

# Proceedings of the NOAA UMS Symposium

October 30 - November 1, 2018

Stennis Space Center, MS



National Oceanic and Atmospheric Administration

## Executive Summary

From October 30 – November 1, 2018 the NOAA UxS Executive Oversight Board (EOB) sponsored a NOAA Unmanned Marine Systems (UMS) Symposium, hosted by the National Data Buoy Center (NDBC) in Stennis, MS. Eighty-four attendees from NOAA labs, programs, and staff offices gathered to share information on UMS activities, and met the symposium’s objectives for increasing our collective knowledge of how UMS are currently addressing NOAA mission requirements, rapidly evolving in-terms of platform design and the sensor packages, and identifying the challenges and opportunities for transitioning the most promising UMS to operations.

Over two days attendees participated in 33 presentations and discussions focused on NOAA’s UMS related programs and facilities, field operations, platform and sensor development efforts, data and information management, and the legal and regulatory environment. On the third day attendees engaged in breakout sessions focused on UMS-related emerging requirements, technologies, and best practices. Several major themes emerged during the symposium including:

- UMS use in NOAA is rapidly increasing.
- UMS NOAA uses are operational, meeting all requirements for safe navigation, and transitioning UMS from research, i.e., evaluating their effectiveness for meeting NOAA mission requirements, to operations can evolve very rapidly.
- UMS Operational models vary across NOAA and include: purchasing, leasing, data buys, and integrated partnerships with other federal agencies, academia, and industry.
- Two programs in NOAA use UMS in a formal, strategic manner: the IOOS Glider program; and the OCS hydrographic survey program.
- The use of Unmanned Surface vehicles (USV) for oceanographic and atmospheric observations, and for fishery surveys has been pioneered by PMEL, is increasing rapidly, and an opportunity is growing to transition these to systematic operations.
- NOAA owns several facilities, and partners with other institutions that provide for UMS research and development, as well as operations.

These complement and validate the results of an extensive online survey prior to the symposium that focused on the current state of UMS-related research and operations, and what respondents envisioned for the future.

This report summarizes the proceedings, and concludes with a series of recommendations for the UxS EOB to consider. As the coordinating body in NOAA the EOB can reference these as NOAA develops a plan for implementing NOAA requirements under the recently enacted “Commercial Engagement through Ocean Technology Act of 2018” (CENOTE) Bill.

## Recommendations

1. Establish a strategic plan that provides a clear path and vision going forward. Establish a cross-line office concept of operations. As required under CENOTE expand and develop partnerships with internal partners and external partners in academia, industry and government that will be beneficial for NOAA. Build upon and support current success such as IOOS glider work, OCS hydrographic mapping and PMEL's work with Saildrone.
2. Improve communications between the NOAA Councils on UMS and other unmanned systems.
3. Develop a process to efficiently transition from research and development to operations. Requirements should drive solutions. Analysis of alternatives and engineering test programs will be a part of this process. Better coordination across line offices will be required at all levels as well as formal coordination. Data users/modelers must be connected with the data collectors. Data should support the models and the models should support the decision making.
4. As UMS data collection expands, the infrastructure to archive, access, and analyze must keep pace. Requirements must be developed for data handling, data storage, and metadata, as well as data analysis. Determination of real-time data requirements as well as post-collection data use is part of this.
5. Use UMS to augment other platforms to fulfill data requirements. NOAA should be platform agnostic and use the most efficient data collection platform for the task. TPIO is a NOAA resource that can be leveraged for observation requirements.
6. Based upon the pre-symposium survey, NOAA should develop a concept of operations that is adaptable - where a centralized approach or a local approach can be utilized based on what is most appropriate. An agile acquisition strategy that has been thought through long-term will be needed for success. Consider the UAS and Small Boat programs as models, and develop a handbook documenting best practices.
7. Use the EOB to establish a community of practice that meets regularly to promote collaboration and develop mutually beneficial relationships within NOAA and with outside partners in academia, industry and government.
8. The agency would benefit from development of personnel trained in UMS applications. NOAA currently has in-house expertise in pockets in the agency and needs to build upon these successes to establish a large-scale UMS program. Best practices should be developed for operations, platform identification, data management plans, sensor integrations, engineering design, training (to include basic operator training as well as an apprenticeship program), safety, environmental compliance and cybersecurity.
9. The NOAA Research and Development Database should be better utilized to capture new UMS research projects.

## **Introduction**

Unmanned Marine Systems (UMS) are becoming increasingly important for collecting data to support NOAA's diverse mission requirements including fishery surveys, hydrographic surveys, making oceanographic and atmospheric observations, and collecting information critical for marine ecosystem characterization and assessment. UMS have become an important tool augmenting traditional methods using ships and aircraft, and are proving particularly adept at missions to remote locations, hostile environments, and of long duration. As a force multiplier they are increasing our presence in and on the ocean, and their use will continue to grow.

As the coordinating body for all NOAA UxS activities, the NOAA UxS Executive Advisory Board (EOB) assigned a group of subject matter experts to design a symposium focused on NOAA UMS-related activities as a first step in developing NOAA-wide policies, procedures, and strategies to improve mission effectiveness and efficiency, reduce redundancies, and to transition the most promising UMS technologies to standardized operations. The symposium was also conceived of as a prerequisite to future symposia engaging external partners.

## **Summary of Presentations**

Over the course of October 30-31, 2018, 29 scientists, technicians, attorneys and others from across NOAA came together and presented talks and led discussions on their UMS activities. Presentations were organized under the following themes: the legal and regulatory environment; data and information management; UMS related programs and facilities; field operations and platform development; and science and sensors, and are available on the UMS website. The following summary provides highlights from each section, including the keynote addresses.

## **Keynote Addresses**

The Symposium opened with three keynote addresses. The Co-Chairs of the UxS EOB, Dr. Gary Matlock and RDML Nancy Hann provided a NOAA corporate perspective on UMS and discussed how the symposium represented a critical first step for increasing and sustaining NOAA's use of UMS to meet current and future mission requirements. Dr. Bill Burnett, Principal Deputy and Technical Director for NAVOCEANO, offered guidance based on his experiences at the University of Oklahoma, NOAA-NDBC and NAVOCEANO.

RDML Hann focused on the intersections of Research to Operations (R2O), legislative interest in UMS at NOAA (CENOTE 2018), and resource challenges. She noted the need for and value of coordinating UMS activities across NOAA, establishing a dedicated UMS operations capability (similar to the unmanned aerial systems (UAS) effort), and that facilitating partnerships was a "must" in the near term. She discussed how the UxS EOB intends to support this by playing a more active coordinating role in identifying missions based on requirements; supporting research and development for improving platforms and payloads; overseeing testing and evaluation of new systems; increasing NOAA-wide support of proper data handling; and transitioning proven systems to operations.

Dr. Matlock focused his comments on the unique role UMS can play in providing additional and higher resolution data and information to meet our current and future mission requirements.

However, to fully realize the potential of UMS it is essential to coordinate across Line Offices and with external partners to conduct the research and evaluations necessary to fully transition proven UMS platforms and associated sensor packages to operations. He discussed how the UxS EOB and the policies NOAA has in place provide a foundation for how this can be achieved, and how this will be critical to ensure the resources – dedicated funding and skilled personnel – are secured and sustained.

Dr. Burnett’s keynote focused on challenging NOAA to take the lead on UMS development and deployment, emphasizing external partnerships with other federal agencies, academia, and industry will be critical to success. He recommended NOAA develop a common “vision” for UMS, recognizing the difficulty given NOAA’s diverse mission. He encouraged NOAA to better define mission requirements and to determine how they may complement one another in terms of data and information needs, and the role that UMS can play. He advised NOAA not to lose sight of the connection between UMS related research and development, operations, data and information management and dissemination, and to take advantage of the support from current leadership within NOAA and on Capitol Hill. He closed by encouraging NOAA to “think like the Navy” and approach UMS from a Program of Record standpoint.

