

DRAFT

**Strategy for the Development of an
Unmanned Aerial Systems Capability
within the
National Marine Sanctuary System**



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Office of National Marine Sanctuaries
National Ocean Service

National Oceanic and Atmospheric Administration
U.S. Department of Commerce



Cover Photo: Launching a PUMA off the F/V Arctic Explorer

Introduction

Purpose.

This document outlines the Office of National Marine Sanctuaries (ONMS) plans for the testing of Unmanned Aerial Systems (UAS). The ONMS is partnering with the Office of Oceanic and Atmospheric Research's (OAR) UAS Program in the implementation of several projects in FY12 and FY13 to test and evaluate a small unmanned aircraft system, PUMA, which is designed for both land-based and maritime operations. Additionally, an unmanned surface vehicle (USV) called the Emergency Integrated Life Saving Lanyard (EMILY) will also be tested.

UAS platforms are still in the infancy stages with respect to civilian government research projects and access to the national air space (NAS) through the Federal Aviation Administration (FAA). UAS-based missions are not likely to replace traditional manned aircraft missions in the short term, but will instead complement and enhance them by providing unique datasets. The NMSP, with its multi-mission requirements, offers the perfect "research laboratory" to further refine the capabilities and specific missions applicable to UAS within NOAA.

The FAA has been mandated to fully integrate UAS operations into the nation's airspace by 2015, which should streamline the clearance process and allow for UAS operations throughout the marine sanctuaries, in accordance with federation aviation regulations that are being developed.

This document also articulates possible work in the future (FY14 and beyond). Potential thematic areas, geographic locations, and platforms are discussed. However, much of the future work will be based on the results from the upcoming short-term testing activities.

Why Test UAS?

UAS offer the ONMS the opportunity enhance how we do business. Testing of UAS technology will help us understand the capabilities and limitations of these systems. Our investments in testing these platforms during the next few years will also help us determine how we would incorporate these platforms into long-term resource protection and management activities at our sites.

These platforms offer the potential for dramatically enhancing sanctuary resource protection. It is expected that UAS will enhance the effectiveness of ONMS activities by allowing us to operate in places and/or times that we might not have the ability to access due to cost, remoteness, or lack of resources. Programmatic efficiencies would also be developed by possibly allowing us to "do more with less". These systems are also much "greener" because they increase our coverage with minimal adverse environmental impact from operations.

The primary objective of the testing in 2012 and 2013 is to determine how we would integrate the PUMA system into standard sanctuary research, monitoring, resource protection, law enforcement, and emergency response activities. It is anticipated that UAS will become more fully integrated into standard ONMS operations, given available air space, as system technologies evolve and enhance over time. UAS seem to be an obvious management tool in future ONMS operations, given the vast geographic expanse that sanctuaries cover and limited resources (i.e., vessels, aircraft, and staff) currently available at these sites.

Background

ONMS Mission.

The mission of the ONMS is to serve as the trustee for the nation's system of marine protected areas and to conserve, protect, and enhance their biodiversity, ecological integrity and cultural legacy. The ONMS protects 13 national marine sanctuaries and one marine national monument that encompass more than 150,000 square miles of marine and Great Lakes waters. The National Oceanic and Atmospheric Administration (NOAA) has managed national marine sanctuaries since the passage of the Marine Protection, Research, and Sanctuaries Act (now the National Marine Sanctuaries Act) in 1972.

The National Marine Sanctuaries Act (NMSA) authorizes the Secretary of Commerce to designate and manage areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, or esthetic qualities as national marine sanctuaries. Regulations are promulgated to provide the means for management and protection of these important places.

ONMS Aircraft Operations.

In 1997, the Channel Islands National Marine Sanctuary (CINMS) initiated an Aerial Survey Monitoring Program to monitor and evaluate marine resources and human activities within sanctuary waters. The Sanctuary Aerial Monitoring and Spatial Analysis Program (SAMSAP) provided vital information for the management of CINMS, most recently critical data for the successful establishment of a network of marine reserves. Currently, the aircraft is providing critical enforcement flights for the newly established reserves. Based in Santa Barbara, Calif., the CINMS utilizes a dedicated Lake Renegade Seawolf (N64RF) in support of CINMS and occasional support for the Monterey Bay National Marine Sanctuary (MBNMS). The Seawolf amphibian aircraft is utilized for marine mammal and vessel traffic surveys, emergency response and enforcement flights. Special onboard equipment includes bubble and camera windows as well as a laptop computer and customized software

linked to the aircraft Global Positioning System (GPS). Position information can be downloaded instantly to register the location of surveyed objects in sanctuary waters and displayed near real-time in a Geographic Information System (GIS) format. The data is archived to provide long-term trend analysis of visitor use, marine mammal distribution and abundance, and kelp forest health and patterns.

