Ocean Exploration: Diving to New Depths & Discoveries

Responses to Questions Submitted for the Record by

Katherine L.C. Bell

to the

Subcommittee on Environment
Committee on Science, Space, and Technology
U.S. House of Representatives

Dear Chair Fletcher,

Thank you for the opportunity to testify on ocean exploration on Wednesday, June 5, 2019. Having never participated in a hearing before, it was an enlightening experience for me, and I greatly enjoyed our discussion about the challenges and opportunities associated with regaining U.S. leadership in the field. I hope our discussion was beneficial for you and your research on the importance of ocean exploration, as well as how we might expand it in the future.

Please find below responses to the questions submitted for the record by Members of the Committee.

I am honored to have had the opportunity to represent the deep sea community at this important hearing. Please do not hesitate to contact me should you need any further clarification or assistance in the future. I stand ready to assist in any way.

With very best regards,

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Submitted by Chairwoman Eddie Bernice Johnson

1. *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. 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?*

Following the hearing, I reviewed the NOAA Office of Ocean Exploration and Research (OER) website. The FACA-convened Ocean Exploration Advisory Board (OEAB) has provided strategic guidance over the last four years, but there does not appear to be a single national strategy for ocean exploration. While the office does excellent tactical work, I believe that a national strategy with clear long-term goals would be beneficial for the nation.

The closest existing document to a national strategy is the 2000 Report on the President's Panel on Ocean Exploration, which recommended a national program of exploration and was the impetus for the creation of OER in 2001. Since then, numerous discoveries have been made, new technologies and communication methods have been developed (including telepresence and social media), and new players have emerged, in particular philanthropic organizations. Nearly 20 years since the President's Panel, it is time to assess the current state of the US ocean exploration enterprise, set ambitious goals, and plan a strategy for the future.

The national strategy should aim to achieve the following:

- **Assess the current status of the US ocean exploration enterprise**
    - e.g. including strengths, weaknesses, challenges, and opportunities
- **Define ambitious, long-term (10-20 year) goal(s)**
    - e.g. to "image and characterize 100% of the seabed by 2040"
- **Establish guiding principles for all aspects of the strategy**
    - e.g. ensuring open, collaborative research and operations; intentionally structuring equity; and, approaching the goal with systems over things
- **Establish a governance structure under which to operate**
    - e.g. aim for a structure that encourages the establishment and growth of collective intelligence for the ocean exploration community, such that the people and systems involved act more intelligently -- and equitably -- toward a larger goal than any individual or organization has done before
- **Determine the existing and yet-to-be developed resources needed**
    - e.g. identify the agency/organization that should lead the effort, keeping in mind that it may not yet exist; identify the capabilities that humans, machines, data systems, etc., will be required to meet the goal(s)
- **Create a timeline to achieve intermediate objectives**
    - While a timeline is helpful to maintain momentum, we must also maintain flexibility to change milestones, so long as changes support the overall goal

To undertake the formulation of the national strategy, an independent panel/commission should be convened, much like the 2000 President's Panel, with representatives from the government, academia, industry, philanthropy, media, and others. We should also consider that, given the global nature of the ocean, the strategy should take into account international partnerships and collaboration. And finally, given how much technology is likely to change in the next 10-20 years, the strategy should chart a course toward discovery, but understand that we may not yet know the most direct path to get there.

Submitted by Chair of the Subcommittee on Environment Lizzie Fletcher

1. *At the hearing, a Member asked about the involvement of U.S. scientists with scientists from other countries such as Russia, China, Brazil, Japan, and India in ocean exploration.*
    a. *Given the oceans know no geographic boundaries, how important are international collaborations to exploring the oceans?*
    b. *What are some examples of successful international collaborations?*
    c. *What are the concerns or risks around international collaborations in ocean exploration, such as with data sharing with other countries, and do you have ideas on how to address them?*

International collaborations are fundamental for exploring and understanding all aspects of the ocean, including geological, physical, and biological oceanography, as well as chemistry and human history.

