COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENVIRONMENT
U.S. HOUSE OF REPRESENTATIVES
HEARING CHARTER

"Ocean Exploration: Diving to New Depths and Discoveries"

Wednesday, June 5, 2019
9:00 a.m.
2318 Rayburn House Office Building

PURPOSE

The purpose of this hearing is to discuss the state and importance of U.S. ocean exploration, ongoing research, scientific discoveries and applications, technological innovations, research gaps, and the future of the field. The witness panel will provide an opportunity to hear perspectives from many of the major players in U.S. ocean exploration enterprise, which is comprised of federal, commercial, academic, and non-profit/philanthropic sectors.

WITNESSES

- **Dr. Katy Croff Bell**, Founding Director, Open Ocean Initiative, MIT Media Lab
- **Dr. Carlie Wiener,** Director of Marine Communications, Schmidt Ocean Institute
- **Mr. Steve Barrett**, Senior Vice President Business Development, Oceaneering International
- **Mr. David Lang,** Co-founder, Sofar Ocean Technologies

OVERARCHING QUESTIONS

- How are the roles of each of the sectors in the U.S. ocean exploration enterprise defined?
- What is the state of the enterprise overall, and how can we strengthen the partnerships within it?
- What are the current challenges in the ocean exploration enterprise, i.e. technology development, data sharing, funding, partnerships, etc.?
- What will ocean exploration look like in 10-25 years?
- What are the tools, technologies, and innovations currently used in ocean exploration?
- How can ocean exploration and discoveries benefit society and the economy?
- How is the U.S. ocean exploration enterprise evolving as new technologies emerge and what is the future of the enterprise?
- Where does the U.S. stand globally in ocean exploration and how can we continue to stay on track?
- What are the current policies guiding U.S. ocean exploration?

BACKGROUND

According to the President's Panel for Ocean Exploration in 2000, – a panel of America's finest ocean explorers that was charged to develop the first-ever national strategy for ocean exploration – ocean exploration is defined as "discovery through disciplined, diverse observations and recordings of the findings." It includes observations and documentation of biological, chemical, physical, geological, and archaeological aspects of the ocean in the three dimensions of space and in time.[1] While ocean exploration may often be thought of as exploration of the deep sea, it also includes exploration of mid and surface waters.

The oceans cover 70% of the earth's surface, yet according to the National Oceanic and Atmospheric Administration (NOAA),[2] over 80% of the world's oceans remain unmapped, unobserved, and unexplored and less than 10% have been mapped in some detail (using sonar). Ocean exploration is more than just bottom mapping or discovering wrecks and new marine species; it has also helped us discover cancer-fighting drugs and understand the origins of life. The motivators driving ocean exploration can be diverse, from pure discovery of the unknown, to collecting baseline measurements of ocean chemistry and biology, to searching for biological or mineral resources for extraction. Research can be hypothesis-driven or discovery based.

Ocean exploration has been likened to space exploration, due to space and the subsea both being cold, dark, and inhospitable to human life; however, ocean exploration has not received the same level of public attention or fascination as space exploration. While most Americans know that the U.S. has a national space exploration program (based at the National Aeronautics and Space Administration), most do not know we have a national ocean exploration program (based at NOAA). Remarkably, 12 people have walked on the moon but only four have gone to the deepest part of the ocean, the Mariana Trench. The first time was in 1960 when Jacques Piccard and Don Walsh descended to the deepest part of the ocean, the Challenger Deep in the Mariana Trench, in the *bathyscaphe*[3] Trieste.[4] Ocean exploration experienced a resurgence in popularity in 2012 when "Titanic" film director James Cameron made the first solo dive to the Challenger Deep.[5] The most recent return to the Challenger Deep was in May 2019, when Dallas businessman Victor Vescovo broke Cameron's record for the deepest dive in history, at 10,927 meters (35,853 feet).[6]

