WRITTEN TESTIMONY OF

Margaret Leinen, Vice Chancellor Marine Sciences
Director, Scripps Institution of Oceanography
University of California San Diego

BEFORE THE UNITED STATES HOUSE OF REPRESENTATIVES COMMITTEE ON SCIENCE, SPACE, & TECHNOLOGY
SUBCOMMITTEE ON ENVIRONMENT

Hearing on *Defining a National 'Oceanshot': Accelerating Ocean and Great Lakes Science and Technology.*

Monday, June 7th 2021

Chair Sherrill, Ranking Member Bice, and Subcommittee Members, thank you for the opportunity to submit testimony for this hearing titled, *Defining a National "Oceanshot': Accelerating Ocean and Great Lakes Science and Technology.* My name is Margaret Leinen and I am the Vice Chancellor for Marine Sciences at University of California - San Diego and Director of Scripps Institution of Oceanography (Scripps Oceanography), a division of the university.

I've had the honor of serving on the Executive Planning Committee for the UN Decade of Ocean Sciences for Sustainable Development, as one of three representatives of the United States, including Capt. Craig McLean, also testifying today. I'm also currently a member of the Leadership Council of the Joint Ocean Commission Initiative and the Vice Chair of the Research Board of the $500 million Gulf of Mexico Research Initiative. I previously served as a US Department of State Science Envoy focusing on ocean science in Latin America, East Asia, and the Pacific, and as Assistant Director for Geosciences and Coordinator of Environmental Research and Education for the National Science Foundation. I have served as president of both of the scientific societies that represent ocean science, the American Geophysical Union (AGU) and The Oceanography Society.

I have a PhD in oceanography from the University of Rhode Island, a master's degree in geological oceanography from Oregon State University, and a bachelor's degree in geology from the University of Illinois.

State of Ocean S&T:

What are the major gaps in our understanding of ocean, coastal, and Great Lakes science, the low-hanging fruit/data that are needed most urgently, and how can we address these gaps, such as the "Ocean of Things"?

The biggest gap in our understanding of ocean, coastal and Great Lakes science is our lack of ability to predict the consequences of the major changes that are affecting this essential aquatic environment. For example, while we know the impacts of harmful algal blooms on coastal ecosystems and tourism, we

don’t know what triggers them or whether we can predict them. Some of the biggest gaps in our knowledge are in the biological links between elements of ecosystems, for example the relationship between the microbes that mediate most biological activity and the larger living organisms in the ecosystem, and the relationships between biological components of ecosystems that control food security, biodiversity, and ecosystem health. I am sure my other colleagues on this panel, including Capt. Craig McLean, will mention seafloor mapping and access to the ocean floor. This is another major example. These are all important gaps in our knowledge of the ocean.

The US has recently taken major steps to address some gaps. For example, Scripps Oceanography is part of a group of institutions recently funded by the National Science Foundation to expand the Argo ocean observation float program to add biogeochemical sensors to a fraction of the Argo floats. These sensors will allow us to see the result of biological processes in the ocean (although not the biology itself) through measurement of nutrients and oxygen used by biota. We have also developed new floats that can make measurements in the full depth of the ocean rather than the upper 6500 ft measured by the current Argo floats. As important as these observations are, they are not observations of the biology itself. New techniques and methods of biomolecular analysis that revolutionized biology and medicine are poised to revolutionize the study of ocean biology and will allow us to understand how the genetics of marine organisms control their resilience to the profound changes in the ocean.

Another gap is our understanding of how extreme events in the ocean like marine heatwaves, hurricanes, severe storms, atmospheric rivers and other phenomena are generated and how these hazards influence both the ocean and land. We know that these ocean phenomena are connected to extremes on land - atmospheric river rainfall, heavy precipitation, elevated sea level, coastal erosion and inundation from El Niño, and drought associated with La Niña, but we do not have the ability to predict the impacts so that we can prepare for them. Our ability to continue to improve forecasts starts with the ocean.

You asked specifically about the Ocean of Things or Ocean Internet of Things (Ocean IoT). Current communications capabilities within the ocean lag far behind communications on land, in the atmosphere, and between Earth and Space because the ocean does not transmit electromagnetic radiation well. There are tens of thousands of instruments and sensors in the ocean, but they cannot talk to each other unless they are connected by wire to the ocean surface, then transmit to a satellite, and the satellite then transmits to another mooring and back down to the second instrument. While this is possible for instruments on mooring, for our autonomous floats and platforms this makes no sense. To really capitalize on all of our investments in sensors and instruments we need to innovate a new underwater communication system that can facilitate communication between our exploration, mapping and measuring tools. Federal agencies are interested in innovation to connect our Ocean of Things to the internet to make data collection and analysis more abundant, effective, efficient, and accessible for all ocean users. This is a major opportunity for the ocean.

