NOAA Uncrewed Marine Systems Highlights Report for Fiscal Year 2023

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About the National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA), under the Department of Commerce, provides science, service, and stewardship to protect life, property, and Earth's natural resources. By collecting scientific data, NOAA provides daily weather forecasts, storm warnings, and climate monitoring; and facilitates fisheries management, marine commerce, and coastal restoration. NOAA uncrewed systems work is organized into uncrewed marine systems (UMS) and uncrewed aircraft systems.

About the Uncrewed Systems Executive Oversight Board

The Uncrewed Systems Executive Oversight Board provides oversight of NOAA's UMS and Uncrewed Aircraft Systems efforts. It assures agency-wide strategies and initiatives are developed collaboratively and implemented consistently. It was established through the Commercial Engagement through Ocean Technology Act of 2018. The Executive Oversight Board includes membership from across NOAA's line offices and reports to the NOAA Fleet Council. Within the Executive Oversight Board is a UMS Working Group that advises the Board on UMS matters. The Executive Oversight Board is co-chaired by the Office of Marine and Aviation Operations and Office of Oceanic and Atmospheric Research.

About the Uncrewed Systems Operations Center

The Uncrewed Systems Operations Center was established in Fiscal Year (FY) 2020, following receipt of funding to improve and expand uncrewed systems operations across NOAA. The Uncrewed Systems Operations Center sits within NOAA's Office of Marine and Aviation Operations and works to expand uncrewed systems applications, transition uncrewed systems into operational use, and provides corporate support to uncrewed systems operations. Within the Uncrewed Systems Operations Center sits the UMS Division that plays a central role in UMS operations across NOAA.

About the Uncrewed Systems Research Transition Office

The Uncrewed Systems Research Transition Office within NOAA's Office of Oceanic and Atmospheric Research worked to leverage the abilities of uncrewed systems to improve NOAA's monitoring and understanding of the global environment. The Uncrewed Systems Research Transition Office focused on the research, development, and transition of uncrewed systems technologies. In FY 2024 the Uncrewed Systems Research Transition Office was discontinued. All references to the Office in this report are for events and activities prior to the closure of the Office.

About the Annual Report

This Annual Report is an overview of the UMS work of NOAA in FY 2023. The information presented is structured to provide insight on NOAA UMS adoption, applications, and integration. This document was developed by the Uncrewed Systems Executive Oversight Board with support from the Uncrewed Systems Operations Center.

Acknowledgements

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Forward

Dear Readers,

On behalf of the NOAA Uncrewed Systems Executive Oversight Board, we are pleased to present NOAA's Uncrewed Aircraft Systems (UAS) Annual Report for Fiscal Year (FY) 2023. UAS are a growing tool which enhance our ability to meet the science, service, and stewardship mission. NOAA is an active agent in the research and development of UAS occurring in the uncrewed systems enterprise, and regularly engages with partners from government, academia, and industry to accelerate innovation with UAS. In many instances, NOAA has transitioned UAS technologies to be a part of regular operations for the Agency. Whether conducting research and development, or transitioning platforms to operations, NOAA seeks to more efficiently, effectively, and safely gather mission-critical data through the operation of UAS.

FY 2023 was an exciting year for NOAA and innovation through UAS. Operations were conducted from the edge of space to the surface of the ocean. The data gathered through this work supports greenhouse gas monitoring, protected species assessments, habitat and infrastructure inspections, and more. UAS were employed in novel ways to inform the life-saving services provided by NOAA such as the Search and Rescue Satellite-Aided Tracking Program and hurricane forecasting. You can read more about all these activities in this report.

Overall, NOAA flew over 28,000 flight minutes and more than 1,900 UAS flights in FY 2023. While many of these flights enhanced NOAA missions, NOAA will continue to engage in active research, development, and transitions of UAS technologies to fully realize the potential of emerging technologies.

This report highlights not only the UAS-enabled work performed by NOAA, but the corporate resources in place for NOAA to conduct such UAS work. Said work and resources, along with the entirety of this report would not be possible without NOAA's dedicated workforce.