Geological features such as mid-ocean ridges, volcanic island chains, and tectonic plates cross international boundaries, and their effects such as volcanic eruptions, earthquakes, and tsunamis can have impacts around the globe. Volcanic eruptions, for instance, can eject tiny bits of volcanic glass, or tephra, high into the atmosphere, disrupting or even shutting down air traffic, killing people in local proximity, and spewing gases that can alter global weather and climate. The 1815 eruption of Mt Tambora in Indonesia is commonly known as the "Year Without a Summer" because it caused average global temperatures to decrease by approximately 1°F, resulting in major food shortages across the northern hemisphere. Earthquakes can cause tsunamis, which can travel and destroy coastlines and communities thousands of miles from their origin. The 2004 Indian Ocean tsunami, for example, originated in Indonesia, but killed more than 200,000 people around the Indian Ocean. The United States could similarly be impacted by volcanic and/or tectonic activity in the Caribbean, or across the Pacific Ocean, which is very geologically active.

Similarly, water travels around the world, driven by oceanic currents. The movement of water drives global heat distribution, and its understanding is critical for weather and climate prediction. Hurricanes that hit the southeast coast of the United States, for example, begin as tropical depressions off the west coast of Africa. Collaborations with countries such as Morocco, Spain, and Mauritania would be beneficial to better understand, predict, and mitigate the

impacts of hurricanes in the United States. Another example of climate- and weather-driving phenomena that affects the US include El Niño in the Pacific Ocean, which is predicted to create a hotter and wetter than normal summer for Washington, DC, in 2019.

Water movement is also important for understanding the reproduction and migration patterns of economically important marine life, such as Atlantic Bluefin Tuna that are known to live and/or spawn across the Caribbean Sea, Gulf of Mexico, and north to Canada. Some individuals have even been shown to migrate across the Atlantic Ocean to/from Europe. We do not, however, have a good understanding of how these and other populations of commercially relevant fish interact with organisms that live, spawn, and thrive across great expanses of seafloor in these regions, nor larger animals such as whales, and all of the interactions between them. Exploration of these, and other regions, on an international level would greatly enhance our understanding of these important ecosystems so that we may more responsibly manage living marine resources today and into the future.

These are just a few examples of the numerous ways understanding natural processes, resources, and hazards far beyond our own Exclusive Economic Zone (EEZ) is critical for US interests, as well as those of our international partners.

Fortunately, there is already interaction between American and international ocean scientists on a regular basis. During the hearing, Dr. Wiener discussed the Seabed 2030 effort to acoustically map the entire seafloor by 2030, led by the Nippon Foundation in Japan and the General Bathymetric Chart of the Ocean (GEBCO), which operates under the joint auspices of the International Hydrographic Organization (IHO) and UNESCO's Intergovernmental Oceanographic Commission (IOC). According to the Seabed 2030 website, the project has "drawn on the experience of some 40 international organizations and networks spread across more than 50 countries," and has now aggregated multibeam bathymetric data of 15% of the world's ocean.

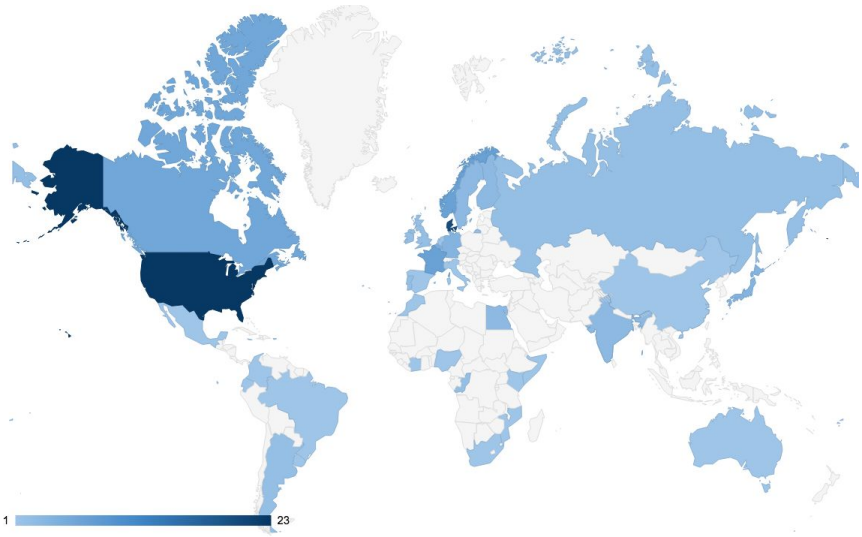

Figure 1. Countries represented at the First Global Planning Meeting of the UN Decade of Ocean Science for Sustainable Development, including Russia, China, Brazil, Japan, and India. Data based on lists of workshop attendees and Executive Planning Group representatives.

