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Blue Technologies: Use of New Maritime Technologies to Improve Efficiency and Mission Performance
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On behalf of the Consortium for Ocean Leadership (COL), I appreciate the opportunity to discuss marine technologies (blue tech) with subcommittee members today. COL represents the nation's leading ocean science, education, and technology institutions with the mission to shape the future of ocean sciences. Geosciences, broadly, and ocean science and technology, specifically, strengthen our homeland and national security, support a safe and efficient marine transportation system, underpin our economy, contribute to improved human health, and further the understanding of complex ocean and coastal processes behind the benefits from the sea upon which our nation relies. I consider this amalgamation of the securities that depend on robust ocean knowledge to ensure our safety and survival as "ocean security." Many overlaps exist between the missions of the United States Coast Guard (USCG) and the Department of Transportation's (DOT) Maritime Administration (MARAD) and ocean security. There are three important ideas you need to take away from my testimony today:

1. Ocean knowledge enables the USCG and MARAD in achieving their missions by enhancing maritime domain awareness (MDA).
2. Blue tech is vital to understanding the ocean.
3. Blue tech innovation and operation rely upon an advanced workforce educated and trained in ocean science, technology, engineering, and math (O-STEM).

This pyramid (mission success ← ocean knowledge ← blue tech ← O-STEM) is the best way to understand how marine technologies not only improve efficiencies and performance but are the very foundation that the USCG and MARAD rely on to meet their congressionally mandated missions. Since we live in a time of rapid technological advancements, it means this is not only true in the historic and present sense, but it is especially true in looking for the solutions of the future. Finally, it is critical to internalize that neither of the first two ideas can be actualized without the third – a strong STEM workforce.

I'm going to start by diving into my first two themes: understanding the ocean underpins the USCG and MARAD in achieving their missions by enhancing maritime domain awareness, and blue tech is vital to ocean security and enables understanding the ocean.

Ocean knowledge enables the USCG and MARAD in achieving their missions by enhancing MDA

As we have seen since the earliest history of our nation, superior knowledge of the ocean and the maritime environment has provided our armed forces with operational and tactical advantages that have ensured victory at sea and enabled the successful defense of our nation, sometimes against overwhelming odds. The late Admiral James D. Watkins, former Chief of Naval Operations, commented on several occasions that "Oceanography won the Cold War," in that our undersea ocean knowledge advantage provided us with operational and strategic advantages over the Soviet Union that deterred potential aggression. In numerous conflicts and other operations at sea, including search and rescue and law enforcement activities, superior ocean knowledge has ensured mission success, enhancing our safety, security, and prosperity.

It is paramount that the USCG maintains its strategic advantage in the maritime domain against threats to our security and safety. Threats such as terrorism, transnational crime, narcotrafficking, illegal fishing, etc., and the activities by rogue regimes (e.g., Iran, North Korea) threaten our nation and our homeland security in the maritime domain on many fronts. Ensuring robust and sustained funding for and prioritization of federal ocean science, technology, and education programs enable partnerships between federal ocean science agencies, research entities, industry, and federal maritime operating agencies and are key to ensuring the culture of innovation and initiative

that DHS and DOT need to meet their mission objectives today and tomorrow. Partnerships such as those enabled through the National Oceanographic Partnership Program (NOPP)—created by the National Oceanographic Partnership Act enrolled in the 1997 National Defense Authorization Act—do just that.

Ocean research and marine technology development provide the critical foundation to ensure continuity of our maritime knowledge superiority that generates advantage. Simply put, our ocean and coastal force must be able to win every potential armed conflict at sea, no matter how small or large. Thus, *we must be able to exploit our superior knowledge of the ocean environment to ensure "home field advantage" at both "home" and "away games."*

Blue tech is vital to understanding the ocean

The ocean contains 1.3 billion cubic kilometers of water. The deepest point in the ocean (the Challenger Deep in the Mariana Trench) is more than one mile deeper than Mount Everest is high (36,070 feet), and you can't just walk down it to explore it. How do we then explore the unreachable areas and understand what we can't see or feel (e.g., salinity, ocean processes)?

The answer lies in ocean science and technology, which have provided our nation with a knowledge advantage against myriad maritime threats. The Navy recently noted, through its Task Force Ocean process, that the nation's competitive advantage in understanding and exploiting the ocean environment has diminished and can only be re-established through investment in and prioritization of science and technology research across all federal ocean agencies.

The USCG, like the Navy, must maximize technological development to best understand the environment it is sending people into or to develop new ways to meet its mission objective without needing to place anyone physically into the environment and possibly in harm's way. A good example of this is the continued acceleration of autonomous undersea vehicles (AUV) and other ground-breaking undersea technology by the Navy and DOD. The impact of the ocean environment on these systems is even more pronounced than it was for the manned and tethered systems of the past.