## **The Legal and Regulatory Environment**

The NOAA Office of General Counsel led a session on the legal and regulatory framework that govern UMS operations; describing existing and forthcoming legal and regulatory challenges (including CENOTE), and providing insight on opportunities to help NOAA work with other federal agencies and provide leadership on the legal and regulatory framework as it evolves.

They discussed how NOAA must operate under current interpretations of the 1982 United Nations Law of the Sea Convention (UNCLOS); the International Convention Preventing Collisions at Sea (COLREGS); and Admiralty & General Maritime law. The greatest challenge UMS currently face is a determination as to whether they are “vessels” under COLREGS or UNLOSC 258-262 regarding research installations and equipment. If UMS are determined to meet the definition of “vessels” under COLREGS, they will be required to maintain lighting, vessel labeling/signage and active look out for avoidance. Their talk also covered several environmental laws that UMS users must be aware of, such as NEPA, ESA, and MMPA, when planning and executing missions using UMS.

## **Data and Information Management**

The Data and Information Management session included talks covering NOAA’s responsibilities and requirements for data stewardship, examples of how more mature/formal UMS programs are handling data and information, and how data analytics can help NOAA make decisions regarding UMS platforms, as well as creating integrated observing systems that utilize UMS data to better meet existing requirements and projected future requirements.

The National Centers for Environmental Information (NCEI) are responsible for preserving, hosting and providing access to the nation’s atmospheric, oceanic, and geophysical data. Senior representatives from NCEI discussed the challenges associated with managing the increased volume of data that is currently and projected to be generated by UMS, and described their planned tiered approach to data stewardship. They provided examples of UMS-related cross

NOAA data management efforts they are engaged in including: the Integrated Ocean Observing System (IOOS) Glider Data Assembly Center; the OMAO hydrographic data-to-product pipeline; and the Office of Exploration and Research Digital Atlas and other data portals. NCEI is also involved in several new initiatives for UMS and ocean data including the World Ocean Database, SEABED 2030, and the NOAA Big Data initiative. They discussed how the lessons learned through these and other similar efforts can help NOAA meet our data stewardship requirements.

NCEI also discussed and demonstrated how the volume of user requests for access to data is increasing in addition to the volume of data itself. They provided the participants critical information on the basic services they can provide using base funds to meet NOAA's mandated data stewardship responsibilities, and stressed the need for engagement in data requirements planning in advance of major data acquisition efforts regardless of the platforms, and clearly documenting the terms of data archive and access in "Submission Agreements," including any requirements for program funds if the requirements exceed basic services.

Participants were provided a detailed overview of how the IOOS community uses buoyancy gliders to increase subsurface operations to improve oceanographic models that serve forecasting needs. Emphasis was given to the Underwater Glider Data Assembly Center that enables data to be processed, analyzed, visualized, archived, and distributed via the Global Telecommunications System (GTS) – a partnership effort that includes multiple NOAA programs, IOOS regional partners, and academia.

The Pacific Marine Environmental Lab (PMEL) presented on a unique data management effort developed in partnership with Saildrone, a company that designs and manufactures a wind and solar powered unmanned surface vehicle (USV). Collaborating under a Cooperative Research and Development Agreement (CRADA), Saildrone transmits formatted and packaged data from the sensor suites on their vehicles to PMEL where it is analyzed and served using the National Marine Fisheries Service Southwest Fisheries Science Center Environmental Research Division's Data Access Program (ERDDAP). The information is made available to scientists as well as the NDBC for distribution on the GTS, often within hours.

NOAA's Technology Planning and Integration for Observation (TPIO) Division spoke to the growing role UMS are playing and the need to assess and evaluate these platforms to determine how well they are meeting NOAA mission requirements, as well as to assess their potential performance as part of NOAA's integrated observing systems of record. The critical need for data concerning mission requirements and the ability of the platforms to collect new or higher resolution data was stressed, as fundamental to evolving NOAA's observing system portfolio.

## **Programs and Facilities**

The Programs and Facilities session was designed to provide participants information on existing operational programs focused on using UMS technology, programs that may be poised to transition from research to operations, and programs that focus on testing and evaluating advanced technology. This session also covered presentations on some of the facilities NOAA owns that either operate, or can be easily adapted to operate UMS.

NOAA's Office of Coast Survey (OCS) has been evaluating UMS for its missions since 2004. The OCS vision for UMS is that OCS will develop and utilize unmanned systems for more efficient and effective acquisition of environmental data to support NOAA's navigation products and services, as well as to support NOAA program requirements for habitat and water column mapping. The presentation described the platforms they currently own and operate, as well as ongoing collaborative efforts with the University of New Hampshire Joint Hydrographic Center and Center for Coastal and Ocean Mapping, and the University of Southern Mississippi. They also discussed the importance of concurrently investing and developing enabling technologies such as shipboard and land-based infrastructure, data management facilities and equipment, and high-bandwidth communications, recognizing the platforms are but one key component of an end-to-end operation. Finally, they spoke to the need for skilled personnel, collaborative partnerships, and the benefits of integrated survey operations utilizing UMS, ships, and other platforms to more efficiently and effectively collect mission critical data

Two talks focused on the IOOS program describing efforts among multiple NOAA programs and external partners to deploy buoyancy gliders in the Gulf of Mexico, tropical north Atlantic, and Caribbean to enhance our understanding of air-sea interaction processes and to improve hurricane track and intensity forecasts. Presenters described a robust end-to-end multi-year program that transmits data to the previously described IOOS Glider DAC, then disseminated via the GTS. The glider data when assimilated with other ocean observations is proving to reduce the error in hurricane intensity forecasts and plans are in place to continue and expand operations in 2019.

PMEL presented on the collaborative program with Saildrone, which has executed a well thought out approach to test, evaluate, and improve both the platform and sensor packages to meet multiple NOAA mission requirements including acquiring meteorological and oceanographic data, and using sonars to support fishery stock assessment and hydrographic survey. The process was based on defining science requirements – what the end users need – platform/sensor design and integration, operations and field testing, automated workflow and data validation, and further field testing. The continued success of the program indicates the technology is poised to transition to operations, and the model PMEL used should be considered by other programs contemplating similar technology transfer activities.

The National Marine Fisheries Service Southwest Fisheries Science Center (SWFSC) discussed how they are incorporating data from buoyancy gliders and USVs to provide science-based advice for the conservation and management of living marine resources, focused on the California Current, Eastern Tropical Pacific and Scotia Sea. This includes participating in the West Coast Underwater Glider Network as part of its research to understand climate variability, as well as using Saildrone vehicles to augment NOAA fish surveys from NOAA Ship *Ruben Lasker*. SWFSC has also conducted habitat surveys using the bottom tracking SeaBED Autonomous Underwater Vehicle (AUV) examining deep sea corals and sponges along west coast, and are using AUVs as part of its work in the Antarctic to enhance routine sampling in challenging environments. Future work includes an integrated sampling program using Saildrones, instrumented moorings, periodic sampling using buoyancy gliders, and seasonal sampling using ships. SWFSC has built a test tank for evaluating UMS platforms and sensors, which is available for agency use.

NOAA's Office of Ocean Exploration and Research (OER) provided participants an overview of their program approach to testing and evaluating advanced technology. This includes coordinating public/private partnership projects such as the recent survey of the sunken USS *Independence* using a large UUV developed by Boeing, a variety of ecosystem and submerged cultural resource projects using USVs and UUVs, and integrated operations involving ships and unmanned technology.

OER invited a partner from the Woods Hole Oceanographic Institution, which operates the National Deep Submergence Facility and its Sentry Autonomous Underwater Vehicle. Examples of NOAA, interagency, national, and international projects designed to explore the deep ocean using WHOI assets were discussed, as well as thoughts concerning the increasing use of UMS in tandem with other platforms or independently to meet growing science requirements.

