WRITTEN TESTIMONY OF

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SUBCOMMITTEE ON COAST GUARD AND MARITIME TRANSPORTATION

BLUE TECHNOLOGIES: USE OF NEW MARITIME TECHNOLOGIES TO IMPROVE EFFICIENCY AND MISSION PERFORMANCE

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Introduction

Chairman Hunter, Ranking Member Garamendi, and members of the Subcommittee, thank you for the opportunity to be here today to discuss new maritime technologies. My name is Eric Terrill and I am the Director of the Coastal Observing Research and Development Center (CORDC) at University of California San Diego's Scripps Institution of Oceanography (Scripps), where I also received a Ph.D. in Physical Oceanography-Applied Ocean Sciences. I have 25 years' experience as an oceanographer leading basic and applied research programs around the globe. We partner with a number of federal and state agencies in our efforts to support national science and technical needs to sense and improve our understanding of the maritime environment.

A better part of my career has been dedicated to the field of ocean observing, environmental sensing, marine technology, and maritime domain awareness. I established CORDC as a research and development center within Scripps Marine Physical Laboratory, one of four original Navy-University applied Research Laboratories established in World War II in response to the need for academic innovation to support national security. Engineers, data analysts, and ocean scientists serve as an interface between Navy Research Development Test and Evaluation (RDT&E), Department of Defense operational commands, mission-driven commands, and agencies such as the U.S. Army Corp of Engineers and the National Oceanic and Atmospheric Agency (NOAA). I also have extensive experience working with industry to develop, improve, and evaluate new ocean technologies and unmanned platforms; the key subject matter of this testimony. I have served on transition and government review teams and Federal Advisory committees including a FACA oversight committee for the Integrated Ocean Observing System (IOOS). I presently serve on a Maritime Domain Awareness (MDA) working group sponsored by U.S. Pacific Command (PACOM) to develop MDA solutions for small island nations in the western Pacific including the Republic of Palau and the Federated States of Micronesia. Lastly, I co-founded Project Recover, a private-public collaborative, which conducts global searches using Unmanned Underwater Vehicles (UUVs) and DoD methodologies to locate WWII-era aircraft crash sites - to date locations of 22 aircraft associated with 60+ MIA have been documented and reported to the Defense POW/MIA Accounting Agency.

I had the opportunity to review the Government Accountability Office report 18-13 on Coast Guard: Actions Needed to Enhance Performance Information Transparency and Monitoring, as well as the Coast Guard Reauthorization Act of 2017 legislation and will address some of these recommendations in my testimony.

Because many Scripps scientists and students are involved in maritime technologies, I sought input for my testimony from experts at Scripps. Aspects of my testimony on the specifics of technologies and data management are drawn from these colleagues. Some of these programs and labs may be familiar from my past testimony to this Subcommittee in 2013 on Maritime Domain Awareness. I will again provide background information for these programs, but the technologies discussed are either new and emerging or have a different application for USCG missions to aid in efficiencies. My testimony is organized as follows: 1. Samples of historic and ongoing ocean observation programs are provided as examples of the research community's role in blue technologies. 2. Unique partnerships to expand and leverage resource capabilities; and 3. Closing recommendations for action.

1. Scripps Research History Leads to Critical Ocean Technology Development

Scripps research areas of expertise relevant to the USCG mission include the mapping of ocean currents, mixing of ocean waters, Arctic prediction, sensor development, unmanned platforms, numerical ocean forecasting, maritime domain awareness including surveillance, and ocean waves. Scripps has technical expertise across all facets of marine technology, with some examples including sensor networks, data management and exploitation, unmanned underwater and surface vehicles, aerial drones, and airborne and satellite remote sensing. Founded in 1903, Scripps Institution of Oceanography became a part of the University of California in 1912. Scripps has a long history of supporting national defense objectives and has provided recommendations and technologies to "improve the efficiency, safety and security of maritime transportation" with a focus on the "better use and integration of maritime domain awareness data."

During World War II, Scripps oceanographers worked closely with the Navy to create surf and swell forecasts for successful Allied landings in North Africa, the Pacific, and the beaches of Normandy. Just as important, Scripps educated active duty weather officers so they could apply this new forecasting science on a daily basis to plan operations.