ONMS Requirements

The NMSP has numerous operational requirements that could be met using UAS technology. Staff regularly responds to animals in distress, such as whales that become entangled in fishing gear or marine debris. In such cases, it is often difficult to monitor the location of the animal for the extended period that may be required for response. The same is true for hazardous spills. It is sometimes necessary to track and measure sediment plumes caused by human activities, such as road construction and repair and dredging. Harmful algal blooms must be assessed and tracked to determine the threat they pose to resources and humans. The extent of damage caused by coral bleaching or vessel groundings can also be evaluated from the air. Vessel traffic monitoring is sometimes necessary to limit threats to migrating or congregating animals. Monitoring vessel activity, such as fishing, recreational boating, diving, and cargo transit is necessary to understand uses and threats to sanctuary resources.

Science:

The NMSP has *scientific* needs in a number of areas that can be addressed by UAS flights with camera payloads. Resource characterization needs include:

- identification and measurement of shallow water habitat types;
- survey and identification of submerged cultural resources;
- documenting the influence of watersheds and other inputs that affect water quality;
- temporal and spatial patterns of habitat use by living resources (e.g., haul out areas); and
- population assessments for large animals, such as birds and marine mammals.

Remote Sensing:

Representative *monitoring* requirements for the NMSP include:

- periodic collection of data along predetermined flight paths to count birds and marine mammals;
- overflights of known haul out and bird nesting areas;
- documenting changes in kelp canopy cover;
- determining the location and extent of potentially productive convergence zones or upwelling areas;
- determining spatial and temporal affects of runoff;
- counting vessels and assessing human use patterns, and

- potential for documenting locations and extent of marine debris, particularly in remote areas such as the NWHI.

Enforcement:

NOAA Office of Law Enforcement (OLE) has identified 14 high priority enforcement issues within the sanctuaries. UAS have high potential for *enforcement* activities to include:

- tracking small vessels;
- identifying and documenting the activities and locations of individual vessels;
- detecting, observing, and identifying vessels, including determination of their activities (fishing, pleasure boating, etc); and
- detecting, observing, and tracking of oil spills, and other surface features.

Emergency Response:

Potential for aiding *response* to emergency incidents in sanctuary waters. These types of emergencies include:

- vessel groundings;
- downed aircraft;
- oil spills;
- observational information; and
- command and control of response activities.

The State of UAS Technology

UAS technology is maturing rapidly. This technology has been used primarily for military purposes. Increasing non-military applications are anticipated for UAS once the FAA clears their use within the National Airspace System in 2015. The systems range widely in terms of operational in endurance, altitude, operating speed, etc. However, UAS now appear to be economically feasible and technologically capable for supporting sanctuary operations.

They are often used for missions that are characterized as too dull, dirty or dangerous for manned aircraft. For example, locations that are extremely difficult to access (e.g., remote portions of national marine sanctuaries) are prime candidates for use of UAS.

These craft are also smaller and quieter than traditional aircraft—resulting in less disturbance to animals than from manned aircraft. Their inherent stealth provides obvious advantages for surveillance and enforcement. These platforms can also be quickly deployed and positioned for use at a site.

Capabilities of a UAS

UAS perform a wide variety of functions. The majority of these functions are some form of remote sensing, which is central to the reconnaissance role an unmanned aerial system fulfills.

Remote sensing

UAS remote sensing functions include electromagnetic spectrum sensors, gamma ray sensors, biological sensors, and chemical sensors. A UAS electromagnetic sensors typically include visual spectrum, infrared, or near infrared cameras as well as radar and video systems. Other electromagnetic wave detectors such as microwave and ultraviolet spectrum sensors may also be used, but are uncommon. Biological sensors are sensors capable of detecting the airborne presence of various microorganisms and other biological factors. Chemical sensors use laser spectroscopy to analyze the concentrations of each element in the air.

Aerial surveillance of large areas is made possible with low cost UAS systems. Surveillance applications include: wildlife monitoring, wildfire mapping, pipeline security, home security, emergency response. Optical Camera Systems mounted in a 360 degree gimballed turret in the bottom of the fuselage have auto-tracking and “lock on target” software

Scientific research

Unmanned aircraft are uniquely capable of penetrating areas that may be too dangerous for piloted craft. NOAA began utilizing the Aerosonde unmanned aircraft system in 2006 as a hurricane hunter. This 35-pound system can fly into a hurricane and communicate near-real-time data directly to the National Hurricane Center in Florida. Beyond the standard barometric pressure and temperature data typically culled from manned hurricane hunters, the Aerosonde system provides measurements far closer to the water’s surface than previously captured. Further applications for unmanned aircraft can be explored once solutions have been developed for their accommodation within national airspace system. UAVSI, the UK manufacturer, also produce a variant of their Vigilant light UAS designed specifically for scientific research in severe climates such as the Antarctic.

Search and Rescue

UAS will likely play an increased role in search and rescue in the United States. This was demonstrated by the use of UAS during the 2008 hurricanes that struck Louisiana and Texas. Micro UAS, such as the Aeryon Scout have been used to perform Search and Rescue activities on a smaller scale, such as the search for missing persons.