Over the two days participants heard from several representatives from NDBC about how their facilities support end-to-end UMS operations, science, and data delivery. Talks focused on the vehicles available through NDBC and their partners, NDBC engineering capabilities and staff, specialized equipment, and their "Mission Control Center" that provides 24/7 situational awareness and data ingest/dissemination from offshore buoy networks and buoyancy gliders. Participants were treated to tours of the Mission Control Center and their industrial facility at the end of the symposium.

This session also included a talk by the University of Southern Mississippi (USM), which offers a training and certification program in UMS operations in response to both a Mississippi Governor's Executive Order and a request from NAVOCEANO.

Run by the USM Marine Research Center, students engage in UMS research and operations involving USM scientists, US Navy, NOAA, and private industry (e.g., Shell, ASV Global, and Saildrone). The UMS training and certification program includes three certificate options: tier 1 – novice level; tier 2 – journeyman level; and tier 3 – degree recipient. The program includes classroom and laboratory training, and offshore field experience.

## **Field Operations and Platform Development**

The Field Operations and Platform Development session included discussions of recent NOAA field projects focused on testing and evaluating the capabilities of a variety of UMS. Participants were also provided information on several new platform development efforts.

Over the past several years OCS has engaged in a series of pilot projects to test USVs in the Arctic; an area that is undergoing a rapid increase in economic development and a subsequent rise in vessel traffic. With only 4.1% of the Arctic Ocean surveyed with modern technology and a limited number of vessels capable of working in the region, UMS will play an increasing role in helping NOAA meet its hydrographic survey requirements. OCS provided information on several cruises using C-Worker 4 and C-Worker 5 USVs, as well as a collaborative effort with PMEL to derive depth sounding measurements from fishery sonars mounted upon Saildrone vehicles. The results are promising, and OCS plans upcoming tests of a survey launch that is being converted to operate in manned and unmanned mode.



OCS also provided an interesting talk on a small USV they have been experimenting with – a Seafloor Systems Echoboat. In a series of missions in Lake Champlain, the Echoboat has proven particularly adept at surveying areas inaccessible by manned launches, acquiring data invaluable for improving flood forecast models. With built-in autonomous navigation software, the vehicle is able to adapt to changing environmental conditions to maintain tracking, with some limitations.

The SWFSC presented on a recent extensive fishery survey off the U.S. west coast from British Columbia to Baja California using Sairdrone vehicles. Over 18,000 nm were surveyed and ship-based tracklines were extended shoreward to depths of 10 m along the central California Coast, allowing data to be collected in areas that had not been surveyed before. The project proved to be very successful, demonstrating the value of integrated operations using ships and USVs.

The Office of National Marine Sanctuaries talked about their Center for Collaboration on Unmanned Technology located at the Channel Islands National Marine Sanctuary. The Center was formed to engage NOAA and non-NOAA partners in testing and evaluating unmanned systems including USV, UUV, buoyancy gliders, and UAS with emphasis on collecting data to support marine resource management requirements. Recent expeditions using the OCS Remus-600 UUV to augment ship-based habitat mapping were highlighted, which included the use of the data to guide remotely operated vehicle (ROV) dives for ground-truthing and sample collection. Examples of UAS missions for marine resource monitoring were also discussed, acknowledging the value of integrated operations and integrated data products to support science and management.

PMEL briefed participants on a collaborative venture with the University of Washington Joint Institute for the Study of Atmosphere and Ocean and Kongsberg to develop the Oculus Coastal Glider. The Oculus was designed to work in the highly stratified, high energy, and shallow depth of the Arctic. Outfitted with sensors for measuring temperature, salinity, dissolved oxygen, sunlight, chlorophyll, and other parameters, the Oculus proved successful for identifying numerous small eddies along the Bering Sea shelf, which had never been observed before, and which may play a significant role in predator-prey relationships among marine species.

## **Science and Sensors**

The final presentation session focused on how UMS are performing in support of NOAA's scientific objectives, as well as the development of sensors and sensor suites to collect new information as well as to increase the resolution of particular observations.

The University of New Hampshire Joint Hydrographic Center and Center for Coastal and Ocean Mapping has been collaborating with NOAA since it was formed in 2001, and are a key partner in furthering the OCS Autonomous Systems Strategy. This talk provided participants an overview of the UMS and sensors in use and examples of how the data acquired is visualized and integrated into hydrographic and non-hydrographic products. Sensors that are furthering efforts toward autonomous navigation and object identification/classification were also covered.

Because biological observations are a critical part of many NOAA missions, the NOS National Centers for Coastal and Ocean Science (NCCOS) has been collaborating with the OAR Great Lakes Environmental Research Lab (GLERL), the OAR Atlantic Oceanographic and Meteorological Laboratory, and the Monterey Bay Aquarium Research Institute (MBARI) to design and integrate

bio-sensors on UMS for autonomous in situ sample acquisition, processing and analysis with near real time data transmission to monitor harmful algal blooms. Case studies were presented providing detailed information on lessons learned, and plans are underway to test a long range autonomous underwater vehicle with the ability to intelligently track and sample harmful algal blooms.

As a complement to the NCCOS presentation, IOOS presented on Texas A&M's deployment of an optical phytoplankton discriminator on a Slocum Glider. This innovation is helping scientists answer fundamental questions about the composition of the background community structure in the Gulf of Mexico, which is important in determining what influence climate change has on harmful algal blooms and other phyto and zooplankton communities.

To wrap up this session, representatives from PMEL described a series of missions using Saildrone vehicles and wave gliders outfitted with CO<sub>2</sub> sensors to address the question – will the ocean uptake of CO<sub>2</sub> keep pace with CO<sub>2</sub> emissions? Using UMS for this purpose allows for making observations in remote locations that are not typically sampled, and for longer periods of time compared to traditional methods. They also described the development of low-power echosounders that were installed on Saildrone vehicles to conduct fishery stock assessment in the Bering Sea. As part of an integrated program scientists were able to conduct in-field and ongoing comparisons of the data collected by the Saildrone vehicles, ships, and moorings. The methodology is proving so successful it is becoming routine, and is being adopted by other NOAA programs engaged in stock assessment.

## **Breakout Group Summaries**

On the third and final day of the Symposium members of the planning team facilitated breakout sessions focusing on emerging requirements, emerging technologies and best practices related to UMS. The following provides a brief summary for each group highlighting the key points that were discussed during these sessions.

### **Emerging Requirements**

This breakout group focused on the need to better understand how mission requirements drive decisions on the most appropriate platforms and methods for collecting data.

Participants discussed how UMS are increasing observations and collecting data in areas where traditional methods do not work, and how individual NOAA programs and multi-program partners make decisions on which platforms to acquire, test, and evaluate. What seems to be lacking is a process for efficiently transitioning these efforts from a series of research-oriented projects to systematic standardized operations. This is especially important in cases where the platforms are delivering results that benefit multiple NOAA mission requirements.

The group discussed the role TPIO could play since they work across NOAA to track current and potential future requirements, as well as how these requirements are currently being met. This enables NOAA to conduct cross-program analyses of requirements and performance that might otherwise be missed, and which provide valuable information to NOAA leadership to make corporate decisions concerning transition to operations.

Finally, the benefits of multi-partner, multi-agency UMS missions that include the end users (modelers and product developers), data managers and processors, and the data collectors was identified, and the IOOS program was highlighted as an excellent example – a potential model for end-to-end programs using UMS as well as traditional techniques.

At the conclusion of this session, participants highlighted the need to engage end-users, data managers and processors, and data collectors in strategic and mission planning; and the need for improved communications between the NOAA Councils on UMS and other unmanned systems – the group recognized each Council has responsibilities that may influence UMS decisions, but there is little cross-Council communication and coordination. The group also felt efforts should be made to formalize how data is managed and accessed since this is fundamental to understanding existing and new mission requirements. Consideration should be given to “how” UMS data is managed – centralized, distributed, or a hybrid.

### **Emerging Technologies**

Recognizing how quickly UMS technology is changing, and how operationally sound platforms are continually being adapted to meet new missions, this breakout group focused on identifying and discussing organizational challenges that impede progress, as well as technology challenges that may limit the use of UMS, or drive innovation.

