-driven or hypothesis-testing data collection activities.

A national mission statement would provide a focus to bring greater coherency among discrete exploration activities and would offer opportunities for greater coordination and collaboration among federal agencies and between the public and private sectors.

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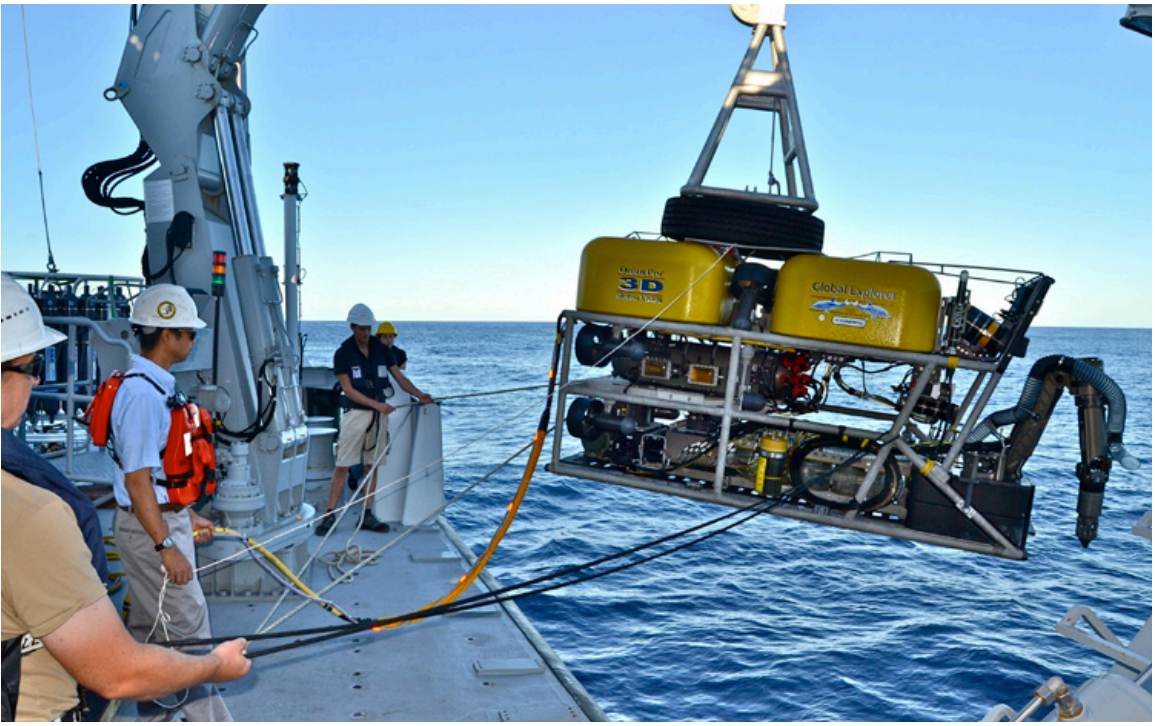
Exploration as Discovery

Exploration is innate to human nature. We are compelled to explore—watch how a baby learns about its surroundings. Exploration (at many scales) has provided the framework for much of what we know about the world we live in. Early explorers ventured out to unknown lands and on the SURFACE of the ocean to discover new territories, extend the sovereignty of nations, and to find new sources of wealth and enterprise. As we have developed tools and technologies to more efficiently and effectively explore, our vision has expanded beyond our own planet and we now venture into space exploring, discovering, and learning about the Universe. And yet… nearly three quarters of our own planet—that part of it that is BENEATH the surface of the ocean—remains virtually unexplored. This is surprising and frightening considering that we DO KNOW that the ocean regulates our climate system and is a critical source of food and fuel—in essence it sustains life on our planet.

It is even more frightening to recognize that despite our current efforts to understand the ocean and despite tremendous advances in technology, we continue to make new and startling discoveries that radically change our view of how our planet works. The discovery of deep-sea vents and the remarkable life forms associated with them, the discovery of many new species of plants and animals, and the discovery of new mountain systems and deep passages on the seafloor that control the circulation of deep sea currents (that in turn control the distribution of heat on the planet) are but a few examples of important ocean discoveries that have changed our understanding of ocean



The *Global Explorer* remotely operated vehicle is launched from R/V *Falkor* during a Gulf of Mexico expedition.

Image courtesy of Schmidt Ocean Institute.

processes but were not part of the planned scientific process.

Just last week, I returned from a mapping cruise off northwestern Greenland. We were looking for a wreck in 300 to 600 meters of water in an area that was supposed to be relatively flat and too deep to be impacted by iceberg keels. What we found was nothing like the preconceived notions. We found a seafloor that had hundreds of meters of relief, we found evidence that iceberg keels had dragged across the bottom to depths well beyond 400 meters and we found surprising passages for warm waters from the continental shelf to enter the fjords and affect the melting of the Greenland icecap. This is not an isolated incident—it happens almost every time we take a close look at the ocean with the right tools. It is difficult for scientists to admit—but we have to admit—that there is so much more that we DON'T KNOW about the oceans. We must put our pride aside and realize that given our limited understanding of the ocean we must extend our study of the ocean to include not only the scientific process of testing specific hypotheses, but also a program of EXPLORATION—a program that is specifically designed to significantly increase the chances of making new discoveries. It will only be after many years of systematic exploration that we will begin to be able to say that we indeed do understand the wondrous ocean system that is so fundamental to sustaining us.

LARRY MAYER
Professor and Director
Center for Coastal and Ocean Mapping/NOAA-UNH Joint Hydrographic Center
University of New Hampshire

Image courtesy of Elizabeth Calvert, University of Alaska, Fairbanks.

"Expeditions to new areas for short periods can provide "snapshots" of the state of the ocean, but they are inadequate for explaining change or transient events, many of which pose considerable hazard to humans and our structures. Examples include phenomena such as El Nino, rapid climate change, volcanic eruptions, and earthquakes."

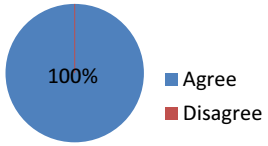
Exploration of the Seas: Voyage into the Unknown. National Academy of Sciences, 2003

PARTNERSHIPS

In 2020, there is an extensive and dynamic network of partnerships that link public agencies, private sector organizations, and academic institutions.

Each individual and each institution brings experience, expertise, and creativity to the table. Partnerships that bring together individuals and institutions that span multiple interfaces among different sectors enhance the potential for significant new advances in discovery, understanding, wisdom, and action. In a time of shrinking federal resources, if there is to be an effective national program of exploration, it will be accomplished through partnerships.

Agree or Disagree: **Leverage gained by partnerships is critical to ocean exploration.**



There was a strong consensus—near unanimity—that in 2020 and beyond, most ocean exploration expeditions and programs will be partnerships—public and private, national and international. NOAA has been assigned a leadership role in developing and sustaining a national program of ocean exploration under the Ocean Exploration Act of 2009 (Public Law 111-11). The act mandated that NOAA undertake this responsibility in collaboration with other federal agencies.

Ocean Exploration 2020 invitees felt that federal and academic programs should be more assertive in seeking partnerships with ocean industries. It was, however, acknowledged that the necessity of sharing data might pose a challenge for some industry partners as well as federal agencies with restricted missions, like the Navy's Office of Naval Research.

There was a strong feeling that the community of ocean explorers needs to be more inclusive and more nimble, two sometimes conflicting qualities. Nimbleness will require more non-governmental sources of support and a small, dedicated, dynamic decision-making group that represents the interests of the ocean exploration community and that commands their trust.

A coherent, comprehensive national program of ocean exploration requires sustained core support at some predictable level from the federal government and demonstrated coordination among the federal agencies involved in ocean exploration, in order to leverage involvement of business, industry, foundations, and NGOs.

Timely and effective communication among partners is necessary to build and sustain the expanded community of ocean explorers.

First Principles for a Maritime Nation

"The U.S. Ex Ex," a creation of Congress (PL 24-24), a voyage of discovery 175 years ago, was a deliberate step by a tentative nation with an eye on becoming a world power. A six Navy ship flotilla, manned by 346 military and civilian scientists was charged by government to explore the vast Pacific, top to bottom. Called "The U.S. Exploring Expedition," it sought to discover the natural characteristics of the great Pacific, extend U.S. presence by connecting to new peoples and collect data useful to U.S. seaborne commerce and naval operations.

Fast forward to 21st century America, no longer a tentative nation, now the greatest maritime nation in world history. Its place in the middle of the great ocean system enables prosperous trade and a unique security situation.

Yet, that ocean system is still largely unexplored. A world power unavoidably dependent on the ocean still does not understand the ocean's full range of opportunities and dangers.

A world maritime power—The World Power, The United States—cannot afford to be surprised by the very natural features that characterize her as a maritime nation.

Exploration projects in the high Arctic have found unexpected (previously undiscovered) ocean bottom variability and changes in water temperature structure. Now that is important to defense, especially safe U.S. submarine operations. It also gives a hint about past climate fluctuations so we can get a better idea of the ocean's and Arctic's role in climate excursions. Arctic exploration discoveries will also help America argue for rights to minerals off its northern coast.

There are a few, scattered ocean exploration efforts within our nation. Federal agencies do make new discoveries incidental to their separate missions. And, privately funded citizen explorers are getting excited about the ocean. While this collection of small efforts survives, each for its own purpose, the Congress expected more. The nation needs more to ensure maritime strength.

A broad, coordinated national program envisioned by Congress in PL 111-11 could help prioritize cross-agency oceanographic campaigns, strain

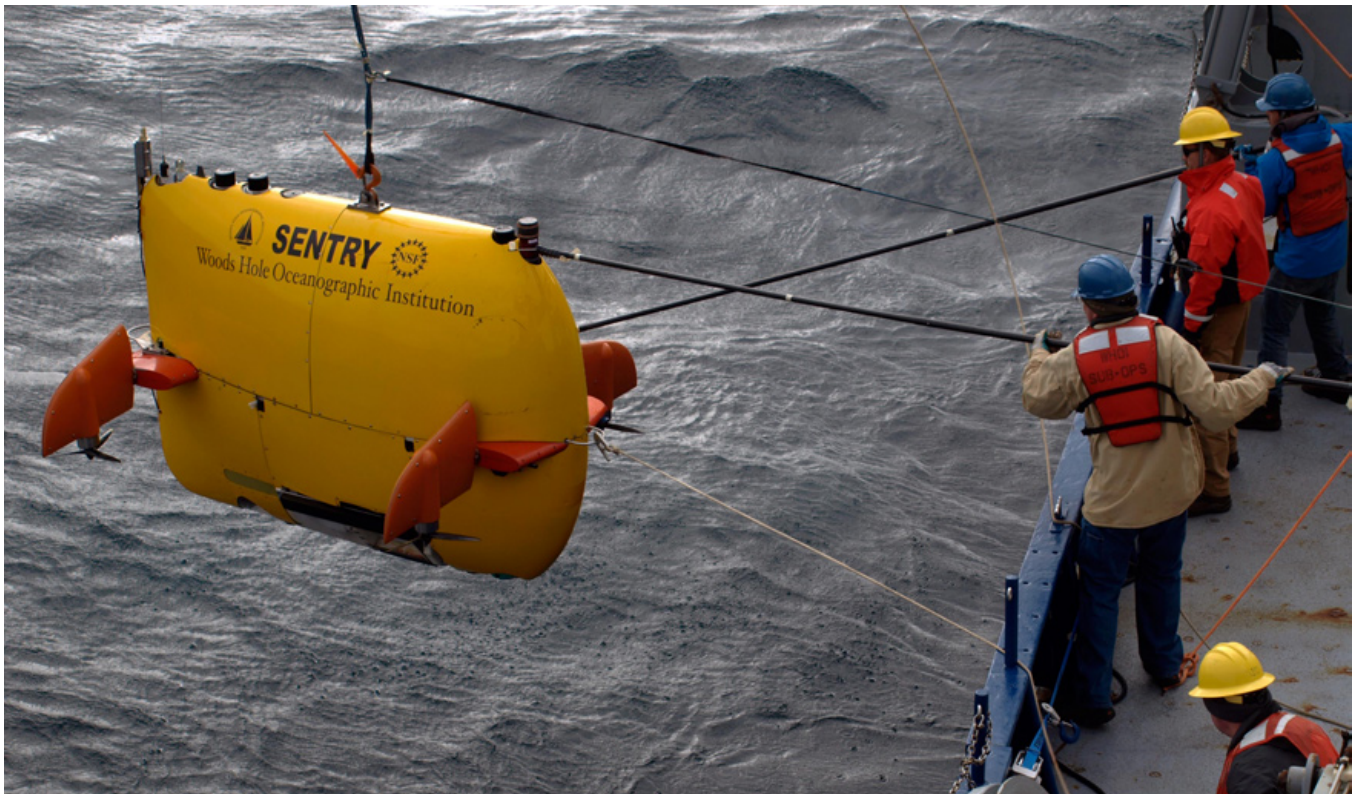


Image courtesy of Chris German and the NOAA Office of Ocean Exploration and Research.

