An Analysis of Uncrewed System Use within NOAA: Navigating the Future

January, 2024

NOAA Technical Memorandum OAR UxS-004

Authors: Mary A. Solokas, Ashley M. Hann, CDR Benjamin M. LaCour
OAR Uncrewed Systems Research Transition Office and OMAO Uncrewed Systems Operations Center

NOAA Technical Memorandum OAR UxS-004
https://doi.org/10.25923/k0ng-nt55

An Analysis of Uncrewed Systems Use within NOAA: Navigating the Future

Mary A. Solokas
Ashley M. Hann
Benjamin M. LaCour

Suggested Citation:
Solokas, M.A., Hann, A.M., LaCour, B.M. (2024). An Analysis of Uncrewed Systems Use within NOAA: Navigating the Future. NOAA Technical Memorandum OAR UxS-004. Silver Spring, MD. doi: 10.25923/k0ng-nt55

Acknowledgements:
This technical memorandum and the associated analysis was supported by the National Oceanic and Atmospheric Adminstration (NOAA) Uncrewed Systems Research Transition Office and Uncrewed Systems Operations Center. We extend our sincere gratitude to the individuals who participated in the request for information, contributing valuable insights and data that greatly enriched the content of this document. A special thanks to Bryan Cole (OAR), Captain Bill Mowitt (OMAO), and Lisa Nakamura (OMAO) for their thoughtful feedback and insight through the request for information and report generation processes.

Cover images (clockwise from left corner): An uncrewed aircraft takes off from a landing pad, the Slocum underwater glider transiting through the ocean, NOAA Corps officers observe a DriX preparing to launch, a balloon-assisted aerial glider named "HORUS" on the ground. Photo: NOAA

Table of Contents

Background image: NOAA operators brace underwater gliders as they transit on a small boat. Photo: NOAA

Executive Summary

As technology evolves, uncrewed systems (UxS) are continuing to emerge as transformative tools across sectors, with incredible potential to advance scientific research and environmental monitoring. The UxSRTO and UxSOC set out to identify potential opportunities for UxS growth to further meet NOAA's mission needs through a request for information, which was distributed across NOAA as a questionnaire. The questionnaire received 225 responses from all NOAA line offices spanning 84 different programs, offices, science centers, and labs. Of the respondents, 68% indicated that their programs are currently using UxS and 26% of respondents indicated that their programs have a data gap or observation need that could be met with UxS within the next year, while an additional 3% indicated the same but on a timeframe that extends beyond the next year.

The results of the questionnaire showed that NOAA engages in a wide array of activities in support of its diverse mission areas through the use of UxS, with no one mission area being supported by UxS usage significantly more so than others. The data collected serve numerous purposes within mission areas, such as flood forecasting within weather monitoring and gear selectivity evaluation within fisheries science and management, as well as cross-mission areas such as educational outreach and general R&D. Current and potential use of UxS across the UAS and UMS domains was about equal, with respondents indicating that they are most commonly using or interested in using imaging sensors for both UAS and UMS missions.

The driving forces for using UxS are often related to data needs, such as filling a data gap that otherwise could not be filled, expanding the amount of data collected by a non-UxS collection effort, or replacing a data need that is currently being met with ships or aircraft to reduce dependency on crewed resources. Questionnaire respondents identified UxS being safer, faster, more efficient, more environmentally friendly, and less expensive as contributing factors in the decision to use UxS over other methods.

The questionnaire was successful in identifying challenges to UxS use and developing concrete recommendations to help alleviate those challenges. Barriers related to UxS use fell into three main categories, including budget and acquisitions (52%), challenges related to personnel and experience (27%), and technical or operational limitations of existing technology (20%). Four specific areas emerged for recommendations of future investment and development (Table 2):

1. Budget and acquisitions of UxS systems and platforms
2. Regulatory challenges and beyond visual line of sight UAS flights
3. Collaboration and coordination
4. Corporate UxS capabilities

Overview

Within NOAA, uncrewed systems (UxS) are being researched, developed, tested, evaluated and used across the agency as tools to make observations and gather data in support of NOAA mission areas. UxS can augment traditional data collection efforts at potentially lower costs, increased safety, reduced risk, and increased efficiency. Through strategic application and development of UxS technologies, NOAA is better able to meet its mission of science, service, and stewardship.

Technological advancements of UxS, including uncrewed aircraft systems (UAS) and uncrewed marine systems (UMS), have enabled significant capabilities such as improved humanitarian aid during crises and the ability to explore the ocean to new depths. The potential for improved safety, efficiency, and efficacy of operations enabled by the use of UxS continues to generate interest from NOAA scientists in considering new and novel uses of such systems.

UxS are already contributing to the success of NOAA's lifesaving, as well as economically and environmentally impactful missions, such as hurricane forecasting and marine mammal monitoring, among many others. The Uncrewed Systems Research Transition Office (UxSRTO) in NOAA's Office of Oceanic and Atmospheric Research (OAR) and the Uncrewed Systems Operations Center (UxSOC) in NOAA's Office of Marine and Aviation Operations (OMAO) provide centralized UxS coordination, support, and guidance for the research and development (R&D) and operations, respectively, of UxS across NOAA.

The UxSRTO and UxSOC set out to identify potential opportunities for UxS growth to further meet NOAA's mission needs. In order to do so, a request for information was developed in the form of a questionnaire to gather up-to-date information on the current state of UxS use within NOAA and to investigate what programs within NOAA see potential for UxS to help meet their mission requirements in the future. The questionnaire was open to all NOAA personnel over a three and a half week period from July 10, 2023 to August 1, 2023 and was circulated widely through NOAA UxS-related email distribution lists, word of mouth, and direct sharing with potentially relevant groups. Subsequently, the results were collated and analyzed to distill current NOAA UxS usage, potential usage, and identify NOAA's UxS interests and needs. This document serves to detail the findings of the request for information for internal NOAA personnel as it pertains to guiding future UxS R&D opportunities and operational investments.

