

During the hearing the panel was asked if there is a national strategy for ocean exploration, and there didn't seem to be a clear response. A) Given that there does not seem to be a single national strategy, do you think there should be one? If so, what should it look like and aim to achieve, and who should develop it?

Yes, there should be a national strategy for ocean exploration. From the great Lewis and Clark expedition, to the U.S. Exploring Expedition thirty years later, to John Wesley Powell's scientific expeditions in the American West, to, more recently, the Apollo missions 50 years ago, and through today, the United States has prospered from opportunities born out of exploration. Exploration should continue to take place and expand to broaden our understanding of the ocean, its resources, and place in Earth's ecological systems. There are multiple ways that exploration will strengthen the United States capabilities including security, science, blue economy, transportation, and better understanding of climate. Exploring the ocean leads to better models, predictions, and connections between systems. The amount of "unknowns" that we still have in regards to 71 percent of our planet's coverage is shocking. We know enough to establish that the ocean is critical to our very survival as humans; however, we do not know enough about how our use impacts this resource and how to wisely manage it for future generations.

With respect to the ocean, the United States has fallen short of other nations, including some of our greatest allies, who have invested heavily in ocean exploration and ocean science. This is an area where the United States should demonstrate leadership and broaden research efforts. An independent group of advisors should be convened similar to the President's Panel on Ocean Exploration, which was the impetus for creating the NOAA Office of Ocean Exploration Research (NOAA OER) in 2001. There seems to be emerging consensus amongst federal, private, and academic partners that such a strategy is needed. The Ocean Exploration Advisory Board has put considerable thought into what legislation for a national program of ocean exploration might include, such as options for councils and other coordinating bodies.

Schmidt Ocean Institute, although pursuing its own mission priorities, would support a national strategy for ocean exploration that aims to pursue scientific knowledge in order to advance basic ecosystem understanding for support of conservation. Consideration for emerging and new technologies, large data management and visualization capabilities, and broad education and outreach should be included in this strategy. NOAA is poised to take leadership on a national strategy, while the private sector including academic institutions, foundations, and nonprofits act as important advisors and partners in development and implementation.

A national strategy should emerge not as a singular mandate; but rather, an organizing strategy that catalyzes progress on multiple fronts. Other considerations could include a priority to characterize all of the "seascapes" within the United States' exclusive economic zones (EEZs) for better understanding and development towards specific strategic reserves. A baseline mapped ecosystem similar to Ecological Marine Ecosystem Units (EMUs) that ESRI, NOAA, USGS, IOC, and others have developed could be extremely useful. It is not too much to say that the future of the United States depends on our ability to manage the rich heritage of our ocean resources and the broader global ocean systems with which they are interconnected.

A national strategy should be designed in the spirit of our race to the moon; engaging the breadth and constancy of the federal government with the competition and ingenuity of the private sector. In every case where the United States has stepped up and pushed for innovation via exploration, our nation has prospered. Our ocean is a great frontier, and one that we must wade into with sensitivity for its fragility and respect for its strength. We should not, however, continue to sit by the shoreside and watch while others lead humankind into the future. It is not just about being the first to explore, but the critical need to understand what we have so that we can manage and use our oceans wisely for the future.

During the hearing there were many comparisons made between deep sea exploration and space exploration. A) What are the connections between the deep sea and space?

There are many connections between the deep sea and space, especially in the human characteristics that are needed to explore both - adventure, ingenuity, risk, and perseverance.

Many of the engineering and human factor design challenges are similar, and ocean and space explorers have much to learn from each other - and do. By working in the deep ocean, we can push the limits of our understanding of existing hardware designs and engineering choices for missions in outer space. There are many challenges that scientists and engineers encounter both in exploration of the deep sea and space, some of these include:

- Latency in communication (in space due to distance - in ocean due to water weakening traditional signal (light, sound) strength).
- Issues in dealing with pressure (in space, a lack of it - underwater, the tremendous weight of the ocean).
- Maximizing battery power (or energy efficiency) after launching a vehicle out of humanity's reach.
- Both require three dimensional coordination/navigation.

Using unmanned robotics have made tremendous advances in both space and underwater exploration. Last year Schmidt Ocean Institute hosted four expeditions where software and robotics targeted for space exploration were engineered and tested (see Table below).

The National Aeronautics and Space Administration (NASA) has just formed a Network for Ocean Worlds to advance comparative studies to characterize Earth and other ocean worlds across their interiors, oceans, and cryospheres; to investigate their habitability; to search for biosignatures, and to understand life—in relevant ocean world analogs and beyond. One of their listed goals is to provide the first opportunity for study between Earth and other planets. The knowledge gained is critical to understanding habitability beyond Earth as well as understanding Earth's ability to sustain life through time.

That said, humankind depends upon the ocean for our very health and existence. The state of our ocean has a direct and immediate impact on our well-being. While supporting exploration of our solar system and the universe is important, does it not make sense to better characterize and understand our own planet at the same time?