During our discussion, I also noted the upcoming Decade of Ocean Science for Sustainable Development, coordinated by the IOC, as an example of a current and upcoming opportunity. Forty-six countries were represented at the First Global Planning Meeting in Denmark in May 2019, including Russia, China, Brazil, Japan and India (Figure 1). A series of 8-10 Regional Workshops are now being organized around the world, the first of which will be held in New Caledonia on July 23-25, 2019, with others anticipated in Japan, Brazil, Italy, Canada, Mexico, and Ecuador in the next 1-2 years.

Another excellent example of successful international oceanographic collaboration is the International Ocean Discovery Program (IODP), which began as the Deep Sea Drilling Project in 1966. "IODP is an international marine research collaboration that explores Earth's history and dynamics using ocean-going research platforms to recover data recorded in seafloor sediments and rocks and to monitor subseafloor environments. IODP depends on facilities funded by three platform providers (NSF, Japan's Ministry of Education, Culture, Sports, Science and Technology, and the European Consortium for Ocean Research Drilling) with financial contributions from five additional partner agencies (China's Ministry of Science and Technology, Korea Institute of Geoscience and Mineral Resources, Australian-New Zealand IODP Consortium, India's Ministry of Earth Science, Brazil's Coordination for Improvement of Higher Education Personnel). Together, these entities represent twenty-three nations whose scientists are selected to staff IODP research expeditions conducted throughout the world's oceans." The twenty-three nations participating in IODP include: Australia, Finland, Japan, Spain, Austria, France. Korea, Sweden, Brazil, Germany, Netherlands, Switzerland, Canada, India, New Zealand, United Kingdom, China, Ireland, Norway, United States of America, Denmark, Italy, and Portugal.

Despite the importance of international collaboration, however, NOAA has seemed to move away from it in recent years. According to the OER Digital Atlas (Figure 2), and my knowledge of OER-sponsored expeditions, since 2001, OER has conducted and/or sponsored 371 cruises around the world, 68% of which were in US waters. If we dig into the details, however, we see that the breakdown of expeditions in US vs non-US waters varies significantly by year, ranging from 11% to 56% of the expeditions in non-US waters.

From 2001 to 2004, OER conducted and/or sponsored 89 cruises, 11-19% of which were in non-US waters. For the next 10 years, from 2005 to 2015, OER became much more international, conducting and/or sponsoring 223 cruises, of which 30-56% were in non-US waters (on the high seas or within EEZs of other countries). In the last 3 years, from 2016-2018, the program has become much more focused on exploration of US waters, conducting and/or sponsoring 62 cruises, 11-21% of which were in non-US waters (Figure 3).