In 1975, Scripps researchers launched the Coastal Data Information Program (CDIP), a program that measures, models, forecasts and publicly disseminates real-time coastal wave information, and that now includes a network of over 70 wave buoys in 22 states and island territories. The conditions at the ocean surface impact all at-sea operations, and the data are critical for the operational maritime community to ensure safe and efficient navigation for military, commercial, and recreational maritime traffic, search and rescue efforts, and are relied upon by dredging project managers for safe operations.

In 1998, Scripps led the development of the revolutionary array of ocean monitoring sensors known as the Argo network. Launched in 2000, the Argo program now deploys a global array of more than 3,800 free drifting profiling floats to gather subsurface ocean data. Combined with satellite observations, these data make it possible to operate global and regional ocean analysis models similar to those for weather forecasting in the atmosphere. They provide enormous amounts of new information on the ocean's changing state at weekly to seasonal to year-to-year timescales. These observations are critical for accurate model analyses that forecast the state of the interior of the ocean, and its fluctuation with a changing climate.

An existing framework that connects local stakeholders to readily accessible ocean information is accomplished through a network of regionally operated ocean observing systems that feeds data to a federal backbone. This system is the Integrated Ocean Observing System (IOOS), initiated 18 years ago at an interagency planning office (Ocean.US) that has evolved to being managed from a formal program office within NOAA. IOOS consists of eleven Regional Associations who operate local ocean measurement platforms, generate tailored products, and connect data to a federal data backbone that is supported by a set of standards. IOOS has shared many successes including providing on-scene environmental information to many of the extreme events that the country has been faced with (tracking pollution at the Tijuana Estuary, 2017 Hurricanes Harvey, Irma, and Maria, countless Northeasters, the Refugio oil spill in Santa Barbara, and Deep Water Horizon Oil Spill in Gulf of Mexico to name a few). As a decision support system, IOOS observations provides many of the 'behind-the-scenes' environment data that is leveraged for day to day decision making.

2. Leveraging Existing Resources Key for Successful Implementation of Unmanned Systems

In 2002, a Joint Harbor Operations Center (JHOC) was developed after the events of September 11, 2001. This center became a model for others to follow nationally and across the globe. In this center, Harbor Police Dispatchers work side-by-side with the United States Coast Guard, United States Navy, California National Guard, and Customs and Border Protection personnel. This system helps to facilitate information sharing, plus provides a fast and timely response to potential incidents to the Department's area of operations.

The San Diego JHOC is an incredible example of the Coast Guard and other enforcement agencies leveraging access to resources and data that could serve as a model for other Coast Guard and Maritime Transportation authorities. This type of interagency partnering is required if there is an expectation to field modern blue technologies to operational agencies for a common maritime maritime domain picture in support of Homeland Security. JHOC demonstrates the value of establishing centers for communities with maritime jurisdiction to streamline collaborations and make processes more efficient, especially as the Coast Guard and Subcommittee consider expansion of implementing new technologies including unmanned platforms into operations.

Unmanned Underwater Vehicles (UUVs) or Autonomous Underwater Vehicles (AUVs) continue to develop as the frontier technology for subsurface exploration and sensing advances. These platforms have matured from developmental prototypes to operational tools as evidenced by Navy initiatives to integrate the platforms into fleet operations. Examples of the technologies include buoyancy driven gliders, such as the SPRAY system developed by Scripps for wide area environmental surveillance and propeller powered vehicles such as the REMUS (Remote Environmental Monitoring UnitS), originally designed by Woods Hole Oceanographic Institution

(WHOI) and now available commercially from Hydroid Inc. These platforms can carry specialized payloads to sense the ocean and are tailored for persistent observation of the ocean (gliders), or highly detailed surveys (propeller driven vehicles). Both vehicles can employ different payload packages, and a have been demonstrated to competently sense ocean currents, light transmission, temperatures, seabed topography, and seafloor imaging. These same sensors can assist the USCG in detecting and tracking oil spills of unknown origin, finding sunken wrecks, mapping bathymetry and hazards, and detecting illegal fishing activities. Sensors now exist to allow for direct measurement of suspended oil and petroleum byproducts.

Unlike ship-mounted sensors, propeller driven underwater vehicles have a distinct advantage to navigate a grid or terrains with consistent and thorough geo-positioned tracks. Scripps currently has been operating for over a dozen years and performs a variety of ocean sensing missions including mapping wastewater, river discharges, and mapping hazards, benthic habitats, and areas of archeological significance including sunken ships and missing aircraft that support the national mission of finding and returning MIA from past wars.