UxS Users

The questionnaire received 225 responses across all NOAA line offices from 84 different programs, offices, science centers, and labs (hereafter simply referred to as programs; Figure 1a). The respondents ranged from scientists and engineers in the field, to program and data managers, to branch chiefs and directors. Of the respondents, 68% indicated that their programs are currently using UxS (Figure 1b). Looking towards the future, 26% of respondents indicated that their programs have a data gap or observation need that could be met with UxS within the next year, while an additional 3% indicated the same but on a timeframe that extends beyond the next year. It is important to note that the questionnaire asked broadly about UxS use, not UxS data use, which may have limited the responses received by those within NOAA who are interested in the data collected by UxS but do not consider themselves users of the systems themselves.

The remaining 3% of respondents were made up of those that did not see any potential for UxS to help meet their program's mission needs, now nor in the future. For the remainder of this report, we will refer to two main groups of respondents: current UxS users, which are those who answered that their programs are currently involved in UxS, and potential UxS users, which are those who answered that their programs have a data gap or observation need that could be met with UxS at some point in the future.

Of the current UxS users, the majority are within the National Marine Fisheries Service (NMFS) (34%), OAR (29%), and the National Ocean Services (NOS, 21%). These individuals work in NOAA offices across the country including all six of the NMFS fisheries science centers, eight of the ten OAR research labs, and seven of the eight NOS program offices.

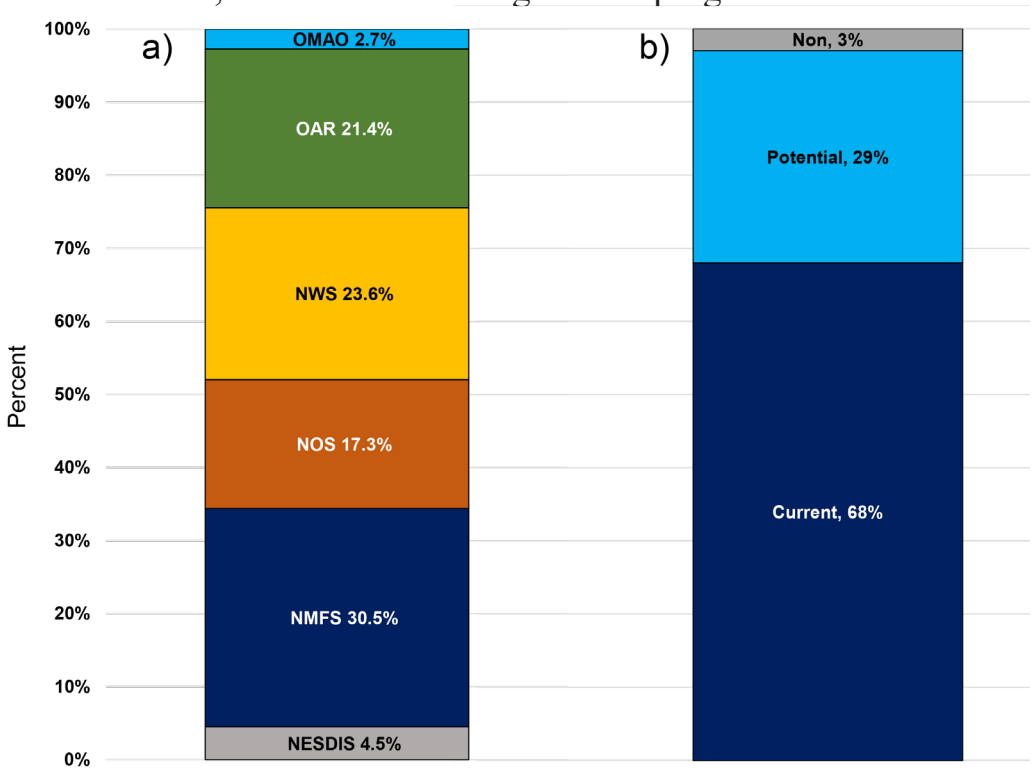

Figure 1: Respondents to the questionnaire by a) Line Office and b) UxS use status (non-user, potential user, current user).

Potential UxS users included individuals across line offices, with highest expressed interest by the National Weather Service (NWS; 53%), followed by NMFS (21%), and NOS (11%). The NWS respondents came from a total of 32 different programs, 18 of which were weather forecast offices (WFOs), indicating a strong interest in UxS use for weather forecasting and prediction.

Of the 218 current and potential UxS users, 216 indicated they envision their programs using UxS as the primary or a supplemental way of executing their mission. This emphasizes the great need for continued focus on developing UxS capabilities within NOAA.

UxS Mission Areas

The results of the questionnaire showed that NOAA engages in a wide array of activities in support of its diverse mission areas through the use of UxS. Respondents indicated UxS has the ability, and in some cases is already being used, to support mission requirements in the areas listed in Table 1 below.

No one mission area was supported by UxS usage significantly more so than others, though the most reported mission areas included: protected resources science and management (15.9%); weather and hydrologic forecasting (13.3%); and ocean, coastal, and great lakes research (12.5%). The least reported uses of UxS –including rapid response and damage assessments and infrastructure– were bins added post-hoc as a result of write-in responses. Commonalities among the write-in responses pointed to mission areas that were not initially included in the questionnaire. For example, multiple respondents included post-storm damage assessments, oil spill assessments, and natural disaster assessments as relevant mission areas that were then all grouped together under the rapid response and damage assessments mission area. Similarly, numerous responses included system maintenance and equipment inspections, leading to the addition of the infrastructure bin.

