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DISCLAIMER

The Consortium for Ocean Leadership (COL) created, organized, and managed the Workshop to Support Implementation of NOAA’s Unmanned Systems (UxS) Strategy with financial support from NOAA. This summary report is informed by the sharing of expertise and information that took place by the participants during the workshop, August 4-6, 2020. The report constitutes community-based input from COL to NOAA but does not reflect consensus statements of external participants.
EXECUTIVE SUMMARY

OVERARCHING CONCLUSIONS AND OUTSTANDING QUESTIONS

The Workshop to Support Implementation of NOAA's Unmanned Systems (UxS) Strategy involved a broad spectrum of participants from government, nonprofit, industry, and academic organizations. No attempt was made to develop consensus statements and recommendations. Based on the discussions and presentations, COL, with input from the workshop Executive Committee, offers the NOAA UxS Implementation Plan writing team the following observations and conclusions that workshop participants repeatedly voiced, along with a number of important unanswered questions raised that are deserving of further consideration:

Conclusions

- Advancing Diversity, Equity, and Inclusion (DEI) with respect to implementing the NOAA UxS Strategy is imperative. NOAA has already made exemplary advances in this area. By their nature, UxS combined with telepresence capabilities affords a unique opportunity to enable a diverse population across the nation to experience many aspects of UxS operation and data analysis virtually in domains spanning ocean to atmosphere.
- Terminology matters when advancing DEI, and immediately after this workshop, NOAA has indicated that it will change the meaning of UxS to Uncrewed Systems versus Unmanned Systems across its broad portfolio.
- *In situ* investigations are an important aspect of career advancement for ocean and atmospheric scientists, yet many scientists are unable to participate in field expeditions for extended periods, and mounting such operations often entail slow turnaround times compared to the use of UxS. The combination of UxS and telepresence will enable many more individuals to actively engage in remote operations and provide greater opportunities for citizen science initiatives. The same applies for public outreach — UxS operations offer an exciting means for engaging a broad spectrum of people, including those at a young age who may be inspired to pursue a career in science, technology, engineering, and mathematics (STEM) fields.
- Public Private Partnerships (PPP) are essential for NOAA to advance UxS applications for ocean and atmospheric sciences. NOAA should lead efforts to promote partnering opportunities with other federal agencies, state and local governments, academic institutions, and the private sector (for-profit and nonprofit) to accelerate UxS development, testing, and applications.
- A feedback loop between UxS testing and requirements development should be formalized. The results of testing should inform system requirements definition in an iterative and directed process.
- Regional scale field exercises are critical for advancing and maturing UxS technology, for training new operators and scientists, and for advancing workforce proficiency. Regional-scale field exercises also serve as proving grounds for discovering and evaluating commercially available systems, as well as testing and refining emergent technologies. Promoting regionally distributed, regularly recurring field exercises will help to showcase common inter-regional challenges and solutions, rapidly transition emergent technologies to operations, and highlight interagency mission overlaps where cooperative opportunities exist.
- UxS owner-operator versus contracting data-as-a-service models should be considered. The approach that NOAA adopts, which could entail a hybrid of the two, should be driven by mission needs and the ability to respond to a wide range of operational requirements. In that regard, consideration should be given to the overall UxS data management enterprise and the establishment of interoperability standards.
- Successful implementation of the NOAA UxS Strategy is highly dependent on tight coordination with NOAA’s complementary Science and Technology Strategies. Bi-directional feedback between the NOAA UxS Strategy and the other strategies is essential. Regionally scaled UxS field campaigns will help to reveal such interdependencies and inform implementation plans for the other strategies. For example,
NOAA’s *Artificial Intelligence Strategy* progress could impact UxS control systems, and field test results will inform theory. Similarly, requirements of the NOAA *Data Strategy* must be considered when defining UxS requirements, and data collected by UxS are expected to form a significant portion of future data.

- Creating subprograms that compete for limited resources should be avoided. Identifying areas of shared need or redundancy can help prioritize research and development (R&D) and procurement funding.
- NOAA’s plurality of mission requirements, operational needs, and public service mandate can be used to drive UxS innovation in new directions, for example by fostering unique PPP.
- A coherent approach is needed to facilitate rapid development and integration of new technologies into an operational framework and drive a R&D process that links requirements to solutions. A concerted effort should be made to reduce the time it takes to get from research to operations, and metrics should be defined that serve to standardize key steps associated with that transition.
- A survey of ongoing UxS efforts and an understanding of the current state of the commercial and research markets will be beneficial. Focus should be placed on the win-win aspects of partnerships and creating value that can be shared. Industry requires a return on investment for directing its R&D priorities and NOAA offers a potential market worthy of industry engagement; a cooperative working relationship in relation to R&D can serve both groups well and provide a catalyst for further academic and nonprofit engagement.
- Consider a paradigm shift from “Research to Operations” to “Research and Operations.” Research is essential to developing and enhancing operational capacity, while real world operations are necessary for guiding and prioritizing research. NOAA’s *UxS Strategy* creates a framework for nurturing this culture by bringing researchers and operators together in a process that addresses shared objectives based on mission goals.
- Promoting a culture of collaboration and shared vision is important for engaging potential partners and identifying priority areas. The National Academies of Sciences, Engineering, and Medicine produce *decadal surveys*, which may serve as models and roadmaps for the NOAA UxS community.
- Allowing for creativity and innovation in NOAA contracting practices can help stimulate technology innovation, particularly in relation to responding to new opportunities and engaging in “high risk, potentially high reward” activities.
- Primary schools, universities, community colleges, and government sponsored Centers of Excellence have a large role to play in developing a qualified and proficient UxS workforce. Students should be engaged throughout the educational pipeline.
- Hands-on experience is invaluable and provides a good perspective for students and future UxS operators to focus their education to make sure they understand the facets of the field. Offering robust internships where this kind of experience is available or partnering with organizations to offer such internships is good investment in developing a proficient and diverse workforce.
- A focus on proficiency rather than just education is required to develop the competency necessary for a robust UxS program within NOAA. Training classes, certification, end-to-end data collection exercises can help NOAA develop a proficient workforce. UxS technology will continually evolve, requiring continuing education to keep the workforce up to date.
- Workforce development will entail more than uncrewed systems operation and maintenance proficiency; training to ensure effective data curation and interpretation, and its use in informing decision making across a broad spectrum of NOAA mission areas, is also needed for successful implementation of the NOAA *UxS Strategy*.
- The ocean is under-observed, which limits the efficacy of ocean understanding, prediction and knowledge-based decision making. NOAA’s strategic application of UxS to both research and operations offer opportunities to develop a networked “ocean of the future,” unlike anything known previously,
and promote development of a sustainable Blue Economy. NOAA’s capacity to disseminate data and information from these systems will inspire inquiry and lead to more thoughtful, science-based decisions concerning future ocean management activities.

Key Questions

- **What strategy should NOAA pursue for effective UxS requirements definition related to procurement and operations?**
  - Requirements definition for platforms can be relatively easy to ascertain, but requirements for sensors and data can be much more challenging, especially for emergent capabilities. In some cases, it may not be possible to define requirements *a priori*; trial and error iteration, particularly in the context of PPPs, will be an important aspect of UxS requirements definition.
  - How will knowledgeable operators from commercial, private, and academic sectors be engaged to assist NOAA with developing requirements specifications and concepts of operation (ConOps)? NOAA must be an active participant in this process, not just a manager.

- **What is an appropriate balance between procuring and routinely operating an array of UxS versus contracting commercial operators for data-as-a-service?**
  - Cost-benefit analyses may be useful in addressing this question, each tailored to specific mission areas as well as national versus regional needs.
  - It is likely that implementation of the NOAA UxS Strategy will entail a mixed portfolio of owner-operator and contractual data-as-a-service initiatives. In that regard, consideration should be given to the overall UxS data management enterprise and interoperability standards.