Ocean Exploration Enterprise: Public, Private, Academic, Non-Profit Sectors

Given the breadth and scope of modern ocean exploration, it is a largely collaborative endeavor, with involvement from federal, commercial, academic, non-profit/philanthropic, and

[1] Report of the President's Panel for Ocean Exploration, "Discovering Earth's Final Frontier: A U.S. Strategy for Ocean Exploration." 2000. https://oceanexplorer.noaa.gov/about/what-we-do/program-review/presidents-panel-on-ocean-exploration-report.pdf

[2] NOAA, "How much of the ocean have we mapped?" 7/11/18. https://oceanservice.noaa.gov/facts/exploration.html

[3] A submersible vessel with a spherical room for research and observation

[4] http://www.deepseachallenge.com/the-expedition/1960-dive/

[5] https://news.nationalgeographic.com/news/2012/03/120325-james-cameron-mariana-trench-challenger-deepest-returns-science-sub/

[6] https://www.forbes.com/sites/jimclash/2019/05/14/businessman-victor-vescovo-sets-new-world-depth-record-for-mariana-trench-dive/#7ca6c6d5d0b3

international stakeholders. An example of this wide-ranging collaboration was the 2012 *DEEPSEA CHALLENGE* mission down to the Challenger Deep led by James Cameron, which was made possible through an international team of over a hundred scientists, engineers, filmmakers, and many other partners including the National Geographic Society, Alfred P. Sloan Foundation, and Rolex Corporation.[7]

Since the President's Panel for Ocean Exploration Report of 2000, there have been great strides in national ocean exploration. The first and only national ocean exploration program was established in the Ocean Exploration Act of 2009,[8] which designated NOAA as the lead federal agency for ocean exploration and created NOAA's Office of Ocean Exploration and Research (OER). Since its inception, OER has operated at a budget of about $20 million per year, despite the 2000 Presidential Panel for Ocean Exploration recommending funding levels of $75 million per year.[9] Authorization for the 2009 statute lapsed in 2015, but Congress has continued to appropriate funds for OER.

The 2009 statute also called for NOAA to establish federal partnerships in ocean exploration. NOAA's primary federal partners in ocean exploration include the U.S. Geological Survey (USGS), the Bureau of Ocean Energy Management (BOEM), the National Aeronautics and Space Administration (NASA), the U.S. Navy, and the National Science Foundation (NSF). Each agency has slightly different missions. The Office of Naval Research and National Science Foundation conduct hypothesis-driven research, and develop technologies as tools of exploration. For the USGS and BOEM, ocean exploration is motivated by the need to characterize ocean regions for natural resource management.

There are a number of academic institutions engaged in ocean exploration expeditions, technology development, and research. In May 2019, the University of Rhode Island was designated the lead of a new NOAA Cooperative Institute for Ocean Exploration, which will also have membership from the Ocean Exploration Trust, the Woods Hole Oceanographic Institution (WHOI), University of New Hampshire, and University of Southern Mississippi, and will work with NOAA's OER to survey and characterize three billion acres of the U.S.'s coastal and ocean waters within the U.S.'s jurisdiction, called the Exclusive Economic Zone (EEZ), to support the Blue Economy.[10]

Non-profits and philanthropic organizations also play a prominent role in engaging in and supporting ocean exploration, such as the Schmidt Ocean Institute (which operates the R/V *Falkor)*, OceanX, WHOI, the Monterey Bay Aquarium Research Institute, and the Ocean Exploration Trust (which operates the E/V *Nautilus*). The missions of non-profits can be diverse, from pure ocean exploration to public education and outreach, with many doing a mixture of both. For example, the Schmidt Ocean Institute, founded in 2009 by philanthropists Eric and Wendy Schmidt, engages in pure ocean exploration through conducting collaborative research