Woods Hole Oceanographic Institution's autonomous underwater vehicle, *Sentry* can dive to 6,000 meters. *Sentry* produces bathymetric, sidescan, subbottom, and magnetic maps of the seafloor and is capable of taking digital bottom photographs.

from mission and research-driven expeditions and private excursions those bits of information that are of new-discovery-quality and guarantee that it will be archived within government and shared with an increasingly excited group of American citizen explorers.

It is government's role to set the nation's priorities, create and maintain the information backbone, and carry out comprehensively over the long term a program to understand the opportunity and dangers in an ocean system in whose middle America sits. Only after it has demonstrated this commitment to leadership can it fully leverage investments from the private sector.

Paul G. Gaffney II
Vice Admiral, USN (Ret.)
President Emeritus, Monmouth University
U.S. Commission on Ocean Policy

Image courtesy of NOAA Office of Ocean Exploration and Research.

"Exploration is an early component of the research process; it focuses on new areas of inquiry and develops descriptions of phenomena that inform the direction of further study, it is the collection of basic observations that later allow hypotheses to be posed to connect those observations with laws of physics, chemistry, and biology."

Exploration of the Seas: Voyage into the Unknown.
National Academy of Sciences, 2003 p. 17

PLATFORMS

In 2020, a greater number of ships, submersibles, and other platforms are dedicated to ocean exploration.

Ocean exploration priorities will frequently dictate the types of platforms needed for a national program of ocean exploration. Since mission priorities change, the mix of platforms needs to include a wide variety of capabilities as well as provide flexibility and nimbleness.

The great majority of Ocean Exploration 2020 participants felt that the current suite of available platforms is not sufficient to sustain an evolving national program. There was a strong consensus that a more diverse and dynamic mix of platforms is needed that includes:

- Dedicated ships of exploration
- Ships of opportunity
- A variety of submersibles—AUVs, ROVs, and HOVs—with a range of depth capabilities that include full ocean depth
- Small, inexpensive ROVs that put ocean exploration in the hands of citizen scientists
- Instrumented marine animals
- Stationary observing networks and sensors

The value of having one or more dedicated federal ships of ocean exploration was endorsed.

In addition to platforms that move through the water in three dimensions, there was strong support for seafloor observatories that document changes in the fourth dimension—time. A fully mature national program of ocean exploration must have both components.

In addition to greater investments in ships, better coordination among ships of exploration and other exploration assets is essential to ensure a maximum science payoff per dollar invested.

In 2020, platforms will be equipped with better, more sensitive, more robust sensors that are capable of measuring priority ocean properties.

• • •

The Future of Exploration Beneath the Sea

When you mention the word "Exploration" most people think of Captain James Cook, Vasco de Gama, Sir Francis Drake, Marco Polo, Ferdinand Magellan, and Christopher Columbus; all of whom died long ago. But when it comes to "Ocean Exploration", the greatest ocean explorers of all time are more than likely still in middle school since that generation of future explorers will explore more of Earth than all previous generations combined.

The reasons are simple. 72% of the world lies hidden beneath the sea and most of it lies in a world of eternal darkness and is unexplored. In fact, we have better maps of the far side of the moon than half of the United States of America. Daunting as this task may seem, new advances in undersea exploration technologies and now greatly accelerating our rate of exploration.

The unexplored regions of our oceans not only contain important keys to unlocking the history of planet Earth, they also contain vast mineral resources, new fisheries, and important places beneath the sea that need to be set aside as marine sanctuaries. The oceans also contain more lost chapters of human history than all of the museums of the world combined.

Within the last few years, our country has taken the first step towards exploring the unknown when it brought two ships of exploration on line, the National Oceanic and Atmospheric Administration's *Okeanos Explorer* and the Ocean Exploration Trust's *E/V Nautilus*.

Using the latest in advanced exploration technologies, these two ships have the ability to map the uncharted landmasses beneath the sea and then, using advanced underwater vehicle systems, explore and document what lies there.

Using the Inner Space Center at the University of Rhode Island, the next generation of ocean explorers can watch the exploration being carried out live on two of America's ships of exploration, and share their discoveries with others in real time.

So tune in to tomorrow!

Dr. Robert D. Ballard
President of the Ocean Exploration Trust and
Director of the Center for Ocean Exploration, URI/GSO

TECHNOLOGY DEVELOPMENT

By 2020, private sector investments in exploration technology development, specifically for the dedicated national program of exploration, exceed the federal investment, but federal partners play a key role in testing and refining new technologies.

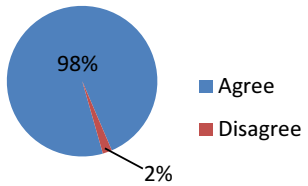
Forum participants agreed that a top priority for a national ocean exploration program of distinction is the development of mechanisms to fund emerging and creatively disruptive technologies to enhance and expand exploration capabilities. In addition to significant federal government investment in ocean exploration technology over time—whether by the U.S. Navy, NASA, NOAA, or other civilian agencies involved in ocean exploration—many felt strongly that to shorten the time from development to unrestricted adoption, more of the required investment would come from the private sector.

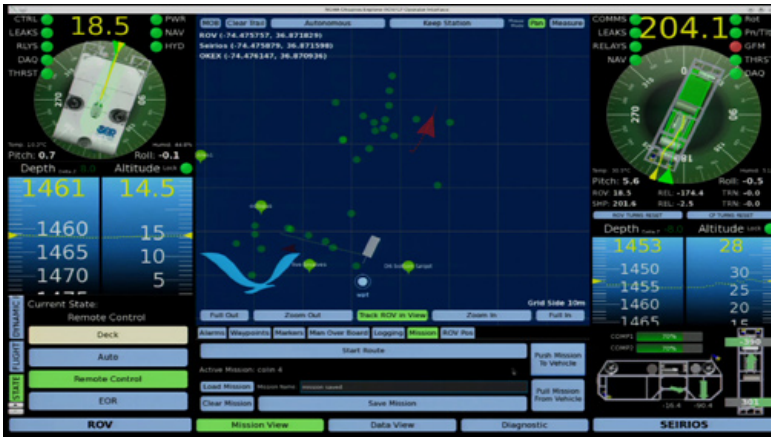
These emerging technologies will likely include the next generations of ships; remotely operated vehicles; autonomous underwater vehicles; telepresence capabilities; and new sensors. Most participants felt that continuing to develop human occupied vehicles should be a much lower priority for a national program than focusing on autonomous vehicles, sensors, observatories, and communications systems.

Participants also felt that federal partners in the national program of exploration should play a key role in testing and refining these technologies as well as working to adapt existing and proven technologies for exploration.

Overall, some of the most important technologies to cultivate are those that collect physical and chemical oceanographic data, biological data, and seafloor mapping data.

Agree or Disagree: **Technology will continue to create efficiencies in ocean exploration and make expeditions more accessible.**





Remotely operated vehicle (ROV) pilots use this control system display screen to monitor and control NOAA's *Deep Discoverer* ROV and its companion camera and lighting vehicle *Seirios*.

Image courtesy of the NOAA Office of Ocean Exploration and Research.

Exploration Seen Through the Lens of Research

There has been some feeling that increasingly sophisticated computer modeling and powerful remote sensing from satellites have reduced the need for ship-based exploration. I do not share this feeling. Computer modeling has been extremely effective in tying down the quantitative relationships, but only after the primary processes have been recognized and described. Computer modeling has not been effective in the recognition of new processes. This takes exploration.

Exploration can be considered as an early phase of research, the phase before scientific hypotheses can be well formulated. While to some it may seem to be too risky, particularly during periods of severe financial constraints, it is a critical phase of a mature national research program. It encourages risk-taking, asking bold questions with little guarantee of success, but when success occurs, the rewards are huge, sometimes turning an entire field on its head causing us to rethink long-held paradigms.

I became a student of Harald Sverdrup in 1940 soon after he returned from seven years in the Arctic aboard the *Maud* to become the third Scripps Director. When telling about his experiences when the *Maud* was frozen in the floating ice sheets he would come back to his concern that nothing was known about the melting processes at the bottom of the ice sheets; all efforts were towards studying the melting processes at the surface due to solar radiation. It was not until 2000, long after computer modeling and satellite remote sensing became powerful tools, that it was realized that an exploration of the ice bottom melting processes was needed for any understanding of the disappearance of the ice cover. The interaction of the underlying warm salty ocean with the cold fresh ice cover involves some unexpected processes (like double-diffusion). Thinking back on the long-term developments, I am uncomfortable that so many of our present graduate students seem to prefer working on improving and quantifying our understanding of known processes ("safe" subjects) rather than the exploratory work when it is even unclear what the vital questions are ("daring" subjects with no assured success). I am afraid that the attitude of the funding agencies may have contributed to the avoidance of daring explorations. (Judith and I used our Kyoto Prize money to establish a Scripps fund to support daring research of our graduate students).

Let me give a personal example I have wrestled with for more than 50 years—wind drag on the ocean. Nothing can be more fundamental to the understanding of ocean dynamics than wind drag. It is responsible for the

Gulf Stream, for upwelling, for aerating the upper ocean, and many other important oceanic processes and phenomena. Of the three forcing functions, winds, tides, and buoyancy, wind drag is the most important. Without wind drag the ocean would be a stagnant polluted pool.

One might expect that after two centuries of ocean exploration we would have a first order understanding of wind drag. We do not! We do not understand what makes wind drag over the ocean different from wind drag on a polished surface or on a cornfield. What scale waves contribute to the essential surface roughness? Solving this fundamental issue will require exploration.

There are many other examples. The age of exploration is not at its end.

Walter Munk
Professor emeritus
Scripps Institution of Oceanography

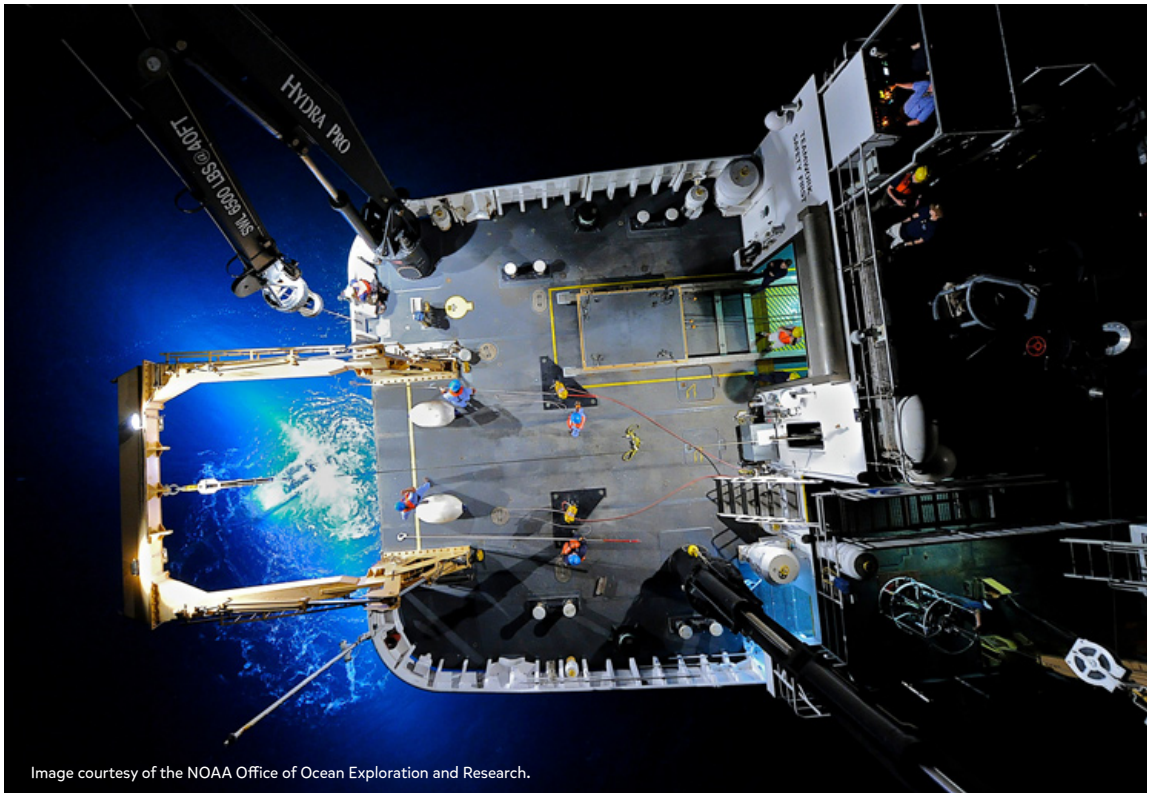


Image courtesy of the NOAA Office of Ocean Exploration and Research.