While focusing on gaps and low hanging fruit it is critical to remember that this new knowledge and capability will be dramatically decreased in value if existing global ocean observations coverage is reduced. It is the backbone of our ability to make sense of new information and it still requires investment and support. This Congress is considering Ocean Exploration legislation that seeks to address some of the gaps in seafloor mapping, and the reauthorization of the National Oceanographic Partnership Program

(NOPP) was critical, but global ocean observation is still an area that is in need of greater investment. For example, the Argo program, funded through NOAA Global Observations. Argo makes major contributions to basic oceanographic research, assessments of the global ocean/climate system, education, and operational ocean and coupled reanalysis and forecasting. It is the observing system that tells us how much heat the ocean is taking up and where, how the waters around Antarctica are affecting the stability of the West Antarctic Ice Sheet, and how glacial melt is affecting ocean circulation. The US provides half of the world's Argo floats with international partners matching our contributions. In FY21, NOAA funded 282 floats compared with the 350 required to sustain the US commitment. If we continue to fund less than our commitment, that impact could be doubled as international partners correspondingly reduce their commitment.

Framework for a National "Oceanshot":

How should we define our national vision, or "oceanshot," for advancing ocean, coastal, and Great Lakes S&T?

Our "oceanshot' needs to be a broad vision of ocean predictability, not a focus on individual problems or single goals. We need to maintain our commitment to ocean observation, combine it with 21st century tools like biomolecular analysis, autonomous observation and mapping, wireless connectivity between ocean sensors and instruments, and a new generation of ocean models that are also coupled to full ecosystem models with a goal of being able to predict major events that impact our health and economy (e.g., harmful algal blooms; impact of warming and acidification on US shellfish; major improvement of seasonal to subseasonal weather forecasting--which is dependent on ocean data and prediction; major improvement of coastal flooding/sea level rise predictions; understanding of the potential of blue carbon sequestration).

What are the potential applications of ocean, coastal, and Great Lakes S&T to help transform American society, the Blue Economy, and contribute to our resilience?

The ocean and Great Lakes play a role in every US citizen's way of life, whether you live, work, and play on the coast, or in a landlocked state. As mentioned above, the ocean plays a critical role in climate and weather systems, and ocean data is critical for forecasting of disasters and hazards including hurricanes, atmospheric rivers, snowpack/melt, El Niño/La Niña, and tsunami warnings. Ocean and coastal data are critical for understanding sea level rise and coastal flooding and associated risks to human life and property. While improving this predictive capability for the Blue Economy is important, improved forecasts also benefit the overall economy, especially agriculture, transportation planning and infrastructure investments, land use, tourism, and broader economic impacts.

We now import more seafood than we harvest in the US. We are poised for major innovation in seafood - new types of aquaculture in the water that result in less pollution and healthier fish, new types of aquaculture on land in recirculating systems that can be carried out anywhere, and new types of 'manufactured seafood' from plant material. Understanding both the physical environment for aquaculture and the biomolecular controls on the productivity and resilience of aquacultured species will

be the difference between continuing to get a substantial portion of our protein from seafood and seeing it become too expensive for most Americans.

The need to enhance the resilience of coastal communities and marine ecosystems is generating enormous excitement and innovation among young entrepreneurs. Our undergraduate and graduate students are full of ideas for how to create companies that provide innovative products and services to coastal communities struggling with the impacts of change, that reduce energy and resource utilization by taking advantage of ocean energy, that develop innovative materials to replace plastics and other synthetics like microfiber, and that address a host of technical and resource issues. Last week, I moderated the Triton Innovation Challenge at UC San Diego at which student-led companies competed for access to advice and a few thousand dollars. The judges had a difficult time choosing between the winners and 'alums' of the competition returned to show students that even those efforts that did not come in first in the past resulted in successful companies. These kinds of efforts will lead to new solutions to vexing problems like plastic pollution and will result in new ways of thinking about our use of resources. And I am sure that this level of innovation for ocean environments is going on around the country.

Which stakeholders and underrepresented minorities need to be engaged, and how do we engage them, in advancing ocean, coastal, and Great Lakes S&T?