- **How can NOAA leverage its network of Cooperative Institutes (CIs), as well as congressionally mandated research and development models such as the National Oceanographic Partnership Program (NOPP) and the United States Global Climate Change Research Program (USGCRP), to promote active engagement with local and regional communities to assist with implementing the NOAA UxS Strategy and take on the risks inherent in any cutting edge, multidisciplinary endeavor?**
  - CIs can provide a “shovel ready” mechanism to rapidly respond to new opportunities and changing priorities for launching regional scale exercises, promoting PPPs, testing new technologies, developing ConOps, and providing training and educational outreach.
  - Mature CI relationships with local and regional communities enable tight communication and feedback loops with local organizations of all sizes to accelerate progress, support entrepreneurs, and strengthen communities of practice.
  - Interagency programs such as NOPP and USGCRP are ideally suited to advancing PPPs in service to UxS development and implementation. What are the cross-cutting opportunities that can galvanize interagency priority alignment and engage a diverse group broadly representative of industry, academia, and non-profit participants?

- **What suite of contractual mechanisms are needed to ensure effective UxS utilization, flexibility, and agility? These mechanisms could include, but are not limited to:**
  - Special purpose Cooperative R&D Agreements (CRADA)
  - Other Transaction Authorities (OTA)
  - Small Business Innovation Research (SBIR) programs
  - Indefinite Delivery, Indefinite Quantity (IDIQ) contracts with task orders, including existing mechanisms, such as those used by the Department of Defense
  - Establishing new CIs
INTRODUCTION

The Consortium for Ocean Leadership (COL), in partnership with the National Oceanic and Atmospheric Administration (NOAA), hosted the Workshop to Support Implementation of NOAA’s Unmanned Systems (UxS) Strategy on August 4-6, 2020. While originally envisioned as a traditional in-person workshop, it was held virtually due to the ongoing COVID-19 pandemic.

NOAA recently finalized a suite of strategies focused on emerging science and technology areas to guide transformative advancements in NOAA science, products, and services: Unmanned Systems, Artificial Intelligence, ‘Omnics, Data, and Cloud. An additional strategy on Citizen Science is currently being finalized. The five existing strategies are interdependent and complimentary; integration across the strategies is critical for the success of each within NOAA.

Released in February 2020, the NOAA UxS Strategy outlines a framework to provide UxS services across NOAA and describes the direction NOAA plans to take in regards to UxS. NOAA is currently drafting an internal implementation plan with detailed actions and milestones to identify what will be done, when, and how. The NOAA UxS Implementation Plan writing team intends to publish the plan in Fall 2020.

The workshop Executive Committee, along with COL staff, structured the program to enable community partners and stakeholders an opportunity to provide recommendations for the implementation of NOAA’s UxS Strategy. Five key focus areas where external community input can best assist NOAA in becoming the national and global leader in UxS operations that support science, public safety, and security were considered:

- Requirements Development
- Research to Operations
- Partnerships
- Developing a Proficient Workforce
- Building a Community of Practice

In order to create a robust conversation in a virtual workshop format, the agenda included a blend of speakers, panels, and breakout sessions. Additionally, in order to solicit written feedback during and following the workshop, participants were asked to submit input via a customized Google Form. All Google Form comments received during and immediately following the workshop have been provided to NOAA, and several excerpts are highlighted as callout boxes at appropriate places throughout this report. The workshop agenda and the Google Form are included as Appendix A and B, respectively.

Workshop participants were selected based on expertise and experience with marine and aerial UxS development and operations, as well as to ensure balanced representation across government, nonprofit, industry, and academic organizations. The workshop included over 120 attendees, including many members of the NOAA Implementation Plan writing team who participated as observers. The workshop participant list is included in Appendix C.
Throughout the workshop, strong recommendations related to diversity, equity and inclusion were voiced; more information on this aspect of the discussions can be found on page 20 of this report and we ask NOAA to strongly consider these recommendations. As highlighted in the Executive Summary, the term UxS is now interpreted as Uncrewed Systems throughout this report given NOAA’s corresponding intent. One workshop participant eloquently justified this change:

Language is important. The use of gendered or discriminatory language can exclude groups that are extremely important for the continued evolution of UxS programs. Emphasis should be placed on creating a community of practice that is welcoming and inclusive.

This workshop summary report is a collection of considerations that the Executive Committee and the COL team consider to be the salient points from the workshop discussions but is not all-encompassing. Workshop participants constituted a broad spectrum of representatives of organizations involved with UxS. As such, a wide variety of opinions were voiced. As stated in the Executive Summary, there was no attempt to reach consensus on specific recommendations and questions for follow on consideration. Nevertheless, COL, along with the Executive Committee, worked to capture the spirit of individual comments and group discussions with the intent of fairly representing the diversity of opinions offered as valuable input for the NOAA UxS Implementation Plan writing team. Due to the workshop’s virtual format, all sessions were recorded, and those recordings are available to NOAA as reference materials. This report, as well as accessible reference materials, is provided for use by NOAA’s Implementation Plan writing team and encompasses UxS for use in both marine and aerial environments.
The workshop began with a series of presentations by NOAA leadership to provide context and vision for the NOAA UxS Strategy. RDML Tim Gallaudet provided an overview of the five NOAA Science and Technology Strategies, followed by a presentation from Charles Alexander and John McDonough on the current status of the UxS Strategy Implementation Plan.

These opening remarks provided additional context for the workshop participants. The recent rapid expansion in availability of UxS, fueled in part by NOAA scientists and discoveries, has brought a corresponding increase in their innovative use as a force multiplier for many NOAA programs, augmenting data collection often at lower cost, increased safety, and reduced risk, especially in remote or extreme environments. Examples include hydrographic and habitat mapping, ocean exploration, marine mammal and fishery stock assessments, emergency response, and at-sea observations that improve forecasting of extreme events, such as storms, harmful algal blooms, and hypoxia. This success highlights an opportunity to dramatically expand the collection and utilization of critical, high accuracy, and time-sensitive data by increasing the application and use of uncrewed aircraft and marine systems in every NOAA mission area. This will allow NOAA to improve the quality and timeliness of NOAA science, data products, and services.

Participants then heard three brief complementary presentations from Bill Michaels on the NOAA Artificial Intelligence Strategy, Cisco Werner on the NOAA ‘Omnics Strategy, and Kim Valentine on the NOAA Data Strategy and NOAA Cloud Strategy. Collectively, the opening presentations provided background on the five existing strategies, as well as perspective on their interrelatedness and integration.
REQUIREMENTS DEVELOPMENT

Building upon the opening presentations on the NOAA strategies, the Requirements Development panel focused on the following encapsulating question: How will NOAA evolve its requirements development processes to incorporate the NOAA UxS strategy and leverage partnerships with external sectors? The panel was moderated by Chris Scholin (MBARI) and included four panelists: CAPT Pete Small (U.S. Navy), Larry Karl (L3Harris), Paul Siegrist (Boeing), and Guy Noll (Esri). A summary of that discussion, including participant questions and responses, follows:

**Approaches for Defining UxS Requirements**

- As a first step, the operational and data requirements for a given mission should be considered, and the rational for using UxS to accomplish that mission clearly articulated. UxS offer many advantages, but effective alternatives cannot be ruled out if UxS capabilities are not clearly defined and quantified to the extent possible.

- There are many different models for determining system specifications, each with its own benefits and limitations. For example, a domain-based approach offers granularity that can accommodate nuances associated with meeting specific mission-based needs, whereas a centralized approach provides an enterprise level perspective across many mission areas. In each case, being an UxS owner-operator versus contracting data-as-a-service should be considered. The type of model that NOAA adopts should be the one that best fits its mission needs and ability to respond to a wide range of operational requirements.

  - **Domain-based approach:** This model allows for smaller groups with coherent areas of expertise that are more unified in mission needs (e.g., undersea, surface, atmospheric, fisheries, hydrologic) to set priorities. This can enhance customer buy-in, as well as create opportunities for more rapid adoption of new and specialized technologies. However, it can also result in many disparate and detached approaches at the organizational enterprise level, which is difficult to explain to stakeholders and makes centralized command and control decision making more complex.