A Predators UAS, operating between 18,000–29,000 feet above sea level, has performed search and rescue and damage assessment. Payloads carried were an

optical sensor (which is a daytime and infra red camera) and a synthetic aperture radar. The SAR is a sophisticated all-weather sensor capable of providing photographic-like images through clouds, rain or fog, and in daytime or nighttime conditions; all in real-time. A concept of coherent change detection in SAR images allows for exceptional search and rescue ability: photos taken before and after the storm hits are compared and a computer highlights areas of damage.

Monitor oil, gas and mineral exploration and production

UAS can be used to perform geophysical surveys, in particular geomagnetic surveys where the processed measurements of the differential Earth's magnetic field strength are used to calculate the nature of the underlying magnetic rock structure. The production side of oil and gas exploration and production entails the monitoring of the integrity of oil and gas pipelines and related installations. For above-ground pipelines, this monitoring activity could be performed using digital cameras mounted on one, or more, UAS.

Table 1. *UAS Sensors Available by Technology and Applicability to Airborne Requirements.*

Type of Sensor	UAS				ONMS Requirement						Notes
	PUMA	Scan Eagle	Manta	Sierra	Marine Mammal Surveys	Visitor & Vessel Use Surveys	Remote Sensing	Enforcement	Emergency Response	Marine Debris	
RGB	√	?			√	√		√	√	√	Limitations: Processing, imagery footprint
Infrared	√	?			√	√		√	√	√	
Thermal		√			√		√	√	√		
LIDAR	To be developed	√					√	√	√		PUMA capability still in research mode
Hyperspectral							√		√		Expensive, huge data sets
SAR	To be developed		√	√	√		√	√	√	√	Interest in use with spills
Temperature Sensor	To be developed						√				
Magnetometer		√					√				

UAS Categories

UAS platforms can be characterized by their range and normal operating altitude. Capabilities and costs of operation typically increase with the greater the range and higher the altitude. ONMS expects to use the PUMA system, which is considered a low altitude short endurance system. The table below summarizes UAS categories.

Table 2. Summary of UAS Categories.

UAS Category	Gross Takeoff Weight (lb)	Operating Altitude	Range (nm)
High Altitude Long Endurance (HALE)	>1,320	>50,000	6,000 - 11,000
Medium Altitude Long Endurance (MALE)	<1,320	18,000 - 50,000	2,000 - 6,000
Low Altitude Long Endurance (LALE)	21 - 1,320	1,200 - 18,000	200 - 2,000
Low Altitude Short Endurance (LASE)	0 - 20	<1,200	10 - 200

Low Altitude Short Endurance (LASE) UAS. The LASE UAS is the focus of ONMS testing in short term, in FY12 and FY13. They most likely will be focus of activities in out years as well (FY14+)—given their cost, availability, and ease of use. These UAS allow the observer to cover more area, with less impact on the marine habitat, in much less time, and with less effort. It is anticipated that LASE will support a range of sanctuary activities, including law enforcement and surveying activities.

LASE offer the capability of landing and recovering aircraft at sea. They also provide increased flexibility for conducting ship-based operations, allowing the human observer to remain on the ship, while surveying remote islands and coastlines. The systems are also easily transportable enhancing their utility at a range of sites, including those where operations may be from remote land-based locations. The flexibility and relative ease of operation also offers the ability for the systems to be utilized by many different mission teams throughout the year—making these systems especially appealing to ONMS, which includes 14 sites.

LASE are easily launched and recovered from shipboard or land based locations. The launch techniques include catapulting or hand-throwing the aircraft. Recovery techniques include a pole and mast capturing device, capturing the aircraft in a net, or landing the device on the water or land.

Low Altitude Long Endurance (LALE) UAS. This UAS has the capability to fly to an operational area from over 1,200 miles away and loiter there for 12 hours before returning home. This capability has not been developed for civilian use at this time.

Medium Altitude Long Endurance (MALE) UAS. A UAV that flies at an altitude window of 10,000 to 30,000 feet for extended durations of time, typically 24 to 48 hours. An example of this type of UAS is the Altair, a civilian version of the Predator.

High Altitude Long Endurance (HALE). This UAS has the capability to operate at 60,000 to 65,000 feet, up to 300 knots airspeed, with a 3,000-nautical-mile range with up to 24 hour time-on-station capability. An example of this technology is the Global Hawk UAS.

ONMS UAS Activities

Prior to 2012

ONMS has already either tested UAS or collaborated on joint UAS projects in recent years. This experience has helped us to better understand the capabilities and potential applications in sanctuaries. In addition, these experiences have positioned us for the implementation of a robust testing program over the next several years. Recent projects include:

- Humpback whale observations in Hawaii in 2006
- Undetected marine surveillance from ships of suspected illegal fishing activity in the Channel Islands National Marine Sanctuary in 2009.
- Penguin population monitoring in Antarctic in 2011.
- Oil Spill drill in California in 2011.