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Rear Admiral Chad Cary & John Cortinas, Ph.D.

NOAA Uncrewed Systems Executive Oversight Board Co-chairs

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Executive Summary

This document is the inaugural edition of the Uncrewed Marine Systems (UMS) Highlights Report, and specifically focuses on NOAA's UMS activities in Fiscal Year (FY) 2023. UMS is a growing asset for NOAA in supporting its science, service, and stewardship missions. In order to employ UMS technologies, NOAA must engage in the research and development of UMS technologies, and the transition of UMS to routine operations all in support of NOAA mission needs. Partnerships with government, academic, and industry groups throughout the UMS enterprise are critical to NOAA's success in UMS research, development, and transitions. Readers will note examples of such efforts throughout this report.

This report contextualizes NOAA's use of UMS across NOAA's six line offices and the two program offices indicated in the Commercial Engagement through Ocean Technology Act of 2018 as critical to NOAA's UMS activities.

Line Offices:

- Office of Marine and Aviation Operations (OMAO)
- Office of Oceanic and Atmospheric Research (OAR)
- National Marine Fisheries Service (NMFS)
- National Weather Service (NWS)
- National Ocean Service (NOS)
- National Environmental Satellite Data and Information Service (NESDIS)

Program Offices:

- Ocean Exploration (OE)
- Integrated Ocean Observing System (IOOS)

This contexualization occurs through office-specific vignettes that highlight the breadth and depth of UMS-related work conducted by NOAA. Vignettes cover efforts across a vast geographic expanse which includes areas from the U.S. East Coast to Hawaii and the U.S. Pacific territories, and from the Great Lakes to the Gulf of Mexico. They also dive deeper into UMS operations that support data gathering across NOAA's mission areas including: weather forecasting, protected species and ecosystem monitoring, resilience to coastal hazards, and more.

NOAA Program FY 2023 Highlights

Automating UMS Data Processing in Partnership with the Navy

Lead Personnel: Jennifer Bowers and Katharine Weathers–NESDIS National Centers for Environmental Information

As the use of UMS by NOAA and its partners grow, there will be an increase in the volume of mission relevant data. While increases in data can enhance the agency's ability to fulfill its mission, it is crucial that the data can be appropriately managed to be as useful as possible. To address the influx of UMS-gathered data, NOAA's National Centers for Environmental Information, in partnership with NOAA's National Centers for Coastal Ocean Science and the Navy, developed a digital pipeline that improves data interoperability. This initiative was realized under the Commercial Engagement through Ocean Technology (CENOTE) Act of 2018.

The pipeline incorporates data and metadata guidelines and templates, enabling the integration of data collected by UMS across a variety of groups engaged in research and defense contexts. Considerations were also made to make it easier to include new or existing UMS that come into compliance. The guidelines are based on internationally accepted standards from the International Standards Organization (ISO) and the Open Geospatial Consortium and were reviewed by stakeholders in academia, industry, and the government. In 2023, the Naval Research Lab- Stennis Space Center started testing the system using NOAA and Navy data collected from two types of UMS: a REMUS 600 and Mark-18 UMS. Testing involved assessing UMS metadata and processing sensor data into an open source data format.The end product included non-proprietary formatted data, a data footprint, and standalone ISO standard metadata files. By automating the data processing workflow, the timeline from collection to usable data was greatly reduced. While NOAA and the Navy have beta tested the pipeline, they continue to work on the process of improving data sharing that could become publicly available.