A unique down-looking view of a remotely-operated vehicle recovery at night on NOAA ship *Okeanos Explorer*. The underwater glow is created by the powerful lights on the NOAA *Seirios* camera sled.

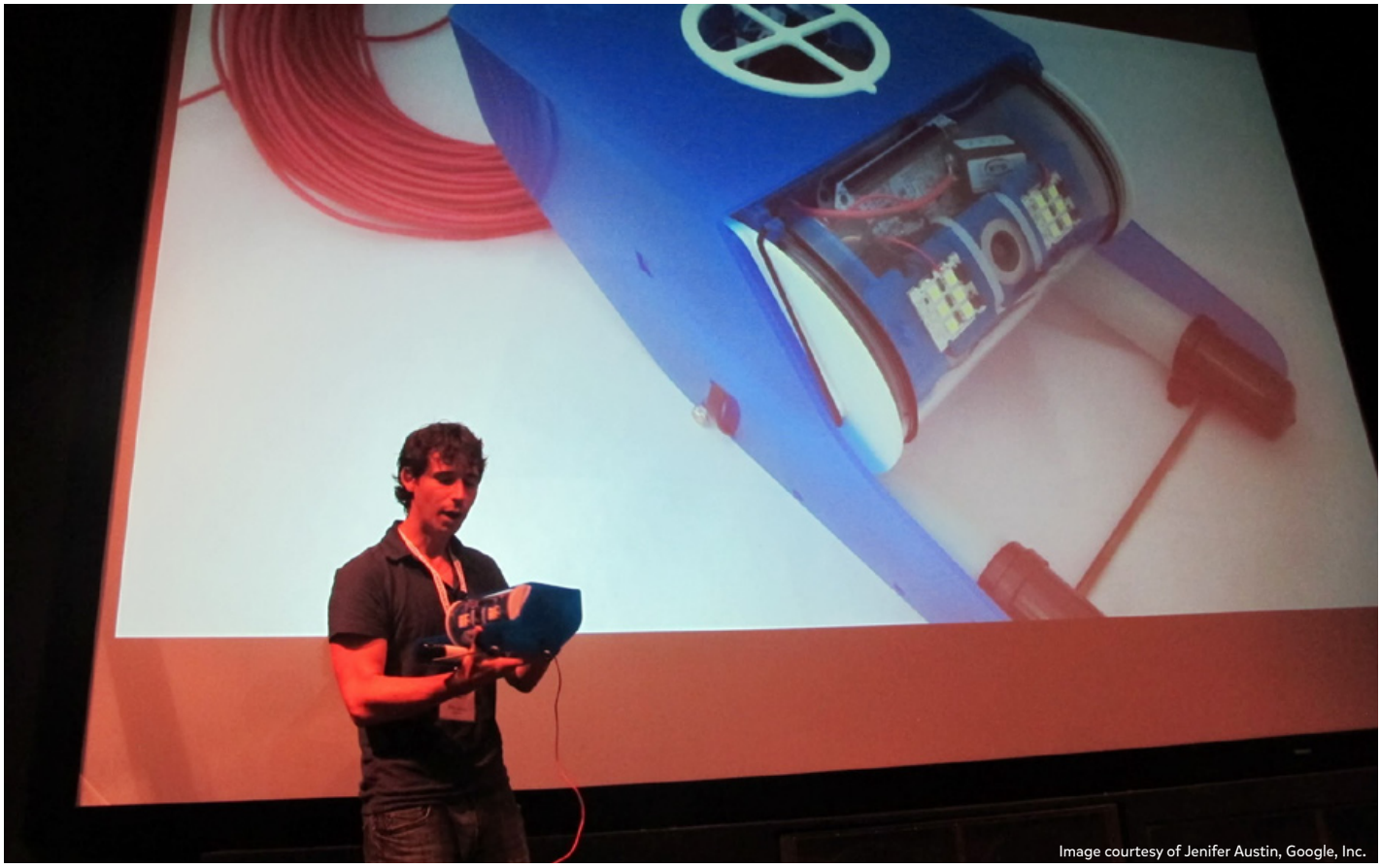


Image courtesy of Jenifer Austin, Google, Inc.

“Exploration is the engine that drives innovation. Innovation drives economic growth. So let’s all go exploring.”

Edith Widder

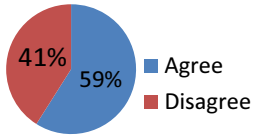
CITIZEN SCIENCE

In 2020, citizen scientists/citizen explorers play an increasingly important role in ocean exploration.

Expanding opportunities for citizens to be involved in all phases of ocean exploration will engage and energize them in efforts to support ocean exploration. Combining "citizen science," or scientific research conducted by non-professional scientists, with the work being conducted by the professional ocean exploration community, has the potential to expand the resources available.

There was a consensus among Forum participants that citizen explorers will play an increasing role in ocean exploration by 2020. These citizen explorers may follow and contribute to national expeditions online, or analyze data from past expeditions and submit their work to relevant national and international data bases. They also may use their own tools, such as small, inexpensive remotely operated vehicles equipped with cameras or measuring devices to collect data that are then quality controlled and included the same national and international databases. Opportunities for citizen explorers to participate in shipboard experiences should also be expanded.

Agree or Disagree: **In 2020, citizen scientists will play a major role in ocean exploration.**



There are excellent models for engaging citizens in large scientific projects such as Citizen Science Alliance's Zooniverse and the USGS National Map Corps. A national program of ocean exploration could provide similar opportunities for citizen participation in classifying oceanographic features or biota.

Appropriate data assurance and quality control mechanisms are required for data collected by citizen scientists/explorers to be incorporated into existing relevant data repositories. Forum participants overwhelmingly agreed that with these mechanisms, crowdsourced data should be eligible for inclusion in national and international data sets. With proper protocols, citizen explorers can play an important role in advancing the objective of a broad-based, national program of ocean exploration.

Forum participants felt strongly that a national ocean exploration program should establish mechanisms that not only allow, but encourage, meaningful participation of citizen explorers in a variety of ways.

On the Importance of a National Program of Ocean Exploration to Education

In the current competitive global economy, the United States faces a distinct disadvantage. Only 16 percent of American high school seniors are proficient in mathematics and interested in STEM careers. And among those who do pursue college degrees in STEM fields, only half choose to work in a STEM-related career.

The benefits of STEM education are clear. By 2018, the U.S. anticipates more than 1.2 million job openings in STEM-related occupations, including fields as diverse as science, medicine, software development, and engineering. STEM workers, on average, earn 26 percent more than their non-STEM counterparts, and experience lower unemployment rates than those in other fields. In addition, healthy STEM industries are critical to maintaining a quality of life in the United States.

A national program of ocean and Great Lakes exploration provides myriad ways to capture public imagination and curiosity to support sustained involvement and more intense exposure not only to STEM topics, but also the humanities and arts. New less expensive tools, such as small ROVs, remote sensing stations, and underwater cameras, enable everyone to participate in ocean and freshwater exploration as citizen scientists. These types of public engagements around exploration, such as through the NOAA kiosks stationed in Coastal Ecosystem Learning Centers, provide a glimpse into the true nature of science: not merely as a bundle of textbook facts, but a dynamic enterprise of investigation that is constantly changing as our understanding evolves.

The effectiveness of STEM-focused programs are evident; studies have shown not only that young people enjoy inquiry-based STEM activities in and out of school settings, but also that sustained involvement and more intense exposure to STEM topics increase youth interest and confidence in their scientific abilities. By engaging the public with ocean and Great Lakes observation, we provide people of all ages with opportunities to explore their natural aquatic environments, and to fall in love with the magic and mystery of scientific exploration.

Ted A. Beattie
President, Shedd Aquarium

Jerry R. Schubel
President, Aquarium of the Pacific

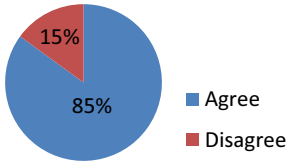
DATA SHARING

In 2020, all data obtained through publicly funded, dedicated civilian ocean exploration projects are available quickly and widely at little or no additional cost to the user.

Ocean exploration missions will typically collect very large amounts of data. It is through the transformation of these data into information that the full value of exploration is realized. The more people who have access to the data, the richer the opportunities are for interpretation and transformation into information that is useful to a wider variety of stakeholders from scientists to educators to policymakers.

There was a strong consensus among Ocean Exploration 2020 participants that all data, including images and access to samples, resulting from publicly supported, dedicated civilian exploration expeditions should be made widely available at little or no additional cost in real time or as soon as appropriate quality assurances have been completed. Participants noted that this requirement should be a condition of a grantee's acceptance of public funding and that any funds necessary to meet this requirement should be included in an expedition's budget. Ocean exploration data should reside within established data repositories and their existence should be made widely known.

Agree or Disagree: **Nearly all publicly funded exploration data should be made available in a timely way at no cost.**



Participants agreed that maps of the seafloor, oceanographic and biological observations, video and still images, and chemical and geochemical data were among the most important ocean data sets to share with the extended exploration community.

There was also agreement that leaders of a national program should have a responsibility to synthesize data collected for ocean exploration and other purposes to identify gaps and help refine priorities.

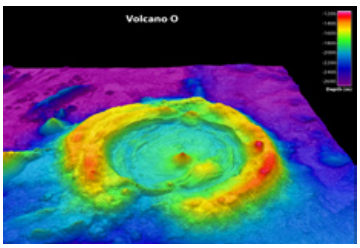


Image courtesy of Susan Merle, OSU, NOAA Office of Ocean Exploration and Research, and the NOAA Vents Program.

Image courtesy of the NOAA Office of Ocean Exploration and Research.

Image courtesy of NOAA Office of Ocean Exploration and Research.

Ocean Exploration

Being territorial animals, we instinctively explore. In the struggle for existence we scout for both threat and opportunity. Territory implies land, but most of the unexplored earth is ocean. The Census of Marine Life (2000-2010) collected tens of millions of observations of marine species from old and new expeditions. We organized data on more than 200,000 forms of marine life. We mapped the known and thus also defined the blank spaces, the unknown.

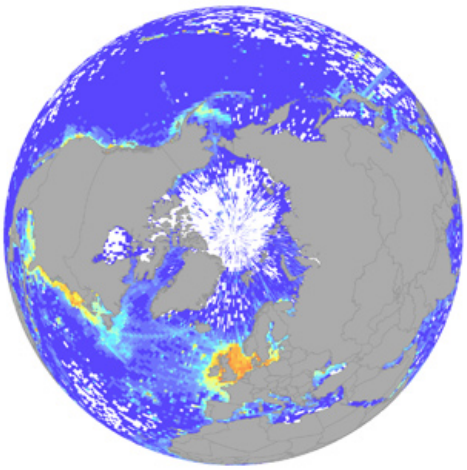


Figure 1

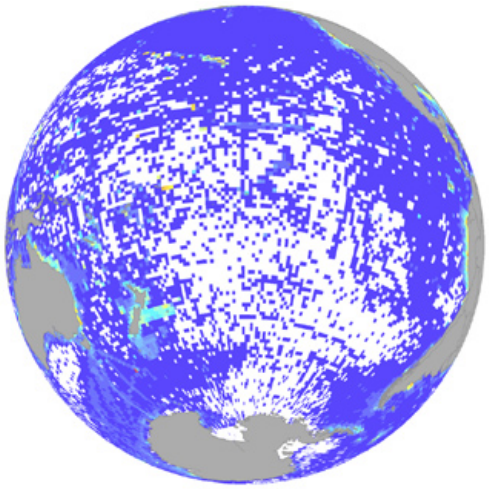


Figure 2

When we mapped from above the seas, we found, for example, that even our huge database had no reliable records of marine life in most of the Arctic (*Figure 1*) or the eastern and southern Pacific (*Figure 2*).