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[7] http://www.deepseachallenge.com/the-team/
[8] Public Law 111-11; 33 USC 3400 *et al.*
[9] ibid.
[10] NOAA names University of Rhode Island to host new Cooperative Institute for Ocean Exploration. 5/6/19. https://research.noaa.gov/article/ArtMID/587/ArticleID/2449/NOAA-names-University-of-Rhode-Island-to-host-new-cooperative-institute-for-ocean-exploration

and expeditions on R/V *Falkor* and engages with the public on shore via live video feeds from the field.[11]

The commercial sector that supports ocean exploration is growing, with more technology companies building autonomous vehicles and sensors to aid in exploration. There are a range of companies specializing in autonomous surface vehicle construction, such as Saildrone,[12] to underwater vehicles, like OpenROV,[13] Oceaneering International,[14] and Teledyne Marine.[15] These companies cater to a range of scientific and commercial applications. For example, OpenROV has pioneered low-cost ROV designs that have fostered a community of citizen scientists, while Oceaneering International provides ROVs to the oil and gas industry.

The Ocean Exploration Act of 2009 also required NOAA to create a National Forum on Ocean Exploration to establish a national strategy and program of ocean exploration. Since 2013, there have been annual National Ocean Exploration Forums that have brought together hundreds of key members of the ocean exploration enterprise and created a dialogue to encourage partnerships, technology development, and investments to advance the extent, pace, and efficiency of ocean exploration expeditions. While progress has been made in cultivating partnerships within the enterprise, significant potential remains, as noted in the Final Report for the National Ocean Exploration Forum in 2017.[16]

Scientific Discoveries and Emerging Research Needs

Over the last century, ocean exploration has led to many important scientific discoveries, such as the existence of plate tectonics, novel marine species, new sources of energy, pharmaceuticals, better understanding of the origins of life, and the role of the oceans in regulating the earth's climate. The advent of state-of-the-art technologies, such as cheaper DNA sequencing, satellite data, and underwater vehicles, has quickened the pace of discovery in recent years. However with over 80% of the oceans unexplored and an estimated 91% of marine species yet to be described,[17] there is much more to be discovered. The following are some examples of seminal ocean exploration discoveries.

- **Sonar:** The advent of sonar during World War I, and the development of multibeam sonar by the U.S. Navy in the 1960s which uses an array of beams at varying angles to cover larger swaths of ocean floor with greater precision, had led to an increase in knowledge of seafloor topography. To date, only 35% of the U.S. EEZ and Extended Continental Shelf (ECS)[18]

[11] https://schmidtocean.org/about/strategic-focus-areas/
[12] https://www.saildrone.com/
[13] https://www.sofarocean.com/
[14] https://www.oceaneering.com/
[15] http://www.teledynemarine.com/SitePages/HomePage.aspx
[16] Final report for the National Ocean Exploration Forum 2017. https://oceanexplorer.noaa.gov/national-forum/media/noef-2017-report.pdf

[17] NOAA, "How many species live in the ocean?" 6/25/18. https://oceanservice.noaa.gov/facts/ocean-species.html
[18] A country's seafloor out to 200 nautical miles.
https://www.un.org/Depts/los/clcs_new/continental_shelf_description.htm

have been mapped using sonar.[19] The U.S. EEZ is the largest in the world, covering 11,351,000 square kilometers,[20] with the continental shelf covering 2.2 million square kilometers, while the U.S.'s land mass is 9,147,000 square kilometers.[21] Given that more of the nation is below water than above water, it is important to understand and characterize what is in the U.S. EEZ in order to better manage and conserve our natural resources.

- **Hydrothermal vents:** In 1977, an expedition on the WHOI-operated deep-sea submersible, *Alvin*, discovered hydrothermal vent communities teeming with life at the mid-ocean ridge north of the Galapagos Islands.[22] Living in complete darkness and extreme pressure and temperatures, it was discovered that the basis for this food web is chemosynthetic bacteria that derive energy from compounds being emitted from the hydrothermal vents. These chemosynthetic bacteria are thought to hold secrets to the origins of life on earth and on other planets.