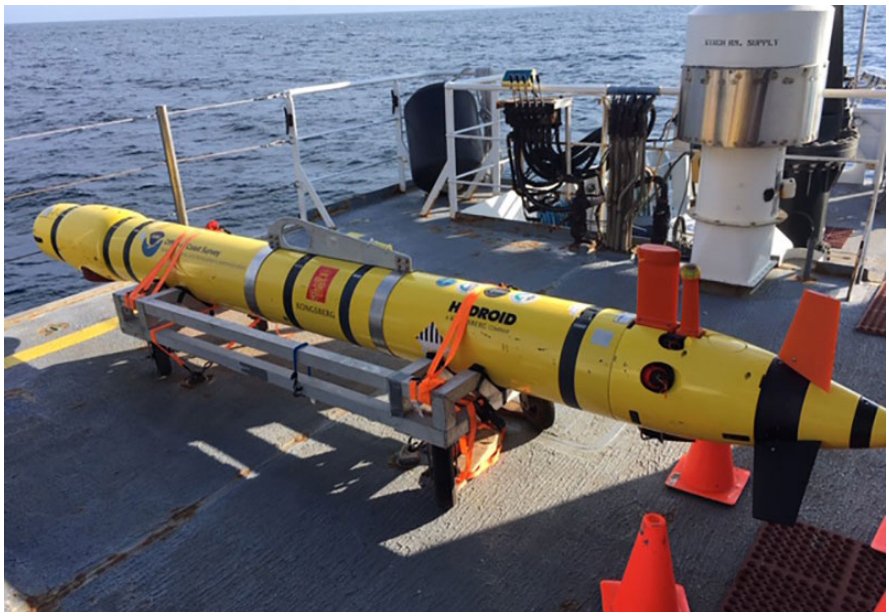

Image 4: A REMUS 600 UMS on board a NOAA ship. Photo: B. Eakins/Colorado University Boulder/NOAA

Advancing Marine Mammal Assessment with Underwater Gliders

Lead Personnel: Erin Oleson–NMFS Pacific Islands Fisheries Science Center

NOAA's Pacific Islands Fisheries Science Center (PIFSC) is in charge of assessing the status of marine mammal populations in the waters surrounding the Hawaiian Islands, American Samoa, U.S. Pacific Remote Island Areas, and the Mariana Islands. This region is the largest area of jurisdiction for NOAA's National Marine Fisheries Service, and includes over 1.7 million square nautical miles of ocean and hosts over 25 whale and dolphin species. Time and resource constraints prevent the complete survey of this region on a regular basis.

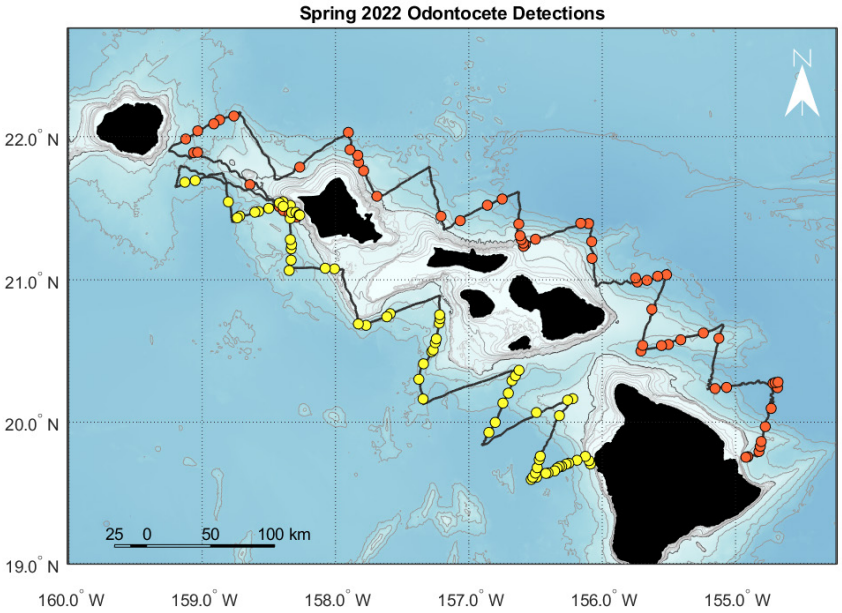

Image 2: A map of the glider paths (yellow=leeward, orange=windward) around the Hawaiian Islands. Photo: NOAA

In 2023, the PIFSC–in partnership with NOAA's Cooperative Institute for Marine Ecosystem and Resources Studies (CIMERS), Oregon State University, and NOAA's Pacific Marine Environmental Laboratory (PMEL)–deployed passive acoustics-equipped Seaglider underwater buoyancy gliders to survey for toothed whales around the Hawaiian Islands. The survey was part of a larger project to advance remote marine mammal stock assessments with passive acoustic gliders. NOAA has previously partnered with CIMERS to explore the use of passive acoustic monitoring and underwater buoyancy gliders to detect marine mammals.