Planned Demonstrations

The over-arching objectives for these projects is to fully integrate the PUMA system as part of standard sanctuary research and enforcement vessel operations within the National Marine Sanctuary Program, including living marine research (LMR) surveys and marine zone enforcement. Additionally, a continued understanding of the PUMA system capabilities, limitations and the development of accepted standardized operational protocols and methodologies are being developed.

Additional details of each project listed below can be found in the Implementation Section.

1. Papahānaumokuākea Marine National Monument (PMNM)

The primary objectives are to conduct operations to survey and monitor seabird colonies, sea turtle, and monk seal populations along the remote islands and atolls of the NWHI flying the PUMA system off a NOAA Ship. This remote and wild archipelago is difficult and expensive to access and survey and yet is critical to annually assess threatened and endangered LMR populations, especially in

anticipation of climate change. In addition, we plan to maximize utilization of the UAS by partnering with scientists and resource managers to deploy the UAS to conduct additional LMR surveys, marine debris surveys, and coral reef habitat characterization.

2. Florida Keys National Marine Sanctuary (FKNMS)

The primary objective is to use the Puma and Hydronalix, Emergency Integrated Lifesaving Lanyard (EMILY) platform to conduct surveillance and enforcement of distant areas of the sanctuary, specifically the remote waters surrounding the Dry Tortugas. In addition, we plan to maximize utilization of the UAS by partnering with scientists and resource managers to deploy the UAS to conduct LMR surveys for sea turtles and manatees, marine debris surveys, and coral reef habitat characterization. In addition to informing the scientific and management communities of the FKNMS, the data collected and the development of operational protocols to collect this applied scientific data will inform the mission planning for the 2013 deployment to the PMNM in 2013.

3. Channel Island National Marine Sanctuary (CINMS)

This project is both an operations project and a science project. It will utilize the AeroVironment PUMA All Environment (Puma) system to develop, test and evaluate various potential concepts and protocols for resource protection, monitoring and enforcement missions in CINMS and to conduct routine, regular UAS operations for enforcement and LMR monitoring. Additionally, the concept is to develop an operational UAS Test Bed that will capitalize on the location, infrastructure (including the military airspace managed by NAVAIR at Point Mugu), personnel and natural resources available to routinely test and evaluate small UAS equipment (platforms and payloads) and to develop operational protocols to be exported to other NOAA programs and missions.

4. Olympic Coast National Marine Sanctuary (OCNMS)

The primary objective is to conduct operations to survey and monitor seabird colonies along the remote wilderness coastline and offshore islands of the Sanctuary. Despite the difficulty of surveying the rugged coastline in Washington State, there is a long-term annual database from manned aircraft, but annual surveys are not always logistically possible and may be disturbing to sensitive species. A small UAS, such as the PUMA, may be the best tool to ensure that long-term monitoring efforts are continued by resource trustees.

Platforms to be Tested in FY12 and FY13

The ONMS will test two systems in FY12 and FY13. The PUMA UAS will be tested in the Channel Islands, Florida Keys and Northwest Hawaiian Islands. The Emergency Integrated Lifesaving Lanyard (EMILY) unmanned surface vessel (USV) will be likely tested in the Channel Islands and in the Florida Keys. It is possible, as opportunities arise, that other tests might occur in these or other areas. All testing will be in or near sanctuaries and focused on supporting sanctuary operations.

PUMA. The Puma All Environment Capable Variant (AECV) Small Unmanned Aircraft System (SUAS) is designed for land based and maritime operations. Capable of landing in fresh or salt water and on land, the Puma provides the operator with an operational flexibility to tailor missions to the specific needs of forward tactical units. The Puma is designed for use in rugged and austere environments, providing a highly reliable, man portable reconnaissance system requiring no auxiliary equipment for launch or recovery operations. The electrically powered system is quiet, reducing the aircraft's acoustic signature.

Table 3. Key PUMA Characteristics

Parameter	Value
Payload	2lb
Endurance	2 hours
Cruise Speed	20-45 knots
LOS Range	8 nm
Ceiling	500 ft
Launch/Recovery	Hand/Deep Stall

The Office of Oceanic and Atmospheric Research (OAR) has acquired two PUMA "systems". Each system includes three aircraft and two ground control stations. ONMS is partnering with OAR to test and evaluate these systems in FY12 and FY13. To the extent practical, ONMS will coordinate with NOAA's Marine Debris Program in testing the PUMA system.