The data serve numerous purposes within mission areas, such as flood forecasting within weather monitoring and gear selectivity experimentation and evaluation within fisheries science and management, as well as cross-mission areas such as educational outreach and general R&D. Using UxS for human-dimensional data and law enforcement was not included on the questionnaire, but received much support in the fill-in responses, as did infrastructure-related purposes. As with mission areas, respondents again indicated a use for UxS in performing system maintenance and facilities inspections.

Often a single UxS platform can be used to meet multiple mission requirements in the same or separate deployments. For example, NOAA has deployed uncrewed surface vehicles equipped with sensors to support fisheries management, climate monitoring research, oceanographic research, and weather research all in the same deployment. Others in NOAA have partnered to use a single UxS platform to interchangeably support hydrographic and fisheries management requirements during different field deployments. Such a use model may prove effective for some mission requirements and UxS platform types more than others and warrants further consideration for specific future development.

Table 1: NOAA mission areas that the use of UxS or potential future use of UxS supports, precent of responses to the survey that noted use of UxS to support said mission area, and example focus areas per mission area.

Mission Areas	Example Focus Areas
Protected resources science and management (15.9%)	Marine mammal monitoring, protected area visitation and use monitoring
Weather and hydrologic monitoring (13.4%)	Flood mapping, ice detection
Ocean, coastal, and Great Lakes research (12.5%)	Ocean exploration, high temporal resolution ocean monitoring
Fisheries science and management (11.2%)	Ecosystem functioning, population assessments
Climate monitoring and research (11.0%)	Greenhouse gas sampling, climate forecasting
Coastal science and assessments (10.1%)	Harmful algal bloom monitoring, coastal mapping
Habitat conservation and restoration (9.8%)	Animal tracking, riverine condition assessments
Weather and air chemistry research (6.7%)	Extreme weather research, fire weather
Navigation, observations, and positioning (5.4%)	Ocean mapping, shoreline assessments
Rapid response and damage assessments (3.6%)	Storm damage assessments, wildfire management
Infrastructure (0.4%)	System maintenance, system calibrations

Platform Preferences

It is evident that the use of UAS and UMS across NOAA's mission space is widespread with support for its continued expansion. Within the current users group, use of UxS across the UAS and UMS domains was about equal with platform types including vertical take off and landing (VTOL), fixed wing, hybrid, and other for UAS; uncrewed surface vehicle (USV, including Saildrone, DriX, and other) and uncrewed underwater vehicle (UUV, including glider and other) for UMS, and remotely operated vehicles (ROV) as a separate platform type (Figure 2). Respondents indicated they are primarily using imaging sensors for both UAS and UMS missions. This is followed closely by oceanographic and biological sensor types. Within UAS platform types, VTOL was the most widely used platform with 75% of current UAS users reporting their use. Within the UMS domain, UUVs (50%) were reported as being used slightly more than USVs (44%). Of the specific UMS platforms, gliders were reported as being used the most at 28%.

Similarly, the potential users group indicated an almost equal split between UAS and UMS for platform type that could help fill the data gaps or meet the observation needs they identified within their programs in the future (Figure 3). Potential users also leaned heavily towards the use of VTOLs on the UAS side. For UMS platform types, potential users indicated an even split between USVs and UUVs. However, for potential users, a larger percent (23%) of respondents indicated they were not sure what type of platform would best meet their needs.

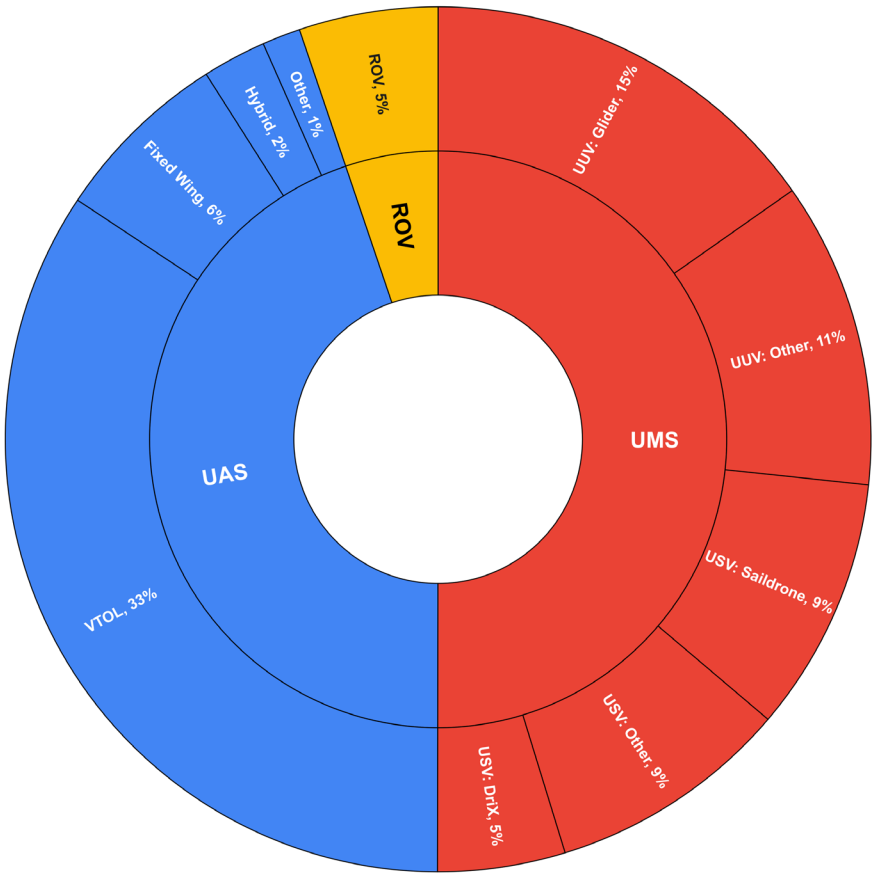

Figure 2: Use of different UxS by platform type of current UxS users. Platforms types include UAS (VTOL, Fixed Wing, Hybrid, and other), ROV, and UMS (UUV: Glider, UUV: other, USV: Saildrone, USV: Drix, USV: Other).