The recent efforts included: 1) testing two gliders outfitted with different archival and near-real-time passive acoustic monitoring and reporting equipment, and 2) the development of standardized and publicly available data processing and management tools. The equipped glider detected 154 toothed whale events around the Hawaiian Islands and carried out the first field tests of a real-time detector onboard a glider to report on the presence of sperm whales. While PIFSC researchers and their partners are still evaluating the technology, if the equipped glider is fully operationalized, it will enable NOAA to more precisely manage marine mammal populations and allow for adaptive fisheries management.

Mapping by UMS for Navigation, Flood Inundation Modeling, and more

Lead Personnel: Michael Annis and LTJG Collin McMillan–NOS Office of Coast Survey, Navigation Response Branch

In order to protect life and property from underwater dangers to navigation, NOAA's Office of Coast Survey Navigation Response Branch maintains mobile Navigation Response Teams (NRTs) around the United States. The teams utilize crewed vessels and UMS to dynamically respond to emergencies and maritime incidents, and to provide time-sensitive information to update navigational charts and other products. UMS allow the NRTs to access waters that are too dangerous or otherwise inaccessible for crewed vessels. In 2023, the Navigation Response Branch expanded its UMS platform types to be able to handle a greater diversity in sea state and improve sonar quality and endurance—making the UMS more effective for navigation safety surveys—while enhancing their capability to collect mapping data that benefits other applications, including flood inundation modeling.

Image 3: An Echoboat UMS on the stern of a survey vessel before deployment. Photo: NOAA

Using funds made available through the Bipartisan Infrastructure Law, the Navigation Response Branch completed two projects in 2023 to gather data for NOAA's National Water Center and Office of Coast Survey Development Lab to inform flood inundation modeling efforts while updating navigational charts. In July of 2023, the NRT deployed an EchoBoat 240 UMS with multibeam and side scan sonar capabilities in tandem with the NOAA survey vessel *Bay Hydro II* to survey the Saint Mary's River off the mouth of the Potomac River. In August, a similar survey was then performed in the Elizabeth River of Virginia using an Echoboat 160 UMS and a mobile survey boat. The UMS allowed data to be gathered farther in shore, and operated in waters less than one meter deep, providing important data to NOAA's scientists. Ultimately, all data collected is made freely available for other uses via the Office of Coast Survey's National Bathymetric Source and NOAA's National Centers for Environment Information.

Performing regular, non-emergency survey operations—like those on the Saint Mary's and Elizabeth Rivers—allow the teams to maintain proficiency in UMS operations. In doing so, the teams are always ready to deploy in emergency scenarios (like hurricane response) while gathering mission critical information.

Replacing Moored Data Buoys with UMS

Lead Personnel: William Burnett, Kathleen ONeil, Dawn Petraitis–NWS National Data Buoy Center

The NOAA National Data Buoy Center (NDBC) maintains a global network of data buoys that provide ocean observation data that informs forecast and warning for weather and ocean conditions, improved coastal ocean circulation models, commercial and recreational marine transportation, environmental monitoring, and other applications. In 2023, the NDBC entered a public-private partnership with Saildrone to deploy an uncrewed surface vehicle to replace a moored data buoy in the Monterey Bay National Marine Sanctuary.