- **Biochemical compounds:** The deep sea is seen as an untapped resource for discovery of drugs derived from biochemical compounds from marine plants and animals. Over the past 30 years, at least 200,000 bioactive compounds have been discovered.[23] For example, marine sponges have been found to contain anticancer and antibiotic properties that are being developed into pharmaceuticals. The promise of developing bio-derived marine compounds into pharmaceuticals, agricultural products, and other products is explored in the National Research Council 2002 report *Marine Biotechnology in the Twenty-First Century*.[24]

- **Human impacts: S**cientists are also learning more about the impacts of humans on the oceans. Scientists have discovered that more than 90% of the excess heat from the atmosphere is stored in the ocean, and that while most is in the top 700 meters, a portion of heat gets stored in the deep ocean.[25] Measurements in the deep ocean revealed that the global warming "hiatus" from 1998 to 2013 was actually due to redistribution of heat content in the oceans.[26] Plastic debris has been found in the deep ocean, including in the deepest part of the ocean, as discovered on Vescovo's recent solo dive.[27]

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[19] ibid.
[20] NOAA Ocean Exploration Review Panel's report, "Ocean Exploration's Second Decade." 2012. https://oceanexplorer.noaa.gov/about/what-we-do/program-review/2012-oe-review-report.pdf
[21] https://data.worldbank.org/indicator/ag.lnd.totl.k2
22 https://www.whoi.edu/feature/history-hydrothermal-vents/discovery/1977.html
[23] "Ocean Exploration" highlights from the National Academies reports. 2007. http://nas-sites.org/oceans/files/2012/05/exploration_final.pdf
24 https://www.nap.edu/download/10340
25 https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content
[26] Cheng, L., et al. 2019. "How fast are the oceans warming?" *Science*. Vol. 363, Issue 6423, pp. 128-129. https://science.sciencemag.org/content/363/6423/128.full
[27] National Geographic, "Plastic proliferates at the bottom of the world's deepest ocean trench." 5/13/19. https://news.nationalgeographic.com/2018/05/plastic-bag-mariana-trench-pollution-science-spd/

Tools and Technology Used in Ocean Exploration

- **Scuba diving:** A more traditional method of ocean exploration, scuba diving technology has evolved greatly over the past two centuries, and still offers advantages to researchers hoping to make discoveries.[28] Divers can directly observe and even manipulate marine ecosystems, an ability which has significantly advanced the fields of marine biology and marine chemistry and has helped uncover archaeological sites and geologic discoveries. For example, in 1982 archaeologist George F. Bass and his team uncovered the world's oldest known shipwreck (circa 14th century B.C.) after more than 20,000 dives off the coast of Turkey. [29]

- **Research Vessels (R/Vs) and Exploration Vessels (E/Vs):** Traditional oceangoing research vessels carry scientists, equipment, and instrumentation from the shore to research sites, collecting data as they travel. They are observation platforms from which explorers deploy divers and submersibles and use onboard computers and navigation systems.[30] Currently, U.S. ships dedicated to ocean exploration include NOAA vessel *Okeanos Explorer*,[31] NSF Ship *Marcus G. Langseth*,[32] Ocean Exploration Trust's E/V *Nautilus*,[33] Schmidt Ocean Institute's R/V *Falkor*,[34] and OceanX's E/V *Alucia*, with the E/V *Alucia 2* on the way.[35]

- **Dredging and Trawling:** Traditionally, scientists collected samples of marine organisms through dredging or trawling methods, which has led to the discovery of thousands of new species but causes damage to benthic ecosystems and results in damaged, distorted specimens.[36] Samplers attached to deep submergence vehicles, or submersibles, have allowed scientists to collect samples without the problems with dredging and trawling.[37]

- **Human-operated vehicles (HOVs):** Submersibles allow scientists to systematically sample and collect intact specimens and watch animal behavior in real time. Submersibles are built to withstand crushing pressures, darkness, and extreme cold at abyssal depths that human divers cannot reach.[38] NOAA OER uses the HOV *Alvin* to carry scientists to 4500 meters of depth.[39]