  - **Centralized approach:** This model is a more holistic approach focused on finding unities of effort across different mission domains. A centralized approach supports the implementation of an overarching, integrated plan which can enhance efficiency and is easy to explain to stakeholders. However, it runs the risk of being overly general and suboptimal in areas that require specific expertise or attention to specific needs. Furthermore, it can disenfranchise domain-based operators, and it requires authority above the level of domain-based stakeholders to acquire and allocate resources for projects, and to set priorities.

  - **Owner-operator vs. data-as-a-service:** The appropriate balance between UxS ownership and data-as-a-service paradigms must be determined. There is a great deal of UxS technology that is commercially available, ready, and reliable; deploying such systems at-scale could be achieved relatively quickly. Nevertheless, the current market and acquisition process tends toward being platform-centric. Some of NOAA’s needs may require variants of existing UxS, or even novel systems not yet commercially available. NOAA has an opportunity to think beyond owning and operating only existing platforms and consider options for realizing capabilities specific to NOAA’s mission. How can existing systems be adapted for other uses, and what sensing modalities are required on such systems to meet NOAA-specific mission needs? Fostering Public Private Partnerships (PPP) is one means of addressing this important question.
Requirements Development Process

- A framework for organizational learning within NOAA that establishes a requirements development process would be beneficial. If adopted, panel participants suggested that the framework should be accessible and usable by all offices within NOAA, to standardize the requirements definition process for all groups that work with UxS.
- An effort should be made to require industry contract standardization to ensure interoperability and improve efficiency. Standardization should be implemented across many domains, such as source code, mission planning, command and control, situational awareness, and concepts of operations (ConOps).
- The requirements writing process differs for platforms and data. Platform requirements are relatively easy to demonstrate and test, since capability can be quantified by the efficacy and number of operational platforms. However, such requirements are often biased towards organizations capable of outputting a large quantity of standardized platforms in a short time, which may not meet small-scale regional needs. Defining data (or mission) requirements are of fundamental importance but are more difficult to write de novo and successfully demonstrate; arriving at data/mission requirements often requires an iterative trial and error process, especially when working with new technologies that offer novel sensing capabilities.

Many of the UxS are emerging technologies. It is essential to develop the requirements and recommendations to ensure data collected by these systems are of high quality and fit-for-purpose for NOAA missions.

- Sustained two-way feedback between the NOAA UxS Implementation Plan writing team and other NOAA Science and Technology teams is essential for success. Close collaboration with the Data Strategy team is particularly critical to ensure UxS collect data in an effective manner consistent with both strategies.
- ConOps are integral to the development of large-scale requirement specifications. In this regard, it is imperative that knowledgeable field operators from industry, as well as the private and academic sectors be involved as appropriate in ConOps development. NOAA personnel can play an active role in ConOps definition by facilitating an iterative series of repeated field exercises. System operator feedbacks should be sought throughout this process; ideally systems should be user-friendly to the maximum extent possible, and their operational limits understood. Life cycle considerations (design, build, operation, maintenance/repair, training, logistics, upgrade) are essential for an effective and efficient NOAA UxS program.
- Customers can sometimes push requirements definition into extremes that make development particularly costly and/or time consuming. By ensuring teams are comprised of a balance of people who understand the technology and its limits, as well as people who understand the data that is needed, such pitfalls can be avoided. Customers and providers must compromise between requirements and cost and set realistic expectations; technology readiness level acceptance tests can serve as go/no-go gates for guiding procurements and research and development (R&D) investments.
- In addition to defining system operational needs, requirements and/or standards for the training of UxS operators should be established. This is particularly important when procuring UxS under the owner-operator model.
Operational Testing

- Getting prototype UxS into the field and tested should be a priority. Real-world testing experience and actual data products are necessary in order to discover what is and is not ready for routine operations, and to reveal the gaps in emergent technology that can help direct warranted R&D efforts. When a system does meet key requirements, even if may not be considered optimal, it should be delivered and pressed into an operational environment. It is important to know when potential incremental system improvements should be deferred for a later time in order to avoid a continual R&D cycle that yields little new real-world operational capacity.

- A feedback loop between prototype testing and requirements development should be formalized. The results of prototyping testing should feed back into the requirements definition in an iterative and directed process; failures can serve as engine of innovation. This mode, when managed properly, can quickly yield mature systems and operational expertise. However, this can also be difficult to implement if the resources for testing and experimentation are not available before detailed requirements and ConOps are codified.

- It is important to build a limited number of systems and test them thoroughly before building more. Building many copies of a system that requires extensive testing limits resources for further design iterations and system refinement based on real world operational experience. UxS should be tested extensively in the environments and under the conditions that they are expected to operate in routinely by those who will be charged with carrying out operations.

Partnerships and Collaboration

- Implementing the NOAA UxS Strategy will require close coordination with the other NOAA Strategies. Creating subprograms that compete for limited resources should be avoided. Identifying areas of shared need or redundancy can help prioritize R&D funding.

- A survey of ongoing UxS efforts and an understanding of the current state of the commercial and research markets will be beneficial. Focus should be placed on the win-win aspects of partnerships and creating value that can be shared. Industry requires a return on investment for directing its R&D priorities and NOAA offers a potential market worthy of industry engagement; a cooperative working relationship in relation to R&D can serve both groups well and provide a catalyst for further academic and nonprofit engagement.

- Commissioning a targeted series of regionally focused white papers that are co-authored by agency, industry, and research representatives as a means of assessing the state of UxS operations relative to different mission areas would be valuable. Such an effort will help identify interagency overlaps and provide insights into how different regional clusters of agency, industry, and research groups collaborate.

- Engage external technology communities when developing system requirements. Proprietary or disparate data formats dictated by different groups of providers can make enterprise level interoperability and collaboration difficult and system maintenance less efficient, all of which make gaining working knowledge of UxS across a broad mission space more challenging.

- NOAA should consider asking for outside assistance on developing requirements for guiding UxS procurements and standardizations.
RESEARCH TO OPERATIONS

CAPT Phil Hall started the second day of the workshop with a presentation focused on the NOAA Unmanned Aircraft Systems program and its progression from R&D to operations, as well as its current transition to the Office of Research Transitions and Applications. The office provides support across NOAA and works to accelerate research to operations through research contracts and partnerships. CAPT Hall’s presentation provided an excellent starting point for a panel later in the day.

The Research to Operations panel focused on the following encapsulating question: What are the NOAA-supported research to operations opportunities and processes for effective/timely meeting of future needs and requirements? The panel was moderated by Monty Graham (USM) and included five panelists: Andy Bowen (WHOI), David Lang (SoFar Ocean), Eric Lindstrom (Saildrone), Parimal (PK) Kopardekar (NASA), and Brain McKeon (Huntington Ingalls). A summary of the discussion, including participant questions and responses, follows.
Developing a Business Model

- With the current state of manufacturing, a paradigm exists where any product can be manufactured quickly and sent anywhere in the world. Consideration should be given as to how this paradigm plays into choosing between the owner-operator and data-as-a-service UxS models.

- NOAA’s UxS Strategy offers some unique strengths and opportunities. It is an organization with widely varying mission requirements from ocean to atmosphere, all of which are driven by an overarching public service mission. That operational profile differs significantly compared to most other organizations that use UxS, including other agencies with much larger work forces and budgets. NOAA’s plurality of mission requirements, operational needs, and public service mandate can be used to drive innovation in novel directions, for example by fostering unique PPP, despite representing a relatively small market value by large industry standards.

Build on Existing Ideas and Infrastructure

- The aerospace industry has a large collaborative infrastructure system for managing UxS traffic and sharing the location of UxS. Organizations will often pay third-party groups to oversee traffic management so that they can focus on data collection and analysis. A similar model for large-scale infrastructure and industry collaboration may be effective for NOAA as its UxS program scales up.

- UxS facilities and test beds are widely available — almost anything NOAA needs in this area probably already exists. NOAA has an opportunity to utilize these existing capabilities and focus its efforts and resources on testing and evaluating UxS for specific mission applications, rather than developing dedicated infrastructure and facilities.

- NOAA’s existing portfolio of partnerships, especially on the research end of research to operations, are a valuable asset. Building on existing partnerships to amplify cooperative opportunities, as well as establishing new partnerships, is one means of rapidly implementing the NOAA UxS Strategy.