Figure 1. Left Panel: REMUS 100 passing over a sunken WWII aircraft; Center Panel: En route to a small boat deployment for two REMUS 100s and Right Panel: En route to a shore deployment of a REMUS 100.

Unmanned Surface Vessel (USVs): Scripps has several years' experience operating self-powered unmanned surface vessels called a Wave Glider; commercially available from the Boeing owned Liquid Robotics Company. A unique attribute of this system is the propulsion of the platform through harnessing the omnipresent ocean surface waves; allowing 100% of the power generated by the onboard solar panels for all electrical requirements. The system can carry onboard payloads as well as act as a gateway between underwater sensors and aerial assets including manned and unmanned aircraft. It can be used for a variety of applications that span basic scientific observation of the ocean to serving as a tactical communications platform filling capability gaps already identified by military users. Additional assessment capabilities for general Maritime Domain Awareness data needs, including payloads that allow for detection of small surface craft needs to be matured. The large footprint of the USV holds promise for supporting the launch and recovery of small aerial systems and deployment of ocean sensors. In my review of unmanned surface platforms, this one is the most mature and experienced at operating in a range of ocean environments. Capabilities in support of USCG include ship traffic monitoring, fisheries protection, ocean sea state characterization, and monitoring of currents in support of oil spill trajectory analysis, communication gateways between surface craft, and ship routing.

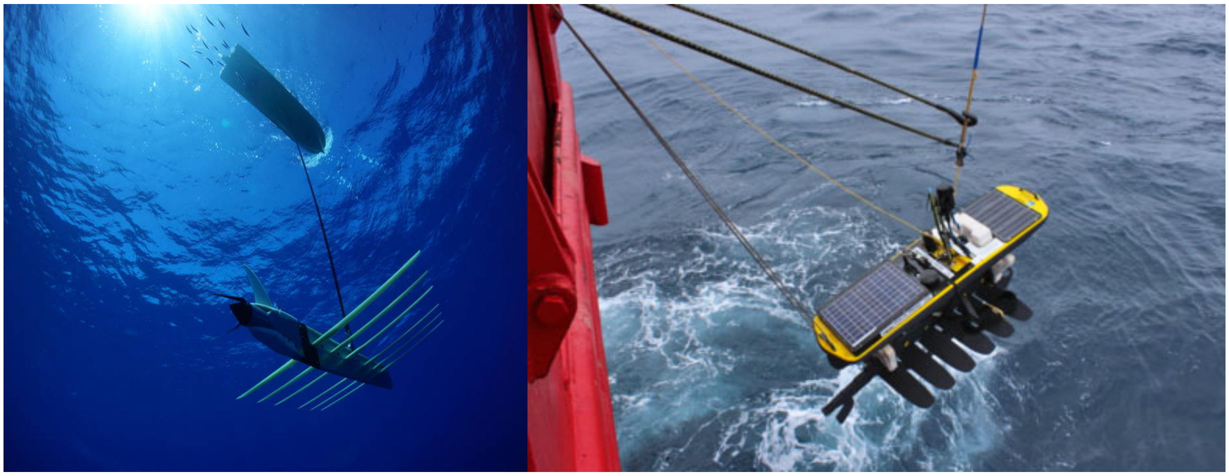

Figure 2. Left. The submerged portion of the wave glider. Right. A wave glider recovery from a surface craft.

Unmanned Aerial Systems (UAS): Scripps has a long experience in developing, testing, or adapting technologies from other communities, and transitioning them into the maritime environment. Unmanned Aerial System (UAS) are no different, and Scripps scientists have led efforts to harden and adopt fixed wing and multi-rotor aircraft for use from research vessels. This same capability could be transitioned to USCG vessels. An emerging technology of interest are hybrid UAS that allow for vertical take off and landing (VTOL), but transit with a fixed wing; similar to an Osprey airplane.

Unmanned systems and data feeds can be of increasing use and benefit for Coast Guard to achieve its mission goals for surveillance, identifying aquatic invasive species in ballast water, identification of oil leaks and spills, tracking direction for oil spills, and other security operations in support of Illegal, Unreported, and Unregulated (IUU) fishing. As the Coast Guard and Congress work together on identifying resources to allow greater access to unmanned system technologies to help the Coast Guard meet its mission goals, mulit-agency partnership are recommended to allow for rapid communication of lessons learned and experience.