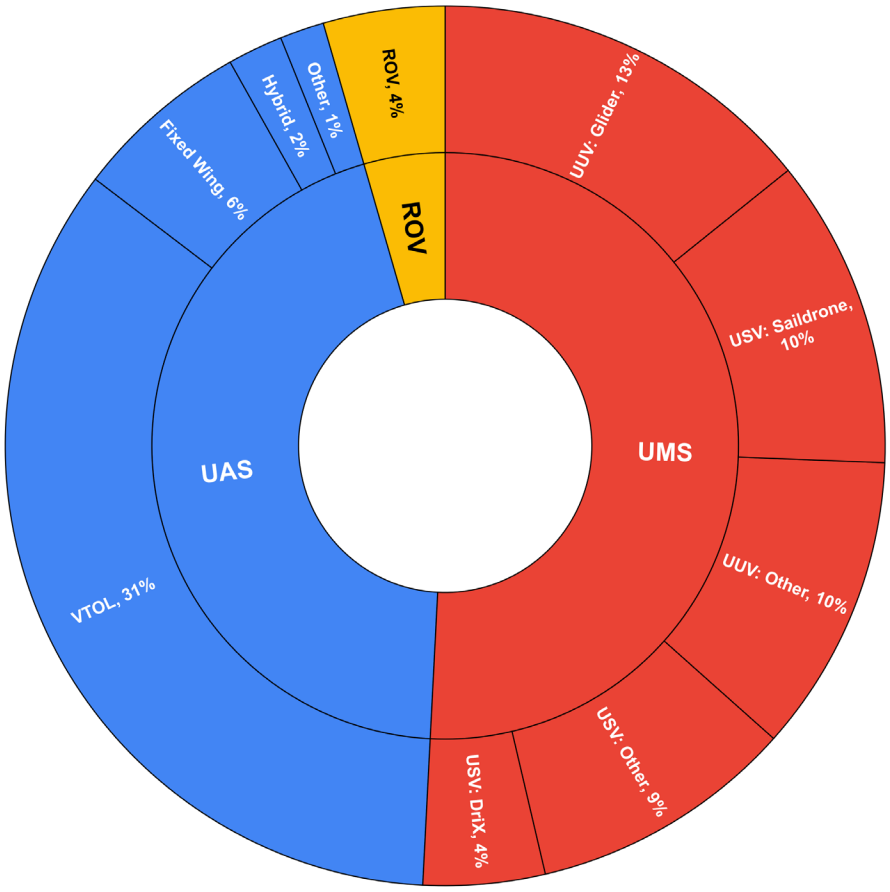

Figure 3: Use of different UxS by platform type of potential UxS users (next 1-5 years). Platforms types include UAS (VTOL, Fixed Wing, Hybrid, and other), ROV, and UMS (UUV: Glider, UUV: other, USV: Saildrone, USV: Drix, USV: Other).

Current and Future UxS Requirements and Execution

UxS use within NOAA, including current and potential future operations, spans both event-driven occurrences, such as during a hurricane or a flood event, as well as periodic/routine operations like daily atmospheric profiles. The driving forces for using UxS are often related to data needs, such as filling a data gap that otherwise could not be filled, expanding the amount of data collected by a non-UxS collection effort, or replacing a data need that is currently being met with ships or aircraft to reduce dependency on crewed resources. Questionnaire respondents identified UxS being safer, faster, more efficient, more environmentally friendly, and less expensive as contributing factors in the decision to use UxS over other methods.

Of the 72 respondents who are not presently using UxS to meet their program's requirements, 66 indicated that they foresee their program using them in the next 1 to 5 years. 50% of these respondents were from within NWS, primarily at WFOs, in contrast to the current users group where NWS only accounts for 10% of respondents. In certain regions, WFOs have used UAS to perform post-storm surveys, river assessments, and equipment maintenance with great success. This indicates an area of potential expansion of UxS (specifically UAS) use within NOAA and warrants further research, investigation and investment.

At present, most respondents who self identified as current users of UxS executed and maintained their UxS operations through a mixture of four strategies (in order of prominence; Figure 4a):

1. Acquiring UxS equipment and training operators within their teams;
2. Partnering with other institutions to operate UxS on their behalf;
3. Acquiring data from industry operated UxS through data buys; and
4. Partnering with another NOAA entity.

Partnering with institutions and industry may include universities, cooperative institute partners, non-profit organizations, commercial operators, and other federal agencies. Looking to the future of NOAA's UxS operations, respondents were still interested in the aforementioned strategies, along with the inclusion of UxS owned and operated as part of a larger NOAA fleet (similar to NOAA's crewed ships and aircraft; Figure 4b).