Transitioning from Research to Operations

- The speed of innovation is increasing — as soon as one technology is completed, a new one is on its way to maturation. A coherent approach is needed to facilitate rapid development and integration of new technologies into an operational framework drive an R&D process that links requirements to mission solutions. A concerted effort should be made to reduce the time it takes to get from research to operations, and metrics should be defined that serve to standardize key steps associated with that transition.

- Models that help guide the rapid integration of new research and technologies into operations are needed to effectively shape and prioritize early in development efforts. For example, the Spiral Development process, originally developed for software creation, is one concept that is well suited for guiding rapid UxS research to operations programs.

- This allows for an earlier start to data collection and a more intimate understanding of the internal system workings as the product and service it provides evolves and matures via an iterative cycle of “develop-test-improve.”

- UxS testing and evaluation should encompass programmatic and facility perspectives in addition to specific platforms and sensors. A holistic, systematic approach is needed for determining the value of new technology in order to understand and evaluate an expected return on investment.

- Consider the paradigm of “Research and Operations” instead of “Research to Operations.” Research is essential to developing and enhancing operational capacity, while real world operations are necessary for guiding and prioritizing research. NOAA’s UxS Strategy creates a framework for nurturing this culture by bringing researchers and operators together in a process that fundamentally addresses shared objectives and goals.
There are a number of steps that can be taken to scale up the use of UxS. Increasing research capacity at operational service centers and creating inter-regional collaborative webs are a couple of good examples. With that in mind, an effort should be made to ensure an UxS observing capability can exist for at least a decade.

“On the horizon” scientific breakthroughs offer tantalizing opportunities for what may be possible in the future, but such research priorities should not drive resource allocation to the extent that deploying operational systems that meet current needs is compromised. A portfolio of PPP, with broad agency, industry, academic and nonprofit representation, offer one means of striking that balance.

Research to Operations Partnerships

- A venue for dialogue and idea exchange is vital for fostering collaborations. Creating a portfolio of commercial and private partnerships that regularly interact with each other will facilitate communication and help reveal common challenges and solutions.
- NASA is innovative with contracting mechanisms to promote cooperation between industry and government entities. Using contracts as a model for buying data allows NASA to interact with and get input from smaller companies. NASA's Frontier Development Lab is near much of the venture capital and talent base due to its location in Silicon Valley, and its collaboration with companies like Google makes it a hotbed for innovation. NASA's partnering with industry to develop private sector transportation to the International Space Station (transportation as a service) may provide lessons learned for NOAA's UxS owner-operator versus contracting data-as-a-service model implementation.
- Promoting a culture of collaboration and shared vision is important. Organizations whose members are overly protective of their work precludes collaboration and reduces the efficiency of the development process.
- There are many ways to foster partnerships. Contracts and prize competitions are especially important for spurring collaborative and innovative efforts. Technology demonstrations, hackathons, and template agreements can also play a role. Industry wants to help, and NOAA's active engagement will be welcomed if a win-win vision is offered.

Thoughts on NOAA Transition Office

- NOAA should consider forming a partnership office rather than a transition office. Such an office could be dedicated to nurturing projects through the research to operations process rather than a transitional hand-off program. The Defense Innovation Unit Experimental (DIUx) model might provide a template for this concept.
- An innovation pipeline is needed, where technology developments based on agency needs are guided from inception to use with appropriate training and feedback loops to direct that process. Models of innovation pipelines can be found at partner agencies, such as the Office of Naval Research and DOE.

PARTNERSHIPS

Setting the stage for later breakout discussions on partnerships, Gerhard Kuska, executive director of the Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS) and vice-chair of the U.S. Integrated Ocean Observing System (IOOS) Association, gave a presentation describing the IOOS Association and its 11 regional partnerships. Established in 2009, the IOOS Association exemplifies successful partnership building within the ocean domain, promoting partnership across different sectors and drawing upon the strengths of each. The federal stewardship of IOOS is within NOAA's National Ocean Service and includes 17 federal agency partners. The 11 regional partnerships are operated through 5-year cooperative agreements with NOAA IOOS, with the IOOS Association serving as a nonprofit, nonfederal umbrella organization.
Development of some UxS has been achieved with a combination of funding from NOAA and the Navy; however, PIs on either side were not aware of the other's interests. Increased effort is needed to ensure that individual PIs are aware and encouraged to collaborate! A vision statement is fantastic, however that needs to be communicated to the individual PIs.

Gerhard Kuska illustrated the demonstrated success and experience of the IOOS Association, making the case that the regional IOOS construct could serve as a model for implementation of the NOAA UxS Strategy. Key points of his presentation include the following:

- Federal certification of network members ensures national consistency while addressing unique and diverse regional needs.
- Development and support of the IOOS User Group promotes a community of practice, while also identifying opportunities for partnership in expanding educational and training opportunities.
- IOOS includes a variety of partnership types to address diverse stakeholder needs and align with NOAA's overarching mission.

An example of technology leadership by the IOOS Association is found in its glider efforts, which include bringing the broader community (government, private sector, and academia) together through a variety of partnerships to share glider expertise and promote improvements to the technology and its applications. The IOOS Glider Data Assembly Center integrates and disseminates nonfederal data, providing access and standards certification to glider data to address stakeholder needs. A specific example of the adaptability of the IOOS Association and its regional partnerships is how IOOS, NOAA, and the U.S. Navy work together using gliders to improve ocean models and hurricane intensity forecasting.

This discussion of Partnerships was continued later in the day during five concurrent breakout sessions. The question posed to workshop participants was:

How can NOAA foster partnerships between and among agency, industry, academe, and philanthropy to meet the requirements of NOAA and entrepreneurial spirit of the U.S. STEM industry?

A distillation of the key discussion points from all five groups follows.

**Find Common Ground**

- Focus on science questions and priority areas to clearly articulate mission areas and gaps as a mechanism to engage potential partners. The National Academies of Sciences, Engineering, and Medicine produce decadal surveys, which may serve as models and roadmaps for the UxS community.
- NOAA and its partners should work together to identify common requirements and objectives that meet NOAA’s mission needs, at all scales.
- In order to leverage and amplify opportunities amongst NOAA’s partners, as well as improve technology via positive feedback loops, transparency is needed between existing partners, such as by disclosing recently signed Memoranda of Agreements.
Leadership and program managers should adapt a culture of commitment to partners and longer-term synergistic activities, as well as championing existing and emergent technologies that will advance NOAA’s mission.

Building trust on all sides is essential for promoting successful partnerships. As mentioned in the previous section, developing a collaborative culture and approaches for technology development facilitation, not hand-off, is critical.

Leverage NOAA’s Sense of Purpose

- Recognizing that NOAA’s budget is not as large as many government agencies with UxS interests, NOAA’s broader benefit to society nevertheless offers an attractive proposition to partners which can help mitigate potential aversion by industry due to budgetary limitations.
- NOAA can be a leader for other agencies by exploring the UxS data-as-a-service model.
- NOAA and its partners can work together towards common goals that are beneficial to all parties; targeted experiments and field exercises offer one means of engendering a sense of shared purpose.

