December 31, 2016

Subcommittee on Ocean Science and Technology
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To the Subcommittee on Ocean Science and Technology:

Representing the leading ocean science, technology, and education institutions, the Consortium for Ocean Leadership's mission is to shape the future of ocean sciences. We appreciate the opportunity to weigh in on the National Science and Technology Council's Subcommittee on Ocean Science and Technology (SOST) 10-year ocean research plan, *Ocean Research in the Coming Decade*. Ocean science and technology strengthen our national and homeland security, support a safe and efficient marine transportation system, underpin our economy, contribute to improved human health, and further understanding of our nation's dependence on the ocean. As we consider priorities for the ocean science and technology community now and into the near future, it becomes clear that we must illustrate how ocean science investments strengthen our nation and benefit our society at large. To that end, we have identified five ocean science and technology research priorities that will help our nation achieve four major societal goals. Example recommendations can be found in Appendix 1.

PRIORITIES FOR RESEARCH

Enhance our ability to observe and monitor the ocean

It is impossible to understand the marine environment, which many of the resources and services our nation depends upon, without observations and monitoring. Ocean observations are critical to not only maintain the economic prosperity historically linked to this rich resource but to unlock the incredible potential of the ocean. From extreme weather events, coastal flooding, and marine bioproductivity to natural or technological catastrophe response, ocean observations provide the essential data and information necessary for science-based management and decision-making. Our country is blessed with vast coastal areas that provide almost 50 percent of the nation's gross domestic product, but unfortunately, our coastal waters are under sampled. Gaps in our nation's ocean observing capabilities limit prediction capabilities, weather forecasting improvements, search and rescue efforts, economic development, conservation of ecosystem integrity, and effective policy and management. Ocean observing infrastructure must be considered part of the nation's infrastructure portfolio.

Advance scientific knowledge of the ocean

Basic research and analysis of the coastal and marine environment is tantamount to our ability to forecast change. Every study creates, confirms, or analyzes data and information, and ultimately moves our national scientific enterprise forward. Whether the scientific progress is in fisheries, the blue economy, technology development, environmental toxicology, or any other discipline, these advances further humanity's foundation of understanding of this critical resource, which ultimately informs decision-making and provides insight into the Earth system.

Increase ocean science education

Almost half of the nation's geoscientists are reaching retirement age (47 percent in the private sector and 43 percent in the federal government were over the age of 55 in 2016). To maintain our nation's global competitiveness, we must prioritize ocean

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education. Increasing ocean literacy; educating the next generation of scientists, technologists, and innovators; and broadening participation in ocean science will bring new perspectives and backgrounds to ocean issues. Cultivating an ocean-literate nation with a new class of marine scientists and technologists is a critical step in keeping our nation's economic driver healthy and productive while we begin to truly address the changes in our ocean (and Earth) system and their impacts upon our very way of life.

Improve access to the ocean and its science

The ocean is too often considered a remote and unreachable place, and yet, if we do not facilitate physical, technological, and societal access to the marine world or its data and information, scientific advances would be impossible. Whether physical access with ships or remote access through observation platforms, drones, sensors, buoys, and satellites, it is abundantly clear that access is critical to bringing data and information from the ocean to answer pressing questions and to address current hypotheses. Access does not end at the shoreline, however. Accessing data, both spatially and temporally, is the future of science in a fiscally-constrained world that still seeks to bring all of science to bear in policy and management efforts. Access to the scientific enterprise is another challenge – to take full advantage of the talents of our nation, we must intentionally foster inclusion of women and minority scientists in science, technology, engineering, and math (STEM) professions.