When we mapped over the ship's side, we found that our huge database recorded almost entirely near the shore, surface, and seafloor (*Figure 3*). The largest habitat on Earth, the vast mid-waters, had almost no observations.

Moreover, between about half a million and two million marine species that would earn a Latin binomial like *homo sapiens* surely remain to be discovered. And inspire us with the wonder of creation.

Census researchers mapped the unexplored oceans for life. Marine historians and archaeologists could try to map the one million or more shipwrecks on the sea floor and put pins on the few that have been visited.

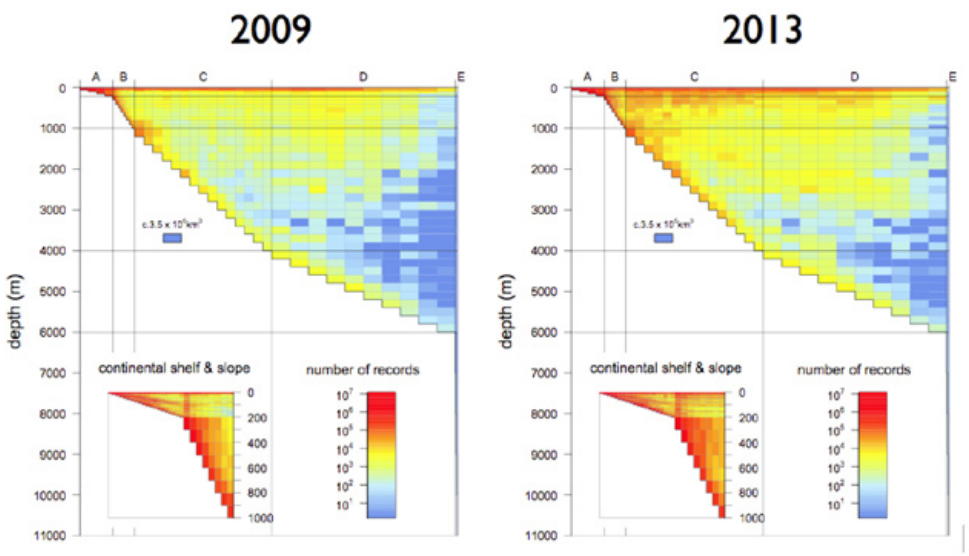


Figure 3

But, of course, we do not know what we do not know, except that surprises await. Maybe giant plumes of methane occasionally stream from the seafloor and sometimes reach the atmosphere and cause an airplane to crash, or erupt in a great bubble that causes a tsunami. And hint at unexpected resource abundance.

The unexplored ocean offers both threat and opportunity. Let's follow our instinct, expand exploration, reduce threat, and seize opportunities, both practical and amazing.

Jesse Ausubel
Rockefeller University and
Co-founder, The Census of Marine Life

Records in the Ocean Biogeographical Information System (OBIS) per 1 degree cell, 2013. Red indicates numerous records, white none.

The density of taxonomically reliable observations of marine species according to water depth. The 2013 chart has around 20 million records, 2.7 times 2009. Source: OBIS, Ward Appeltans.

From Exploration to Engagement

The solutions to the challenging issues facing our oceans—global warming, acidification, over-fishing—require the right combination of strong science, informed policy, and skilled engineering. However, there is one challenge (indeed, the grandest ocean challenge) that doesn't fit that formula: public engagement.

Solving the ocean challenges require an engaged and supportive public. A public that understands what is at stake, and can draw a clear connection between ocean health and the health of their families and communities. Unfortunately, the same tactics needed to address the pressing ocean issues also work to cognitively erase that public connection with the ocean. The immensity of the ocean and its corresponding challenges create a willful blindness among the public—it's just too overwhelming to comprehend, so people stop trying.

The most effective way to build an engaged and informed public is just the opposite. Instead of highlighting the problems, we need now more than ever to use a positive approach to show what's wonderful about our oceans. We need to strengthen the public connection through positive association.

From a postive perspective, there's no better tactic than ocean exploration. It taps into everything that's awe-inspiring about the ocean: its vastness, its mystery, its wonder. But it also taps into everything that's awe-inspiring about our humanity: our curiosity, our ingenuity, our wonder.

Public engagement is the highest imperative—every other issue is derivative. People will only protect and pursue something in their field of awareness. We need a direct emotional connection. Ocean exploration gives us the power to tell that story.

DAVID LANG
Co-founder, OpenROV

PUBLIC ENGAGEMENT

In 2020, ocean explorers are part of a coordinated communication network and have the tools they need to engage the public.

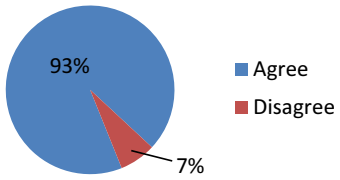
The public clearly has a stake in federally funded ocean exploration, and their support is required to create a sustained, successful, and comprehensive national program of ocean exploration. Forum participants felt that we are falling short of effectively engaging the broader public in the excitement and importance of ocean exploration and that this needs to change.

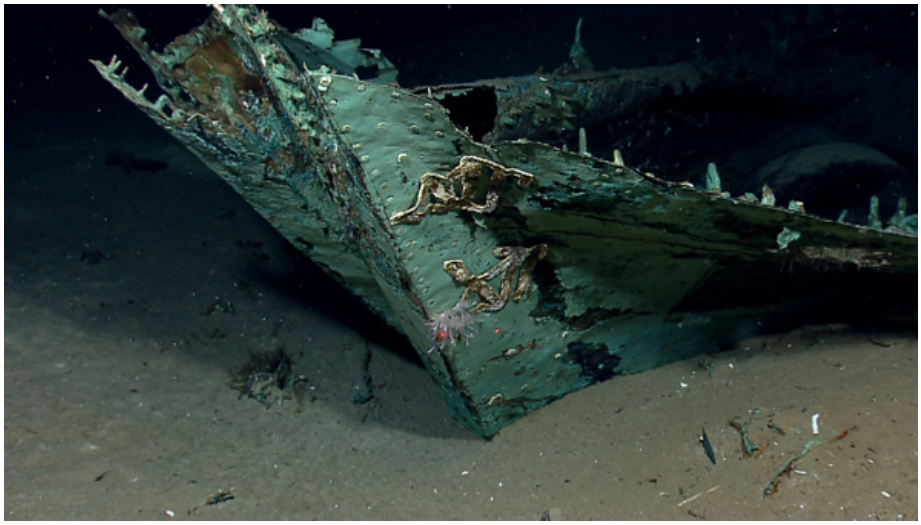
Participants were in strong agreement that we must enhance and expand existing efforts and find new ways to communicate with the public about ocean exploration. We must provide better interaction with scientists during expeditions, especially by taking telepresence beyond passive viewing and into active participation.

Ocean Exploration 2020 participants agreed that we need a shared strategy to communicate effectively and engage with the public about ocean exploration. Many ocean exploration scientists need more experience and better resources, tools, and partnerships to implement this communication strategy and to build public support for the national program.

Partnerships of ocean explorers with professional science communicators and with informal science institutions, including aquariums—which specialize in this domain—have the potential to expand the size of the audience and to broaden it to include a larger cross section of society.

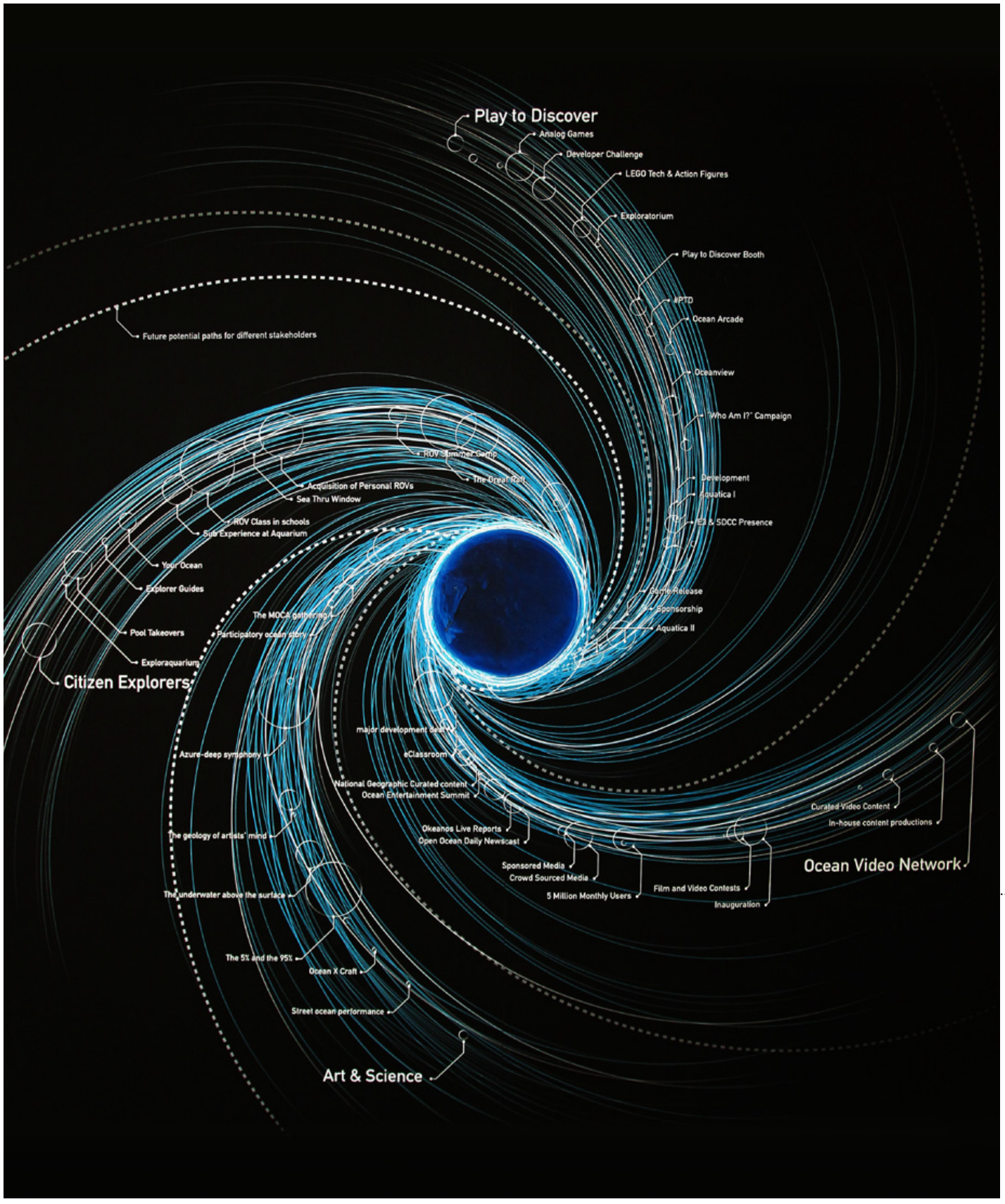
Agree or Disagree: **The science community must engage with the public in an active two-way dialogue to bolster support for ocean exploration.**





A shipwreck in the northern Gulf of Mexico discovered by scientists on board the NOAA Ship *Okeanos Explorer* in 2012 and explored further via the E/V *Nautilus* in 2013.

Image courtesy of the NOAA Office of Ocean Exploration and Research.