In this partnership between NOAA and Saildrone, Saildrone operates their UMS in a specific region that a data buoy would typically gather data from and provides that data to the NDBC as a service. The operating model was originally trialed in the Gulf of Mexico in 2022 following outages of two moored buoys. The Saildrone UMS is able to gather comparable data to a moored data buoy that meets the NDBC's operational time and space requirements. The use of UMS in place of a moored data buoy can serve many purposes, such as reducing seafloor disturbance from moored buoys in protected areas and providing an on-call platform to replace data buoys with problems.

Thus far, over 97 percent of the data gathered from the UMS has been usable. Data gathered includes information on wind, air and sea surface temperature, pressure, weather conditions, and wave conditions. At one point in the deployment, the UMS measured a wave height of over 25 feet and wind gusts of over 50 nautical miles per hour. The platform will be deployed through June, 2025 and will continue to gather in-situ real-time oceanographic and atmospheric data in the meantime.

Image 6: A team of NOAA and Saildrone personnel in front of a Saildrone at the OCEANS23 conference. Photo: NOAA/Saildrone

Expanding Awareness of Great Lakes Fishes with UMS

Lead Personnel: Steve Ruberg–OAR Great Lakes Environmental Research Laboratory

NOAA's Great Lakes Environmental Research Laboratory (GLERL) is responsible for conducting research directed towards understanding the environmental processes in the Great Lakes and their watersheds. This research contributes to products and services that support the Great Lakes region and other freshwater systems, impacting over 34-million people who live, work, and recreate in the Great Lakes region.

In June of 2023, GLERL researchers partnered with the Monterey Bay Aquarium Research Institute to deploy two Long Range Autonomous Underwater Vehicles in support of larval fish research in Lake Michigan. Understanding larval fish dynamics and the variables that influence their distribution, growth, and survival is critical to improving the management of the region's recreational, commercial, and subsistence fisheries. Temperature, wind-generated lake currents, and predation are thought to greatly influence the survival of larval fishes and thus their contributions to fisheries. However, the mechanisms for this are poorly understood.

The deployed LRAUV gathered data on environmental conditions and predator fish presence over a period of five days. The LRAUV were launched from a nearby beach, delivering ecosystem observations during severe weather when research vessel operations were not possible. In doing so, the LRAUVs helped increase situational awareness of the environment while increasing the team's ability to operate the UMS platform. In the future, GLERL plans to use the lessons learned during the June 2023 deployment to launch the LRAUV in Lake Erie during the winter to continue to support ecosystem research. Ice and harsh conditions make it difficult to perform ship-based observations in the Great Lakes during the winter. If successful, the use of the LRAUV may substantially increase observations and understanding of fish dynamics and the Great Lakes at-large during the presently understudied winter season.

Image 7: Two LRAUVs on the Muskegon Pier on Lake Michigan before launch. Photo: Steve Ruberg/NOAA

Utilizing Corporate UMS Assets as Force Multipliers to Crewed Platforms

Lead Personnel: Dexter Malley, Erica Fruh, Joshua Bergeron–OMAO Uncrewed Systems Operations Center, UMS Division

NOAA utilizes numerous operating models when it comes to deploying UMS to gather mission critical data. In some instances, programs within the agency own their UMS and operate them for their specific missions like Northwest Fisheries Science Center's autonomous underwater vehicle, Popoki. Other times, programs collaborate with partners who operate UMS on their behalf like the Integrated Ocean Observing System Regional Association's glider fleet. Alternately, NOAA programs will sometimes partner with industry to operate a UMS and provide the data as a service. In recent years, NOAA has explored another operating model in which the agency acquires corporately owned UMS assets that would be a resource for all of the agency to use, similar to the NOAA white hulled ships.

Image 5: A DriX uncrewed surface sits in its docking station alongside the NOAA Ship Thomas Jefferson. Photo: NOAA

In 2023, NOAA's Uncrewed Systems Operations Center committed to procuring their second corporate UMS platform, a DriX uncrewed surface vehicle. This commitment came on the heels of the transition to operations of the Center's first DriX in performing hydrographic surveys in tandem with the NOAA Ship Thomas Jefferson. In 2024, the DriX will be deployed alongside the NOAA Ship Thomas Jefferson to perform hydrographic surveys.