Encourage adequate and sustained federal commitment to ocean science and technology

Every fiscal year, the ocean science and technology community is reminded again of its relative importance. In the proposed $3.9 trillion 2015 president's budget, $131 billion was dedicated to research and development (R&D) spending – roughly 3.4 percent. That year, $40 billion was invested in military aircraft (one acquisition program for the F-35 joint strike fighter alone was $3 billion more and $1 billion more than the entire National Oceanic and Atmospheric Administration and National Science Foundation budgets, respectively), and across the entire federal family, $12.5 billion was spent on ocean science. This is mere 10 percent of the R&D budget – but our nation has more sovereign area in the marine environment than in the terrestrial one. Without a stronger federal commitment to the national scientific enterprise, ocean observations, access, basic research, and education are all wishful thinking – and with them the societal benefits they bring – economic prosperity, food security, a dynamic workforce, national and homeland security, and a healthy population. Federal investment in ocean science and technology makes our nation safer (e.g., advances in extreme weather models, made possible by improved ocean observing, provide more timely hurricane evacuations, which in turn save American lives) and more prosperous. Federal commitment must be adequate and sustained to achieve these goals and must be more than just policy promises. Budget prioritization needs to echo policy initiatives, and intentionally moving beyond the status quo is required to address issues we haven't faced before.

Advancing these five research community goals has benefits that extend far beyond the scientific field – the well-being of our society at large is dependent upon them.

SOCIETAL GOALS

Improve National and Homeland Security

Ocean science and technology provide our maritime nation with a knowledge advantage against myriad oceanic threats we face now and in the future. The critical foundation ensuring continuity of our superior maritime domain awareness that generates warfare advantage and preserves our homeland security operations is basic research. To maintain global stability, it is critically important that we understand the factors of conflict catalysts. The shifting climate and ocean systems are altering not only when and where our military and Coast Guard may be called to duty but also *how* they can respond. Rising sea levels influence amphibious landing opportunities and extreme weather disturbs deployment, intelligence, surveillance, search and rescue, and reconnaissance capabilities. To successfully navigate a physically, chemically, and biologically changing ocean while maintaining geopolitical establishments, the sea-dependent agencies must understand baseline and forecasted conditions, vulnerabilities of marine and coastal infrastructure, and the threats facing human populations. This will only happen through the robust federal support of basic and applied research, maintaining superiority in technology development and integration, and collaborative partnerships with ocean science and technology institutions.

Expand Economic Prosperity

A strong ocean economy drives a strong national economy. The U.S. coastal and ocean economy contributes $359 billion to our gross domestic product (e.g., marine construction, $5.8 billion; ship building, $17.3 billion; marine transportation, -95 percent of all imports to the U.S.- $59.1 billion; offshore oil and gas, $167 billion; living marine

resources, $7.3 billion; and tourism and recreation, $101.1 billion).This includes 149,000 business establishments and three million employees (more than telecommunications, crop production, or building construction sectors), providing $117 billion in wages annually. By 2020, employment in the ocean economy is expected to increase by another 10 million employees. Additionally, the ocean economy withstood the recession of 2007 to 2009 better than the U.S. economy as a whole. Weather forecasting plays an important and widely-understood role in our nation's economy, but we lack the same robust ability to forecast the ocean at a similar level. Comprehensive ocean observations are required to understand the sea's role in weather forecasts (as well as ocean-specific forecasts) if we are to reap similar industry benefits. Ocean science data and information support analysis and understanding of our rich ocean resource. From this, businesses and communities can build new ocean-dependent enterprises and maintain and grow current endeavors, all while effectively managing risk.

Foster Human Health

Like the body itself, human health depends on complex information, integrated networks, and a fragile framework. However, ocean-related health components for our nation include food safety, food security, harmful algal blooms, aquaculture, environmentally-adaptive healthcare infrastructure, and seafood fraud. The ocean is usually not the first thing that comes to mind when one thinks about food security. The ocean's role in human protein consumption and the water cycle makes it an important player in food security. Whether considering ocean conditions to improve drought forecasts, model changes in fish distributions, understand the spread of seafood disease, or develop aquaculture, data and information from the sea strengthen the nation's ability to understand and predict crop loss, food availability and pricing, contamination, disease, and conflict catalysts. Linking health professionals and ocean scientists enables both communities to better address how humans fit in the ocean ecosystem, including health effects on our nation's citizens. The direct (e.g., drought, wildfires, and floods) and indirect (e.g., risk multipliers of freshwater access, sanitation, or easier pathogen distribution pathways) health impacts of extreme weather events both increasingly indicate the changing Earth (and ocean) is also a global human health crisis. We will successfully care for our most vulnerable – the sick, the poor, the young, and the old – through multilevel, interdisciplinary, integrated approaches implemented from both the top down and the bottom up.