Play to Discover
Analog Games
Developer Challenge
LEGO Tech & Action Figures
Exploratorium
Play to Discover Booth
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Ocean Arcade
Oceanview
"Who Am I?" Campaign
Development
Aquatica I
E3 & SDCC Presence
Game Release
Sponsorship
Aquatica II
Future potential paths for different stakeholders
ROV Summer Camp
The Great Raft
Acquisition of Personal ROVs
Sea Thru Window
ROV Class in schools
Sub Experience at Aquarium
Your Ocean
Explorer Guides
Pool Takeovers
Exploraquarium
Citizen Explorers
The MOCA gathering
Participatory ocean story
major development deals
eClassroom
Azure-deep symphony
National Geographic Curated content
Ocean Entertainment Summit
The geology of artists' mind
Okeanos Live Reports
Open Ocean Daily Newscast
Sponsored Media
Crowd Sourced Media
5 Million Monthly Users
Film and Video Contests
Inauguration
Curated Video Content
In-house content productions
Ocean Video Network
The underwater above the surface
The 5% and the 95%
Ocean X Craft
Street ocean performance
Art & Science

CONCLUDING REMARKS

These characteristics of a national program of ocean exploration imply a network of universities, nongovernmental organizations, the private sector, and government agencies working together in pursuit of shared goals. Federal—and in particular, NOAA—leadership is essential to help design and maintain what might be called an "architecture for collaboration" that convenes national and international ocean exploration stakeholders regularly to review and set priorities, to match potential expedition partners, to facilitate sharing of assets, and to help test and evaluate new technologies. The program should facilitate the review and analysis of new and historical data and the synthesis and transformation of data into a variety of informational products. In this leadership role, NOAA would promote public engagement, and guide and strengthen the national ocean exploration enterprise.

A conventional federal government approach won't work. In describing characteristics of the national ocean exploration program in 2020, participants used words including: nimble, flexible, creative, innovative, and responsive. A program with these qualities just might ignite the ocean exploration movement envisioned by the participants in the first gathering of the community of ocean explorers.

In summer 2013, the Aquarium of the Pacific partnered with Designmatters, the social impact department at Art Center College of Design to bring ocean exploration to the forefront of public consciousness. Led by the Graphic and Interaction Design departments, the class devised a system of interventions designed as catalysts to drive public support for ocean exploration. This spiral represents the four "core-strands" or entry points to the Open Ocean movement: Play to Discover; Art + Science; Citizen Explorer; and the Open Ocean Network.

Image courtesy of Laura Rock, Ocean Exploration 2020 Photo Contest Marine Life category winner.

"Discovery is the prelude to new paradigms. It jolts us out of the ruts of incremental scientific progress and fuels great leaps forward."

Report of the President's Panel on Ocean Exploration. 2000, p. 11

EXPLORERS DAY: A PUBLIC DAY OF EXPLORATION FOLLOWING OCEAN EXPLORATION 2020: A NATIONAL FORUM

On Sunday, July 21, 2013, the Aquarium of the Pacific, in partnership with NOAA, hosted Explorers Day for the public featuring a rich diversity of opportunities for visitors to interact with explorers and to engage in exploration activities. Most of the 7,534 visitors—the most diverse attendance of any major aquarium in the country—participated in two or more of these activities.

ROV Technology

Aquarium visitors had the opportunity to view and drive remotely operated vehicles created by OpenROV and by Long Beach City College. People of all ages learned about the kinds of tools used to explore the ocean and were inspired to engage with a technology that is becoming increasingly available to the public—small, inexpensive ROVs. Entrepreneurs Eric Stackpole and David Lang from OpenROV and Scott Fraser, Long Beach City College professor, and his students, were ideal ambassadors for the ocean, getting visitors excited about exploration. OpenROV held demonstrations in a small outdoor pool and drove their ROV inside the Aquarium's 350,000-gallon Tropical Reef habitat, where they displayed a live video feed from the ROV as it explored the reef. The Long Beach City College ROV staff and students let visitors drive ROVs they had designed and built, and introduced them to their program that provides students pursuing technology-based careers with experience and creates employment opportunities in companies engaged in undersea exploration.

Live Feeds from Ships

Explorers Day visitors viewed live feeds from ships of exploration including NOAA's *Okeanos Explorer*, the Ocean Exploration Trust's *Nautilus*, and the Schmidt Ocean Institute's *Falkor*. These live feeds (an ongoing program at the Aquarium) allowed visitors to see what it's like to be an ocean explorer living at sea conducting exploratory missions. Visitors interacted live with the explorers and ship crews to learn about what they were observing and the tools used for exploring. Explorers Day also provided outreach to Spanish speakers, featuring a live presentation with bilingual explorer Santiago Herrera of the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution.

The Octonauts

The children's television program, The Octonauts, hosted meet-and-greet sessions with the show's creators and character mascots, and premiered a new Octonauts episode focused on the Mariana Trench. The Octonauts books and television shows celebrate ocean exploration and marine life. NOAA explorers participated in question and answer sessions about the science that underlies Octonauts episodes. Many Explorers Day attendees were attracted to the events because of the popularity of this

television program—including one family, who traveled from Mexico to participate in the Octonauts events.

Ocean Explorers

Visitors met renowned ocean explorers, including Sylvia Earle, Don Walsh, and Greg Marshall, each of whom gave a presentation. These three and other ocean explorers attended public breakfast and lunch events and communicated one-on-one with visitors. Drew Stephens, a forum participant from the mapping and data management firm Esri, shared this story:

I had the distinct pleasure of sharing lunch on Explorers Day with a family of four, the Hasslers. The two middle school boys and their parents had already attended an ROV demonstration, followed by Dr. Earle's public presentation. The boys were quick to produce a notepad, each sharing with me the ROVs they were inspired to design. To our delight, Sylvia joined us at the table, and we collectively worked through their design before she dispatched the boys to question ROV battery efficiency with explorers at the next table. Coming back a few minutes later, the younger boy leaned to me and said, "This is the best day of my life." My unflinching response: "Mine too."

Explorers Day inspired Aquarium visitors to become ocean stewards and explorers by providing them with hands-on experiences with ocean exploration technology, one-on-one interactions with ocean explorers, and educational shows and activities geared toward all age levels.

Explorers Day was made possible by generous support from Felix Williams and Susan Slavik Williams.

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Appendix

Acknowledgements
Agenda
Participants
Introduction to Survey
Survey Results

ACKNOWLEDGEMENTS

Ocean Exploration 2020 was a collaborative effort that could not have happened without the commitment of many people. We especially thank the following for their outstanding contributions.

- Ocean Exploration 2020 Executive Chair: Marcia McNutt
- Marketplace of Ideas Moderator: Richard Spinrad
- Marketplace of Ideas Speakers: Kate Moran, Chris German, Dawn Wright, Jen Austin, David Lang, Eric Stackpole, and Marcia McNutt
- Keynote Speakers: Kathryn Sullivan, David Gallo, and Michael Jones
- Reaction Panel: Larry Mayer, Bruce Robison, Jim Kendall
- Facilitators: Jamie Austin, Patricia Fryer, Richard Spinrad, Margaret Davidson, Chris German
- Rapporteurs: Betsy Suttle, Kim Thompson, Rachel Fuhrman, Alie Lebeau, Barbara Ramone, Kathie Nirschl
- Virtual breakout session: Andrew Kornblatt and Online Ocean Symposium

- Logistical Coordinator: Linda Brown
- Facilities Coordinators: Erica Noriega, Nicole Meek, and Jesse Meir
- Operations: John Rouse
- Audio Visual and Information Technology Crew: Derek Balsillie, Keith Miller, Andrew Cohen, Brian Dalley, Michael Plell, Tim Balcomb
- Aquarium's Housekeeping Team, Security Team, and Food Service—SAVOR …
- Dinner Cruise: Harbor Breeze Cruises
- Media Coordinators: Claire Atkinson, Marilyn Padilla
- Aquarium Education Staff: David Bader, Lori Perkins, Emily Yam
- Graphic Designers: Brian Gray, Alice Heish
- Social Media Managers: Anitza Valles and Emily Crum
- Graphic Recorder: Julie Stuart, of Making Ideas Visible
- Survey Coordinator: Lisa Wagner
- Social Media Campaign, Planning and Operations: Emily Crum
- Octonauts, Media, and Publicity: Court Squires
- Event Development: Craig Russell

July 21, Explorers' Day

- Lesli Zador and Captain Barnacle of the Octonauts, along with Octonauts creators MEOMI and writer Stephanie Simpson for bringing a message of "Explore ! Rescue ! Protect !" to Aquarium visitors
- Steve Hammond, for his role as the Octonaut's chief scientist for the day
- Crews of the E/V *Nautilus*, NOAA Ship *Okeanos Explorer*, and R/V *Falkor* for engaging with Aquarium visitors from at sea
- OpenROV's David Lang, Eric Stackpole, and Colin Ho for demonstrating the small robots that can make anyone an ocean explorer
- Online Ocean Symposium for their Google+ Hangout on Ocean Exploration 2020 results
- Scott Fraser and his students from Long Beach City College for engaging the public in the challenges of designing, building, and operating small ROVs.

OCEAN EXPLORATION 2020: FORUM AGENDA

19 July 2013 **Ocean Exploration 2020: A Marketplace of Ideas**

1330-1400 Ocean Exploration 2020 Welcome
Jerry Schubel, President and CEO, Aquarium of the Pacific; Marcia McNutt, Editor in Chief, *Science* Magazine; Robert Detrick, Assistant Administrator for NOAA Research

1400-1410 Introduction to A Marketplace of Ideas, Richard Spinrad, Vice President for Research, Oregon State University, Moderator

1410-1430 Observation Networks, Instruments and Platforms, Kate Moran, Director Neptune Canada

1430-1450 Exploration and Research—Chris German, Chief Scientist for Deep Submergence, Woods Hole Oceanographic Institution

1450-1510 Data, Data Quality, and Access to Data—Dawn Wright, Chief Scientist, Esri

1510-1530 Data Visualization, Jennifer Austin Foulkes, Manager of Google Ocean

1530-1550 Citizen Exploration, David Lang and Eric Stackpole, Co-founders, OpenROV

1550-1610 Break

1610-1630 Ocean Exploration from 2000 to 2020, Marcia McNutt

1630-1745 Participants' Ideas for Ocean Exploration in 2020

1745-1800 Reflections from the Moderator, Richard Spinrad

1830-2100 Reception and Dinner
Presentation: Art Center College of Design
"Creating a Movement for Ocean Exploration"

20 July: **Ocean Exploration in 2020: A National Forum**

0830-0840 Welcome and Introduction, Jerry Schubel

0840-0900 Opening Plenary: National Goals for Ocean Exploration 2020: A National Forum, Marcia McNutt, Executive Chair

0900-1000 Keynotes: "Ocean Exploration in 2020—Three Perspectives"
Kathryn Sullivan, Acting Administrator, NOAA (via recording)
David Gallo, Director of Special Projects, Woods Hole Oceanographic Institution
Michael T. Jones, Chief Technology Advocate, Google

1000-1015 Greetings from Ships of Exploration at sea: *Okeanos Explorer*, *Nautilus*, *Atlantis*, and *Falkor*

1030-1130 Setting the Stage for a National Program: Reaction Panel by Three Leading Explorers
Moderator, Larry Mayer, Director, Center for Coastal and Ocean Mapping, University of New Hampshire
Bruce Robison, Research Division Chair, Monterey Bay Aquarium Research Institute

James Kendall, Director, Alaska Region, Bureau of Ocean Energy Management

1130-1400 Working Session Breakout groups discuss: What qualities should the National Ocean Exploration Program have in 2020?

- Exploration priorities (geographic, phenomena, processes)
- Partnerships and funding
- Technology
- Platforms
- Citizen exploration
- Data and information management and sharing
- Public engagement

Online breakout session hosted in "Google+ Hangout on Air" for virtual participants. Breakout session facilitators: Richard Spinrad, Patricia Fryer, Margaret Davidson, Jamie Austin, and Chris German.

1400-1500 Identifying Qualities of a National Program of Ocean Exploration
Breakout groups present their results

1500-1600 Driving Toward Consensus in search for research.
The five breakout groups reconvene to explore the major points of divergence in search for common ground.

1600-1700 Converging on a National Strategy
Breakout groups report their results. Plenary discussion highlights convergence on elements of a National Strategy for Ocean Exploration

1700-1800 A National Program for Ocean Exploration
A response panel of the keynote speakers and distinguished explorers summarize the day and highlight critical elements for a National Program for Ocean Exploration.

21 July: Explorers Day: Aquarium of the Pacific

Explorers Day is a series of exhibits, lectures, meetups with ocean explorers, live interactions with ships of exploration, including NOAA's *Okeanos Explorer*; and other events to engage the public in ocean exploration.