Tools needed for interfacing to data:

The Government Accountability Office report on the USCG implementation of the Common Operational Picture (COP) identified a number of concerns regarding data sharing and displays. The use of mapping overlays for data visualization can be extremely useful for displaying observations that assist in USCG missions such as search and rescue operations, marine safety and security, marine environmental protections, and ice operations. There is a wealth of direct observations and derived products that can be integrated into these systems including, but not limited to:

1.) Automatic Identification System (AIS)
2.) Bathymetry
3.) Navigational Charts
4.) Waves

5.) Surface and subsurface currents
6.) Satellite imagery
7.) Ice distribution

Many of these observations are available in a common data format that can be self-describing, machine-independent and delivered through a web service. Examples of these observations are found within the Integrated Ocean Observing System (IOOS) which, for many gridded products, utilize a Network Common Data Format (NetCDF) for file structure and are distributed via a Thematic Real-time Environmental Distributed Data Service (THREDDS). The Open Geospatial Consortium (OGC) provides recommendations and examples of data formats and services for data sharing and delivery. These technologies are developed and have proven examples for in-situ time series data (e.g. AIS, temperature, wind speed, salinity); gridded data and model output (e.g. HF radar derived service currents, waves, ice coverage); and imagery feeds (e.g. remotely sensed ocean color, pictures, charts). The data can also be displayed via open source – online platforms such as OpenLayers and Google Earth for unclassified interfaces or desktop applications such as TOPSIDE emerging from the Naval Undersea Warfare Center (NUWC) as a result of ONR-sponsored MDA and surveillance programs.

3. The Role for Technology Demonstrations, Technology Transitions, and Modular, Problem Driven Applications

A significant investment of time, funds, and process documentation is required for a full-scale analysis of developing technologies for USCG applications and implementation. Process studies through demonstration projects at established testbeds are one means to efficiently determine applicability and feasibility of new technologies. Scripps recommends developing partnerships with agencies within the Department of Defense that are already making investments in developing maritime surveillance systems. The Office of Naval Research (ONR) routinely conducts small-scale demonstrations to develop and test new concepts of operations and technologies, and leverages the expertise of their program managers in operating efficient Research, Development, Test, and Evaluation (RDT&E) initiatives. These science and technology investments have the ability to provide a low cost, flexible, and timely analysis of capabilities that can transition to operational users. Science and technology in a spiral development allows the capability to incrementally evolve and improve with lower risk. Successful demonstrations can be transitioned to support operations, while unsuccessful demonstrations provide valuable lessons learned and save significantly on a USCG-wide full-scale information technology guidance procedure.

For the last decade, ONR has made investments at Scripps and elsewhere, to develop, test, and evaluate new sensors and operation procedures for improving tactical ocean and atmospheric environmental information collection. One example of ocean technology development driven by emerging mission requirements is ONR’s investment in autonomous vehicles. The employment of unmanned air, surface and subsurface platforms has transformed environmental sensing in the maritime environment. Unmanned platforms, outfitted with appropriate payloads, have conducted unprecedented open water autonomous missions and data collection in support of improving ocean forecasts. Through a robust communications architecture and data fusion software, in-situ collections are now available at time and space scales applicable to the investigation. The investment in maritime technologies and platforms has resulted in the development of tactics, techniques and procedures that are applicable to today's discussion of Blue Technologies and the use of new maritime technologies to improve USCG efficiency and mission performance.

Demonstrations and Partnerships:

Scripps research helps identify threats, challenges, and risks in marine environmental management and conservation and surveillance and enforcement. Specifically, the technologies being developed and evaluated address the following issues:

- Ecosystem Based Management of the Large Marine Ecosystem
- Performance assessment and enforcement of local Marine Protected Areas
- IUU Fishing – industrialized
- Transshipment – Contraband
- Fishing Aggregation Devices (FADs)
- Poaching
- Human smuggling

The use of emerging technologies such as unmanned platforms and fusion of data from commercially available satellite data with in-situ sensors and numerical weather forecasts can assist in efficiently overcoming the tyranny of distance that is common with surveilling large maritime EEZ. The U.S. Exclusive Economic Zones (EEZ) is the largest in the world, spanning over 13,000 miles of coastline and containing 3.4 million square nautical miles of ocean - larger than the combined land area of all fifty states. Contained within our EEZ are Marine Protected Areas, where natural and/or cultural resources are given greater protection than the surrounding waters.