All US citizens and organizations have a stake in ocean/coastal/Great Lakes science because the ocean has such a profound influence on every aspect of our lives:

from the ocean's dominant role in climate and its strong role in seasonal to subseasonal weather;

to its impact on food resources (directly through seafood and indirectly through its influence on the hydrologic cycle, rainfall, drought and flood);

to its impact on hazards (hurricanes, severe storms, tsunamis, sea level rise);

to its importance for national security;

to its traditional role in our economy through recreation and tourism and its new role in blue technology;

to its importance as an inspiration through exploration of some of the most challenging and unique environments on the planet, of the ocean's fascinating biological diversity, of the ocean's great beauty, and its role in our culture and history.

Representatives of all of these interests should be reminded of their dependence on the ocean and engaged in identifying their needs from ocean/coastal/Great Lakes science. As scientists and as a nation we have in the past sometimes neglected to pay enough attention to the impact of ocean/coastal/Great Lakes issues on communities. But this is changing. A wonderful example from my own region is the experience of the community of Imperial Beach, California, a small ocean community with spectacular beaches, an estuary and marsh environment, located next to the US-Mexico border. This small community has traditionally been a mecca for surfing big waves traveling across the Pacific and a destination for those wanting to swim its shores. But recently, a combination of sea level rise that threatens the homes along the shore during every high tide, and raw sewage and other pollution from Mexico streaming down the Tijuana River that causes the beaches to be closed to swimming and surfing most of the year, are creating a double threat that reduces income to the community at the same time that it creates a health threat and a threat to property. The community does not have the resources to deal with this double threat to its

livelihood. Our Scripps Oceanography Resilient Futures initiative has now instrumented the shoreline with equipment that allows us to predict when storm systems will combine with high tide events to threaten beach property so that the city can prepare defenses and if necessary, evacuate residents. We are able to give them 48 hours' notice so that preparations can be put in place. In addition, we have the ability to develop models of the Tijuana River pollution plume under different conditions that would allow us to identify when the river plume will make landfall at Imperial Beach rather than further north along the coast, helping them open or close beaches based on predictions rather than after the fact measurements. This experience has shown the citizens of Imperial Beach how important ocean science is to their future and how it directly contributes to their economy.

In order to engage underrepresented stakeholders and enlarge the human resources of ocean science, we need to bring scientists from underserved populations and communities into our field. For many years our ocean science community focused on 'creating a pipeline' of diverse individuals interested in aquatic environments. We assumed that the primary reason that we had few applicants from underrepresented groups to study these environments was that they hadn't heard about our science and weren't interested in it. We focused on bringing stories of the ocean to underserved communities. But decades later most majority institutions still struggle to find diverse applicants for graduate school. Why? We now know that the problem is not a lack of interest, but insufficient recruitment at undergraduate schools with highly diverse student bodies, an unwelcoming recruiting culture, and admissions processes that place too much emphasis on the number of (often unpaid) enrichment experiences when most underrepresented students must work to continue to go to school, and too little emphasis on the potential of the student. Our own experience at Scripps Oceanography is that when we reach out to students from diverse backgrounds, when we provide them opportunities to talk with our students and faculty before they apply, when we rank them on their potential - not just their enrichment experience - we are able to attract bright, motivated, diverse students. Eighteen of the PhD students who accepted our offer of admission for this Fall term - 25% of our new PhD students - are students of color. And they are outstanding. The good news is that this means that we do not have to wait 15 or 20 years to have people of color in ocean science. We can engage them as graduate students now and have a more representative ocean science workforce before the decade is over.

Do you have ideas for how to strengthen dialogues between different communities working across the science-policy interface to foster interdisciplinary research, connect research applications to decision-making, and involve innovators in the development of ocean, coastal, and Great Lakes science and technology?

I think that the culture related to ocean research at universities and other research organizations is undergoing a rapid change to foster more partnerships focused on working with communities to solve problems. Twenty-five years ago, universities wanted to have policy centers or institutes. Their faculty studied how we could learn from successful policy instruments like the Montreal Protocol. Scholarly journals focused on policy study flourished. While these activities continue, universities and research centers are now creating centers and institutes focused on partnering with local/regional/state governments to solve marine and other environmental challenges. This 'solution science' is attracting students who want to solve problems for communities. Basic research will continue to thrive, as will policy research, but just as universities invested in solutions for agriculture resulting in the incredibly

important land-grant system of the 1800s, universities are now investing in solutions for the environment. These vibrant partnerships need to be encouraged and fostered by policy-makers. NOAA's SeaGrant College Program has such partnerships as an objective, but has minimal resources to seed activity. It would be natural for NOAA to consider additional mechanisms to link communities and researchers. The Department of Energy is investing in a wide variety of marine research, whether for energy generation, or for carbon sequestration. At the same time, it works with communities on energy related projects. Having DOE develop mechanisms to foster and support partnerships between local/regional/state communities and research at universities (as well as at national labs) could support DOE's goals with increased reach.