OCEAN EXPLORATION 2020 PARTICIPANT LIST

Alexander, Vera	University of Alaska Fairbanks (OEAWG)
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Austin, James	University of Texas (OEAWG)
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Bernstein, Josh	Explorer-at-Large
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Bowen, Andy	Woods Hole Oceanographic Institution
ten Brink, Uri	U.S. Geological Survey
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Caress, David	Monterey Bay Aquarium Research Institute
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Herrera, Santiago	Woods Hole Oceanographic Institution
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MacGillivray, Barbara	MacGillivray Freeman Films
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Schrope, Mark	Schmidt Ocean Institute
Schubel, Jerry	Aquarium of the Pacific

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Stackpole, Eric	OpenROV
Stephens, Drew	Esri
Stone, Gregory	Conservation International
Stratford, Greg	JLOOP
Strychar, Kevin	Annis Water Resources Institute
Sullivan, Brian	Google, Inc.
Symons, Christina	DEEPSEA CHALLENGE Expedition
Trezzo, Jim	OpenROV
Vevers, Richard	Underwater Earth
Walsh, Don	International Maritime Inc.
Welsh, Chris	Deep Sub
Williams, Susan	The Donald Slavik Family Foundation
Williams, Felix	The Donald Slavik Family Foundation
Wright, Dawn	Esri
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Zerr, Pete	Schmidt Ocean Institute
Zykov, Victor	Schmidt Ocean Institute

(OEAWG is the Ocean Exploration Advisory Working Group of the NOAA Science Advisory Board)

Other Contributors

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Patel, Roshan	Montana State University School of Film and Photography
Savoie, Gianna	Montana State University School of Film and Photography
Spence, Steve	Montana State University School of Film and Photography

INTRODUCTION TO THE SURVEY

Ocean Exploration 2020: A National Forum spanned two days, Friday, July 19, and Saturday, June 20, 2013. To establish a foundation for discussions during Ocean Exploration 2020, the organizers formulated online surveys for seven guiding themes.

The survey was sent to 161 forum invitees. The average response rate for all surveys was 39%, and ranged from 37-62% for the first several surveys to a low of 26% for the final survey. This is considered to be a very good response rate considering the detailed nature of the questions.

The survey responses and the rich content provided in respondents' comments were of great value in Ocean Exploration 2020 discussions and in the development of this report. The survey results are summarized in the report's appendix.

In addition to the surveys distributed to Forum invitees, the public was invited to take a separate online survey. Forty members of the public responded. Results from the public survey are very similar to the survey responses of the Forum invitees. Public survey results are posted at http://oceanexplorer.noaa.gov/oceanexploration2020/2013/welcome.html.

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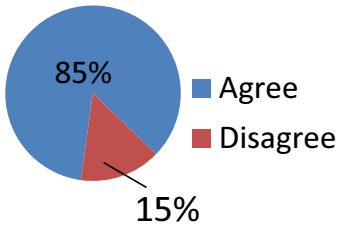
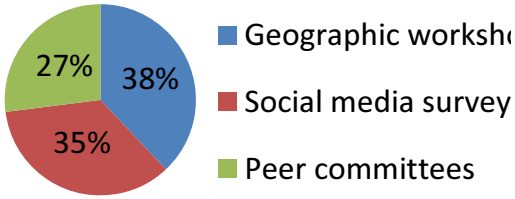
OCEAN EXPLORATION PRIORITIES

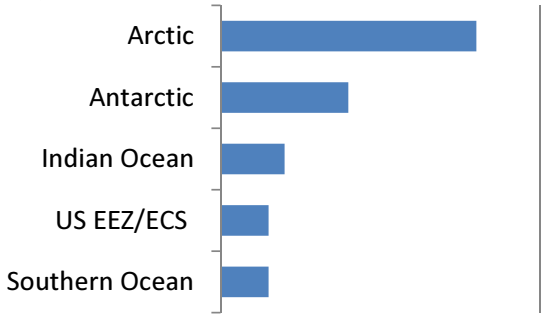
Agree or Disagree: **Priorities for exploring geographic areas of the global ocean are driven by the ocean exploration community.**



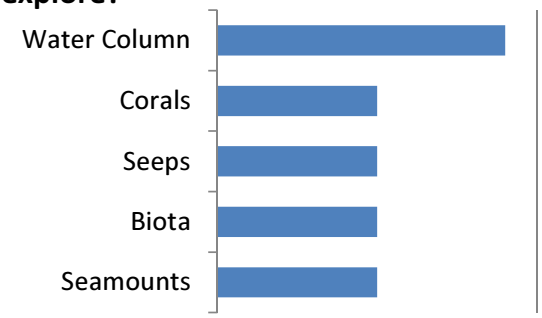
What is the best mechanism for collecting community input?



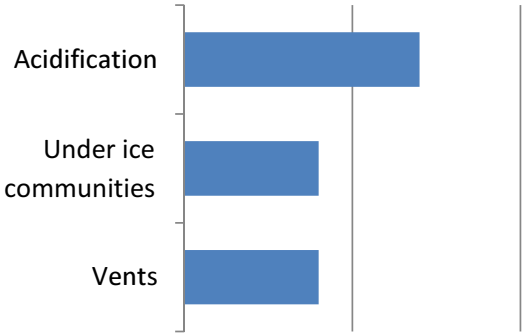
What are the five most important geographic areas to explore?



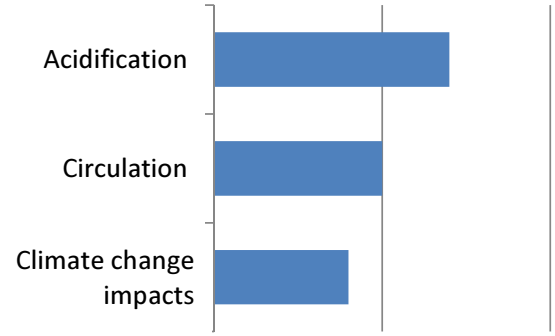
What are the five most important classes of features of the ocean environment to explore?



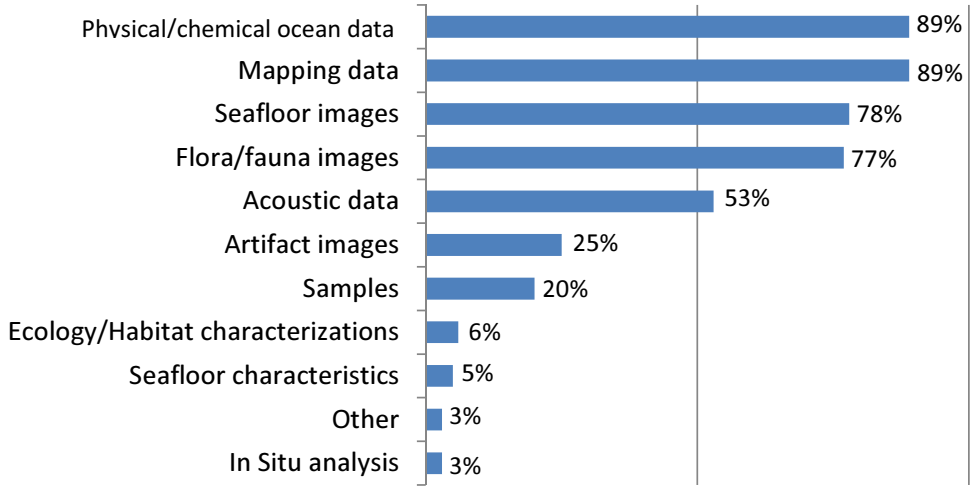
What are the three most important <u>phenomena</u> to explore?



What are the three most important <u>processes</u> to explore?



What data should be collected so that important areas/phenomena will be noted as explored? (check all that apply)

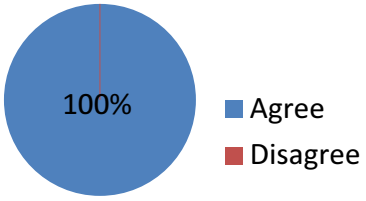


Topline Summary

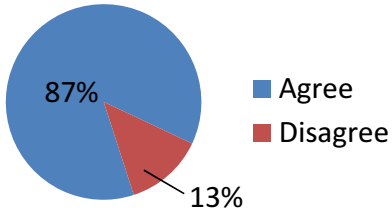
- A significant majority of respondents (85%) felt that global ocean exploration priorities should be determined by the ocean exploration community.
- There was a fairly even split regarding what the best mechanism is for gathering community input with geographic region workshops the highest (38%), followed by social media surveys (35%) and lastly peer committees (27%).
- Participants voted the Arctic as the most important geographic area to explore, followed by the Antarctic, Indian Ocean, US EEZ/ECS & Monuments, and lastly the Southern Ocean.
- Survey takers selected Water Column as the most important class of features of the ocean environment to explore, followed by Corals, Seeps, Biota and Seamounts.
- Participants felt that Acidification is the most important phenomena to explore, followed by Under Ice Communities and Vents.
- Respondents rated Acidification again as the most important process to explore, followed by Circulation and Climate change impacts.
- Physical/chemical ocean data (89%), Mapping data (89%), Seafloor images (78%), and Flora/fauna images (77%) were rated the most important data to collect so that areas/phenomena will be recognized as explored.

PARTNERSHIPS

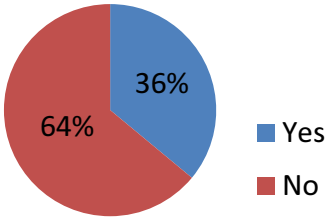
Agree or Disagree: **Leverage gained by partnerships is critical to ocean exploration.**



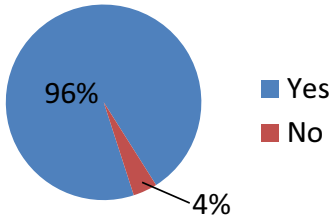
Agree or Disagree: **Partnerships between agencies and private sector entities is crucial for ocean exploration.**



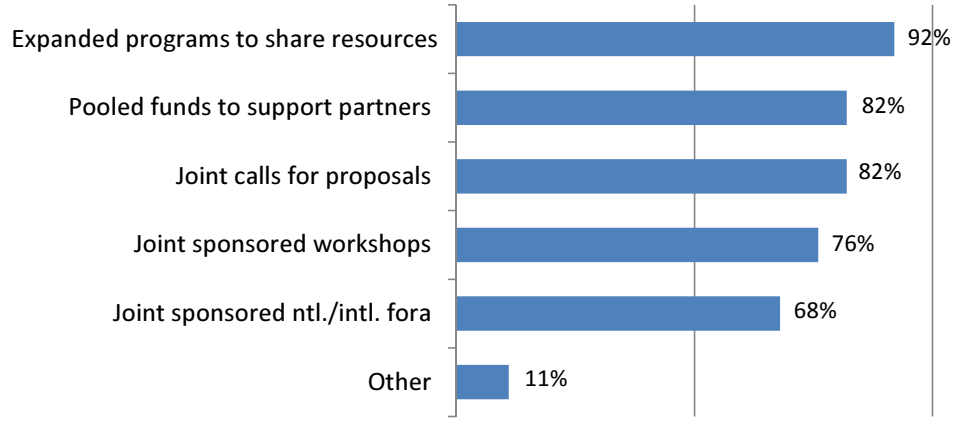
Should a single federal agency be responsible for expeditions?



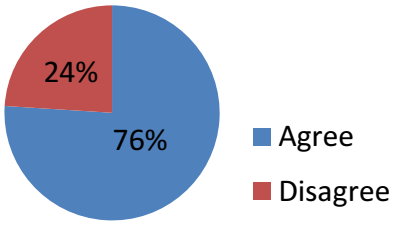
Should a national program include mechanisms to encourage federal agency collaboration?