Build a Dynamic Workforce

A secure, healthy, and prosperous nation belongs to a society willing to evolve its workforce to meet the needs of a changing world. A diverse, well-educated, ocean literate workforce provides the necessary base from which innovation grows, but we are at the precipice of disaster with our innovation workforce. Our nation's STEM workforce need is growing (from 2012-2022, there is a 12.5 percent projected growth of STEM jobs and a 14 percent projected increase of geoscience jobs), while almost half of the country's geoscience workforce is greying. Not only does the nation depend on an available pool of scientists but also upon those who will train the following generation and those whose work supports novel and emerging science solutions. A dynamic workforce moves our nation from siloed sectors, agencies, and incremental changes to interdisciplinary, multi-agency, public-private partnerships, and inclusive approaches. From business professionals who can commercialize scientific advances to technicians who maintain observing infrastructure and employees cross trained in scientific advances to a nation-wide broadening of participation in sciences, our future depends upon how we will meet these challenges and with whom.

In sum, we share your commitment to advancing the future of ocean research and appreciate the opportunity you have given the ocean science and technology community to provide input. We look forward to working with the SOST as you develop the 10-year ocean research plan.

Sincerely,

RADM Jonathon White (ret., USN); M.S.
President and CEO
Consortium for Ocean Leadership

Appendix 1. Example Ocean Science and Technology Research Recommendations to Meet Societal Goals

Recommendations to improve national security through the five research priorities:

Observations – To increase maritime domain awareness, it is essential to fill critical gaps in the Integrated Ocean Observing System that supports environmental intelligence gathering, search and rescue efforts, oil spill response, prediction of harmful algal blooms, and advancement of scientific understanding. Investing $10 million annually for the next five years would allow the ocean science community to complete the first phase in addressing gaps while sustaining existing systems, including:

- Complete the surface current monitoring network;
- Expand the national network of land-based coastal high-frequency radars;
- Modernize the Tropical Pacific Observing System for understanding and forecasting of the El Niño Southern Oscillation (ENSO);
- Implement the global Deep Argo Program for observation of the full ocean water column;
- Establish and maintain extratropical and high latitude ocean time series sites;
- Observe the ocean's boundary currents using ocean gliders and other new technologies; and
- Streamline data and information sharing to national and homeland security agencies.

Research, Analysis, and Prediction – Extreme weather event response and restoration planning is as important as forecasting. Develop a federal initiative led by the Department of Homeland Security, in conjunction with National Oceanic and Atmospheric Administration (NOAA)'s National Centers for Coastal and Ocean Science, Department of the Interior (DOI)'s Coastal Barrier Resource System, Department of Defense (DOD)'s Army Corps of Engineers, and Federal Emergency Management Agency (FEMA)'s National Flood Insurance Program to reevaluate the definitions of regional, periodic storm events (such as 100- and 1,000-year storms and floods) in our currently changing paradigm. This information should then feed into the response and restoration programs of all agencies to reduce the risk to and cost of federal investment.

Education – Historically the U.S. has led the world in science and engineering, but Southeast, South, and East Asia (with China leading the group) now account for 40 percent of global R&D and are quickly closing the gap on our science primacy. South Korea doubled R&D spending (as a share of GDP) over the last 20 years as part of its five year science and technology basic plans; China has tripled their R&D funding since 1997 and are on track to overtake the U.S. in total R&D spending by 2019. U.S. investment in R&D has declined in recent years, not even keeping pace with GDP growth since the Great Recession (0.8 percent R&D growth vs. 1.2 percent GDP growth, annually). Asia is also taking the lead in science and engineering education, with China producing the most undergraduates with those degrees (accounting for almost half of all bachelor's degrees awarded in China vs. 33percent of U.S. degrees). While the U.S. continues to produce the most science and engineering doctorates, it is clear that Asia's prioritization of science and engineering education to buoy research and development alters the dominant paradigm of global science primacy. To maintain our nation's global science primacy, expand R&D funding by 0.01percent of GDP per year over the next 10 years, specifically including ocean science and engineering education programs.