Puma operates autonomously providing persistent Reconnaissance Surveillance, and Targeting Acquisition (RSTA) data directly to operators and forward deployed commanders. Puma carries a dual-mounted electro-optical (EO) (2592x1944; 3X Zoom) and infrared (IR) (640 x 480) camera in a lightweight mechanically and digitally stabilized gimballed payload, allowing the operator to keep "eyes on target." A bore sighted laser illuminator is also mounted in the payload. The air vehicle's modular design allows for future payload development to meet the needs of specific



Image of the PUMA

military applications. The UAV is operated from the modular Ground Control Station (GCS) and is compatible with the Raven GCS. Mission planning is aided by the incorporation of a rugged laptop linked to the GCS and running Potable Flight Planning System (Falcon View). The Falcon View application provides a moving map displaying flight plan, aircraft location, and other telemetry data. The Puma may be controlled at ranges up to 20 km. The Puma AECV flight endurance is 2 hours using rechargeable Lithium Ion (Li-Ion) battery packs

EMILY. ONMS will also be testing the Emergency Integrated Lifesaving Lanyard (EMILY) unmanned surface vehicle (USV). The EMILY was developed and built by Hydronalix and this system will be evaluated through a series of three missions:

- Marine sanctuaries testing (testing what??) - Channel Islands
- Coral mapping (how??) - Florida Keys
- Tropical cyclone testing -Florida keys region

Table 4. *Key EMILY Characteristics*

Parameter for 65" Hull	Value
Tethered Buoy Sleep Mode	100+ Hours
Battery Storage	240Whrs to 1920 Whrs (1 to 8 packs)
5 mph Patrol	600 minutes
Speed	13 mph with 46 lbs payload (30 mph max)
Duration	30 mph - 20 minutes
	13 mph - 39 minutes with 46 lbs
	1-2 mph - approximately 20 hours
Dimensions	65" length, 15" width, 8" high
Payload Capacity	Up to 80 lbs
Buoyancy	80.0 L (4882 inch ³) or 170 lbs



EMILY, a 65-inch watertight craft, is one of the newest of NOAA's hurricane research platforms. Outfitted with a satellite link, camera, battery and gasoline motor, and a variety of sensors, EMILY will collect sea-level data from within a hurricane beginning with the 2012 hurricane season. Credit: Hydronalix Inc.

EMILY's sensors will collect barometric pressure, air and sea surface temperatures, salinity, and wind speed and direction. An onboard high-definition camera will also relay images back to NOAA scientists. Such surface data and imagery were previously impossible to obtain and represent a critical data gap for hurricane forecast improvement. It is anticipated that the EMILY would be deployed into a hurricane in Florida Keys region (it will be deployed prior to hurricane approach and loiter at sea until storm passes).

With a battery and a gasoline motor, EMILY can run for up to 10 days. Scientists will remotely guide EMILY into a storm system's eye. A "short burst data" satellite link on EMILY will facilitate a stream of data to scientists from the storm, and will allow scientists to steer the craft.

Other Platforms of Interest

There are a number of other potential UAS platforms that could be tested in out years. We have limited our list of platforms of interest to ONMS in the future to the ones shown below.

Scan Eagle.

The ScanEagle, empty, weighs less than 25 pounds. It can carry up to 12 pounds of fuel in addition to a scientifically significant payload for a mission endurance of over 20 hours. At cruise speed, it flies between 45 and 70 knots, and has a 10-foot wingspan.

In 2009, NOAA successfully used this UAS to study ice seals in the Bering Sea from the NOAA ship Oscar Dyson.

Manta and Silver Fox.

- The NOAA currently owns one Manta UAS that includes two aircraft.
- Currently has observation and carbon sampling sensors integrated.
- This platform was demonstrated to NOAA (NOS and NMSP) in 2006 from Hawaii. Mission flights evaluated tracking small vessels, humpback whale observations, tracking marine debris, and accessing UAS operations.



Manta in foreground and Silver Fox on launcher.

FY12 and FY 13 ONMS UAS Implementation Plans

The ONMS plans to test the PUMA (UAS) and the EMILY, an Unmanned Surface Vessel (USV) during four inter-related projects in unique geographic areas that maximize opportunities for multiple missions and successes over the next two years. The primary missions would consist of living marine resource (LMR) surveys, enforcement, and habitat mapping and characterization within the Channel Islands National Marine Sanctuary (CINMS), Florida Keys National Marine Sanctuary (FKNMS), and Olympic Coast National Marine Sanctuary (OCNMS) in 2012 and 2013; all leading to a deployment to the remote Papahānaumokuākea Marine National Monument (PMNM) in the northwestern Hawaiian islands (NWHI) in 2012 and 2013.

PMNM Demonstration and Workshop (2012)

Operations:

The goal is to develop an operations and deployment plan for the PUMA to operate as part of a multi-mission research cruise to the Northwest Hawaiian Islands (NWHI) aboard a NOAA Ship in the summer/early fall of 2013. Due to the extreme travel and expense required to reach the NWHI, joining an ongoing research cruise is the only cost effective method for deploying a PUMA system in PMNM. Given the complexity of integrating small UAS operations into a fully operational cruise with multiple researchers and objectives, this main Hawaiian island demonstration is critical for getting the buy-in, approvals, and permits necessary from the scientific and resource management communities for success.