Case Studies

IUU Fishing

Let's dig into what these two look like in the real world. Illegal, unregulated, and unreported (IUU) fishing is the term used when pirate fishers catch fish in violation of international agreements and treaties. IUU fishing is a global scourge with far-reaching consequences—like funding terrorist activities such as the 2004 al-Qaida bombings in Spain. There are clear links between IUU fishing and in addition to terrorism, other transnational criminal activity, specifically human, drug, and arms trafficking and smuggling.

The USCG supports enforcement of IUU fishing as part of its mission protecting our natural resources, endangered marine species, and marine sanctuaries—as well as in its mission to ensure our homeland security. The USCG detects and interdicts those fishing illegally in our waters (such as fishers from Mexico catching red snapper in the Gulf of Mexico), and enforces U.S. fishery and maritime laws. The Coast Guard estimates boats from Playa Bagdad (approximately five miles from our southern border) annually steal, at a minimum, $11 million worth of fish from U.S. waters. But their ability to stem the problem is limited - detecting them is hard, and catching them even harder, especially when ocean conditions are rough. What role can technology play, not only in spotting and catching illegal activity, but in anticipating it?

We should be gathering data from the sea every possible place – from the air, space, and water (boats, buoys, unmanned autonomous vehicles, gliders, and any other ocean sensor). Imagine what we could learn with an increase in ocean data. But don't stop there – now imagine if each ocean sensor, no matter its purpose, incorporated monitoring and surveillance technologies, allowing it to serve a secondary enforcement mission. This increased data collection would enhance MDA, informing scientists and law enforcement agents where the fish are so they can head off illegal fishing activity before it even begins – improving management, monitoring, and enforcement.

This will give them the needed head start to stop illicit activity before it even starts and will allow them to collect evidence necessary to prosecute the offenders. Blue tech – helping us understand the ocean, facilitating the USCG in its mission.

Arctic

For our second example, let's look north. We know the Arctic is dramatically changing, creating drastic increases in maritime access and activity. As it continues to do so, the U.S. (as an Arctic nation) has many economic opportunities but also faces significant challenges to the security, safety, and sustainability of this unique maritime domain, including our territory and our exclusive economic zone. Our capability and capacity to monitor and respond to threats and hazardous incidents in this dynamic and dangerous region is limited, difficult, and expensive, especially when considering ships and other manned craft and their associated support infrastructure. The implementation of unmanned and autonomous technology provides great promise for effectively monitoring and responding to threats and hazards while minimizing cost and risks to the safety of men and women at sea in the Arctic.

In summer 2017, the first ship to traverse the Arctic Northern Sea Route without assistance from ice-breaking vessels completed its journey. This transformational moment drives home both the opportunity and the imperative for the U.S. to ready itself for the new Arctic. The region is warming at twice the rate of the rest of the Earth with far-reaching consequences both for these polar residents and for those in the lower 48 states. On a global level, Arctic change will fundamentally alter climate, weather, and ecosystems in ways we do not yet understand, but we know there will be profound impacts on the world's economy and security. Rapid loss of sea ice and other changes will also bring new access to the area's natural resources, such as fossil fuels, minerals, and new fisheries, and this new access is already attracting international attention from industry and nations seeking new resources. Current Arctic observations are sparse and inadequate for enabling discovery or simulation of the processes underlying Arctic system change or to assess their environmental and economic impacts on the broader Earth system. One of the National Science Foundation (NSF)'s *Big Ideas* is the initiative *Navigating the New Arctic* (NAA), which would establish an observing network of mobile and fixed platforms and tools across this polar region to document these rapid biological, physical, chemical and social changes, leveraging participation by other federal agencies.

In 2013, the USCG released its Arctic Strategy to guide efforts in the area over the next decade. One of the strategy's key objectives is improving awareness, as "Coast Guard operations require precise and ongoing awareness of activities in the maritime domain. Maritime awareness in the Arctic is currently restricted due to limited surveillance, monitoring, and information system capabilities."

How do we improve those surveillance, monitoring, and information system capabilities? This is where autonomous vehicles come in. Whether we are discussing autonomous undersea vehicles (AUV) or autonomous surface vehicles (ASV), these robotic vehicles are programmable and can drive, drift, or glide (depending on their design) without humans crewing on board or even remote operators having to control them in real time. This technology can even go a step further when we incorporate artificial intelligence (AI). Imagine an AUV or ASV that can make decisions – changing its activities or course based on the environmental conditions it is encountering or data it has collected. It can make intelligent decisions, such as when, where, or how to sample and could even partake in cooperative activities and the transference of capabilities between vehicles.