Dr. Peter Girguis, Harvard University, offers a great analogy in that exploring space before our own planet is akin to owning a home in which you have never been to the basement. Instead, you hire contractors, surveyors, and many others to study your neighbor's home, all while ignoring your own.

There is no question that the wonders of the deep--whether space or the ocean--awe and inspire us, but we should not forget how much we have to gain. To cite but one example, the strange and wondrous biology of the deep, is rich and diverse. Deep ocean life does not yield just a beautiful image or scientifically interesting sample, it may hold cures for cancer or Alzheimer's, as an example. There is no life that we know of thus far in space. Oceans, in that way, have something unique to offer.

Table: Schmidt Ocean Institute Space-Related Expeditions

Expedition Title	Year	Lead Principal Investigator	Region/Area	Country of Work	Collaborators	Vehicles
Seeking Space Rocks	2019	Mark Fries	Oregon Coast	United States of America	NASA, NOAA Office of National Marine Sanctuaries, Harvard University, Rice University, Case Western Reserve University	ROV SuBastian
New Approaches To Autonomous Exploration At The Costa Rican Shelf Break	2018	Richard Camilli	Costa Rican Shelf	Costa Rica	Woods Hole Oceanographic Institute, Australian Centre for Field Robotics (University of Sydney), National Aeronautics and Space Administration, Massachusetts Institute of Technology, University of Michigan, University of Athens	ROV SuBastian, Slocum Gliders,
Interdisciplinary Investigation of a New Hydrothermal Vent Field	2018	Robert Zierenberg	Baja Peninsula	Mexico	Monterey Bay Aquarium Research Institute, University of California - Davis, California Institute of Technology, Occidental College, Scripps Institution of Oceanography, Oregon State University, University of Rhode Island, Pontificia Universidad Catolica de Chile	ROV SuBastian, Autonomous Underwater Vehicle (AUV) D. Allan B (MBARI Mapping AUV)

Characterizing Venting and Seepage Along the California Coast	2018	Peter R. Girguis	Coast of Southern California	United States of America	Woods Hole Oceanographic Institute, Harvard University, Texas A&M University, National Science Foundation, National Aeronautics and Space Administration	ROV SuBastian, Autonomous Biogeochemical Instrument for In Situ Studies (ABISS) Lander
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B) Are there lessons we can take from the success and excitement around space exploration that can be applied to ocean exploration?

Yes. Much of the success of space exploration is due to the human dimension. We are naturally drawn to the excitement of the unknown. We can “see” space in a way that makes it accessible for everyone, and dreams of journeys into space long have been part of our cultural fabric--well before we were able to celebrate astronauts as national heroes with ticker tape parades down Madison Avenue. The space age evolved and accelerated science-fiction/popular culture creating both real/factual and imaginative futures. This model could go a long way in garnering excitement for the ocean, which has not been front and center in global popular culture in recent times.

The initial excitement surrounding space exploration was not just about getting to the moon, it was about competition to be the first and the advancement of technologies at an unprecedented pace. It was about the danger of going into space; watching the steps of exploration take place on the television or radio. How do we get the sense of adventure back? Today, going to the bottom of the ocean, while anything can happen, is relatively safe, internet access allows us to livestream and tweet from the bottom of the ocean, always being connected when we are away.

While connectivity can be vital to teaching people about what is going on and sharing beautiful images, how do we instill a sense of adventure? How do we ignite a passion for our ocean that inspires the public to want to do more? If current technology leaves little to the imagination, perhaps new developments in data science and visualization can help restore the sense of wonder. This could be accomplished by allowing anyone to participate in ocean exploration through immersive environments and advanced visualization tools that help to achieve new scientific breakthroughs. There are rich opportunities to share research results and engage the public in the process. A national ocean exploration strategy can help mobilize the resources and create the opportunities for partnership that will make these opportunities real for all Americans.

During the hearing, many questions were directed from the Committee about other countries. While competitive, space exploration has always been global in perspective. The United States collaborates internationally with academic institutions and governments and today, the space agencies of different nations regularly celebrate the successes of one another. This is not, however, always the case with respect to ocean exploration science. If we are to understand the global ocean, gain access to it for data collection and analysis, or collaborate on high seas issues,

international partnerships are essential. The ocean is a fluid system that does not recognize national jurisdiction's. Broader international partnership and data sharing will help to better advance and plan for future changing systems. This has been recognized and is beginning to be considered as part of the [United Nations Decade of Ocean Science](#).

Competition has always been a powerful driver in human history, including exploration. But perhaps it is time for a new paradigm; perhaps we should consider how a national strategy for ocean exploration can set the stage for international collaboration that encourages us to share technology and data with other ocean nations--especially developing nations--to the benefit of us all. The U.S. EEZ is important, but it is a healthy and productive global ocean that is needed now and for the future. Instead of fearing how other countries are advancing their ocean programs, our nation should take leadership with science and engineering excellence and innovation, and re-frame the discussion into how we can advance ocean exploration for the greatest technical and societal benefit globally.