Marine Debris:

The goal is to develop the ability to conduct routine PUMA and/or RESOLUTION UAS missions for marine debris surveys off a NOAA Ship and determine the optimum flight parameters to maximize sensor performance and anomaly detection system reliability. Marine debris experts will participate in the 2012 Hawaii based demonstration and the 2013 mission to NWHI aboard a NOAA Ship. Airborne Technologies, Inc. (ATI) continues to evolve the RESOLUTION UAS airframe as well as its payload and anomaly detection software. AeroVironment and Sentient have signed an exclusive global license agreement that allows AeroVironment to distribute Sentient's automatic target detection software for full motion video for use with small unmanned aircraft systems (UAS). Sentient's Kestrel Maritime software is specifically designed to enable automated detection of targets, in real time, from small UAS. We plan to evaluate the Kestrel Maritime software in conjunction with the RESOLUTION UAS at the 2012 Hawaii demonstration and planning meeting.

Workshop:

A two-day workshop is planned, featuring one day of a vessel-based PUMA operational demonstration and a one-day planning workshop (There will be a second day of operations planned as a weather back up). The workshop will be conducted on Oahu or Kauai in May or June of 2012 with PMNM researchers and partners, and OMAO personnel.

Criteria for success will be the scheduling of a PUMA and crew with defined goals and parameters for operating as part of a NOAA Ship cruise in 2013.

CINMS Demonstration (2012-2013)**Operations and Enforcement:**

The goal is to develop the ability to conduct routine small UAS missions using the PUMA operating from aboard the sixty-two foot NOAA research vessel *Shearwater* and from remote shorelines within military special use airspace around the Channel Islands and along the coast of Vandenberg Air Force Base and Point Mugu Naval Air Station. Seven mission-days consisting of multiple sorties will be conducted to optimize enforcement flight plans and protocols with the primary enforcement objective being the CINMS Marine Reserves. Both day and night flights will be conducted in conjunction with vessel operations in partnership with the United States Coast Guard (USCG) and the California Department of Fish and Game (CDFG). Under a separate proposal, the NOAA Marine Debris Program may be “buying” dedicated days at sea (DAS) aboard *Shearwater* to do additional testing and development prior to the 2013 NWHI deployment aboard a NOAA Ship.

Criteria for success will be the seamless integration of the PUMA into vessel operations and the understanding of the systems capabilities and limitations for future missions.

Living Marine Resource Surveys:

The goal is to perform targeted LMR surveys of shipping lanes, seabird colonies and pinniped haulouts to determine optimum flight parameters and protocols for future LMR surveys in CINMS and other locations. In addition, a goal is to determine the ability of the system to operate discreetly without disturbance to sensitive seabird colonies or marine mammals.

Criteria for success for the NOAA UAS Program will be the understanding of the systems capabilities and limitations for future LMR missions and the development of accepted standardized operational protocols. For CINMS, the seamless integration of the PUMA into CINMS research operations will be the criteria for success.

It is our intention to consider all of the LMR survey data collected in the CINMS, FKNMS and OCNMS to be development and validation of protocols and methodologies that we will be using to prototype for deployment of the Puma system to the NWHI on a NOAA ship.

FKNMS Demonstration (2012)

Operations and Enforcement:

The goal is to develop the ability to conduct routine PUMA missions operating from aboard the fifty-three foot NOAA vessel *Peter Gladding*. Seven mission-days consisting of multiple sorties will be conducted to optimize enforcement flight plans and protocols with the primary enforcement objective being the Tortugas Ecological Reserves. Both day and night flights will be conducted in conjunction with vessel operations in partnership with the USCG and Florida Fish and Wildlife Commission (FL FWC). Using the PUMA to enhance on-the-water enforcement will enable officers to determine if a vessel is permitted to be in the Reserves, or if the vessel is otherwise conducting prohibited activities. The PUMA will allow the law enforcement patrol vessel to remain out of visual range of the targeted vessel and evaluate whether an enforcement action was required. The PUMA will also be able to assist with quantifying visitor use in other remote areas of the FKNMS to determine if increased enforcement presence is needed to deter potential violations.

Criteria for success will be the seamless integration of the PUMA into vessel operations and the understanding of the systems capabilities and limitations for future enforcement missions. In addition, the transition from system testing to actual enforcement operations where the PUMA is providing targets for investigation and situational awareness during live boardings will be the ultimate milestone.

Living Marine Resource Surveys:

The goal is to develop the ability to conduct routine PUMA missions for LMR surveys. The PUMA will augment sea turtle research done in conjunction with NOAA Fisheries. Currently, sea turtles are captured, tagged and released within particular marine zones of FKNMS. Because this research is labor and time intensive, the PUMA will be utilized to locate and target areas where turtles are active while the tagging team completes their dockside preparations. This would reduce the associated vessel fuel costs and running time to find the sea turtles, and therefore contribute to overall project efficiency. Secondly, using the PUMA to collect HD video over remote 'back country' islands, FKNMS will collaborate with USFWS to identify seabird rookeries that are most at risk for human disturbance.