Improving Hurricane Awareness through UMS and Partnerships

Lead Personnel: Kathleen Bailey–NOS Integrated Ocean Observing System

Since 2018, NOAA has supported the deployment of over 400 gliders that have captured temperature and salinity profiles in the vicinity of 50 tropical cyclones, including 9 Major Hurricanes. Data from the gliders helps fill observing gaps in forecasting models and assess upper ocean conditions before, during, and after hurricanes. Modeling studies have shown promising results on reducing hurricane intensity forecast errors from the incorporation of glider data.

Image 8: A Navy glider is prepared for deployment off the R/V Nancy Foster. Photo: Gulf of Mexico Coast Ocean Observing System

NOAA's Integrated Ocean Observing System (IOOS) Office coordinates the seasonal glider field campaigns with participation from over 20 partners, including the Navy, academic partners, IOOS Regional Associations, and NOAA's Atlantic Oceanographic and Meteorological Laboratory. The 2023 hurricane season marks the 6th year of this coordinated partnership, and this season, gliders broke a record since 2018 for the most days at sea: 3,741. Gliders captured data in the vicinity of seven tropical cyclones, including Major Hurricane Idalia, which passed over two gliders operated by IOOS Regional Association partners from the University of South Florida.

This collaboration has not only benefited hurricane research and operational models; it has also been a success story of partnering across numerous federal programs and nonfederal partners. For example, the Naval Meteorology and Oceanography Command provides 10-12 oceanographic gliders each season for deployment by IOOS Regional Association partners. The gliders are then piloted by the Navy's Glider Operations Center, with guidance on ocean conditions from academic partners. This has served as an educational experience for the Navy Glider Operations Center, while also providing benefits to NOAA models that in turn provide resources that benefit society. Future year efforts include further coordination across NOAA's cadre of hurricane-deployed uncrewed systems (including gliders, Saildrones, uncrewed aircraft, and more) to better provide models and forecasters with a full ocean-atmosphere picture of hurricane conditions to save lives and property.

Partnering in Programs and UMS to Advance NOAA's Ocean Exploration Mission

Lead Personnel: Aurora Elmore–OAR Ocean Exploration Program Office

NOAA's Ocean Exploration office, in partnership with the Ocean Exploration Cooperative Institute (OECI), works to map and characterize the nation's vast ocean territory, while developing and implementing new technologies and educating the future blue workforce. In this pursuit, the partnership currently operates 12 UMS platforms, including uncrewed surface vehicles, uncrewed underwater vehicles, and tethered remotely operated vehicles.

In 2023, OECI conducted their third annual technology demonstration of UMS technologies on the Ocean Exploration Trust's E/V Nautilus around the Geologist Seamounts, which are south of the main Hawaiian Islands. In this demonstration, the team operated two UMS platforms, sometimes in tandem, to advance emerging exploration technologies. UMS platforms included a DriX uncrewed surface vehicle (from the University of New Hampshire) and Mesobot autonomous underwater vehicle (from Woods Hole Oceanographic Institution).

Image 7: A DriX UMS transits near the E/V Nautilus. Photo: Ocean Exploration Trust

The operations included over 270 hours of UMS operations between 10 deployments of the DriX and 19 deployments of the Mesobot. DriX was able to map over 180 square miles of seafloor and collect water column observations across 360 miles, while Mesobot collected imagery and eDNA samples throughout the understudied midwater environment. The two UMS were able to operate simultaneously using collaborative operations. This allowed Mesobot and DriX to operate independently of the E/V Nautilus. DriX was able to serve as a communications and tracking relay for Mesobot and identify key layers in the water column for Mesobot to collect targeted eDNA samples from. Initial results showed the density of eDNA in these directed samples to be exponentially higher than using previous sampling techniques Collectively, the operations showcased the value of UMS in gathering scientific data and optimizing days at sea.