- **Remotely-operated vehicles (ROVs):** ROVs are robotic vehicles that transmit information to controllers above the water through physical cables. They are equipped with cameras and sensors with data collection capabilities and can reach depths of 3000 meters.[40]

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28 https://oceanexplorer.noaa.gov/technology/diving/scuba/scuba.html
29 http://dels.nas.edu/resources/static-assets/osb/miscellaneous/exploration_final.pdf
30 https://oceanexplorer.noaa.gov/technology/vessels/vessels.html
31 https://oceanexplorer.noaa.gov/technology/vessels/vessels.html
32 https://www.ldeo.columbia.edu/research/office-of-marine-operations/langseth
33 https://www.oceanexplorationtrust.org/nautilus-exploration-program
34 https://schmidtocean.org/rv-falkor/
35 http://www.oceanx.org/
36 http://dels.nas.edu/resources/static-assets/osb/miscellaneous/exploration_final.pdf
37 https://oceanexplorer.noaa.gov/technology/tools/suction/s_d_sampler.html
38 https://oceanexplorer.noaa.gov/technology/subs/subs.html
39 https://oceanexplorer.noaa.gov/technology/subs/alvin/alvin.html
40 https://www.rigzone.com/training/insight.asp?insight_id=343&c_id=

- **Autonomous underwater vehicles (AUVs) and gliders:** These unmanned underwater vehicles are distinct from ROVs in that they have no physical link to above water controllers. Like ROVs, they carry sensors to collect environmental data. They are much cheaper than fully-equipped research vessels and operate independently of human direction. Gliders can further cut energy costs if they are propelled by gravity and buoyancy.[41]

- **Telepresence:** Developed by NOAA OER, telepresence enables live streaming video, data, and information to be transmitted from ROVs to anywhere in the world in real time. This ability to participate remotely in deep sea exploration is important for education and outreach and helps to involve more scientists directly in missions in real time.[42]

- **Sensors and exploration instruments:** As the oceans are one of the most challenging environments to study, special technologies have been developed to examine its characteristics.[43]

  - Mounted on the bottom of ships, the Acoustic Doppler Current Profiler (ADCP) measures the speed and direction of ocean currents by emitting high frequency sounds that scatter off of moving particles in the water.[44] *Drifters* are floating, sailed data collection devices that also investigate ocean currents.[45]

  - Underwater acoustic monitors like *sonobuoys* and *cabled or autonomous hydrophones* collect sounds in the ocean.[46]

  - Deployed from submersibles, *mechanical arms* and nets like the *"Bushmaster and "Chimneymaster"* collect marine specimens.[47]

  - Water column samplers such as *sondes* and *CTDs (conductivity, temperature, depth)* can record a range of water quality data such as pH, dissolved oxygen, and salinity as often as once every four seconds.[48]

  - *Semipermeable Membrane Devices (SPMDs)* are sampling devices used to monitor trace levels of organic contaminants.[49]

  - *SONAR, or Sound Navigation and Ranging,* is used to find and identify objects in water, and determine water depth.[50]

[41] https://oceanexplorer.noaa.gov/facts/auv.html
[42] https://oceanexplorer.noaa.gov/technology/commstech/telepresence/telepresence.html
[43] https://oceanexplorer.noaa.gov/technology/tools/tools.html
[44] https://oceanexplorer.noaa.gov/technology/tools/acoust_doppler/acoust_doppler.html
[45] https://oceanexplorer.noaa.gov/technology/tools/drifters/drifters.html
[46] https://oceanexplorer.noaa.gov/technology/tools/acoustics/acoustics.html
[47] https://oceanexplorer.noaa.gov/technology/tools/bushmaster/bushmaster.html
[48] https://oceanexplorer.noaa.gov/technology/tools/sondectd/sondectd.html
[49] https://oceanexplorer.noaa.gov/technology/tools/spmds/spmds.html
[50] https://oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html