Four mission-days with multiple sorties will be conducted to support tagging efforts, island surveys, and opportunistic sightings of other species.

Criteria for success will be the seamless integration of the PUMA into tagging operations and the understanding of the systems capabilities and limitations for future LMR missions. The ultimate milestone would be the identification and positioning of a sea turtle from the PUMA followed by the directing of the small boat for a successful capture.

It is our intention to consider all of the LMR survey data collected in the FKNMS to build upon the CINMS work and continue to be development and validation of protocols and methodologies that we will be using to prototype for deployment of the Puma system to the NWHI on a NOAA ship.

Habitat Characterization and Mapping:

The goal is to develop the ability to conduct routine PUMA and EMILY missions for remote sensing surveys, specifically collecting HD video data, processing it, and developing geo-referenced, ortho-rectified seafloor habitat maps. It is anticipated that video of the seafloor will be capable up to 30m water depth given the typical water clarity around the Dry Tortugas. The UAS systems provide a valuable alternate to commercial satellite imagery, typically used, that can optimize collection to avoid obscuring cloud cover, wave heights, or sea surface effects. Furthermore, satellites cannot be tasked to capture short-time period episodic events, which given the flexibility of UAS and autonomous surface vessel deployment, can be optimized to capture specific events.

Criteria for success will be the seamless integration of the PUMA and EMILY into remote sensing operations and the understanding of the systems capabilities and limitations for future remote sensing missions with upgraded sensor packages. Complete success will entail the development of the processes and procedures for data collection and the production of a final habitat map of a specific island.

OCNMS Demonstration (2013)

Operations:

The goal is to develop the ability to conduct routine PUMA missions operating from aboard the thirty-eight foot NOAA research vessel *Tatoosh* and from remote coastlines. The PUMA will be launched and recovered from the *Tatoosh*, while it operates along the rugged coastline during the summer and flown at altitudes below one thousand feet. The PUMA will also be deployed via backpacking into wilderness coastline areas for launch and recovery from beaches along the coast. Seven mission-days consisting of multiple sorties will be conducted to optimize flight plans, protocols, and procedures with the primary objective being seabird surveys.

Criteria for success will be the seamless integration of the PUMA into vessel operations and launching and recovering from remote beaches as well as the understanding of the systems capabilities and limitations for future missions.

Living Marine Resource Surveys:

The goal is to develop the ability to conduct routine PUMA missions for LMR surveys, specifically seabird colonies. The PUMA will survey major seabird colony islands within the Washington Maritime National Wildlife Refuge Complex, which extends from Cape Flattery in the north, to the southern sanctuary boundary. UAS High Definition (HD) video data collected will be evaluated and compared to existing datasets to determine if the video resolution would be sufficient to assess seabird colony population dynamics for long-term monitoring. A critical potential benefit of the PUMA is to minimize potential wildlife disturbance that is an inherent factor in conducting low level survey flights with conventional aircraft. Disturbance data will be collected and analyzed for potential future expansion of aerial living marine resource monitoring.

In addition, partner agencies and researchers will be participating to collect data on seabird distribution and abundance in nearshore waters, sea otters, and pinniped haul-outs that are needed for year-round survey efforts to establish seasonal baseline data prior to catastrophic events (e.g., oil spills, harmful algal bloom events, etc.).

Criteria for success will be the seamless integration of the PUMA into seabird colony surveys and the understanding of the systems capabilities and limitations for future LMR missions that require “packing a system” in to remote locations. The ultimate milestone would be the ability to successful transition from manned aircraft surveys to small UAS seabird surveys within OCNMS.

It is our intention to consider all of the LMR surveys and seabird disturbance data collected along the Washington coast, combined with CINMS and FKNMS work, to be development and validation of protocols and methodologies that we will be using to prototype for deployment of the PUMA system to the NWHI on a NOAA ship. Seabird disturbance is the primary concern of many resource managers in regards to utilizing a UAS for surveys in the NWHI. This data will be critical in securing the necessary approvals and permits from partner agencies including the US Fish and Wildlife Service USFWS).

PMNM Demonstration (2013)

Operations:

The goal is to develop the ability to conduct routine PUMA missions operating from a NOAA Ship including safe and reliable deployment and recovery from a ship’s launch and remote beaches. The concept is to integrate the PUMA system as part of standard NOAA Ship operations in the NWHI for living marine resource surveys, marine debris surveys, and remote sensing. The ability to survey and map the coral reefs of the islands, atolls and surrounding waters from a large research vessel

vastly increases the effectiveness, capabilities and safety of these cruises. A demonstration and workshop in 2012 prior to the full NOAA Ship deployment in 2013 will be necessary to coordinate with OMAO and all research partners.