Whether it's with AI or without, maritime autonomous vehicles let us explore regions of the Arctic that humans can't get to alone. For example, you may remember the AUV nicknamed "Boaty McBoatface." That AUV recently spent 51 hours under ice at the opposite pole, traveling 67 miles over the duration, reaching depths of more than half a mile below the sea surface. It even spent 20 hours beneath a section of ice shelf 550 meters (1804 feet) thick. AUVs and ASVs in their current state allow for new and increased data collection in regions previously inaccessible. Just imagine how much more they can do in the future as AI technologies are incorporated. Technology helps us learn about the Arctic, which in turn helps the USCG achieve its mission of safety, security, and stewardship in the region.

Natural Hazard Forecasting

For our last example, let's consider hazardous weather events such as hurricanes and other storms that increasingly threaten our homeland security, specifically the forecasting of their movement, intensity, and impact. Storm surge is often the greatest threat to life and property from coastal storms and hurricanes. Researchers are quantifying how future tropical storm surges may impact U.S. coastal properties, using past patterns of coastal sea-level change. From 1990 to 2008, population density increased by 32 percent in Gulf Coast coastal counties, 17 percent in Atlantic coastal counties, and 16 percent in Hawaii, according to the U.S. Census Bureau. In 2011, 45 percent of our nation's gross domestic product (GDP) was generated in the coastal shoreline counties along the ocean and Great Lakes. In 2016, the USCG saved 5,450 lives and responded to 16,298 events. Last year during Hurricane Harvey, they saved 4,322 lives in the Houston area alone. A storm surge of 23 feet has the ability to inundate 67 percent of interstate highways, 57 percent of arterial roads, almost half of all rail miles, 29 airports, and virtually all ports in the Gulf Coast area. U.S. ports are the heart of the nation's economy, delivering imports and transferring exports. When ports are closed due to storms and damage, the nation can lose $600 million to over $1 billion in a single day. Data and information on coastal property risk, emergency preparation, and storm forecasting are vital to owners, insurers, and the government.

How can blue tech matter in the face of natural disasters? The U.S. Navy is partnering with academia and the petroleum industry to launch ocean gliders in the Gulf of Mexico that autonomously and continually monitor seawater conditions (including heat content), aiding in improved hurricane *intensity* forecasting. These data and information enable more timely and informed preparation and emergency response by offshore industry as well as coastal communities and facilities. This type of blue tech partnership can be expanded to many other maritime safety and security applications through more robust implementation of NOPP by the federal ocean agencies.

Blue tech innovation and operation rely on an advanced workforce educated and trained in ocean STEM (O-STEM)

It is clear: without a substantial STEM education base, the USCG (not to mention the Navy, the rest of the government, industry, or anyone else) will be unable to depend on advancing technology developments to help meet their missions. Blue tech depends on O-STEM education; therefore, entities (this committee included) unused to supporting federal investments in STEM education must consider their futures as intrinsically linked to the success of STEM education programs. It's really rather simple: greater technology requires greater technicians, and that requires enhanced STEM education.

A secure, healthy, and prosperous maritime 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. In 2016 it was estimated that STEM-based jobs account for up to 26 million U.S. jobs. From 2012 to 2022, there is a projected 12.5 percent growth of STEM jobs in the U.S. and a 14 percent projected increase in U.S. geoscience jobs in that same period. Coupled with the greying of America's geoscience workforce (47 percent of American geoscientists in the private sector and 43 percent in the federal government were over the age of 55 in 2016), it is clear we will experience major changes with our innovation workforce. Not only does the nation depend on the available pool of scientists, but it also needs those who will train the following generation and those whose work supports novel and emerging science solutions. A dynamic workforce moves our nation forward. From business professionals who can commercialize scientific advances to technicians who maintain observing infrastructure and employees trained in scientific principles, our future depends upon how we will meet these demographic and educational challenges.

Other nations are advancing rapidly with the hopes to overtake the U.S. as a scientific and technological superpower. Countries such as China, Singapore, and the United Kingdom are already identifying gaps and are making substantial federal investments in basic research, tech development, education programs, and workforce training. In January, NSF reported that for the first time China produced more scientific publications than the U.S. A metric for discovery and advancement, this is a concerning data point showing the U.S. is falling behind. Another can be found in venture capital investment—confidence in China's science and technology innovation was evident with $10.7 billion invested in the second quarter of 2017. While the value is lower than investments

in U.S. tech ($18.7 billion during the same time), it shows a dramatic increase from 2013 when less than $5 billion was invested for the entire year.