In terms of organizational challenges the group discussed the value of a strategic plan focused on UMS and unmanned technology, which would help establish a shared vision for the role UMS will play for NOAA. The group also debated the pros and cons of a centrally managed fleet of UMS, and while no conclusions were made, the concept of centralized coordination was discussed – centralized management of owned assets, as well as centrally coordinated management of operational partnerships with other federal agencies, academia, and private industry where it makes sense. This could be incorporated into transition planning to ensure NOAA programs can continue to apply their scientific and engineering expertise to experimenting with new systems. This led to identifying the need for hiring and training engineers, technicians, operators, and others required to make the best use of UMS technology.

With regard to technological challenges, the group discussed the need for standardizing data sets collected by a variety of UMS platforms to ensure they meet the needs of the end-users. This would include identifying common standards, as well as establishing procedures for quality assurance and quality control that could be met by the data collectors and providers, especially when working with external partners. The need to improve cross-platform coordination – to select the right platform for the right job – was also identified as a technological challenge, and would most likely stimulate more integrated operations using multiple technologies, allowing for simultaneous collection of surface and subsurface information.

### **Best Practices**

This breakout group focused on discussions concerning the need for developing, documenting, and applying best practices for creating and sustaining an operational UMS program. The group talked about the value of a distributed program similar to how NOAA currently operates UAS, which allows for centralized management of corporate assets that meet multiple mission

requirements on a systematic and ongoing basis, as well as providing governance and guidance for UMS still undergoing test and evaluation, or those designed to meet a focused set of program objectives. The NOAA Small Boat Program was also mentioned as a prospective model.

The group discussed best practices for safe navigation, and the need to review existing best practices and developing a document – an operator’s handbook – to meet NOAA needs. This would include best practices the US Coast Guard and US Navy have in place, as well as those documented by OCS and the operational risk assessment procedures for UMS developed by the SWFSC.

The group concluded their session by developing an outline for UMS activities that would benefit from the development of best practices as follows:

- Platform identification and selection
- Engineering design
- Sensor design and integration
- Operations – deployment and recovery, contingency plans for loss
- Data and information management
- Training
- Cybersecurity

*The preparers of this report are NOAA staff who drafted this summary and recommendations informed by the sharing of expertise and information at the symposium. The report and recommendations do not reflect consensus input and advice of industry or other external partners.*

## Appendix I – Agenda

### - Agenda - NOAA Unmanned Marine Systems (UMS) Symposium

October 30 –November 1, 2018

Logtown Conference Room  
1100 Balch Boulevard  
Stennis Space Center, MS 39529

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**Objective:** The NOAA Unmanned Marine Systems Symposium (UMS) is intended to provide an opportunity for NOAA labs and programs to share information on what they are doing with UMS - field activities, platform and sensor development, managing and disseminating data, and developing products. This is an information sharing non-advisory symposium.

**Outputs** - The outputs will consist of a value-added summary report of the survey results, the presentations, and a symposium summary report. These products will provide:

- Increased understanding of how UMS meet current NOAA mission requirements
- Increased understanding of data, data management and workflow and information availability and applications
- Increased understanding of the need to account for increased data volume
- Increased understanding of the legal and policy landscape, e.g., for operating and acquiring UMS
- Information for improving transition to operations efforts
- Information on future trends and opportunities

**Definition:** UMS are defined as waterborne systems that are capable of executing pre-programmed missions without operator interaction, and are operated on continuum from attended to fully autonomous. These include:

- Unmanned Underwater Vehicles (UUVs) - unmanned, untethered, systems capable of autonomous submerged operation
  - Unmanned Surface Vehicles (USVs) - untethered, self-propelled surface craft ranging in size from man-portable systems to small boat-size vessels that are capable of autonomous, semi-autonomous, or remote-controlled operations
  - Buoyancy Gliders - use small changes in buoyancy in order to move up, down and forward in the ocean
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**Participants:** This symposium will focus on NOAA Labs and programs and include representatives from formal NOAA affiliate partners such as the US Navy, Cooperative Institutes, and select academic institutions. Attendees will include engineers, scientists, operators, program and data managers, and users of the information.

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#### DAY – 1

8:00 AM	Coffee and Refreshments
8:15 AM	Welcome – host facility

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- 8:30 AM Introduction – overview of workshop goals, objectives, agenda – McDonough, OMAO
- 8:45 AM Keynote presentation – NOAA UxS Executive Oversight Board Co-chairs 9:15 AM
- Keynote presentation – USN Dr. Bill Burnett

#### Legal and Regulatory Environment Talks

- 9:45 AM International Regulatory Framework – Peter Oppenheimer, NOAA General Counsel
- 10:15 AM BREAK
- 10:45 AM Domestic Regulatory Framework – Marty McCoy, NOAA General Counsel

#### Data and Information Management Talks

- 11:15 AM Maximizing ROI on UMS Data – Eric Kihn and Sharon Mesick, NESDIS/NCEI
- 11:45 AM LUNCH
- 1:00 PM IOOS Data Assembly Center – LCDR Benjamin LaCour, NOS/IOOS
- 1:20 PM Sairdrone Data Handling – Eugene Burger, OAR/PMEL
- 1:40 PM Connecting Emerging Capabilities to Service Outcomes – David Helms, NESDIS/TPIO
- 2:00 PM BREAK

#### Programs and Facilities Talks

- 2:20 PM Use of Gliders for Hurricane Intensity Forecasts – Gustavo Goni, OAR/AOML
- 2:40 PM Sairdrone: Development and Tech Transfer – Chris Meinig, OAR/PMEL
- 3:00 PM UMS for Ocean Exploration – Chris Beaverson, OAR/OER
- 3:20 PM AOML-CARICOOS Hurricane Glider Program – Julio Morell and Gustavo Goni, NOS/IOOS
- 3:40 PM Overview of Coast Survey’s Unmanned Systems Strategy – Rob Downs, NOS/OCS
- 4:00 PM SWFSC Test Tank Facility and UMS Activities – Roger Hewitt, NMFS/SWFSC
- 4:20 PM UMS Certification Program – Monty Graham, USM
- 4:40 PM Wrap Up Day-1

Evening Social – [BJ’s Restaurant and Brewhouse](#)

#### **Day – 2**

- 8:30 AM Coffee and Refreshments
- 8:45 AM Introduction – Recap of Day – 1 and overview of plan for Day – 2 – McDonough, OMAO

#### UMS Field Operations and Platform Development Talks

- 9:00 AM Ocean Mapping Activities with UMS in Alaska and the Arctic – Rob Downs, NOS/OCS
- 9:20 AM ONMS Collaborative Center for UMS – Todd Jacobs, NOS/ONMS
- 9:40 AM Recent Activities Using Small USVs in Lake Champlain – Alex Ligon, NOS/OCS
- 10:00 AM BREAK
- 10:20 AM Sairdrone: West Coast Fisheries Survey – CDR John Crofts, NMFS/SWFSC
- 10:40 AM Sairdrone and Wave Glider: Data Collection – Noah Lawrence-Slavas, OAR/PMEL
- 11:00 AM Oculus Underwater Glider Development – Chris Meinig, OAR/PMEL
- 11:20 AM Exploring the Deep Ocean with UMS – Mike Jakuba, WHOI
- 11:40 AM Toward Ship-free Long Range Deep Ocean Observations – Mike Jakuba, WHOI
- 12:00 PM LUNCH

#### UMS Science and Sensors Talks

- 1:00 PM Technology to Support USVs for Ocean Mapping – Val Schmidt, UNH
- 1:20 PM UMS for Biological Targets: A HABs Case Study – Gregory Doucette, NOS/NCCOS
- 1:40 PM 3 H’s in the Gulf of Mexico – Barb Kirkpatrick, NOS/IOOS