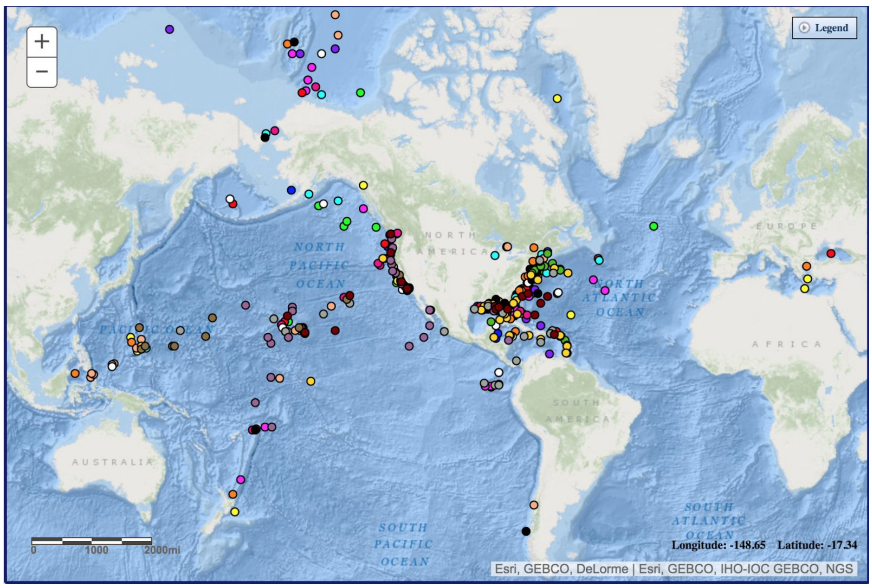

Figure 2. Since 2001, according to the OER Digital Atlas, OER has conducted and/or sponsored 371 cruises around the world, 68% of which were in US waters. Map does not include ~22 cruises conducted by the Ocean Exploration Trust in the Mediterranean, Aegean, and Black Seas.

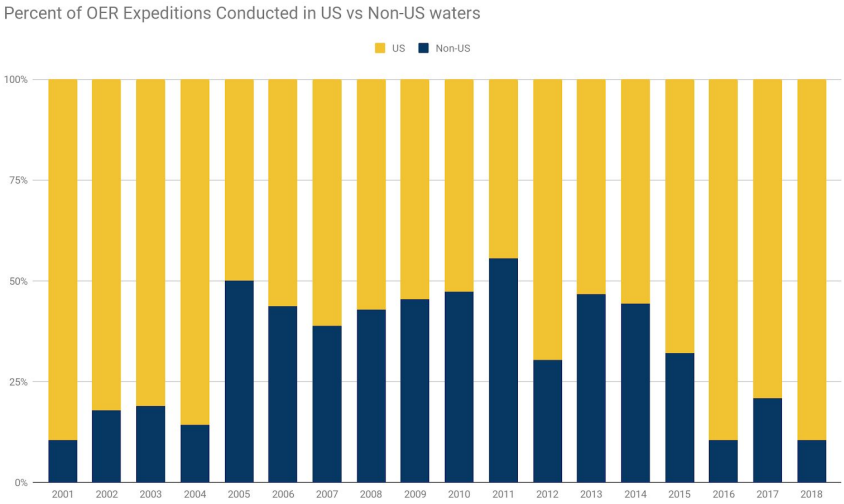

Figure 3. Percent of expeditions conducted and/or sponsored by NOAA OER from 2001 to 2018 in US (yellow) and non-US (blue) waters, according to the OER Digital Atlas.

If we assume that international exploration and collaboration is important for US and global interests, then it would stand to reason that US-led exploration should once again expand to international and other non-US waters, with an emphasis on open, collaborative research. There may be risks in increasing international collaborations, such as allowing other countries access to US-collected data, but I believe that the benefits of collaboration far outweigh the risks. Some of those benefits include the acceleration of data collection, analysis, and understanding about the ocean that can benefit everyone in the world, as well as enhanced strategic relationships with countries that may not have partnered with the US in the past.

2. *In your written testimony and in the hearing, it was brought up that the number of students studying ocean engineering has stagnated while those in other fields such as aeronautical engineering has grown.*
    a. *Can you expand upon what may have contributed to this stagnation?*
    b. *What are the skills needed to advance modern ocean exploration, and how can we build a workforce to achieve it?*

Allow me to begin with a specific case of decline of Ocean Engineering, at my alma mater and current home institution, MIT. As early as 1886, a course in marine engineering was offered at MIT, and due to its popularity, the Department of Naval Architecture was established in 1893. Over more than 110 years, its name changed several times, but its mission remained the same: to offer instruction in the theory and methods of designing, building, and operating marine systems, such as ship design, aeronautics, nuclear propulsion, acoustics, and, most recently, robotics. In 1901, MIT began a special course for the U.S. Navy, extending over three years for the professional training of naval constructors, and supported the Navy and merchant marine throughout its history.