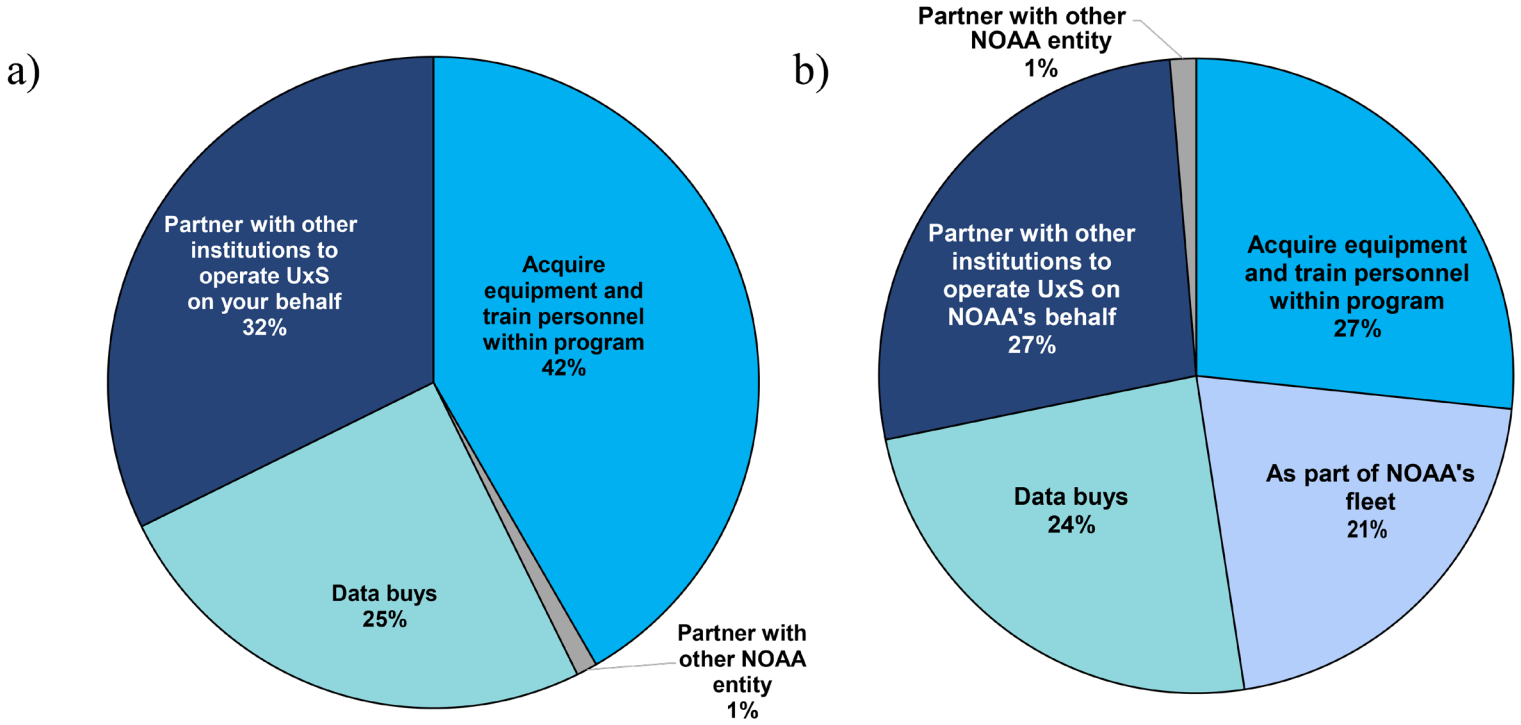

Figure 4: The methods by which NOAA a) is currently executing and maintaining UxS activities and b) would like to be executing and maintaining UxS activities in the future.

Recommendations

The request for information was successful in better characterizing NOAA's current and future uses of UxS. It was also successful in better understanding the business models used to own and operate them, challenges facing their use, and ways in which the UxSRTO and UxSOC can better support NOAA's current and future UxS stakeholders. Specific recommendations are listed below, in Table 2.

Table 2. Recommendations for NOAA to advance UxS use. Includes insights from the request for information, along with suggested entities for implementing each recommendation.

Insight from Request for Information	Recommendations	Involved Entities
1. Uncertainty around outyear budgets is a prevalent barrier to UxS use.	1a. Raise awareness of the support services available in transition plan development and ensure there is significant end user support early in the R&D process. 1b. Support the UxS Executive Oversight Board (EOB) and other entities in enhancing outyear budget planning and funding resources. 1c. Increase coordination between funding entities to ensure cross collaboration and broad-sharing of funding opportunities.	1a. ORTA, UxSRTO 1b. UxSOC, UxSRTO, UxS EOB 1c. NOAA
2. UAS regulations are challenging to navigate; BVLOS flights would greatly expand UAS capabilities.	2a. Raise awareness of support capabilities offered by UASD/UxSOC to overcome policy and regulatory hurdles. 2b. Continue to invest in fleet infrastructure to further support offshore UAS flights. 2c. Work to further integrate BVLOS capabilities into NOAA.	2a. UxSOC 2b. UxSOC 2c. UxSOC, UxSRTO
3. The most common UxS operational model within NOAA is program owned and operated, which can be restrictive as mission goals expand.	3a. Increase facilitation of collaborations among NOAA personnel who are working towards similar goals. 3b. Increase advertising for the Uncrewed Systems Project Update Series. 3c. Provide more staff support and resources for complex UxS operations; expand capabilities with additional infrastructure. 3d. Execute a cross-NOAA corporate UxS requirements gathering effort to inform decisions and investments in corporate assets.	3a. UxSRTO, UxS EOB, NOAA 3b. UxSRTO 3c. UxSOC 3d. UxSOC
4. It is difficult to keep up with rapidly evolving UxS technology.	4a. Establish a UxS industry forum where NOAA personnel can become familiar with UxS technology, with guidance from AGO.	4a. UxSOC, UxSRTO

Background image: A Saildrone uncrewed surface vehicle pilots through small waves. Photo: NOAA

Insight from Request for Information	Recommendations	Involved Entities
5. A large gap exists between current UxS users within NWS and those within NWS that expressed interest in using UxS.	5a. Engage more with NWS to build UxS capabilities.	5a. UxSOC, UxSRTO

Barriers to UxS Use

Barriers related to UxS use fell into three common categories, listed in order of prominence:

1. **Budget and acquisition (52%)**
   E.g., outyear budget uncertainty, cost of testing & development, difficulty with acquisitions, lack of suitable contract/grant vehicles
2. **Challenges related to personnel and experience (27%)**
   E.g., training/certification of existing personnel, finding qualified personnel
3. **Technical/operational limitations of existing technology (20%)**
   E.g., technical limitations of sensors/platforms that do not fully meet mission requirements, operational/regulatory restrictions, lack of established data pipelines

Future Direction & Overcoming Barriers

UxS technology is evolving rapidly. There are many NOAA-led efforts to develop and transition UxS technology into operations. Many of these efforts, if successful, have applicability beyond the program developing them. In certain scenarios, these efforts are intended to augment an existing effort while in other cases, these projects may open up a whole new class of observations not otherwise accessible. What is certain is that the use and application of UxS to meet NOAA's requirements will continue to expand for the foreseeable future.