2:00 PM BREAK  
 2:20 PM Saildrone: WG Carbon Measurements from UMS –Adrienne Sutton, OAR/PMEL  
 2:40 PM Saildrone: Bering Sea Fisheries – NOAA Lawrence-Slavas, OAR/PMEL  
 3:00 PM Saildrone: In-field Data Comparisons and Methodology –Ned Cokelet, OAR/PMEL  
 3:20 PM Operating Unmanned Underwater Vehicles at NDBC – Dawn Petraitis, NWS/NDBC  
 3:40 PM NDBC Lithium Battery Storage and Handling – David Crawford, NWS/NDBC  
 4:00 PM NDBC Engineering Capabilities – Craig Kohler, NWS/NDBC  
 4:20 PM NDBC Operational and Industrial Capabilities – Brett Taft, NWS/NDBC  
 4:40 PM Tours: NDBC and NCEI Facilities  
 End of Day-2 – Dinner on your own

Day – 3 (half-day)

8:30 AM Coffee and Refreshments  
 9:00 AM Introduction – Recap of Days 1 and 2 and overview of plan for Day – 3 – McDonough, OMAO  
 9:15 AM Breakout Sessions – Emerging Technologies, Requirements, and Best Practices  
 Emerging Requirements Breakout Group  
     models, forecast products public/private partnerships  
 Emerging Technologies Breakout Group  
     technology gaps  
     organizational challenges  
 Best practices breakout group  
     operations and safety data management training/human capital  
 11:00 AM Plenary briefs by each breakout group  
 11:45 AM Wrap-up and next steps  
 12:00 PM End of Day 3

Anticipated Results:

- Pre-symposium survey report
- Symposium summary document
- Presentations
- Breakout group summaries

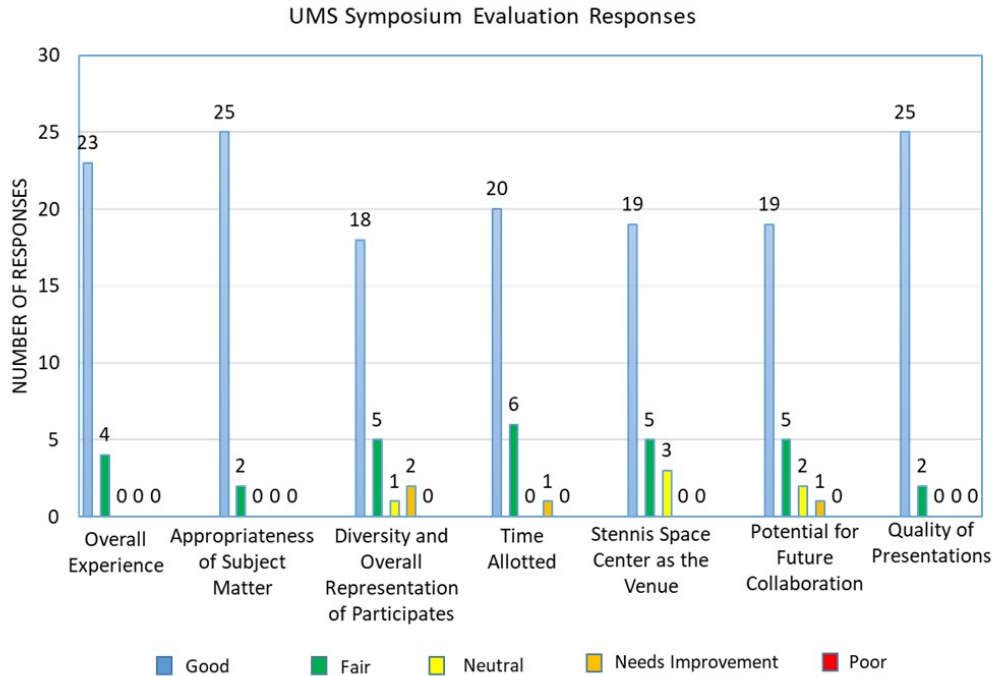
## Appendix II - Participants of the Unmanned Marine System Symposium

Allison-Holman, Roxie	General Counsel, Weather	Kirkpatrick, Barb	NOS, IOOS
Armor, John	NOS, DAA (acting)	Kohler, Craig	NWS, NDBC
Asper, Vernon	USM	LaCour, Benjamin	NOS, IOOS
Averill, Lindsey	OMAO, IMD-MACC	Lassally, Gonzalo	NWS, OBS
Baczkowski, Joseph	OMAO, IMD-MACC	Lawrence-Slavas, Noah	OAR, PMEL
Baltes, Becky	NESDIS, TPIO	LeBlanc, Lex	NWS, NDBC
Battista, Tim	NOS, NCCOS	Leonardi, Alan	OAR
Beaverson, Chris	OAR, OER	Ligon, Alex	NOS, OCS
Bergeron, Joshua	NOS, OCS	Lodato, Frank	NWS, NDBC
Boscarenno, Salvador	NWS, NDBC	Lomnicky, John	NOS, OCS
Brown, Chris	NWS, NDBC	Manda, Damien	NOS, OCS
Bryan , Mensei	USN, Navy glider ops center	Matlock, Gary	OAR, DAA
Buras, Melissa	NWS, NDBC	McArthur, Shannon	NWS, NDBC
Burger, Eugene	OAR, PMEL	McCoy, Marty	GC, Oceans
Burnett, William	USN, CNMOC	Mcdonough, John	OMAO, PPMD
Cokelet, Edward	OAR, PMEL	Meinig, Chris	OAR, PMEL
Cooley, Kevin	NWS, OPPSD	Mesick, Sharon	NESDIS, NCEI
Crawford, David	NWS, NDBC	Moorhead, Robert	MSState
Crofts, John	NMFS, SWFSC	Morell, Julio	NOS, IOOS
Derex, Becca	NOS	Oppenheimer, Peter	GC, International
Dillen, Jeff	GC, Deputy GC	Parsons, Rost	NESDIS, NCEI
Doucette, Greg	NOS, NCCOS	Petratis, Dawn	NWS, NDBC
Downs, Rob	NOS, OCS	Pidgeon, Ryan	NWS, NDBC
Dreflak, Frank	OMAO, PPMD	Portmann, Helmut	NWS, NDBC
Gallagher, Michael	NMFS, S&T	Regan, Kyla	NWS, NDBC
Gay, Eric	NWS, NDBC	Riley, Rodney	NWS, NDBC
Gledhill, Chris	NMFS, SEFSC	Ruberg, Steve	OAR, GLERL
Goni, Gustavo	OAR, AOML	Saraf, Neeraj	NOS, OCS
Graettinger, George	NOS, ORR	Schmidt, Val	UNH, CCOM-JH
Graham, Monty	USM, UMS cert program	Smith, Bill	NWS, NDBC
Hann, Nancy	OMAO, DAA-MO	St Germain, Karen	NESDIS, OSSAP
Helms, David	NESDIS, TPIO	Stalin, Scott	OAR, PMEL
Hewitt, Roger	NMFS, SWFSC	Sutton, Adrienne	OAR, PMEL
Hilmer, David	NOS, NCCOS	Taft, Brett	NWS, NDBC
Hoffman, Philip	OAR, OPPE	Taylor, Jeremy	NMFS, PIFSC
Hogan, Bob	GC, Enforcement	Todd, James	OAR, CPO-OOMD
Jacobs, Todd	NOS, ONMS	Van Parijs, Sofie	NMFS, NEFSC
Jakuba, Michael	WHOI, Deep Submergence Lab	VanWaes, Mark	OAR, UAS
Jones, Donald	OMAO, MO-EEB	Vasquez, Mike	NWS, NDBC
Kamphaus, Robert	OMAO retired	Wang, Zhankun	NESDIS, NCEI
Kihn, Eric	NESDIS, NCEI	Yapur, Martin	NESDIS, TPIO
Kim, Hyun-Sook	NWS, EMC, MDAB	Youngman, Monica	NESDIS, NCEI



## Appendix III – Summary of Symposium Evaluation

After the conclusion of the UMS Symposium, an evaluation survey was sent to all survey attendees to solicit feedback on the symposium. Seven questions covered various aspects of the symposium, and attendees were asked to rate each as Good, Fair, Neutral, Needs Improvement or Poor. Space was also provided for comments at the end. Twenty-seven attendees answered all of the questions and sixteen provided comments. Results follow below.