Access - Complete the Service Life Extension Program of the Auxiliary General Oceanographic Research (AGOR) research vessels AGOR-23 class, which adds 10-15 years of life to the vessels and ensures the availability of unique platforms capable of performing multidisciplinary, high endurance missions that support Navy information needs around the globe.

Adequate and Sustained Federal Commitment – A secure nation and safe homeland require certain tools, specifically ships – military oceanographic vessels to survey and measure the global ocean for maritime superiority, Coast Guard vessels for search and rescue activities, and University National Oceanographic Laboratory System ships for oceanographic research to inform decision-making. The development and implementation of a comprehensive, long-term, federal science ship building and recapitalization plan will leverage core competencies between partners, address infrastructure gaps, and prioritize needs for both the agencies and the legislative appropriations process. Thoughtfully evaluating the next generation of oceanography rather than the last will be crucial in the planning process, given the community's movement to interdisciplinary and collaborative research (and the increase in berth space that implies).

Recommendations to expand economic prosperity through the five research priorities:

Observations – To reduce risk and increase certainty in business models, it is important to have a better understanding of current and future environmental conditions. To do this, we must improve the ocean observing systems and analyses to monitor the rapid ecological change taking place to: ensure adequate and sustained operational budgets are available to maximize the use of federal investments in infrastructure (e.g., Ocean Observatories Initiative), expand

focus areas to subseasonal to decadal forecasts, develop baseline observing capacity in the Arctic (e.g., expanding Argo into areas with seasonal and permanent sea ice coverage), bring observations inshore to inform local decision-making, create a deep-water observing network in the Gulf of Mexico, and develop techniques to transform observational data and information into products and formats suitable for use (e.g., prediction models, information services, interdisciplinary efforts, etc.)

Research, Analysis, and Prediction – Economic prosperity increases with understanding and purposefully growing the blue economy. In particular, the creation of regional *BlueTech Clusters* will bring academia, government, and industry together to promote innovation, economic development, and science-based ocean and water industries. Using the San Diego BlueTech cluster as a model, establish a BlueTech cluster for each of the nation's coasts (e.g., Gulf of Mexico, Atlantic, Hawaii, Alaska, and Great Lakes) with a scalable implementation plan to develop additional BlueTech clusters.

Education – Diversity breeds innovation in the science and technology sector; the gender, race, and ability gap in professional STEM fields implies we must actively foster broader participation to achieve this diversity. Facilitating inclusion in science demands broader participation from women, minorities, and people with disabilities. The National Science Foundation (NSF) should bridge the gap between education and profession by making seminars, workshops, and online portals dedicated to bringing applicable students together with industry and government entities seeking these young STEM graduates.

Access – Ocean planning facilitates sustainable, safe, and suitable economic development activities while supporting conservation and restoration of the ocean ecosystem, enabling long-term production of resources and services that the country was built upon and will need into the future. The most basic requirement of successful ocean planning is access – access to data and information and stakeholder access to the process. As regional ocean planning begins, the academic ocean science community should be brought in at all levels – planning, implementation, and evaluation. The ocean science and technology community can provide necessary data input at all stages and are a trusted national resource for the ultimate evaluation of this new effort.

Adequate and Sustained Federal Commitment – The National Ocean Policy highlights nine priority objectives that, if implemented broadly, are the building blocks for sustaining and enhancing the productive economic driver that is our ocean ecosystem. Prioritizing the interagency federal approach to ocean and coastal management provides continuity and protects the long-term usage of this resource. The priority objectives are:

- Ecosystem-based management;
- Coastal and marine spatial planning;
- Inform decisions and improve understanding;
- Better coordinate and support federal, state, tribal, and local and regional management;
- Resiliency and adaptation to climate change and ocean acidification;
- Regional ecosystem protection and restoration;
- Water quality and sustainable practices on land;
- Changing conditions in the Arctic; and
- Ocean, coastal, and Great Lakes observations, mapping, and infrastructure.

Recommendations to foster human health through the five research priorities:

Observations - Our nation needs a marine biodiversity observation network to provide critical information on status and trends of the diversity of living marine resources to operational agencies, academic researchers, industry, and the public. Sustained, long-term biological and biodiversity observations are critically needed to complement existing meteorological and physical observations to guide scientific understanding and the informed management of our marine resources. A national marine biodiversity observation network is crucial to provide the data, technology applications, and expertise that support ecosystem-based science, forecasting, modeling, and management as a part of our national ocean observing enterprise.