I declared Ocean Engineering as my undergraduate major as a sophomore in 1997, not knowing anything about it other than the fact that I liked both the ocean and engineering. I was often teased by classmates from other departments, wondering *what in the world would I do with a degree in Ocean Engineering*? My class in 2000 graduated two undergraduates. In 2005, the Ocean Engineering Department was merged with Mechanical Engineering. MechE students can still concentrate on ocean research, but it is not a standalone department any longer, and the number of students graduating with a marine engineering focus has dropped precipitously since the department's peak in the 1970-1980s (Figure 4).

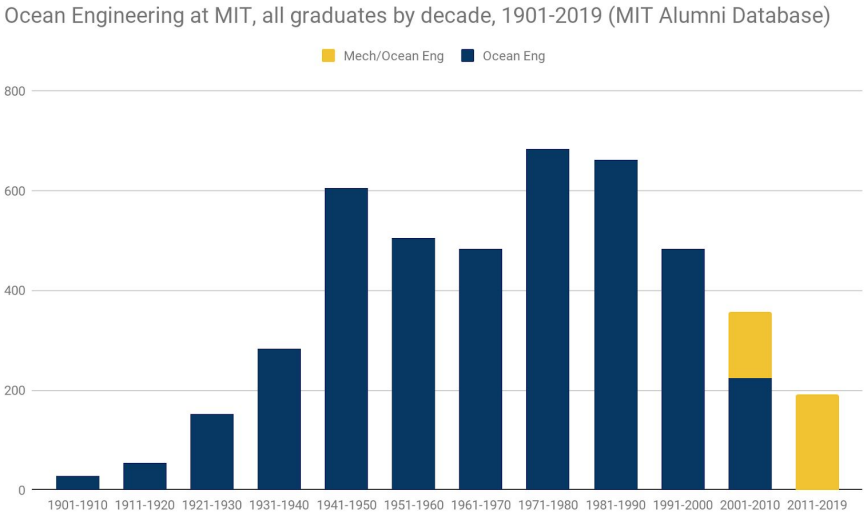

Figure 4. MIT Ocean Engineering graduates, all degrees by decade, show the height of the department occurred between 1941-1990. Blue bars indicate students graduating with any degree (SB, SM, PhD) in Ocean Engineering. Yellow bars indicate students graduating from Mechanical Engineering, with an ocean focus, after the departments were merged in 2005. Students who were admitted under Ocean Engineering pre-2005 were allowed to graduate with that degree title. Number of graduates is approximate; from the MIT Alumni Database.

Why is this occurring? I cannot say definitively, and I am sure that there are numerous factors in play. One very basic reason could be that most of the population does not know that this career option exists. Everyone knows about rocket scientists and astronauts -- even more so now with the new surge in the privatization of space exploration, and the resurgence of such franchises as Star Trek and Star Wars. Perhaps the difference stems from the very public Space Race vs the covert Cold War occurring under the sea in the 1960s, or the magically infinite vastness of space, which evokes feelings of wonder and possibility. Whatever the reason, in more than 20 years in this field, I have met only a handful of people who know what ocean engineering is, let alone any pop culture "hero" that has a background in the field, or a child who expresses interest in wanting to be an ocean engineer or ocean explorer when she grows up. Fact of the matter is: if people don't know what it is, then it won't occur to them to study it, and we need to do something about that if we are to regain and maintain leadership in the field.

The skills needed for the next generation of explorers to advance modern ocean exploration can be broken into three categories: (1) fundamental mathematics, physics, and engineering; (2) knowledge of the environment, including earth science and oceanography; and (3) critical thinking, problem solving, and practical, hands-on skills. Increasingly, given how international the field is (or should be), I also believe that at least an introduction, if not a firm foundation, in international ocean law and policy will also serve the next generation of modern ocean explorers to succeed in the field.

I can hypothesize about many activities that could or should be done to address the dearth of ocean engineers -- from increasing diversity in water sports to producing television shows and films that highlight [diverse] ocean engineers and oceanographers as the heroes of well-written stories. But before we begin speculating, my recommendation would be to commission the National Academy of Sciences to look into the problem in systematic detail, including all potential factors from academics to popular culture; make recommendations for how to address it; and enthusiastically prosecute those recommendations. Given the importance of the ocean for human survival on Earth, we do not have time to waste.