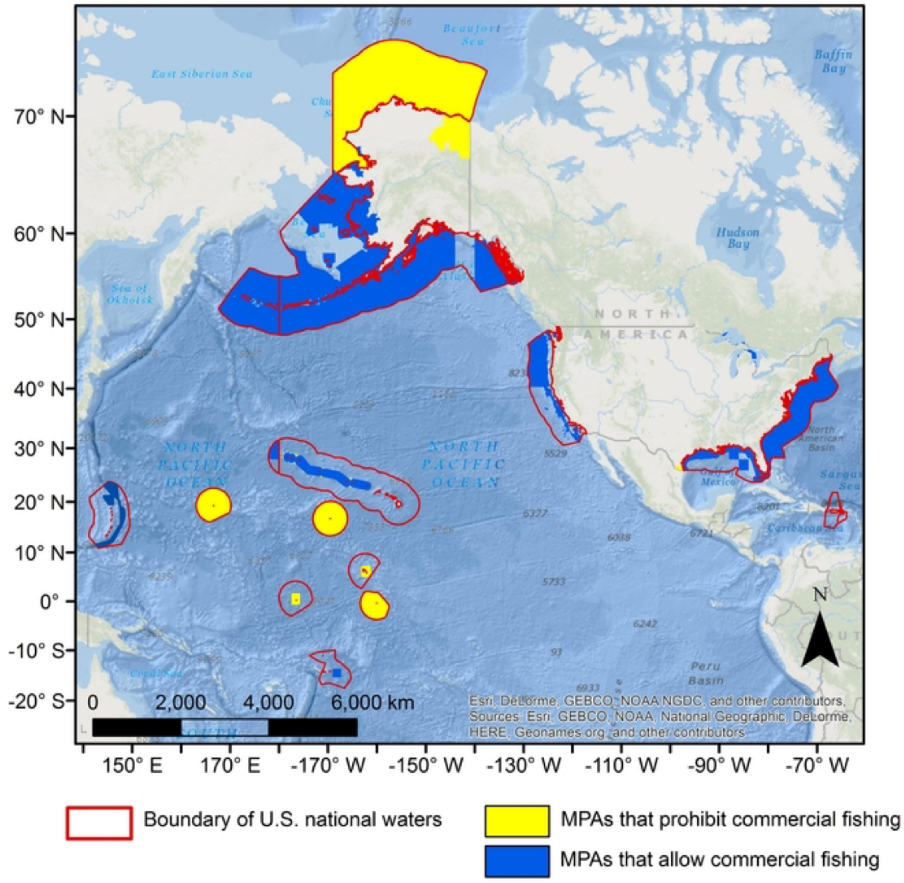

Figure 2. The U.S. Exclusive Economic Zone spans over 13,000 miles of coastline and covering 3.4 million square nautical miles of ocean. Contained within our EEZ are Marine Protected Areas.

The physical expanse of our EEZ and MPA creates a challenge for monitoring. Today, few data are collected and synthesized in a manner that allows for deterrence, detection, interdiction, and prosecution of illegal activities, including illegal, unreported, and unregulated (IUU) fishing; transshipment of contraband; and human trafficking or ecosystem-based management decisions. Data collected through deployment of new maritime sensing technologies will increase monitoring and surveillance of the EEZ and also allow our government to assess environmental issues such as sea level rise, coastal erosion and other maritime related issues in order to take appropriate actions.

Along the California coast, the network of HF radar stations measures surface currents over a range of up to 200 km. I have previously discussed this program and its benefits for maritime domain awareness. Although the network was originally funded to track oil spills, and brings tremendous value for surveillance, it is also essential for search and rescue missions, marine navigation, and fisheries and water quality management that fall under the USCG's jurisdiction. The data is fed to operational watch standers within the National Weather Service, and at Coastguard Search and Rescue support centers. HF radar technology is also being developed for over-the-horizon ship tracking applications and is an emerging technology for maritime domain awareness. However, this opportunity will remain elusive under the current funding model for this national asset as the network is funded only at 50% operational capability of the $10M/year build out plan as identified in the U.S. IOOS National Surface Current Mapping Plan.