Research, Analysis, and Prediction – Sustainable aquaculture is one major key to feeding the future. Akin to the National Institutes of Health (NIH) challenge to cure cancer, establish a federally-supported challenge to develop a safe, sustainable, and scalable aquaculture model able to be deployed in various regions with a variety of commercially viable fishes. Challenge grants should be available for basic research (e.g., recirculation technology, fish selection, feed, and ecosystem studies) through commercialization.

Education – To ensure resilient health care system infrastructure, we must position hospitals and health centers to respond to human health issues into the future, amidst the impacts of climate change. Develop a national health care system resiliency taskforce to include a national evaluation to identify areas of strength and gaps; opportunities for

peer-to-peer education and sharing of best practices; supporting action by state and local governments that prioritize innovation, rapid response, and science; and connecting ocean and climate scientists with the hospital industry sector.

Access – Hook to plate tracking and labeling of marine foodstuff is one way to decrease risk in human consumption and empower consumers to make better decisions for their family's health. Seafood fraud and safety issues are easily addressed if chain of custody style tracking is in place. Given food safety-related outbreaks, fully-tracked marine products would ease the investigation of root cause and allow for a more streamlined response. Develop a single species (or suite of species) pilot project to examine the value and benefits of hook to plate tracking and labeling system with a scalable expansion plan.

Adequate and Sustained Federal Commitment – Presidential action can save lives and fundamentally change the way the world responds to health issues. Ocean and climate change presents a parallel global health crisis today as AIDS previously did. Using the successful Presidential Emergency Plan for AIDS Relief (PEPFAR) as a model, a similar 10-year global initiative to meet climate change challenges to health (President's Emergency Response to Climate Change) should be created. Additionally, expand presidential-level plans and task forces to include ocean science, inputs, and perspectives in food security topics and food security in ocean science and management topics, including the Global Food Security Plan and the Presidential Task Force on Combatting Illegal, Unreported, and Unregulated (IUU) Fishing and Seafood Fraud.

Recommendations to build a dynamic workforce through the five research priorities:

Observations – Strong and successful ocean observation networks gathering data and information critical for security, economy, and health require technicians to build, maintain, and repair their sensors and platforms. Investing in marine vocational technology training provides the workforce necessary to run observing systems sustainably. Promote marine technology vocational training through the Department of Education's grants, scholarships, and loans.

Research, Analysis, and Prediction – A dynamic workforce able to pivot quickly in times of change depends upon professionals having a more holistic view of issues and opportunities. Work with professional certification associations to expand continuing education programs to include state of ocean science courses/credits.

Education – Science education and training rarely includes management, communication, or budget training, but scientists are often elevated to leadership positions requiring these (and many more) skills. Instead of a vending machine style leadership progression, we need to actively cultivate leadership in the innovative, out-of-the-box thinkers able to see interdisciplinary connections and opportunities to partner across sectors. Establish a junior and mid-career level leadership training program specifically for STEM professionals across the federal family and make it available to academia, industry, and NGOs for eligibility. Creating cohorts of science leaders at a variety of levels facilitates public-private partnerships, interdisciplinary and multi-sector approaches, and decreases siloes.

Access – To foster greater access to STEM professions, mandate NSF to develop discipline-specific programs to provide educational and research opportunities, mentoring, career counseling and guidance, and leadership training for minorities and women. NSF should prioritize the research disciplines lacking similar programs and require grantees to work with existing programs in other fields for best practices.

Adequate and Sustained Federal Commitment – Federal support can be expressed in more than just funding for example, programmatic support for increased collaboration and interdisciplinary approaches in the federal ocean science enterprise. Through the Office of Science and Technology Policy (OSTP), develop, implement, and oversee an initiative for federal science mission entities (NSF, NASA, NOAA, ONR, etc.) to encourage and streamline multi-investigator collaborations, interdisciplinary studies, and interagency activities. Revitalizing the National Ocean Partnership Program is a key manner in which the interagency component of this could occur using established mechanisms.