Criteria for success will be the seamless integration of the PUMA into NOAA Ship operations and the understanding of the systems capabilities and limitations for future LMR and marine debris missions in NWHI. The ultimate success would be the integration and OMAO acknowledgment of a PUMA system as a future standard-capability of a NOAA Ship.

Living Marine Resource Surveys:

The goal is to develop the ability to conduct routine PUMA missions for LMR surveys from a NOAA Ship in the remote NWHI. The primary mission would be to survey seabird colonies and monk seal populations along the NWHI as part of a joint mission in conjunction with NMFS and USFWS aboard a NOAA Ship. This would allow ground-truthing, data comparison and an objective, expert assessment of the threat, if any, of disturbance to sensitive species. Due to the extreme travel time and expense required to reach the NWHI, joining an ongoing research cruise is the only cost effective method for deploying a PUMA system. The ability to survey resources on these remote islands without interference, without the potential for the introduction of invasive species, and safely without landing a shore party is the transformative aspect of using the PUMA for this mission.

The PUMA HD video data collected will be evaluated and compared to existing datasets to determine if the video resolution would be sufficient to assess seabird colony population dynamics for long-term monitoring and the ability to identify individual monk seals. These surveys will be calibrated and compared with traditional survey methods. A critical potential benefit of the small, quiet PUMA is to minimize potential wildlife disturbance that is an inherent factor in conducting low level survey flights with conventional aircraft. Disturbance data will be collected and analyzed for potential future expansion of aerial living marine resource monitoring

Criteria for success will be the seamless integration and acceptance from researchers of the PUMA into LMR surveys along the NWHI.

Habitat Characterization and Mapping:

The goal is to develop the ability to conduct routine PUMA missions for remote sensing surveys off a NOAA Ship, specifically collecting HD video data, processing it, and developing geo-referenced, ortho-rectified seafloor habitat maps. It is anticipated that video of the seafloor will be capable up to 30m water depth given the typical water clarity around the NWHI. The PUMA system provides a cost-effective alternate to commercial satellite imagery, typically used, that can optimize collection to avoid obscuring cloud cover, wave heights, or sea surface effects.

Furthermore, satellites cannot be tasked to capture short-time period episodic events, which given the flexibility of PUMA deployment, can be optimized to capture specific events.

Criteria for success will be the seamless integration of the PUMA into remote sensing operations from a NOAA Ship and the understanding of the systems capabilities and limitations for future remote sensing missions with upgraded sensor packages. The ability to collect remote imagery and develop habitat maps for a broad range of resource protection and management issues ranging from climate change to marine cultural landscapes. Complete success will entail the development of the processes and procedures for data collection and the production of a final habitat map of a specific island or atoll.

Marine Debris:

The goal is to develop the ability to conduct routine PUMA and/or RESOLUTION UAS missions for marine debris surveys off a NOAA Ship and determine the optimum flight parameters to maximize sensor performance and anomaly detection system reliability. Marine debris experts will participate in the 2012 Hawaii based demonstration and the 2013 mission to NWHI aboard a NOAA Ship. Airborne Technologies, Inc. (ATI) continues to evolve the RESOLUTION UAS airframe as well as its payload and anomaly detection software. AeroVironment and Sentient have signed an exclusive global license agreement that allows AeroVironment to distribute Sentient's automatic target detection software for full motion video for use with small unmanned aircraft systems (UAS). Sentient's Kestrel Maritime software is specifically designed to enable automated detection of targets, in real time, from small UAS. We plan to evaluate the Kestrel Maritime software in conjunction with the RESOLUTION UAS at the 2012 Hawaii demonstration and planning meeting. Under a separate proposal, the NOAA Marine Debris Program may be "buying" dedicated days at sea (DAS) aboard the CINMS Research Vessel Shearwater to do additional testing and development prior to the 2013 NWHI deployment aboard a NOAA Ship.

Longer Term UAS Activities: FY14+

Each project segment in 2012 and 2013 will generate a Field Operations Report and a Scientific Results Report specific to the mission and operations for each Sanctuary. In addition, ONMS will combine all four segments into an ONMS-wide UAS Operations 5-year Plan. This report will be modeled after the ONMS Airborne Platforms Requirements document and incorporate the UAS site reports, the ONMS Enforcement Needs document, and the ONMS Science Needs Assessment. This document will build on the experience developed in the four sanctuaries of this proposal and build out UAS platform requirements, instrumentation/payload, and mission parameters for as many of the thirteen sites within ONMS as applicable.

The most important deliverable of this project will be the acceptance and integration of small UAS into routine NOAA Ship and small vessel operations for research and enforcement. For those of us familiar with the capabilities and ease-of-use of the PUMA system, it is a given that it is a powerful capacity multiplier for on-water operations. This project will convince the researchers, operators, and OMAO that this mature technology is ready for implementation in NOAA and will begin the transition from manned aircraft operations for a variety of marine resource management requirements. This two-year project is critical for building the baseline support to outfit multiple NOAA platforms with small UAS capabilities as standard equipment.