Incentivize NOAA and Private Industry

- A variety of formal agreements, for both multi-year grants/contracts and short-term partnerships, can be utilized to ensure flexibility and agility. These mechanisms could include, but are not limited to:
  - Special purpose Cooperative R&D Agreements (CRADA)
  - Other Transaction Authorities (OTA)
  - Small Business Innovation Research (SBIR) programs
  - Indefinite Delivery, Indefinite Quantity (IDIQ) contracts with task orders, including existing mechanisms, such as those used by the Department of Defense
  - Existing and new CIs
- To help build long-term and stable partnerships, it is essential that NOAA project funding is available across fiscal years and therefore not subject to continuing resolutions, changes in administration, and other potential challenges in the federal appropriations process.
- NOAA can help create near-term, nonmonetary rewards with and for partners, such as press releases and promotional videos that businesses can use for marketing and public outreach purposes (and vice versa).
- NOAA should strive to engage the interests of large industry firms. In addition to bringing extensive experience and capability in UxS development and operations, engaging such companies will encourage them to invest their own internal R&D funds to advance the state of UxS technology and operations. Firms demand a return on investment in order to invest their R&D capital. Such a return requires multi-year contract commitments by NOAA to evidence sustained, viable, long-term partnership opportunities.
Foster Creativity and Innovation

- Encourage program managers to focus on partnerships and give them the latitude to allow for competition to drive innovation. Providing incubation funding can stimulate technology R&D.
- Opportunities for expanding an initial scope of partnership should be encouraged.
- NOAA can think of data as currency, of which they have much and which is enticing to potential and existing partners; data can be captured as an asset and made easily accessible.
- An opportunity to drive creativity and innovation in multiple sectors exists by increasing mobility between NOAA, academia, nonprofits, and industry. This would also help address some aspects of workforce development.
- Allowing for creativity and innovation in NOAA contracting practices can help stimulate technology innovation, particularly in relation to “high risk, high reward” innovations.

Reduce Barriers

- Different circumstances and needs will dictate either a build, buy, or partner strategy; a standardized process for determining the appropriate fit to meet specific needs or requirements is important.
- Work to synergize across agencies and line offices to identify projects of mutual interest, align timelines, and mitigate contractual and regulatory impediments. This could be accomplished through programs such as the National Oceanographic Partnership Program and the United States Global Climate Change Research Program.
- Create a coordination entity for fostering UxS partnerships across NOAA line offices, to assist NOAA in meeting mission requirements and identify appropriate contacts within NOAA for internal and external partnership networking.
- Clearly articulate data requirements and adopt data standards to ensure streamlined data curation, management, and application.
- There is a need for pivotal gap funding to fill the void between R&D, specifically late-stage prototype refinements, and routine operations.
- Encourage CIs to work with local industries; CIs can use their flexibility to rapidly kick start new partnerships and respond to new opportunities.
DEVELOPING A PROFICIENT WORKFORCE

The workshop discussions for Developing a Proficient Workforce began with remarks by William (Bill) Burnett, technical director for the Naval Meteorology and Oceanography Command. His presentation provided context for this topic by describing the organizational systems that have worked with 20 different UxS vehicles over the course of 20 years, to achieve cumulative operational miles equivalent to 20 times the Earth’s circumference.

Bill Burnett emphasized that all facets of UxS missions stem from the mission planning element. All other decisions regarding personnel and training extend from the mission requirements, including testing and training, command and control, deployment and recovery, repair and storage, and data utilization.

Trained operators are essential, as every one of these steps noted above require skilled personnel. If operators don’t understand the environment they are working in, the equipment will almost certainly be lost. This includes understanding bathymetry and bottom hazards, surface and subsurface currents, human-made debris in the operational area, freshwater pockets that may affect vehicle performance, etc., or aspects of local weather and terrain that may impact aerial operations. Operators must also understand how data is used to inform decision making.
In the Naval Oceanography program, all equipment testing is performed during field operations and almost all training is on the job. However, a six-week certification program in partnership with the University of Southern Mississippi is now in place where operators are trained in the basics of UxS operations before being hired. Through the Commercial Engagement Through Ocean Technology (CENOTE) Act of 2018, Naval Oceanography has also partnered with other agencies, including NOAA, to test new equipment in low-risk environments in the Gulf of Mexico. This has led to greater interagency cooperation and the sharing of best practices. This is one living example of how training the next workforce generation can be achieved through partnerships.

This discussion of Developing a Proficient Workforce was continued later in the day during five concurrent breakout sessions. The questions posed to workshop participants were:

What are the generic and specific proficiencies of a diverse and proficient workforce? How do NOAA and partners define and promote an educational and workforce development pipeline so that there is a constant supply of scientists, engineers, and operators available to both the private and public sectors?

A distillation of the key discussion points from all five groups is included below. These discussions focused primarily on training operators specifically within the context of the UxS community and not necessarily related fields such as computer science, engineering, and marine sciences.

**Education**

- Universities and community colleges have a large role to play in developing a qualified workforce. There is a need to keep students engaged throughout the educational pipeline, from undergraduate to Ph.D. programs.
- Federal agencies are already partnering with academic institutions to develop a qualified workforce. Colleges are starting to offer degrees in UxS, and NOAA can capitalize on this opportunity. Engaging in these programs can help recruit scientists, engineers, and operators from the same (or related) academic programs.
- NOAA-supported CIs have tremendous value in promoting partnerships among academic institutions, nonprofits, industry, and regional groups. These programs provide unique opportunities for attracting a diverse group of students to pursue education and careers in UxS.
- The FAA Unmanned Aircraft Centers of Excellence are located at more than 50 colleges and universities geographically distributed across the U.S. These Centers are ideally suited to recruiting individuals trained in operating uncrewed aircraft. If funded, the proposed NSF Center for Precision Meteorology will create an opportunity for cooperation and synergy in the use of aerial systems for meteorological measurements.
- Hands-on experience is invaluable and provides a good perspective for students and future UxS operators to focus their education and make sure they understand the facets of the field. Offering robust internships where this kind of experience is available, or partnering with organizations to offer
such internships, is a good investment in developing a proficient and diverse workforce. NOAA’s Pacific Marine Environmental Laboratory and the Joint Institute for Marine and Atmospheric Research’s summer internship program to utilize Advanced Surface Vehicle data provides a good example of this; while the program supports only 10 interns, over 100 applications were received, illustrating the keen interest in these types of opportunities.

- Lack of business knowledge is prevalent in the UxS field. Scientists and engineers aren’t necessarily receiving business training as part of their technical training. A successful start-up community is imperative for NOAA future developments. NOAA-supported business education and mentorship opportunities could play an important role in promoting this element of UxS workforce development.

- The UxS industry needs project managers with the skills to manage diverse teams, including contractors, plus address financial/budgeting and schedule issues, as well as challenges associated with permitting, regulatory issues, etc. These are not science or engineering roles, but still critical to this field; UxS project management education is needed.

**Training Certifications**

- A focus on proficiency rather than just education is required to develop the competency necessary for a robust UxS program within NOAA. Training classes, certification, end-to-end data collection exercises, and job rotation with the industry, can help NOAA develop a proficient workforce. These technical jobs are not exclusively science or research oriented, and a Ph.D. is not necessarily required; potential workforce recruits should be aware that there are a multitude of other avenues for playing an important role in the UxS community.

- The UxS industry needs standard requirements for certifications. Different agencies currently have different requirements, and these standards often change within an agency from year to year. Standardized training certificates can reduce on the job training time and reduce costs for the entire industry. Students should emerge from these programs ready to actively contribute to field operations. Working with other organizations to institute such standards will be beneficial.

- Service contractors should have to pass proficiency standards, but these should be centralized. Commercial operators for NOAA, NASA, DOE, etc., spend a considerable amount of time certifying aircraft and operators, and re-certifying as the process and metrics change. Ideally, at least for aircraft, this can be centralized through NOAA’s coordination on certification, possibly with the FAA.

- Training programs should be developed based on specific job roles that students should be able to fill once the program is completed. A systems perspective is important in this regard; more jobs/needs exist beyond that of an operator. What training is needed to fill those positions within the UxS field as a whole, and what programs of other agencies can be leveraged to meet matched needs?

- UxS technology will continually evolve, requiring continuing education to keep the workforce up to date.

- Training of UxS operators should include associated life skills, such as how to:
  - Mentor and train others
  - Practice good judgement
  - Mitigate risk
  - Create and update proper documentation
  - Manage teams effectively
  - Communicate

- Partner with and support professional societies to offer add-on training modules to cover material that formal training may not, particularly in relation to meeting NOAA’s specific needs.
Cross Training

- Support a high level of interaction between UxS operators and research scientists. Operators would benefit from an understanding of the kind of data scientists are trying to collect and why they are trying to collect it. Likewise, scientists would benefit from understanding the capabilities and limitations of the platforms and instruments that operators deploy and maintain. Understanding how instruments work from both engineering and science perspectives will yield the most useful data.