Overall the responses and comments were very favorable.

While acknowledging that having a broad span of topics was appropriate for this first ever NOAA UMS Symposium, there were a number of comments that mentioned focusing on specific topics of importance to the UMS user community. This would allow a deeper delve into the particular topic. In this vein, more breakout group sessions as occurred on day three that would allow for a more in depth discussion and less power point presentations were also suggested. As far as the group discussions, getting the discussion topics out earlier would help participants be better prepared. It was also stated that the Symposium focused too much on a few UMS such as Sairdrone and gliders and not enough on other systems.

It was noted that the scientific user community, particularly modelers, were not well represented at the symposium. As a large beneficiary of UxS data it is important to include modelers in future discussions. Some comments include having more higher-level involvement. The dates of the symposium, while carefully chosen, left some key players in the UMS community unable to attend. While acknowledging that diversity of platforms and across disciplines was good, one respondent stated that the overall race and gender of participants was not diverse.

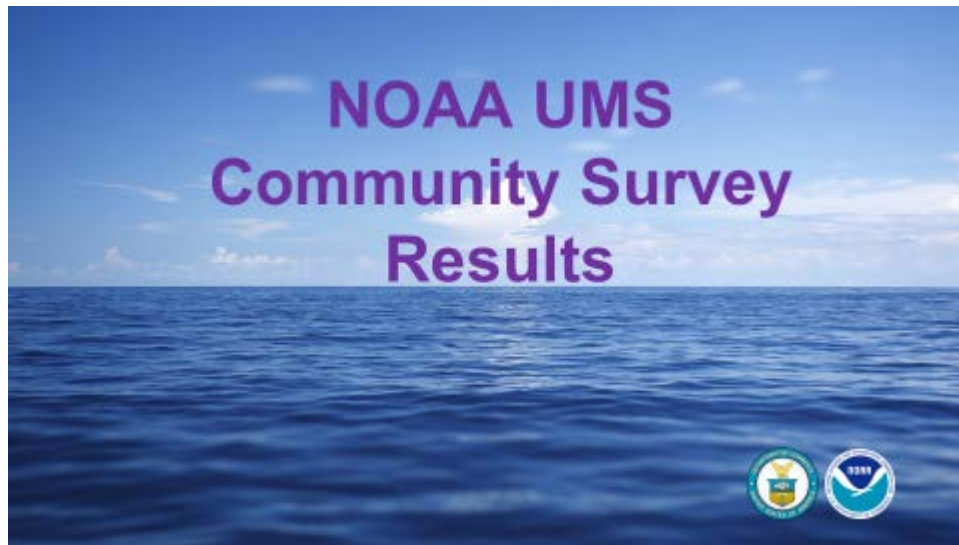
It was expressed by more than one respondent that more time was needed for specific topics.

While having mostly positive responses, more Navy/NASA involvement would have potentially made the Symposium that much better. Stennis was chosen due to its central location, low cost, and great hospitality of the hosts, in addition to all the NOAA UMS activity in the area.

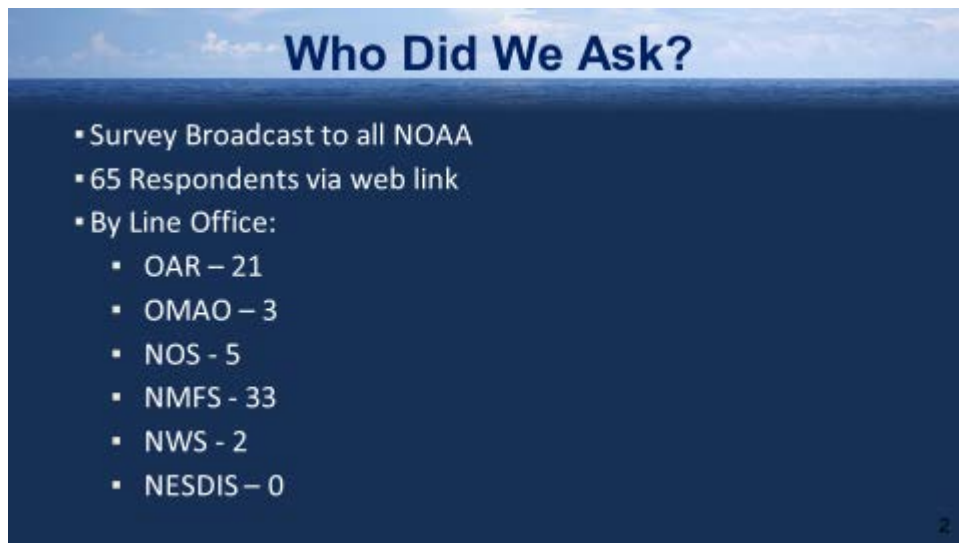
There were a number of comments expressing the view that more time to go more in-depth in to a subject and perhaps less presentations would have been preferable. There were a number of comments praising the speakers.

One comment regarding a future direction for NOAA UMS that did not fit neatly above is presented in its entirety as food for thought: “A great start for UMS. The real challenge for NOAA is not continuing symposia, which are important for information exchange, but to define and fund a requirements-based acquisition program. NOAA has a tendency to jump from play toy du-jour - first it was wave gliders, now its sail drones. Platform agnostic requirements should be defined by the user community, followed by analysis of alternatives that end up identifying candidate platforms that should then be competed in a rigorous Engineering Test program with quantified pass/fail measures. Next should come an Operational Test Program that produces the best solution(s) and is followed by a FUNDED acquisition program.”

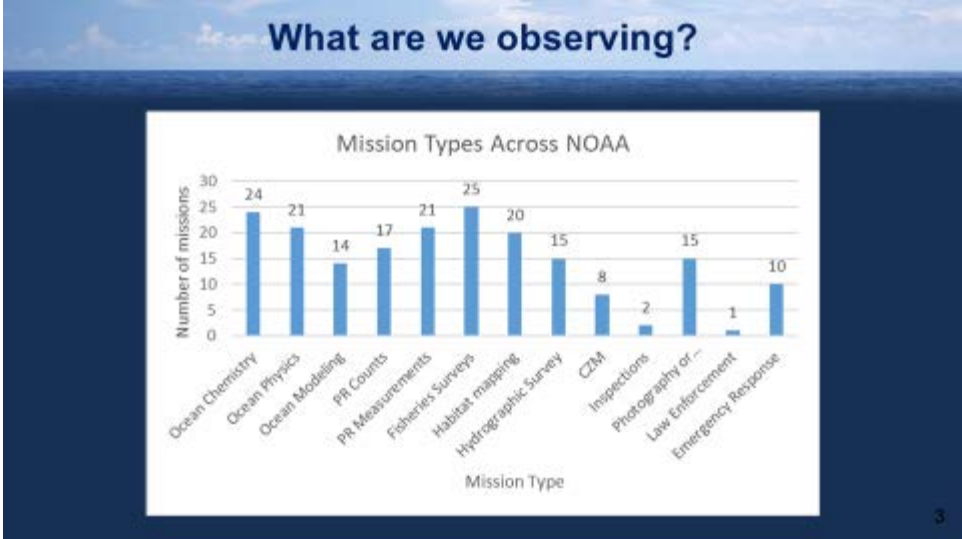
## Appendix IV – Results of the Pre-Symposium Survey