Dynamic Under Keel Clearance at Nation's Ports and Waterways

Sponsored by Andeavor, the nation's biggest oil refiner, the Under Keel Clearance Precision Navigation project at the Port of Long Beach highlights the importance of technology for public-private partnerships. Combined, the Ports of Los Angeles and Long Beach are the busiest port in the United States, and host a significant portion of California's economy. As vessels become more economically efficient, vessel length and draft have been increasing in size. During long-period wave activity, in which swells last over 12 seconds, conditions can cause a dangerous loss of draft (9.6 ft of draft for every degree of pitch) reducing the under-keel clearance to below safe levels. The objective of the Under Keel Clearance project is to minimize the offshore lightering, so that the deeper crude oil tankers can transit into the port. In partnership with NOAA which provides water depth, tides and wave forecast models, CDIP is providing high resolution wave observations and short term forecasts. To date, 32 additional deep draft tankers have been able to transit safely into the port. Every foot of additional draft equates to 40,000 barrels of crude oil valued at an approximately additional $2M in trade value. These efforts are critical for the economic, environmental and safety of marine operations.

Arctic Challenge: Monitoring and Promoting Safe Passage

The Arctic presents another set of challenges for ocean technology development. Arctic ice has begun to retreat, and is forecasted to continue doing so for the coming decades. This implies that what was learned about Arctic acoustics during the Cold War is now obsolete. One program tackling the change in the Arctic acoustic environments is the Canada Basin Acoustic Propagation Experiment (CANAPE). The overall objective of CANAPE is to determine the fundamental limits to the use of acoustic methods and signal processing imposed by ice and ocean processes in the new Arctic. Characterizing the changing operational environment in terms of ice coverage and sea state will be required before new infrastructure, including floating offshore platforms, can be designed to operate in this extreme environment. Partnerships developed with other federal ocean-minded agencies including the Navy, NOAA, National Science Foundation, and DARPA should be considered to leverage the respective investments of those agencies in improving U.S. sensing and forecasting capability for the Arctic.

Additionally, maritime commerce, including the world's navies, is expected to begin taking advantage of new Arctic shipping lanes during summer months. Commercial activity on the sea floor is also expected to grow. In response to changes in atmospheric and oceanographic conditions, large areas of the Arctic Ocean previously covered by pack ice and "insulated" from the wind and surface waves are now exposed. This change has lead to Arctic pack ice cover evolving into the Marginal Ice Zone. The emerging state of the Arctic Ocean features more fragmented thinner sea ice, stronger winds, ocean currents and waves. Modeling difficulties are compounded due to unique "local effects" including downslope winds, channeling and barrier jet, and shallow water storm surge. Lastly, the scarcity of in-situ data in the region limits situational awareness for maritime operations and numerical modeling.

CDIP will be deploying a new wave buoy offshore from the port of Nome in July 2018. Nome is the northernmost deep water port in Alaska that is called on by tankers, tugs and barges, passenger ships, government vessels, fishing and research vessels. Northern communities are heavily dependent on the safe operation of this port that is affected by weather and currents. In addition, a pilot program will assess the feasibility of expendable wave buoy technology in the harsh extremes of the Arctic. These small wave buoys are easily deployed by hand and require no special training to deploy. The ease of deployment and relatively low cost afford the opportunity to seed areas with in-situ sensors to help close the data shortfall and advance Arctic Ocean wave modeling.

These technologies allow stakeholders and government entities a better understanding of ice cover in the Arctic as traffic in the area increases. This could help inform many of the Coast Guard's statutory missions including navigation, Cutter operations, defense readiness, and enforcement.

Conclusion

In closing, I would like to thank the Committee for the opportunity to testify on the role of ocean technologies and provide suggestions for the U.S. to leverage ongoing investments and use new maritime technologies to improve efficiency and mission performance. Scripps' scientists are leaders in research and operational use of maritime technologies and have a long history with national defense-related science, as and organization, we are privileged to be in a position to provide national service to this increasingly important topic. I believe that development of partnerships between USGS and other agencies (e.g. ONR, NAVY, NAVAIR, DARPA) for purposes of pursuing defense-related observational strategies and unmanned vehicle operations is very important.

Scripps recommends developing these partnerships with agencies that specialize in conducting maritime RDT&E (e.g. ONR) to provide low cost demonstrations of emerging technologies that can then be applied to full-scale operations, providing valuable feedback and business case requirements such as risk, cost, and manning requirements. Designing problem driven, modular applications for USCG missions will improve data reliability and performance as well as reduce complexity for watch standers. The use of data products from existing networks such as high frequency radar, wave buoys, and research vessels will significantly improve all aspects of USCG missions.

Additionally, leveraging joint operations such as Joint Harbor Operations Centers (JHOC) or the Joint Interagency Task Force (JIATF) will combine staffing, technologies, data services, and resources from multiple sources for improved response capabilities.