- Successful field operations of early stage UxS requires expertise in multiple fields, including computer science, IT, mechanical systems, electronic systems, operations and safety, collision avoidance regulations, etc. It may be impossible to find one person with all these skills, but NOAA can cross-train small teams to maximize operational safety and efficiency.

- Support rotational training programs between industry, government, and academia. This would provide NOAA staff with additional experience and perspectives to understand the needs of private companies and universities.

Operations

- As UxS programs and their operations become more standardized and robust, the required expertise in the field is reduced. Investing in ways to reduce operational overhead associated with field operations as they mature is worthwhile.

- Examine which technical capabilities can be outsourced and which should be kept in-house. Consider the feasibility of training NOAA scientists to use new technologies while they are also doing their other daily tasks. Retaining only as much operations/engineering support in-house as is necessary will allow for a larger focus on the science and data products associated with UxS. This is proven to be a cost effective strategy, and one that is also compatible with companies that employ the data-as-a-service business model.

Youth and Early Career Engagement

- UxS offers many ways to attract young talent and prepare them for careers in the field. This should start at the K-12 grade level to cultivate passion for science and technology. Junior high and high school students should be exposed to UxS technology and associated career opportunities, so they consider moving towards this industry. Attempting to do this at the college level might be too late, though NOAA can certainly make an impact at career fairs. There should be emphasis on the many career pathways into the UxS field — as scientists, engineers, and operators.

- Hands-on involvement with technology is an effective way to capture the interest and attention of students. Extensively utilizing telepresence from the field has also proven to be effective in generating excitement. Augmented and virtual reality experiences are a new way to engage a broad audience. The more that school-aged future scientists and engineers are involved in hands-on experiences, the more the community will grow. Consider these effective ways to engage the future workforce, including by offering immersive internships.

- Harness the passions of a young workforce. This includes more outreach to educate young students about NOAA's mission, especially as it relates to stewardship of the planet. Merging robotics with environment and sustainability issues is one way to get young people engaged; students interested in working with NOAA will at least be partially drawn by this idealism. Make it clear in NOAA’s messaging how they can have an impact; maintaining interest is difficult when other career paths provide more clarity on such matters or offer more lucrative salaries.

- Private industry groups have found that an ability to pay off student debt can provide a strong incentive in hiring young talent.
**Diversity, Equity, and Inclusion (DEI)**

- Workforce recruiting efforts should include a dedicated and clearly defined push towards diversity, equity, and inclusion. Since the pool of candidates from underrepresented groups is relatively small at this time, this task must be enthusiastically embraced. The UxS community needs leaders who are enthusiastic about adopting a diverse workforce and who will work hard to draw them into the UxS field by the means noted earlier.

- Consider institutionalizing support for different marginalized communities (e.g., women and people of color) who would benefit from dedicated, intentional DEI efforts. Mentoring programs are essential for fostering success.

- Private companies, the military, and NOAA often partner with schools and colleges that have diversity requirements and initiatives. These schools can be part of the solution in meeting diversity goals and in offering young people job opportunities following educational programs.

- Advancing and maturing UxS applications provide a significant opportunity to improve DEI. Since field work is critical for many scientists’ career advancement, UxS and telepresence can significantly improve DEI by enabling career advancement for people who are unable to go into the field for physical or personal reasons.

**Workforce Retention**

- Embrace the career pipeline, from attraction, to retention, to growth. Understand that recruitment is not as difficult as retention. Show potential talent that this field offers security, stability, and growth opportunities to encourage retention.

- The UxS industry faces strong competition for employees from other technology industries from both salary and innovation excitement standpoints. Opportunities for career advancement and pay scales are important incentives particularly for graduates in technology industries. NOAA may have challenges competing with industry, but it can offer a public service component that for-profit industry and academia may not.

- Younger generations move around in their careers more frequently than in the past, and employers need to be aware of and prepare for this. Constantly training individuals only to have them leave for new opportunities is a challenge, which speaks to the need to prioritize and incentivize retention.

- Designing, building, and testing UxS technology is exciting, while routinely operating the same systems in the field can quickly become repetitive and dull, resulting in employee turnover. Opportunities for continuous growth and advancement for operators should be highlighted.

- The requirement to work away from home for long periods of time in support of UxS operations is a challenge in retaining a workforce. Hiring former military operators who are used to working away from home improves the chances of retaining such employees.

- It is important to understand that some individuals want to innovate, and some want to dedicate themselves to a specific mission. Attempt to recognize individual motivations and how they fit within the overall system workforce model.

- Institute a program to help qualified UxS operators move into leadership roles. The John A. Knauss Marine Policy Fellowship Program create marine leaders in government; similar efforts are needed in the UxS field.

- There is a need to recruit mid- and senior-level personnel, not just entry-level. It is possible to hire retired individuals from companies like Google, who are interested in taking on new and challenging problems.
BUILDING A COMMUNITY OF PRACTICE

To help frame a panel discussion on building a community of practice, Craig Woolcott from the Department of Commerce presented his thoughts on legal, regulatory, and doctrinal considerations and constraints for UxS at NOAA. He reviewed primary legislative drivers for NOAA’s UxS community of practice, such as the Weather Research and Forecasting Innovation and CENOTE Acts; and international policy principles, such as the 1982 Law of the Sea Convention, International Regulations for Preventing Collisions at Sea, and Admiralty and General Maritime Law. Craig Woolcott encouraged consideration of nontraditional partnerships, such as the potential role of ocean and technology drivers, the finance sector, charitable trust and philanthropic organizations, and the offshore alternative energy sector.

The Building a Community of Practice panel focused on the following encapsulating question: What UxS lessons can NOAA learn from other communities and how can NOAA leverage their diverse models and frameworks? The panel was moderated by Bill Burnett (Navy) and included four panelists: Francisco Chavez (MBARI), Chelle Gentemann (Earth and Space Research), John Kreider (Kreider Consulting, formerly Oceaneering), and Jyotika Virmani (Schmidt Ocean Institute). A summary of the discussion follows, including participant questions and responses.

Data users, scientists, operators, modelers, the AI community, and more all work together to innovate on UxS programs. It is vital to develop a close working relationship between all aspects of the program, including the instrument developers, R&D, and operations. The development of a robust and efficient network of communication is necessary to support collaboration.

A community of practice is important because it creates an adaptive and resilient workforce. The pace of development is rapid and often difficult to adequately capture, and continuous learning and adaptation is necessary to keep up to date. Facilitating learning in the workforce is one of the most important aspects of a community of practice.

Ensure that a community of practice reflects and is aligned with organizational culture. What is the tolerance level for accepting risks? How agile is NOAA with contracting? This sort of introspection is important for building a consistent community of practice.

There is no perfect data. Releasing data with transparency about uncertainties can bring new ideas and new analyses that may give insights into what is going right or wrong. Sometimes efforts to build community can start with documenting where there is or isn’t a community of users and why. Transparency about data strengths and flaws can help establish trust and a community of early adopters to amplify science.

General Recommendations

- Data users, scientists, operators, modelers, the AI community, and more all work together to innovate on UxS programs. It is vital to develop a close working relationship between all aspects of the program, including the instrument developers, R&D, and operations. The development of a robust and efficient network of communication is necessary to support collaboration.

- A community of practice is important because it creates an adaptive and resilient workforce. The pace of development is rapid and often difficult to adequately capture, and continuous learning and adaptation is necessary to keep up to date. Facilitating learning in the workforce is one of the most important aspects of a community of practice.

- Ensure that a community of practice reflects and is aligned with organizational culture. What is the tolerance level for accepting risks? How agile is NOAA with contracting? This sort of introspection is important for building a consistent community of practice.

Breaking down barriers between multiple contractors may be helpful, as heavy divisions often create silos. For example, more collaboration during a competitive effort may yield two better and potentially collaborative solutions, instead of a single non-collaborative solution.
• Consider developing exchange programs where NOAA employees will be sent to train at other companies. This would allow for more versatile and skilled workers. It would also help motivate future collaboration, since both organizations would have a trusted point of contact.

• A systematic effort is necessary to evaluate the effectiveness of a community of practice. Looking to history for past examples of success is vital, but anecdotes are insufficient for determining the value of the community of practice.