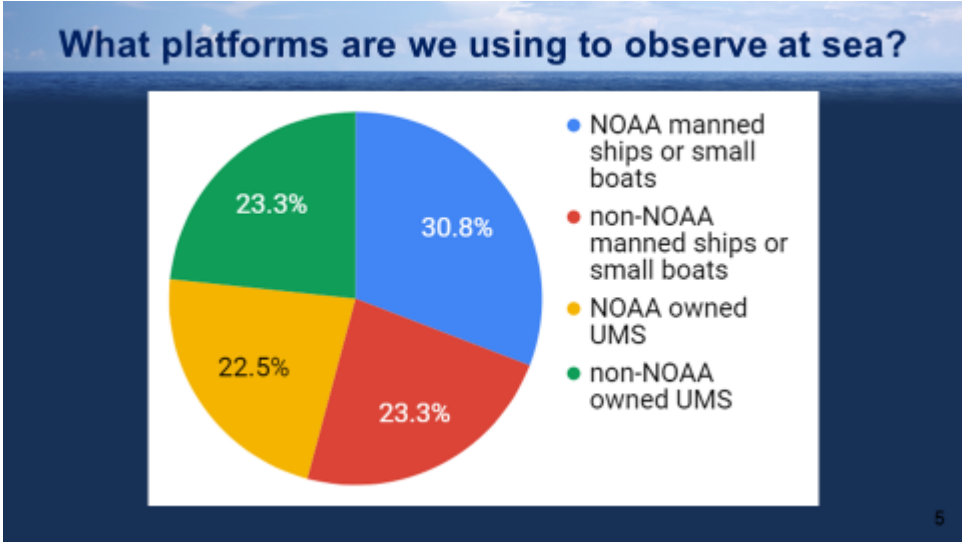
Prior to the Unmanned Marine Systems Symposium held from October 30 –November 1, 2018, the UMS Symposium planning team asked all of NOAA their opinion on the current state of UMS and what they envisioned for the future.



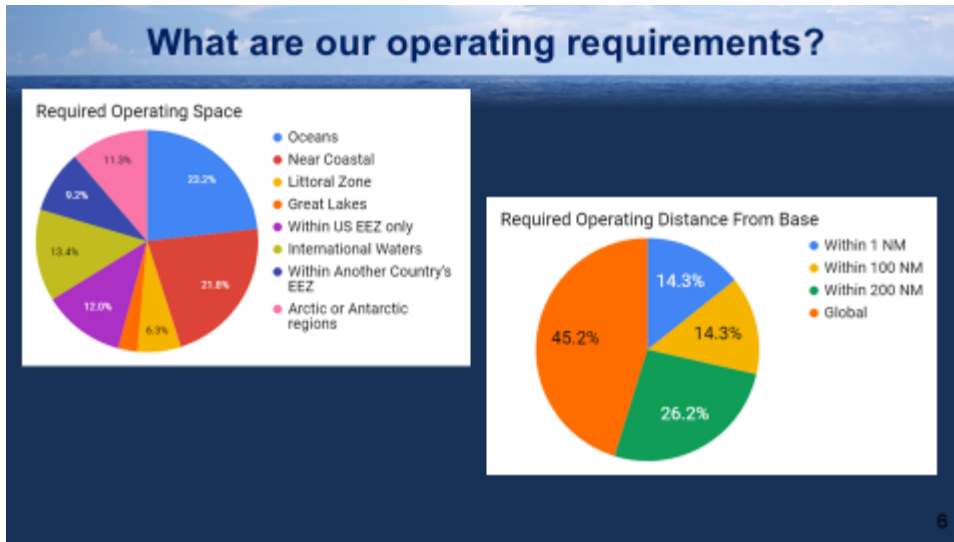
Sixty-five responses were received from across NOAA, including 21 responses from OAR staff, 3 from OMAO, 5 from NOS, 33 from NMFS, two from NWS and none from NESDIS. Multiple questions were asked in order to best to characterize what parameters are being collected across NOAA. The data from the survey responses is summarized over the next few pages.



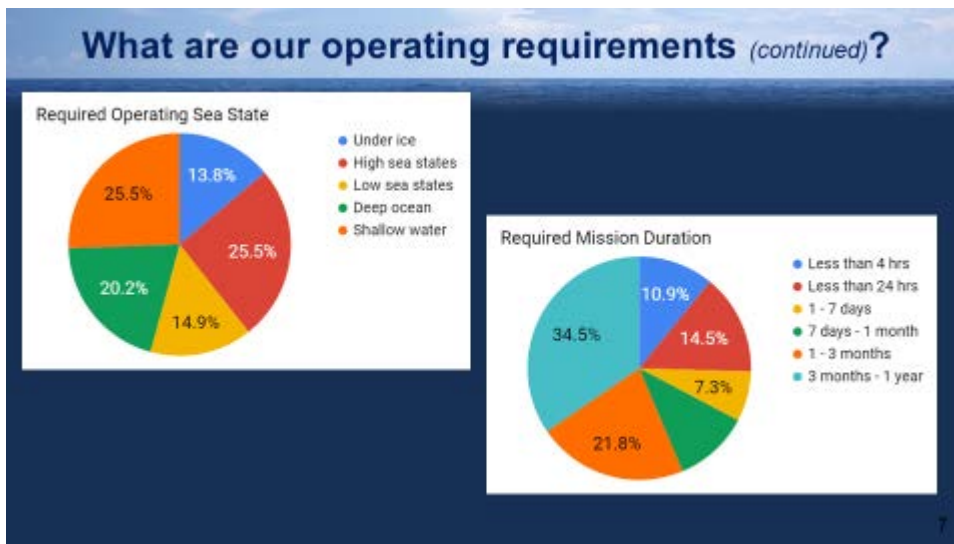
The respondents indicated that a wide variety of mission types were represented across NOAA as shown above. Multiple mission types could be classified in each mission.



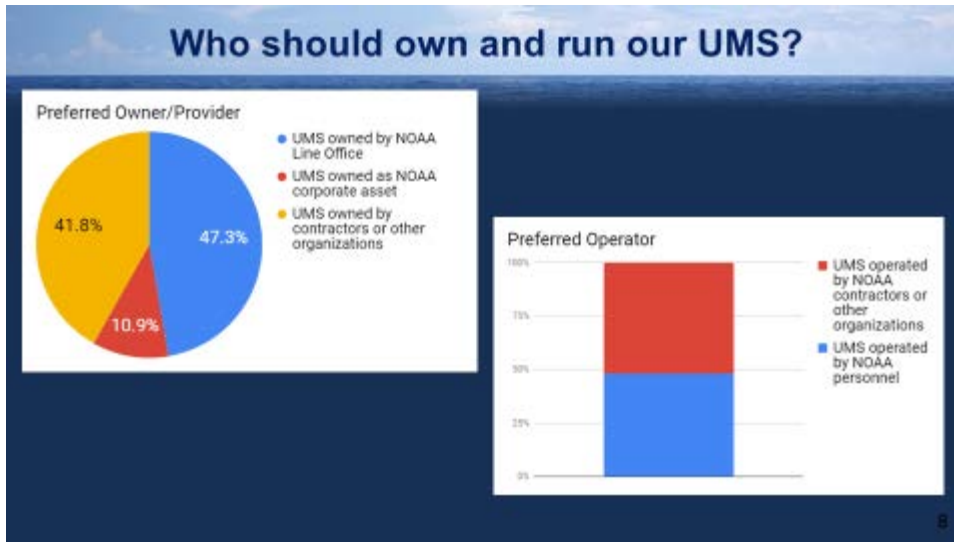
NOAA is currently using multiple platforms to make observations at sea and had a fairly even distribution identified between ships/small boats and UMS, as well as NOAA owned and non-NOAA owned. Identifying the correct observational platform for given data collection will require evaluating all options, including UAS, UMS, Ships, Aircraft, small boats, etc.