Like all technology, blue tech involves an interconnected web of disciplines and expertise, including software and hardware development; industrial manufacturing; computer programing and data management; and equipment calibration, maintenance, operation, and repairs. While innovation and design is an important part of technology there is an even larger demand for producing, operating, maintaining, and repairing the technology after it has been developed and commercialized. Skilled and knowledgeable technicians could be the limiting factor for blue tech growth, and capitalizing on two-year degree programs for blue collar O-STEM can help. Of the 26 million U.S. STEM jobs in 2016, 20-50 percent were seeking applicants with a two-year STEM degree (blue collar). Growing recognition for this demand is critical for decreasing the skill gap and building the O-STEM workforce. It is paramount that investments are made to establish this workforce and critical that industry skill needs are at the forefront when developing educational, apprenticeship, training, internship, and partnership programs to ensure the technologically advanced workforce being produced can be successfully deployed into the waiting jobs. A dynamic workforce of the future with abundant technicians knowledgeable in ocean science and trained in blue tech platforms is essential for maintaining current and allowing for future blue tech growth.

Formal and informal education programs train the technologically advanced future workforce and create an ocean-literate society. Currently the U.S. has over 400 college programs educating the next generation of ocean STEM workers. While the vast majority of these programs are four-year degrees, there is a distinct opportunity to expand two-year programs for the training of blue tech technicians. However, formal education is the not the only factor. Getting students and the community involved and interested in blue tech and ocean science is critical. Since most high school curricula don't include oceanography, informal educational programs, like the National Ocean Sciences Bowl (a program managed by COL) are increasingly important as a way to introduce students to, and get them excited, about a career in ocean science. The NOSB promotes collaboration, teamwork, ingenuity, critical thinking, and professional development, which are valuable skills for the O-STEM workforce. With some suggesting teenagers choose a major before even graduating high school, it's critical to engage these students and open their eyes to opportunities in this arena before it's too late. Additionally, immersive training, such as the Sea Grant College Program and NSF's I-Corps program, provide experiences and interactions with the professional world that cannot be obtained in the classroom. These programs and many other private internships, apprenticeships, and mentoring bridge academia, industry, government, and NGOs.

Increased O-STEM education and training will help ensure future USCG sailors have the requisite skills to embrace new and emerging blue tech to advance mission capabilities on par with (or ahead of) competing entities and threats. The 2012 transition of NOAA Corps officer training to the USCG Academy is an excellent example of how cross-agency and cross-community O-STEM education and training can be implemented to mutual benefit related to maritime safety, security, and economic growth. The Navy has extensive O-STEM education and training programs for officers, enlisted sailors, and government civilians that might also benefit the multi-service and multi-agency federal maritime work force.

Meeting the challenge of developing this foundation requires a substantial and focused effort on the education and training of the next generation of scientists to ensure we have the intellectual resources to take full advantage of new knowledge that will come from this investment in ocean sciences and technology, but it also needs those who will train the following generation and those whose work supports novel and emerging technology solutions. A dynamic workforce moves our nation forward. From business professionals who can commercialize scientific advances to technicians who maintain observing infrastructure and employees trained in scientific principles, our future depends upon how we will meet these demographic and educational challenges.

Conclusion

To successfully navigate a changing physical, chemical, and biological ocean while maintaining secure geopolitical boundaries and ensuring the safety and prosperity of those within them, the USCG and MARAD must regain their competitive advantage in knowing the ocean and coastal baseline conditions, changing conditions, forecasted conditions, vulnerabilities of maritime and coastal infrastructure, and the threatened

human population. The changing climate and ocean systems are altering when and where our maritime forces (uniformed and civilian) may be called to duty but also *how* they can respond. Rising sea levels increase coastal and near shore hazards; extreme weather could impact deployment, intelligence, surveillance, and safety capabilities; and the opening of previously inaccessible lands and waters will require additional response and rescue capacity. It is through the robust federal support of blue tech, STEM education, and collaborative partnerships across the federal family and with ocean science and technology institutions that the USCG and MARAD ensure that this will happen – ultimately enabling them to successfully fulfill their missions more effectively and efficiently.

Chairman Hunter, Ranking Member Garamendi, and members of the subcommittee, the ocean science and technology community appreciates the interest the subcommittee has in blue tech and I want to reiterate my themes:

1. Ocean knowledge enables the USCG and MARAD in achieving their missions by enhancing maritime domain awareness (MDA).
2. Blue tech is vital to understanding the ocean.
3. Blue tech innovation and operation rely upon an advanced workforce educated and trained in ocean science, technology, engineering, and math (O-STEM).

We urge the subcommittee to translate their interest in blue tech as a tool for USCG and MARAD to improve mission performance into prioritizing federal ocean science, technology, and education investment and programs. Working across committees and jurisdictions to do this is the way we ensure the U.S. maintains its superiority, security, success, and safety at sea. The ocean science, technology, and education community is well positioned to assist the subcommittee in addressing the role blue tech, ocean knowledge, and O-STEM can be more fully actualized for our nation's current and future maritime needs. We greatly appreciate your consideration and look forward to working with you to support the ocean science and technology innovation and education that enables our maritime superiority, coastal safety, economic prosperity, and ocean security.