• Pay attention to the speed and disruption of new technologies. Plan for the speed at which technology is evolving and adapt to new information to avoid being left behind. Procurement processes that take a year or more will not be sufficient.

• Create a framework for supporting innovation and exploration that allows NOAA to take the initiative in funding future technologies. Partners serve different purposes (i.e., philanthropy can take risks funding projects early in their development) and government, academia, nonprofits, and industry all play a part in encouraging innovation. The shorter the time allowed between new projects, the more incremental innovation will be. Develop multi-year funding models to support and encourage long-term innovation needed for breakthrough advancements.

• Different types of communities of practice exist. One type of community of practice is broad and engages everyone, while another is more focused and emphasizes learning best practices. Consider which of the two (or a combination) would be most helpful for fulfilling NOAA’s mission.

• Make contracting processes more efficient and agile. Move toward easier contracting with less oversight and fewer obstacles for approval. Educate industry groups (particularly start-ups) on the contract process and timing.

Inclusiveness

• Language is important. The use of gendered or discriminatory language can exclude groups that are extremely important for the continued evolution of UxS programs. Emphasis should be placed on creating a community of practice that is welcoming and inclusive.

• Innovation can happen in many different countries. Restricting competition prize pools and funding to one country inhibits innovation.

Public Engagement

• Consider or require openness of findings when assessing new projects. Open science enhances community acceptance and enthusiasm, as well as opens new doors for future collaboration. There are many models for mutually beneficial partnerships between researchers and providers in private industry.

• The tax-paying public is one of NOAA’s biggest partners. Telepresence allows people who can’t go to sea or the atmosphere to get actively involved. Broadcasted dives and flights garner community support. Promoting an understanding of how such operations make a tangible difference in the lives of Americans is beneficial.

• Expanding education and outreach programs is an effective means for reaching younger audiences who are considering their career paths. Robots are inherently interesting and engaging the public through demonstrations and social media brings kids to the table. Kids are also fascinated with the more mundane parts of operating UxS — what do you eat on a ship, what are the beds like, etc. — things that most experienced workers take for granted.
Open science can advance community acceptance. More access means more people trust, use, and build on results. As a funding agency, it is important to be aware of opportunities that exist to benefit not just NOAA, but global Earth system science and where ‘open’ can be applied to amplify the investment. Community change is most effective when it comes from the community itself, with support and amplification from leaders. As an agency, how you frame opportunities and how you set metrics for success can act to prioritize openness.

Data

- Having open access to data is key to its utility. Data centers and archives have yet to catch up to the ability of the instruments that take measurements, and free access can help to avoid undermining collection of data.
- Data are collected and interpreted in a variety of formats and wrangling disparate datasets into something cohesive can be extremely difficult. Data should be compiled with the goal of making it analysis ready so that is easily usable for anyone who might be interested in it. However, some caution needs to be taken with this, as the data format that is best for archives may not be the same data format that is best for science. Data science is currently undergoing an exponential change, and NOAA should consider closely monitoring this as it may be important in the implementation of NOAA’s UxS Strategy and its relatives.
IN CONCLUSION:

The Consortium for Ocean Leadership was honored to convene the marine and aerial UxS community in support of the implementation of NOAA’s UxS Strategy. This workshop was originally intended to be held in-person but shifted to a virtual model early in the planning process due to the COVID-19 pandemic. Hosting this event online allowed the opportunity to invite a larger list of participants than would have been included in an in-person workshop and resulted in very broad and robust feedback. There were many lessons and best practices learned that COL will incorporate when planning future virtually hosted workshops.

The recommendations included in this summary report are not consensus statements from the community, but a distillation of individual comments and group discussions shared throughout the three-day workshop. The community members who participated, from industry, agencies, and philanthropic organizations, were thoughtful, engaged, and stand ready to partner with NOAA to reach its goal of leading national and global UxS operations that support science, public safety, and security. Specific conclusions from the workshop dialogue and associated material are provided in the Executive Summary at the beginning of the report.

NOAA’s efforts to develop strategies and implementation plans in key mission support areas such as UxS are exemplary and should be adopted by other government agencies and organizations. Implementation plans such as these are essential to ensuring the success of strategic priorities through the consistent and codifiable application of fiscal and human resources and are key to the prioritization and advancement of new and evolving mission capabilities. Furthermore, broad UxS expertise and experience displayed at the workshop holds great promise for realizing a highly successful implementation plan that will set the standard for the rapid and continuing integration of new technologies to enhance NOAA’s mission success. COL strongly recommends that NOAA continue to engage the broader, private sector community (including commercial, academic, and philanthropic organizations) not just for its development of implementation plans, but for the crucial development and maintenance of partnerships across the larger ocean and atmospheric science and technology community.
Day One: 4 August, 2020

1:00pm  Welcome by RADM Jon White, President and CEO of Consortium for Ocean Leadership
1:15pm  Remarks on NOAA UxS Strategy by RDML Tim Gallaudet, NOAA
1:30pm  Remarks on NOAA UxS Implementation Plan by Charles Alexander & John McDonough, NOAA
1:45pm  Presentations on other NOAA Science and Technology Strategies
   • Bill Michaels, NOAA Artificial Intelligence Strategy
   • Cisco Werner, NOAA ‘Omics Strategy
   • Kim Valentine, NOAA Cloud Strategy & NOAA Data Strategy
2:25pm  Participant Q&A with Presenters
2:45pm  Break (15 minutes)
3:00pm  Introduction to Interactive Workshop Elements
3:15pm  Panel Discussion on Requirements Development
   How will NOAA evolve its requirements development processes to incorporate the NOAA UxS Strategy and leverage partnerships with external sectors?
   • Chris Scholin, MBARI (Moderator)
   • Larry Karl, L3Harris
   • Guy Noll, Esri
   • Paul Siegrist, Boeing
   • CAPT Pete Small, Navy
4:15pm  Participant Q&A with Panelists
4:45pm  Day 1 Closing Remarks by RADM Jon White
5:00pm  Day 1 Adjourn
## Day Two: 5 August, 2020

### 1:00pm  Welcome and Review of Day 1 by RADM Jon White

### 1:15pm  Presentation on *Research to Operations* by CAPT Phil Hall, NOAA UAS Program

### 1:30pm  Presentation on *Partnerships* by Gerhard Kuska, IOOS Association

### 1:45pm  Participant Q&A with Presenters

### 2:00pm  Break (15 minutes)

### 2:15pm  Panel Discussion on *Research to Operations*

> What are the NOAA-supported research to operations opportunities and processes for effective/timely meeting of future needs and requirements?

- Monty Graham, USM (Moderator)
- Andy Bowen, Woods Hole Oceanographic Institution
- Parimal Kopardekar (PK), NASA
- David Lang, SoFar Ocean
- Eric Lindstrom, Saildrone
- Brian McKeon, Huntington Ingalls

### 3:15pm  Participant Q&A with Panelists

### 3:45pm  Break (15 minutes)

### 4:00pm  Breakout Session on *Partnerships*

> How would NOAA foster partnerships between and among agency, industry, academe, and philanthropy to meet the requirements of NOAA and entrepreneurial spirit of the U.S. STEM industry?