The application within NOAA of these new and novel technologies is limited more so by our ability to evaluate, adopt, and resource them, than by industry's ability to create solutions for NOAA's use.

Budget & Acquisition

A prevalent barrier to UxS use, as indicated by the respondents (17%), was the uncertainty related to outyear budget for continued operations and maintenance. While uncertainty in outyear budgets is a fundamental component of a government agency, steps can be taken early in UxS R&D efforts to help alleviate these concerns. One step that is highly encouraged of all NOAA R&D projects is the writing of a transition plan, which serves as a vision for what the project can accomplish in the future. Transition plans facilitate end-user and leadership engagement early in the process, outlining how the project fits into NOAA's missions long-term. Although transition plans do not solve the funding issues for continued operation and maintenance of UxS, they initiate conversations around what would be needed if the project is successful and ensure all parties involved in the project are aware. Resources are available within NOAA to assist in the transition planning process and help navigate such concerns, including the UxSRTO and the Office of Research, Transition, and Application (ORTA). It is recommended that the UxSRTO work with ORTA and other NOAA entities to increase awareness of the support services available in transition plan development and ensure there is significant end user support early in the R&D process (Table 2, Recommendation 1a).

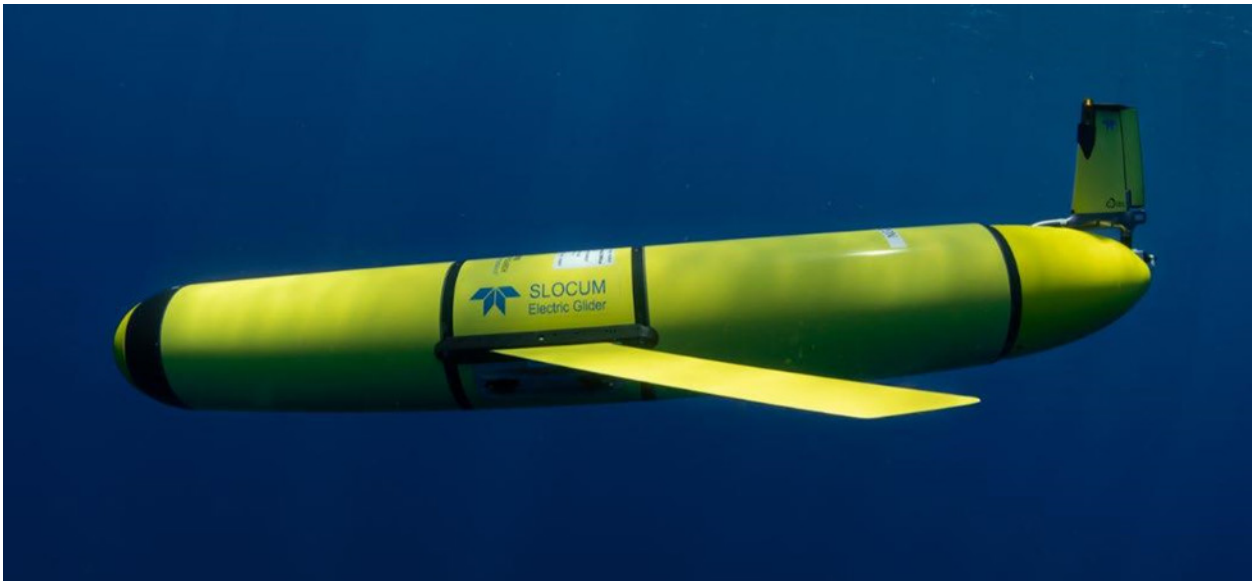

Image 1: A Slocum underwater glider transits underwater. Photo: NOAA

Regulatory Challenges & Beyond Visual Line of Sight Operations

Within the UAS domain, operations are heavily regulated. Line of sight operations have a myriad of rules and policies operators must comply with, which, as respondents indicated in the write-in responses, can be challenging for NOAA programs to navigate. It is critical that NOAA provide tools and support for programs interested in UAS in order to ensure their full utilization across the agency. The UxSOC's Uncrewed Aircraft Systems Division (UASD) has extensive experience and expertise in navigating the complex UAS landscape. It is recommended that the UASD be better elevated to NOAA programs as a resource to help navigate these regulatory challenges (Table 2, Recommendation 2a).

In addition to UAS policies and regulations, a significant obstacle preventing full utilization of UAS within NOAA is beyond visual line of sight (BVLOS) operations. Except in specific situations where exemption has been granted by the Federal Aviation Administration (FAA), UAS can only be flown within line of sight of the operator despite many technologies being capable of flying BVLOS. The FAA is working with industry, government, and the public to develop a rule-making for BVLOS but given the complexity of the issue, is likely years away. Once a path to routine BVLOS operations is available, it is expected that UAS operations will significantly expand within and outside of NOAA.

While the regulatory aspect is outside of NOAA's control, there are areas where BVLOS flights can be enabled on a broader scale within NOAA prior to FAA rulemaking. One such area is BVLOS flights at sea beyond 12 nautical miles from the coast. The UxSOC is currently exploring the path to enabling this capability through continued investments in partnership with NMFS and others in NOAA (Table 2, Recommendation 2b). This includes efforts to evaluate different detect and avoid systems for marine applications, which will be key to enabling ship based BVLOS (Table 2, Recommendation 2c). Once approved, these at-sea flights would allow for expanded UAS support of missions such as living marine resource surveys and marine mammal monitoring.