How can partnerships be leveraged to advance ocean, coastal, and Great Lakes S&T?

Progress is occurring at three levels in ocean S&T public-private partnerships and is resulting in real solutions to challenges, spurring innovation, and leveraging ocean resources for societal needs.

1) Individual research institutions are demonstrating a strong commitment to startup and technology: entrepreneurs-in-residence, accelerators (like our federal Economic Development Administration funded Scripps Oceanography startBlue program), and corporate affiliates programs, all of which enable innovation and increased collaboration between academia and industry. Areas of opportunities include expanding inclusivity and diversity of students and industry leaders.
2) Professional organizations and workshops are connecting the private sector, government, non-profit, and academic partners. Examples include the recent Ocean Visions Summit, the now regular US meeting of Oceanology International in San Diego, and the MarineTechnologySociety/IEEE meeting. These events are becoming more inclusive of all stakeholders, and this has accelerated in the virtual environment of the last 15 months. Panels and side events are increasingly represented by individuals from each of the four sectors, and are driving conversations on real solutions to problems, e.g., hazards, food security, climate impacts.
3) Professional societies like the AGU and The Oceanography Society and the Marine Technology Society are making greater efforts to engage the private sector.

Please provide any additional information you think is relevant for Environment Subcommittee Members to know.

The UN Decade of Ocean Science for Sustainable Development offers a once in a generation opportunity to leverage US leadership and science investments with contributions from around the world. The UN agency responsible for managing the Ocean Decade is the Intergovernmental Oceanographic Commission (IOC). The IOC recruited an Executive Planning Group of ocean science experts from around the world to design both a process of engagement for the ocean science community and ocean stakeholders, as well as an Implementation Plan for the Ocean Decade. We were fortunate to have three US representatives on that Executive Planning Group -- more than any other nation. This reflects the leadership position that the US has had in conceiving of large multiyear multinational ocean science campaigns in the past: the International Geophysical Year in the 50s, the ocean drilling programs starting in the 60s and continuing until today, The International Decade of Ocean Exploration in the 70s, the ocean programs of the International Geosphere Biosphere Program in the 90s, and so on. None of those programs had the backing of the entire membership of the United Nations, as well as the Ocean Decade's large-scale efforts to engage philanthropic organizations as well as governments. This has the potential to supply very

substantial resources to address major ocean challenges that are priorities for the US as well as other countries.

The US presence in the Ocean Decade is already deep. Many of the 'programme proposals' (multiyear, multidisciplinary, multinational efforts) that were submitted in Fall of 2020 as initial large scale Ocean Decade efforts are led by US scientists. For others, US scientists play a major role in proposals submitted by scientists from other nations. The US has already captured the attention of the world with its 2021 call for OceanShots by the National Academy of Science (NAS). Many ideas submitted to the NAS OceanShots process were based on US proposals for UN Ocean Decade programs. Other OceanShots ideas will be proposed to upcoming UN calls for projects and programmes.

It is important for both US scientists and US government agencies to be involved in this process because we can propose our great ideas and attract resources and partners from around the world to complete them. This allows us to propose ambitious ocean activities that even the US cannot do on our own in spite of our excellent capabilities, like Argo (28 nations are currently contributing Argo floats to the program), or mapping the entire seafloor. These challenges require many contributors, and heavily leverage our own investments.

The UN Ocean Decade does not require agreements between nations or with the IOC to participate in the Ocean Decade process, so the US can benefit enormously while not being pulled into legal entanglements. This is a once a generation opportunity for us to enhance our US national vision for the ocean.

Margaret Leinen

Vice Chancellor for Marine Sciences, Director of Scripps Institution of Oceanography, Dean of the School of Marine Sciences

Dr. Margaret Leinen is the Director of Scripps Institution of Oceanography and Vice Chancellor for Marine Science of University of California at San Diego. She is an ocean biogeochemist and paleoceanographer whose research includes study of ocean carbon cycling and the role of the oceans in climate. She is a Fellow of the American Geophysical Union, the AAAS and the Geological Society of America. She served as Assistant Director for Geosciences at the National Science Foundation from 2000-2007. She has served as the President of the American Geophysical Union, the President of The Oceanography Society and the Chair of the AAAS Section on Atmospheric and Hydrospheric Science. She has been the Vice Chair of the International Geosphere Biosphere Programme, Chair of the US Global Change Research Program and Vice Chair of the U.S. Climate Change Science Program. She currently serves as a member of the Executive Planning Group of the UN Decade of Ocean Science for Sustainable Development.