- Partnership types and vehicles
  - Providing UxS services and/or data
  - R&D partnerships
  - Hybrid model
- Geographic considerations
  - Integration of regional models and approaches
- Communication and transparency
- Agility, flexibility, and adaptability in partnerships
- Entrepreneurial opportunities
- Workforce development
- CENOTE Act considerations
- NOPP considerations
- Setting and managing expectations for each partner

### 5:00pm  Day 2 Adjourn
## Day Three: 6 August, 2020

**1:00pm** Welcome and Review of Day 2 by RADM Jon White

**1:15pm** Presentation on *Developing a Proficient Workforce* by Bill Burnett, Navy MetOc Program

**1:30pm** Presentation on *Building a Community of Practice* from Craig Woolcott, Department of Commerce

**1:45pm** Participant Q&A with Presenters

**2:00pm** Break (15 minutes)

**2:15pm** Breakout Session on *Developing a Proficient Workforce*

- What are the generic and specific proficiencies of a diverse and proficient workforce? How do NOAA and partners define and promote and educational and workforce development pipeline so that there is a constant supply of scientists, engineers, and operators available to both the private and public sectors?
  - Education
    - Knowledge required for operational environment; could be oceanographic, meteorological, policy/ethics, mission/project, organizational, engineering/computational
    - Undergraduate and graduate degree programs and opportunities
    - Certification programs
    - Supporting researchers/engineers to enter high-level R&D community
  - Training
    - Maintenance, repair, and operation functions of personnel
  - Recruitment and retention
    - DEI considerations
  - Insourcing vs. outsourcing
    - Advantages and disadvantages
  - External models and lessons learned
  - Networks of expertise

**3:00pm** Break (15 minutes)

**3:15pm** Panel Discussion on *Building a Community of Practice*

- What unmanned systems lessons can NOAA learn from other communities and how can NOAA leverage their diverse models and frameworks?
  - Bill Burnett, Navy (Moderator)
  - Francisco Chavez, Monterey Bay Aquarium Research Institute (MBARI)
  - Chelle Gentemann, Earth and Space Research
  - John Kreider, Kreider Consulting (formerly Oceaneering)
  - Jyotika Virmani, Schmidt Ocean Institute

**4:00pm** Participant Q&A with Panelists

**4:30pm** Concluding Remarks and Next Steps, COL and NOAA Staff

**5:00pm** Workshop Adjourn

**5-6:00pm** Virtual Happy Hour
APPENDIX B: GOOGLE FORM

UxS Community Workshop Comment Form

Form description

Name *
Short answer text

Affiliation *
Short answer text

Discussion Topic
1. Requirements Development
2. Research to Operations
3. Partnerships
4. Developing a Proficient Workforce
5. Building a Community of Practice

Please provide your comments and suggestions about the selected discussion topic here. Your feedback will inform NOAA’s Unmanned Systems Strategy Implementation Plan.

Long answer text

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APPENDIX C: PARTICIPANT LIST

Participants

Steven Anderson – Arete
Brian Argrow – University of Colorado – Boulder
Rick Babicz – EdgeTech
Joshua Baghdady – University of Hawaii
Bob Ballard – Ocean Exploration Cooperative Institute
Jim Bellingham – Woods Hole Oceanographic Institute
Brian Bingham – Naval Postgraduate School
Jimmy Board – Liquid Robotics
Andy Bowen – Woods Hole Oceanographic Institute
Hunter Brown – OceanServer
Cathy Cahill – University Alaska Fairbanks
Ping Tuck Chai – SeaTrac
Francisco Chavez – Monterey Bay Aquarium Research Institute
Brian Connors – University of Southern Mississippi
Ronald Corvalo – BAE Systems
Chris Coyle – Exocetus
Scott Craig – US Coast Guard
Rich Delgado – University of Southern Mississippi
Catherine Edwards – Skidaway Institute of Oceanography
Jack Elston – Black Swift Technologies
Paul Fermo – Ascent AeroSystems Inc.
Vicki Ferrini – Lamont-Doherty Earth Observatory
Duane Fotheringham – Hydroid
Allison Fundis – Ocean Exploration Trust
Chelle Gentemann – ESR
Bill Gilmour – Chevron
Matt Graziano – General Dynamics
Dennis Grignon – Northrup Grumman
Mark Gunderson – Marine Advanced Robotics, Inc.
Sebastien de Halleux – Saildrone
Jenny Hauser – Liquid Robotics / Boeing
Richard Hine – Thayer Mahan
Todd Holland – US Navy
Adam Houston – University of Nebraska – Lincoln
Bob Houtman – National Science Foundation
Mike Incze – US Navy
Jamey Jacob – Oklahoma State University
David Jochum – Tridentis AMV

Patrick Jones – Persistent Systems
Dave Jones – L3Harris
Larry Karl – L3Harris
Eric King – Schmidt Ocean Institute
Gerhard Kuska – IOOS Association
David Lang – SoFar Ocean
William Latham – Tridentis AMV
Luc Lenain – UNOLS Scientific Committee for Oceanographic Aircraft Research
Edward Leopold – Persistent Systems
Eric Lindstrom – Saildrone
Mary Lockhart – PEMDAS Technologies and Innovations
Dave Lovalvo – Global Foundation for Ocean Exploration
Dickie Martin – Fugro
Charlie Maynard – HySky Technologies
Reid McAllister – US Navy
Greg McFarquhar – University of Oklahoma Cooperative Institute for Mesoscale Meteorological Studies
Brian McKeon – Huntington Ingalls
Brian Midson – National Science Foundation
Subhashree Mishra – National Science Foundation
Robert Moorhead – Mississippi State University
Calvin Mordy – University of Washington
Guy Noll – Esri
Suzanne Novak – ERUdyne, Inc.
Ken Perry – Thayer Mahan
James Peverill – GreenSight
Milly Pitts – Ocean Exchange
Josie Quintrell – IOOS Association
Nicole Raineault – Ocean Exploration Trust
Raymond Robichaud – Northrup Grumman
Mattie Rodrige – OceanX
Dan Rudnick – Scripps Institute of Oceanography
Melissa Ryan – Global Foundation for Ocean Exploration
Val Schmidt – University of New Hampshire
Oscar Schofield – Rutgers University
Brian Schwatka – L3Harris
David Shane – Boston Engineering
Invited Observers:

Charles Alexander – NOAA
Robyn Angliss – NOAA
Becky Baltes – NOAA
David Bidwell – Lynne Carbone & Associates
Dylan Blakeslee – NOAA
CAPT Rick Brennan – NOAA
Lynne Carbone – Lynne Carbone & Associates
John Crofts – NOAA
Rob Downs – NOAA
Tomo Eguchi – NOAA
Michael Gallagher – NOAA
Gustavo Goni – NOAA
Carl Gouldman – NOAA
CAPT Philip Hall – NOAA
RDML Nancy Hann – NOAA
CDR Paul Hemmick – NOAA
Philip Hoffman – NOAA
Todd Jacobs – NOAA
Eric Kihn – NOAA
LCDR Ben LaCour – NOAA
Tony Lavoi – NOAA
Alan Leonardi – NOAA
LCDR Damian Manda – NOAA
Gary Matlock – NOAA

Eric Terrill – Scripps Institute of Oceanography
Lance Towers – Retired (formerly Boeing)
Neil Trenaman – Ocean Aero
Peter Vandeveenter – US Coast Guard
Ron Vien – US Navy
Jyotika Virmani – Schmidt Ocean Institute
David Waldrop – IGC LUX (IGC Solutions)
Dana Yoeger – Woods Hole Oceanographic Institute
Dongziao Zhang – University of Washington

Martha McCoy – NOAA
John McDonough – NOAA
Craig McLean – NOAA
Chris Meinig – NOAA
Sharon Mesick – NOAA
Bill Michaels – NOAA
Hassan Moustahfid – NOAA
Mark Noto – NOAA
Jim O’Sullivan – NOAA
Steve Penny – NOAA
Dawn Petraitis – NOAA
Helmut Portmann – NOAA
Mark Rogers – NOAA
RADM Michael Silah – NOAA
RDML Shep Smith – NOAA
Randall TeBeest – NOAA
Kim Valentine – NOAA
Ken Vierra – NOAA
John Walker – NOAA
George Watters – NOAA
Anthony Weeks – The Public Listener
Cisco Werner – NOAA
Gary Wick – NOAA
APPENDIX D: GRAPHIC ILLUSTRATIONS

Graphic artist Anthony Weeks provided visual facilitation throughout the workshop, which included listening, idea synthesis, and capturing the variety of sessions to create illustrations that tell the story of the workshop discussions. All of the graphics produced are presented below and follow the sequence of the agenda.

Credit for all images is as follows: Anthony Weeks, The Public Listener.

4 August, 2020
Illustration #1

4 August, 2020
Illustration #2
3 August, 2020
Illustration #3

4 August, 2020
Illustration #4

4 August, 2020
Illustration #5
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