Image 2: A UAS performs flight operations over Mississippi River following Hurricane Delta in 2020. Photo: Mississippi State University

Increased Collaboration and Coordination

Internally

While NOAA is still growing its UxS usage, many programs have developed significant UxS capabilities with regards to routine operations of UxS and the research and development of UxS technologies to meet a NOAA need. Despite this internal ability, questionnaire results indicate minimal collaboration and coordination within NOAA on growing or expanding UxS usage. When asked how UxS users currently execute or maintain their UxS operations, and how they hope to do so in the future, ~1% of respondents expressed interest through write-in answers in coordinating with another NOAA entity. Future requests for information should directly address this topic to better understand the complexities of within-NOAA collaborations. Responses to the questionnaire also note significant overlap in UxS platforms, geographic areas of interest, and broader mission needs across programs that may not be presently collaborating. Given NOAA's current capabilities and shared interests, it is recommended that current and potential UxS users look internally throughout the agency to advance UxS applications (Table 2, Recommendation 3a). This can take many forms including, but not limited to: 1) informal and formal information sharing, 2) collaboration on research and development, and 3) deployment of multi-mission platforms.

Some resources are already in place to facilitate information sharing, such as the monthly Uncrewed Systems Project Update Series. In this forum, current and potential UxS users can hear about ongoing UxS activities across NOAA. NOAA should continue to take advantage of and expand upon such forums for collaboration (Table 2, Recommendation 3b). Internal-to-NOAA abilities may help address barriers in personnel and experience, as well as technical limitations.

NOAA programs are also investing in providing UxS-related funding opportunities and resources that are available to the entire agency (Table 2, Recommendation 3c). For example UxSOC, UxSRTO, and the Ocean Acidification Program are currently jointly funding 12 projects conducting UxS-related work. In the future, such funding opportunities should be widely circulated within relevant audiences, and programs should consider what other opportunities exist for pooling resources (Table 2, Recommendation 1b). Coordination between funding entities can be increased to ensure cross collaboration and broad-sharing of funding opportunities (Table 2, Recommendation 1c).

The UxS Executive Oversight Board (EOB) exists to provide oversight of NOAA's UxS activities. Given the UxS EOB's cross-NOAA membership and its broad role providing oversight to the agency, it is in position to play a greater role in increasing internal NOAA collaboration and coordination on UxS. It is recommended that the UxS EOB consider what efforts its members can take to facilitate increased collaboration and coordination within NOAA (Table 2, Recommendation 3a). Actions in the UxS EOB's FY24 Work Plan support this recommendation, such as creating a funding and hardware allocation plan, laying the groundwork for continued cross-NOAA funding opportunities and discussions, and others. Supporting internal NOAA collaboration and coordination should be on the forefront of the UxS EOB's priorities. For deliverables of the UxS EOB to be truly impactful, it is recommended that the appropriate audiences engage in the development and use of said deliverables.

Image 3: The DriX uncrewed surface vehicle is piloted into its docking station along side the NOAA Ship Oscar Dyson. Photo: NOAA

Externally

Research, development, and operational use of UxS spans work outside of NOAA mission areas and beyond the federal government. Academia and private industry have made significant progress on UxS technology development and use. While NOAA programs are presently engaged with these sectors, it is recommended that, if NOAA is to stay on the cutting edge of UxS technology, the agency should consider how it can increase such opportunities for collaboration. At a minimum, the agency must have effective tools to learn about the current state of UxS technology. One strategy could be producing a forum (similar to the aforementioned Uncrewed Systems Project Updates series) in which current and potential NOAA UxS users can hear from those working to develop and operate UxS technology outside of NOAA (Table 2, Recommendation 4a). UxSOC and UxSRTO are organizing such sessions to hear from vendors awarded UxS-related contracts, and others have organized more specific or informal gatherings over the years. Creating a consistent platform for learning to occur could benefit the agency and the U.S. at-large.

Corporate UxS Systems

The list of commercial off the shelf (COTS) systems, such as buoyancy gliders, UUVs, and UAS continues to grow. While these platforms themselves are operational, there are new and exciting developments in the application of these systems specific to NOAA's missions. As these new applications transition into operations, demand for these types of systems across NOAA's mission space will only increase. Many smaller UxS such as sUAS do not require a lot of support infrastructure, personnel, or expertise to own and operate. Larger or more complex systems usually require dedicated personnel with experience and infrastructure investments to maintain, configure, and operate. When multiple programs are making these investments on their own, as 42% of current users indicated, duplication and inefficiencies can occur within NOAA. Time periods where such large, expensive systems are not being operated are especially inefficient. In order to address this, it is recommended that more staff support, resources, and infrastructure are provided, especially regarding complex UxS operations (Table 2, Recommendation 3c).

Given the challenges mentioned, the UxSOC has endeavored to stand up certain corporate UxS capabilities, such as the USV DriX, to support wider adoption and application of these systems where NOAA programs on their own would not be able to, or where doing so might create unnecessary duplication. It is critical that cross-NOAA corporate UxS requirements be collected to inform decisions and investments in corporate assets. It is recommended that data from the questionnaire be used to inform a cross-NOAA UxS requirements gathering effort similar to what was recently done for the NOAA Fleet Plan (Table 2, Recommendation 3d). While UxS were included in the most recent Fleet Plan, results from that survey indicated it was not comprehensive of NOAA's corporate UxS requirements. Conducting a similar requirements gathering process will greatly aid NOAA in the process of acquiring and resourcing corporate UxS best suited to meet NOAAs highest priority mission needs.

Gaps Between Effort & Interest

By combining questionnaire responses and metrics gathered in other venues, certain areas of focus for UxS-supported NOAA work were identified. While some focus areas have well established use of UxS, others stood out as areas in which NOAA should expand its UxS capabilities. For example, the NWS made up only ~10% of current users, yet ~53% of potential users, highlighting a significant opportunity for UxS growth. Weather forecasting and hydrologic monitoring was one of the top supported mission areas (13.4%) and engagement with NWS across forums has indicated a strong desire for increased observations to inform mesoscale weather analyses. It is recommended that UxSRTO and UxSOC direct more engagement towards NWS, as well as the additional focus areas, to build UxS capabilities (Table 2, Recommendation 5a).