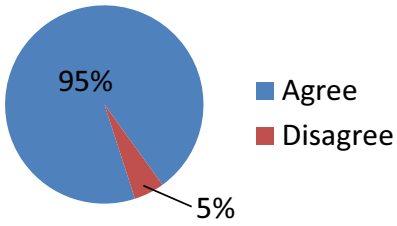
How can federal agencies best support effective ocean exploration partnerships?
(check all that apply)



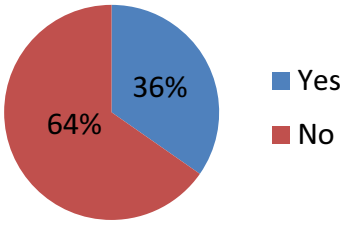
Agree or Disagree: **In 2020, most expeditions will be partnership based.**



Agree or Disagree: **A national program should facilitate partnerships among U.S. and international communities.**



Agree or Disagree: **Crowdfunding platforms will increase in importance for ocean exploration science/research.**

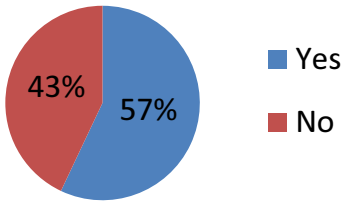


Topline Summary

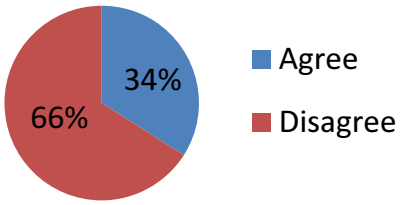
- All respondents (100%) agreed that leverage from partnerships is crucial for ocean exploration.
- A significant majority (87%) felt that partnerships between agencies and the private sector are critical to ocean exploration.
- Most thought that a single federal agency should NOT be responsible for expeditions. The general consensus was that organization collaboration is key and that an umbrella agency would be ideal.
- Most participants (96%) believed that a national program should encourage federal agency collaboration.
- When asked where are the gaps in ship/platform capabilities, the majority felt they are in expanded programs to share resources (92%), pooled funds to support partners as well as joint calls for proposals (both 82%).
- Most (76%) agreed that expeditions will be partnership based in 2020.
- A significant majority (95%) agreed that a national program should facilitate partnerships among U.S. and international communities.
- Most survey takers (66%) felt that crowdfunding platforms will NOT increase in importance for ocean exploration science/research.

PLATFORMS

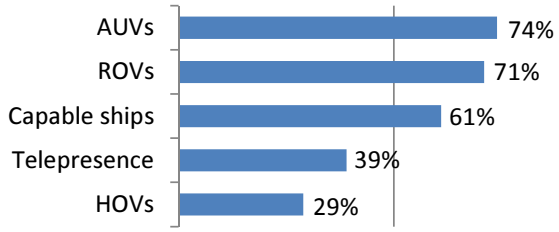
Are dedicated ships and assets essential?



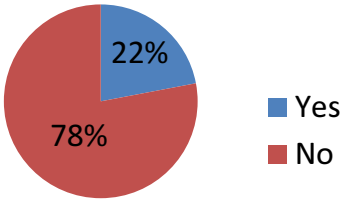
Agree or Disagree: **Expedition ships/platforms are capable of meeting national exploration needs.**



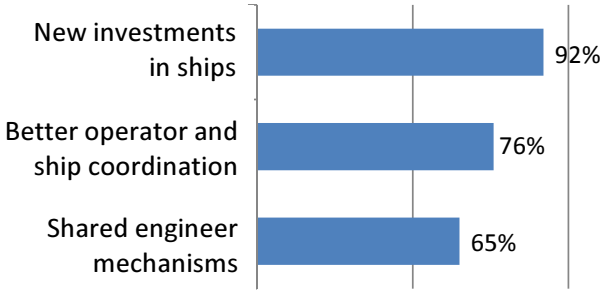
Where are the gaps in ship/platform capabilities? **(check all that apply)**



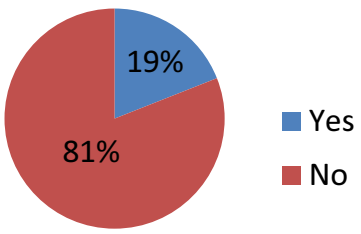
Will the existing U.S.-based fleet be able to meet 2020 national program needs?



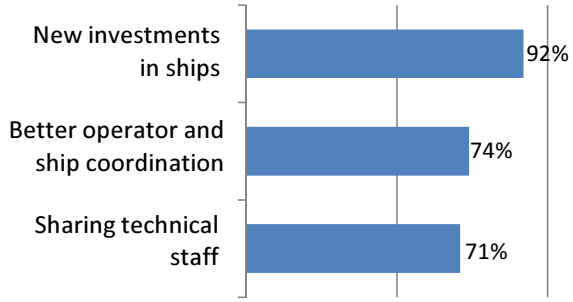
What will help meet national ocean exploration program needs in 2020? **(check all that apply)**



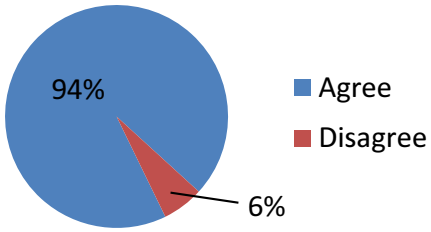
Will the existing inventory of HOV/ROV/AUV be able to meet 2020 national ocean exploration needs?



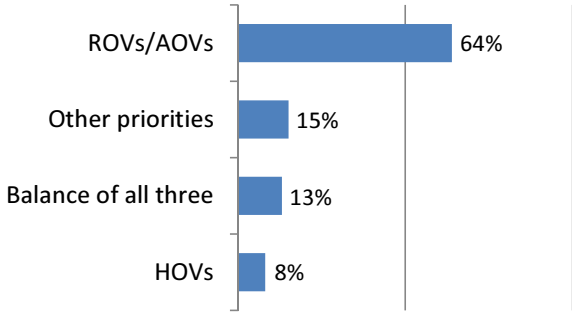
What will help meet exploration requirements for HOVs/ROVs/ AUVs in 2020? (check all that apply)



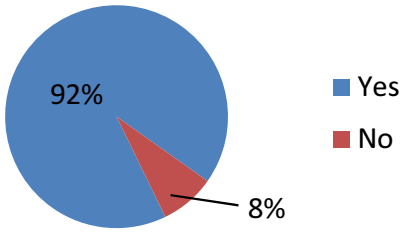
***Agree or Disagree:* Platforms (AUVs/gliders) that can replace samples collected by ships are essential in 2020.**



What should have priority between ROV/AUV investments and HOV investments in 2020?



Is there a role for systems to collect observations in fixed locations?

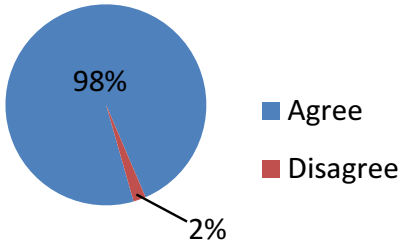


Topline Summary

- Slightly more than half of survey takers (57%) said that dedicated ships and assets are essential.
- The majority of respondents (66%) did NOT think that expedition ships/platforms are capable of meeting national exploration needs.
- Most felt that the gaps in ship/platform capabilities are in AUVs (74%), ROVs (71%) and capable ships (61%).
- Most (78%) said that the U.S.-based fleet will NOT be able to meet 2020 national program needs.
- A significant majority (92%) said that new investments in ships will help meet national ocean exploration program needs in 2020, followed by better operator and ship coordination (76%).
- The majority (81%) thought that the existing inventory of HOV/ROV/AUVs will NOT be able to meet 2020 national ocean exploration needs.
- When asked what will help meet exploration requirements for HOV/ROV/AUVs, most said new investments in ships (92%) followed by better operator and ship coordination (74%).
- A significant majority (94%) agreed that platforms (AUVs/gliders) that can replace some samples collected by ships are key for 2020.
- The majority (64%) felt that ROVs/AUVs should have priority for investments in 2020.
- A significant majority (92%) said there is a role for systems to collect observations in fixed locations.

TECHNOLOGY DEVELOPMENT

Agree or Disagree: **Technology will continue to create efficiencies in ocean exploration and make expeditions more accessible.**

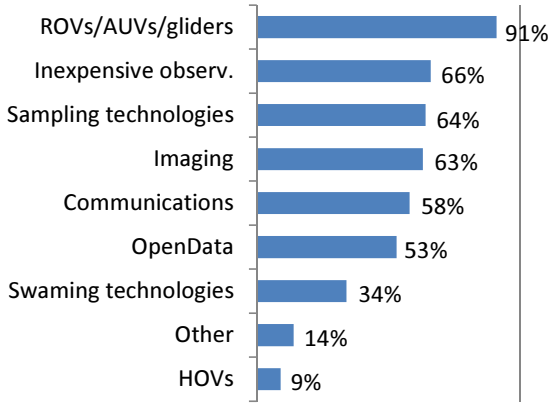


What emerging technologies will be important in 2020?

- 1st – Autonomous vehicles and ships
- 2nd – ROVs/AUVs/UAVs/HOVs
- 3rd – Telepresence and improved real-time control/communications/data access
- 4th – Lower-cost sensors and capabilities
- 5th – In situ sensors and sampling
- 6th – Swarms and networked systems/sensors
- 7th – Sensors and systems with greater endurance and capable of deeper depths
- 8th – Better imaging and mapping
- 9th – And many others…

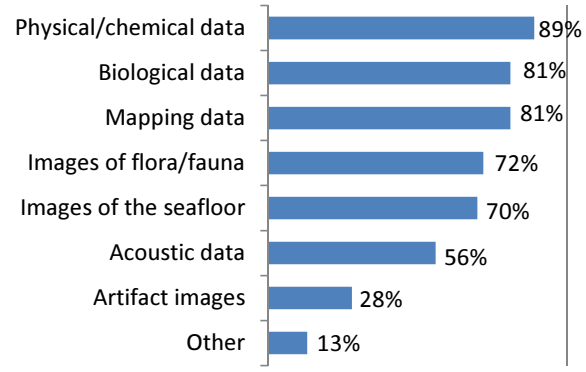
What new technologies should a National Program promote?

(check all that apply)



What data should be collected so that areas/phenomena can be described as having been explored?

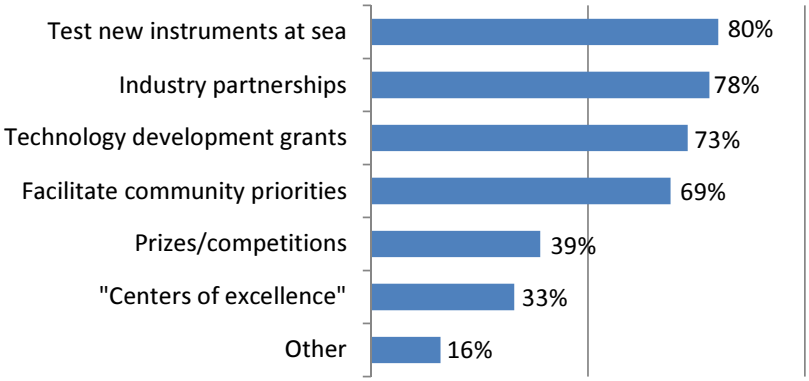
(check all that apply)



How can the National Ocean Exploration Program support technology engagement for the ocean exploration community?

- 1st priority – Fund emerging technology development for exploration capabilities.
- 2nd priority – Adapt proven technologies for ocean exploration.
- 3rd priority – Test emerging technologies for exploration capabilities.
- 4th priority – Fund basic research for new technologies.

What are effective tools for promoting ocean exploration technology development? (Check all that apply)

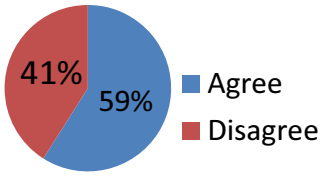


Topline Summary

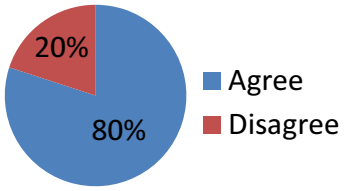
- Nearly all respondents (98%) agreed that technology will continue to create efficiencies in ocean exploration and make expeditions more accessible.
- Survey takers rated autonomous vehicles and ships as the most important emerging technology in 2020, followed by ROVs/AUVs/UAVs/HOVs and the telepresence and improved real-time control/communications/data access.
- The majority felt that a National Program should promote ROVs/AUVs/gliders (91%) followed by inexpensive recoverable observatories (66%) and sampling technologies (64%).
- Participants thought that physical/chemical oceanographic data (89%) should be collected so that areas can be noted as explored, followed by biological data (81%) and mapping data (81%).
- The ways that the National Ocean Exploration Program can support technology engagement is through the 1st priority of developing fund emerging technology for exploration capabilities and the 2nd priority of adapting proven technologies for ocean exploration.
- Effective tools for promoting ocean exploration technology are to test new vehicles/instruments at sea (80%), industry partnerships (78%), and technology development grants (73%).