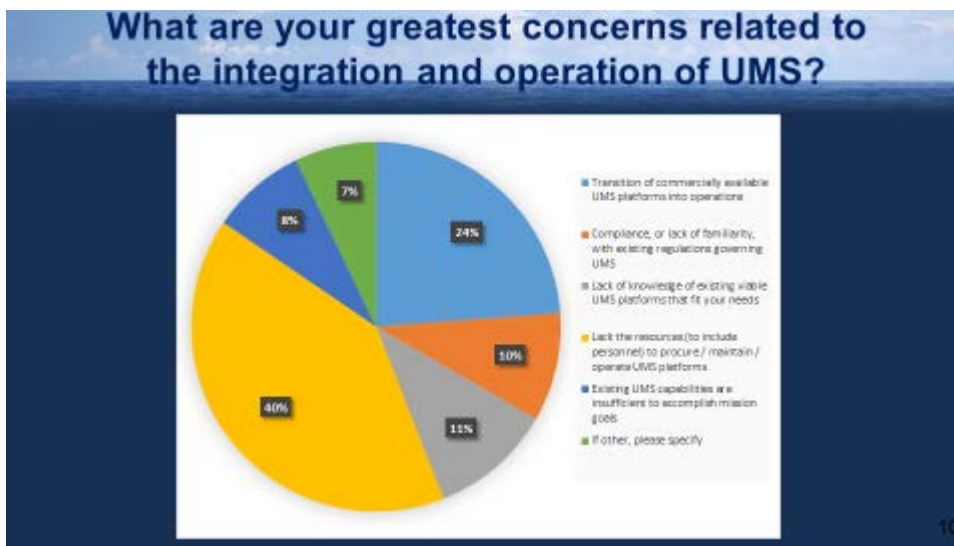
The ideal UMS platform can operate for long periods well away from its base in a variety of sea states. Based on current mission profiles, platforms should be able to take basic oceanographic data, engage in hydrographic mapping, and be able to monitor living marine resources. NOAA data collection requirements require operating platforms across the globe and in many different areas as identified in the two following charts.



NOAA requires UMS to operate across a spectrum of sea states and environmental conditions from the surface to deep-ocean and under ice. Mission duration requirements run the gamut from less than 4 hours to year-long time frames.



The respondents preferred UMS assets to be owned by the line office or contractors/other organizations versus being corporately owned by NOAA, and a fairly even split was indicated as far as being run by NOAA personnel versus contractors/other. This indicates the need to determine which missions would benefit from corporately owned and operated assets. For instance, hydrographic surveys may be one area where this is appropriate.



The respondents were asked what their most significant challenges were in meeting at-sea mission requirements and how UMS may help to overcome them. Responses can be divided into two categories, those that capture how UMS will help overcome the challenges in meeting at-sea mission requirements and the challenges to implement UMS implementation and use.

Insufficient ship time was identified by multiple contributors as a major challenge that could be mitigated where UMS can augment ship time and act as a force multiplier. Difficult to reach

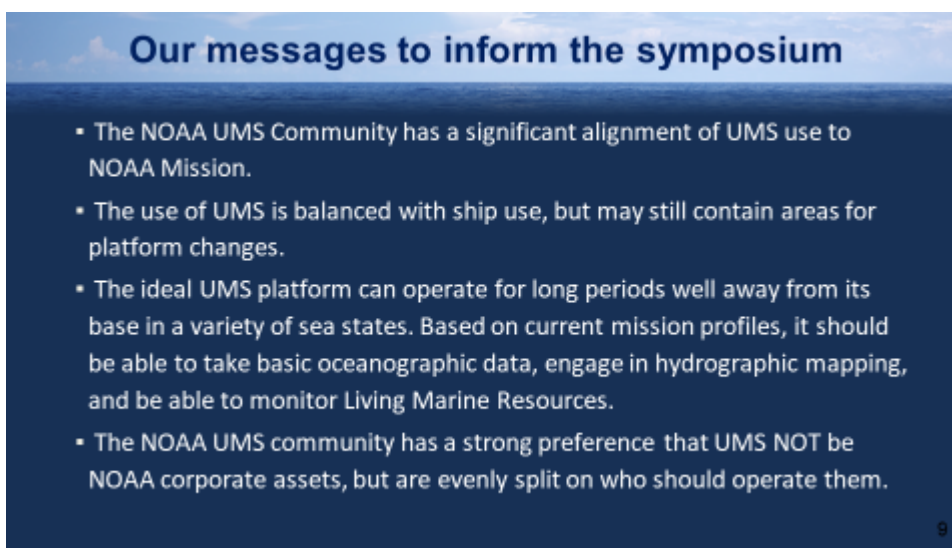


locations, such as nearshore/shallow areas, were also identified as areas where using UMS could lower logistics/operating costs and provide higher quality data. Respondents felt UMS also allow for collecting mission critical data when ships may not be available, or when the cost of using a ship to collect single-mission data may be too prohibitive. It was noted that UMS can operate in adverse weather/sea states that ships and small boats cannot and often collect data over longer time periods and farther from port. In short, continued development of UMS can provide robust agile sampling systems for optimal performance in a variety of environments, locations, sea states and time frames that will augment the capabilities of the NOAA fleet.

Costs for the assets and their maintenance and operation were noted as a challenge, as well as the need for policies, guidance, and overall coordination in order to maximize the return on investments. Other challenges identified include requirements for operation and having access to trained personnel. Another important consideration is developing a repository of knowledge so that knowledge can be shared and does not reside in one specific lab or investigator.

Respondents noted that integration of UMS into fleet operations will require new network designs and architectures; increased bandwidth and data communication requirements; increased command and control communications systems to safely and efficiently operate UMS vehicles; integration of these new requirements into existing ship infrastructure as well as designing them into new ship construction requirements and design documents.

Other concerns identified include 1) realistic assessment of the limitations of data from UMS platforms, 2) untested capabilities of UMS and comparison to ship based data, 3) lack of resources to manage and analyze the data, 4) organization and cross LO challenges, 5) sensors and data quality, 6) the loss of the ability to quickly (in real-time) adapt UMS missions in response to changing conditions, 7) the loss of control of the UMS mission for the end user of the data, 8) poor UMS choices, and 9) lack of a NOAA transition pathway and resources to move from demonstration to routine operations.



**Our messages to inform the symposium**

- The NOAA UMS Community has a significant alignment of UMS use to NOAA Mission.
- The use of UMS is balanced with ship use, but may still contain areas for platform changes.
- The ideal UMS platform can operate for long periods well away from its base in a variety of sea states. Based on current mission profiles, it should be able to take basic oceanographic data, engage in hydrographic mapping, and be able to monitor Living Marine Resources.
- The NOAA UMS community has a strong preference that UMS NOT be NOAA corporate assets, but are evenly split on who should operate them.

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Main points from the pre-symposium survey are summarized above.

## Appendix V – Acronyms

CENOTE	Commercial Engagement through Ocean Technology Act of 2018
COLREGS	International Convention Preventing Collisions at Sea
DAC	Data Assembly Center
EOB	Executive Oversight Board
ESA	Endangered Species Act
GLERL	Great Lakes Environmental Research Lab
GTS	Global Telecommunications System
IOOS	Integrated Ocean Observing System
MBARI	Monterey Bay Aquarium Research Institute
MMPA	Marine Mammal Protection Act
NAVOCEANO	Naval Oceanographic Office
NCCOS	National Centers for Coastal and Ocean Science
NCEI	National Centers for Environmental Information
NDBC	National Data Buoy Center
NEPA	National Environmental Policy Act
NESDIS	National Environmental Satellite, Data, and Information Service
NMFS	National Marine Fisheries Service
NWS	National Weather Service
NOS	National Ocean Service
NRDD	NOAA Research and Development Database
OAR	Office Oceanic and Atmospheric Research
OCS	Office of Coast Survey
OER	Office of Ocean Exploration and Research
OMAO	Office of Marine and Aviation Operations
PMEL	Pacific Marine Environmental Laboratory
R2O	Research to Operations
ROV	Remotely Operated Vehicle
SWFSC	Southwest Fisheries Science Center
TPIO	Technology Planning and Integration for Observation
UAS	Unmanned Aerial System
UMS	Unmanned Marine System
UNCLOS	1982 United Nations Law of the Sea
USM	University of Southern Mississippi
USV	Unmanned Surface Vehicle
UUV	Unmanned Underwater Vehicle
UxS	Unmanned Systems, Marine or Aviation
WHOI	Woods Hole Oceanographic Institution