Furthermore, environmental eDNA and acoustic sampling received substantial attention through write-in responses. Environmental DNA and other methods used to measure biological molecules, referred to as the field of 'omics, are used to study a range of marine organisms and is a rapidly growing area of research, within NOAA and externally. Many current and potential UxS users are interested in continuing to expand eDNA capabilities through UxS, as well as continuing to expand acoustic sampling capabilities. NMFS has already taken part in projects analyzing the use of USVs to work in tandem with NOAA ships to improve the efficiency of acoustic data collection with much success. The increased understanding of common interests and priorities gained through the questionnaire allows for more focused allocation of efforts towards facilitation and collaboration. Additional focus areas for expanded UxS capabilities can be found below.

Focus Areas for Expanded UxS Capabilities

- Observations to inform mesoscale weather analyses
- Oceanic eDNA sampling
- Fisheries surveys via echosounder-equipped UMS
- Ocean carbon uptake and acidification observations
- Fire weather observations
- UxS-based marine mammal surveys
  - Passive acoustic monitor-equipped gliders
  - Aerial survey UAS beyond visual line of sight

Conclusion

The invaluable information contributed by the NOAA community has not only solidified current UxS initiatives but also revealed obstacles and areas that require further investigation. These insights highlight current and future uses of UxS within the agency, paving the way for well-informed strategies to guide the path forward. The UxSRTO and UxSOC are committed to fostering R&D opportunities and making operational investments that align with NOAA's core values of science, service, and stewardship.

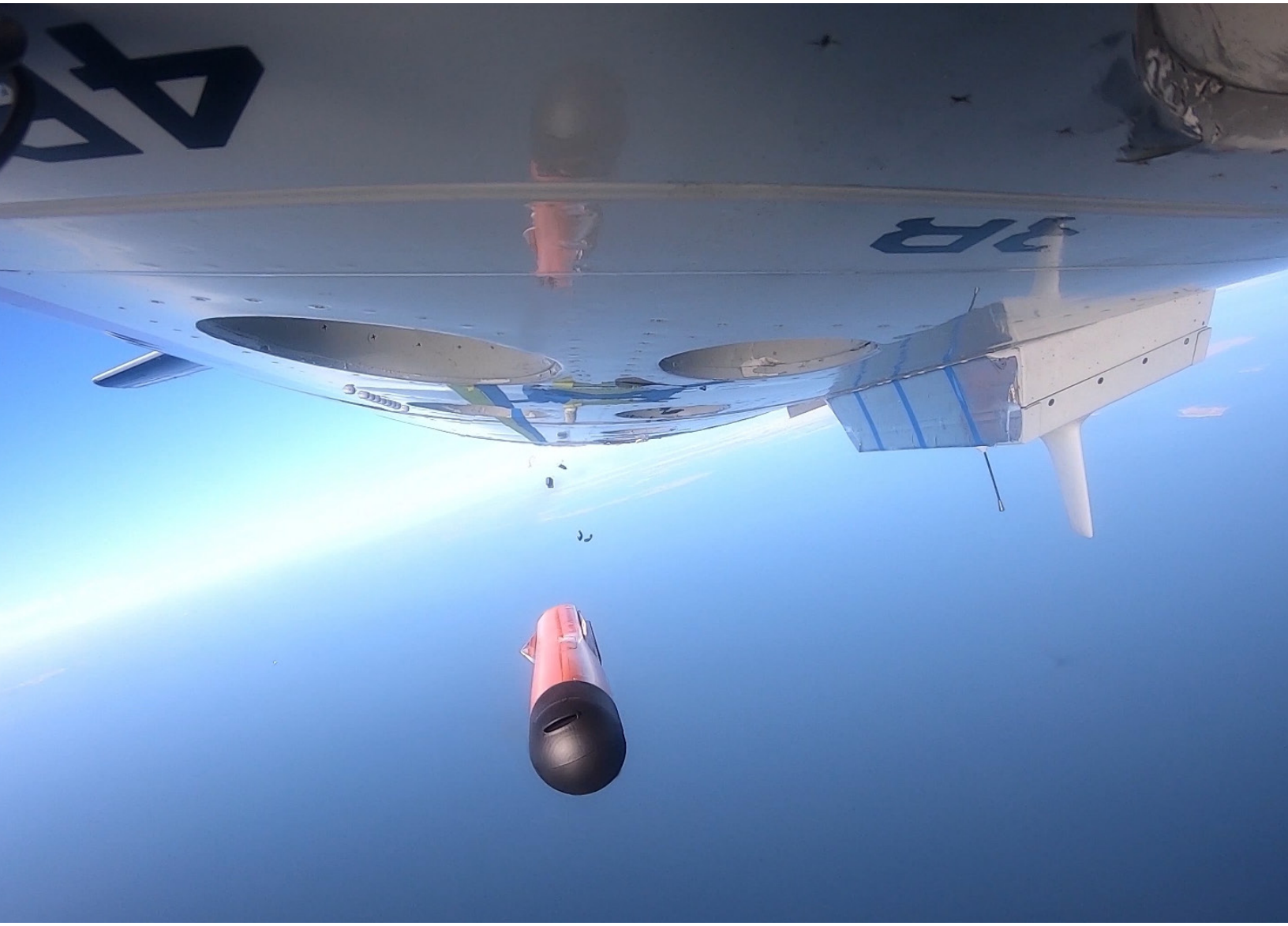

Image 4: The Anduril Altius-600 UAS is deployed from a NOAA hurricane hunter aircraft. Photo: NOAA