CITIZEN SCIENCE

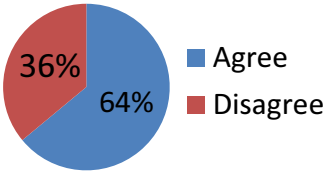
Agree or Disagree: **In 2020, citizen scientists will play a major role in ocean exploration.**



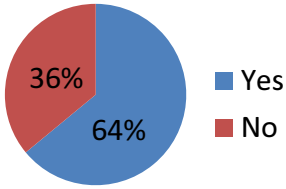
Agree or Disagree: **Citizen scientists will be able to participate usefully in major expeditions.**



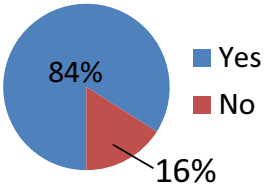
Agree or Disagree: **Citizen scientists will be able to contribute their own ROV/AUV expedition results, usable by the global community.**



Should a national program serve as a clearinghouse to collect citizen explorer observations?



Should a national program encourage citizen explorers to participate virtually in expeditions to train their own community?

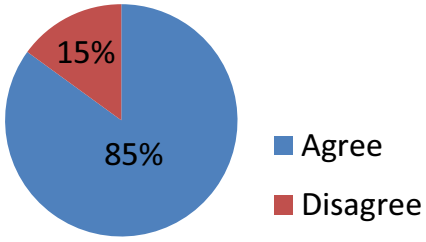


<u>Topline Summary</u>

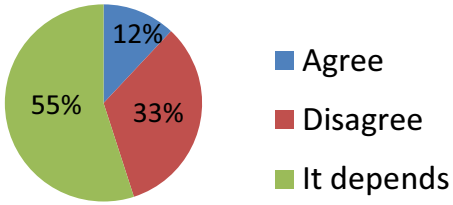
- 59% agreed that citizen scientists will play a major role in ocean exploration
- The majority of respondents (80%) felt that citizen scientists can be a part of major expeditions.
- The majority thought that citizen scientists can contribute their own results to the global community and that there should be a national program to serve as a collection clearinghouse (both 64%).
- A majority (84%) said that citizen explorers should be encouraged to participate virtually to train their community.

DATA SHARING

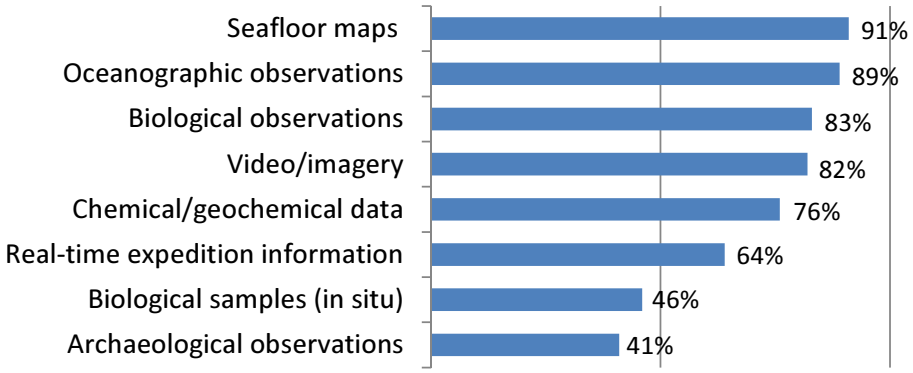
Agree or Disagree: **Nearly all publicly funded exploration data should be made available in a timely way at no cost.**



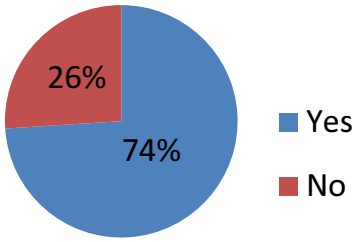
Agree or Disagree: **Data collected using public funds should not be made public until scientists have analyzed results.**



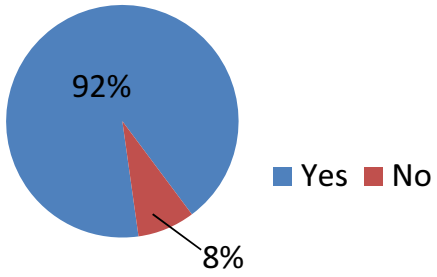
What are the most important data sets to share? **(check all that apply)**



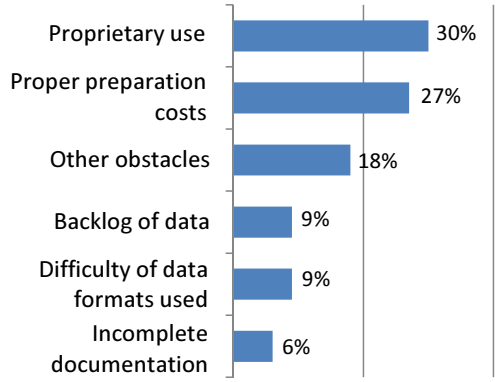
Are data collected and analyzed by citizen scientists via crowdsourcing important?



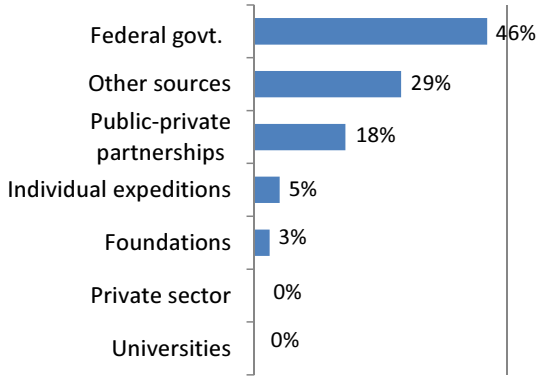
Should crowdsourced data be included in national/ international data sets?



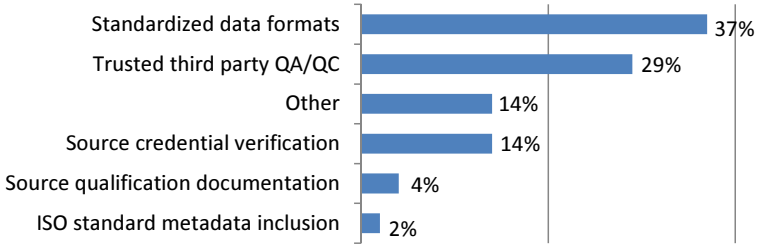
What are the biggest obstacles to sharing data?



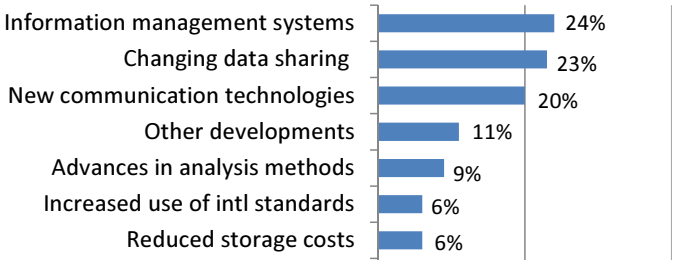
Who should bear the cost of making data widely available for free?



What is the most important prerequisite for citizen scientist data inclusion in international data sets?



What development has the greatest potential to change the way exploration data are shared?

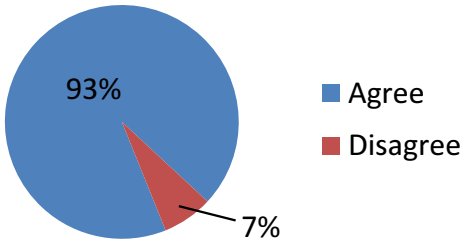


Topline Summary

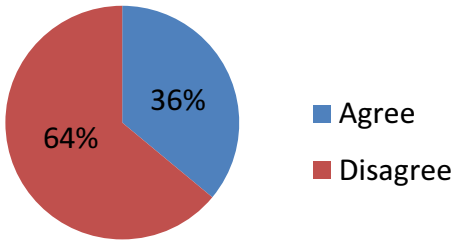
- 85% agreed publicly funded data should be made available quickly and free.
- 91% felt sea floor maps were most important to share; 89% oceanographic observations; 83% biological observations; and 82% video/imagery.
- 74% felt citizen science data are important.
- 45% felt the federal government should fund making data widely available for free followed by other sources (29%), e.g. expedition sponsors and public-private partnerships.

PUBLIC ENGAGEMENT

Agree or Disagree: **The science community must engage with the public in an active two-way dialogue to bolster support for ocean exploration.**



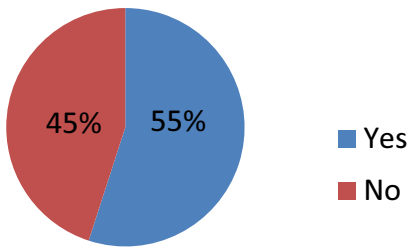
Agree or Disagree: **Scientists/organizations have the necessary tools to have meaningful interactions with the public about ocean exploration.**



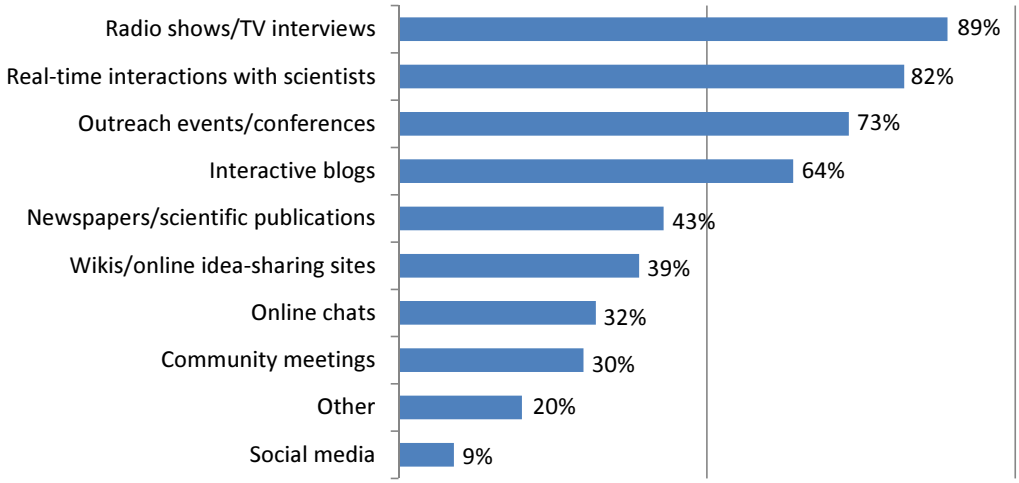
How can the National Ocean Exploration Program support public engagement for the ocean exploration community?

- 1st priority – Provide consistent communications strategy to engage the public.
- 2nd priority – Provide tools to scientists for public engagement.
- 3rd priority – Engage public on behalf of exploration community.
- 4th priority – Provide training to scientists on how to engage public.

Does real-time streaming data, video, and images via telepresence effectively engage public?



What are the best ways to engage the public about ocean exploration? (check all that apply)



Which public audiences are most critical to engage as ocean exploration moves forward?

- 1st priority – K-12 students
- 2nd priority – Ocean-interested public of any age
- 3rd priority – Undergraduate/graduate students
- 4th priority – Aquaria/museum visitors
- 5th priority – Young people newly entering workforce (18-25)

Topline Summary

- A significant majority (93%) agreed that the science community must engage the public in a two-way dialogue to bolster ocean exploration support.
- Most (64%) felt that scientists/organizations do NOT have the necessary tools to have meaningful interactions with the public about ocean exploration. They said that they need better training, motivation, resources and new tools.
- In order for the National Ocean Exploration Program to support public engagement for the ocean exploration community, the 1st priority is to provide consistent communications strategy to engage public followed by the 2nd priority to provide tools to scientists for public engagement.
- 55% felt that real-time streaming data, video, and images via telepresence effectively engage the public.
- The majority (89%) said that radio shows/TV interviews rank among the best ways to engage the public about ocean exploration, followed by real-time scientist interactions (82%) and outreach events (73%).
- When asked which public audiences are most important to engage for ocean exploration K-12 students were ranked as the top priority, followed by ocean-interested public of any age (2nd), and undergraduate/graduate students (3rd).

“If we knew what was there, we wouldn’t have to go.”

Jacques Cousteau

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