Arctic Shield 2015
Unmanned Aircraft Systems (UAS)
Test Plan and Operational Assessment

Todd Jacobs, NOAA UAS Program Office

John "JC" Coffey, NOAA UAS Program Office

ABSTRACT

The USCG Research and Development Center and the NOAA UAS Program will be evaluating several airborne systems including the Puma AE unmanned aircraft systems (UAS) provided by the National Oceanic and Atmospheric Administration (NOAA) to net-capture landings of UAS onboard Coast Guard ships and support other unmanned systems operations/exercises as part of Arctic Shield 2015. Coordination with Aerostat, ScanEagle, and Flexrotor for Intelligence, Surveillance and Reconnaissance (ISR), Maritime Domain Awareness (MDA) and Search and Rescue (SAR) missions will also be conducted with possible operational control hand-off of these platforms to operators onboard USCGC Healy. Data fusion, distribution and collaboration tools including: 2d3's imagery fusion, INMARSAT's satellite based data distribution and NOAA's ERMA collaboration tools will also be evaluated.

USCGC Healy Unmanned Aircraft Systems (UAS)
Test Plan and Operational Assessment

1. OVERVIEW

1.1 Purpose

The USCG Research and Development Center and the NOAA UAS Program will be evaluating several airborne systems including the Puma AE unmanned aircraft systems (UAS) provided by the National Oceanic and Atmospheric Administration (NOAA) to net-capture landings of UAS onboard Coast Guard ships and support other unmanned systems operations/exercises as part of Arctic Shield 2015. Coordination with Aerostat, ScanEagle and Flexrotor Intelligence, Surveillance and Reconnaissance (ISR),), Maritime Domain Awareness (MDA) and Search and Rescue (SAR) missions will also be conducted with possible operational control hand-off of these platforms to operators onboard USCGC Healy. Data fusion, distribution and collaboration tools including: 2d3's imagery fusion, INMARSAT's satellite based data distribution and NOAA's ERMA collaboration tools will also be evaluated.

1.2 Background

Arctic Shield 2015 will be the RDC's third trip with NOAA and the Puma AE onboard USCGC HEALY. Last year, Puma AE flew as part of a joint technology demonstration in the Beaufort and Chukchi Sea. The Puma AE was used to search, detect, and map the ice flow from the air, conduct marine surveys, conduct marine debris and oil spill exercises, and assess Healy's shipboard UAS capabilities. Utilizing its standard payload configuration, the Puma AE provided real-time imagery back to the ship improving situational awareness of the exercise. The imagery depicted actual on-scene ice conditions, ice movements and simulated marine debris and oil spill locations, dimension, and size which was vital to the success of the Oil Spill/Marine Debris Response Demonstration. Due to its success last year, the Puma AE will be utilized again during Arctic Shield 2015 for another ISR, MDA, SAR Arctic and Ice Exercise. The Puma AE conducted successful water, ice, deck and net capture recoveries during Arctic Shield 2013 and 2015.

Unfortunately, due to lack of permissions and policy last year, landing the Puma AE on HEALY's using the autonomous net-capture system was not permitted. Instead, the Puma AE was landed using manual flight deck and net-capture landings. This relieved the HEALY's Arctic Survey Boat (ASB) crew from UAS retrieval duty which posed a threat to the boat crew's safety and often exposed them to the Arctic's harsh environmental conditions for an extended period of time (see Figure 1).

Figure 1. Boat recovery of Puma AE during Arctic Shield 2013.

As a result, one of the recommendations for future operations was to develop autonomous landing procedures for the Puma AE and to obtain the necessary permissions to continue to reduce personnel and equipment safety risks. This operation was recently successfully tested onboard the NOAA UAS R/V Shearwater. The system was successful during 10 perfect autonomous captures during this developmental testing (see Figure 2).

Figure 2. Autonomous net recovery of Puma AE in 2015 on NOAA R/V Shearwater.

Other recommendations that were provided during the Arctic Shield 2014 Post Mission Review and 2015 Mission Concept Review for future operations follow (as outlined in Figure 4):

- Due Regard Operations
- Beyond Line-of-Sight (5 NM)
- Puma Envelope Expansion – Winds 30 knots gusting to 35 knots
- Weather Criteria Expansion – Clear of clouds
- Advanced payload development and testing
- Ice Prediction System development and testing
- Anti-/De-icing System development and testing
- Data Fusion (2d3), Data Transfer (INMARSAT) and Common Operating Picture (ERMA)

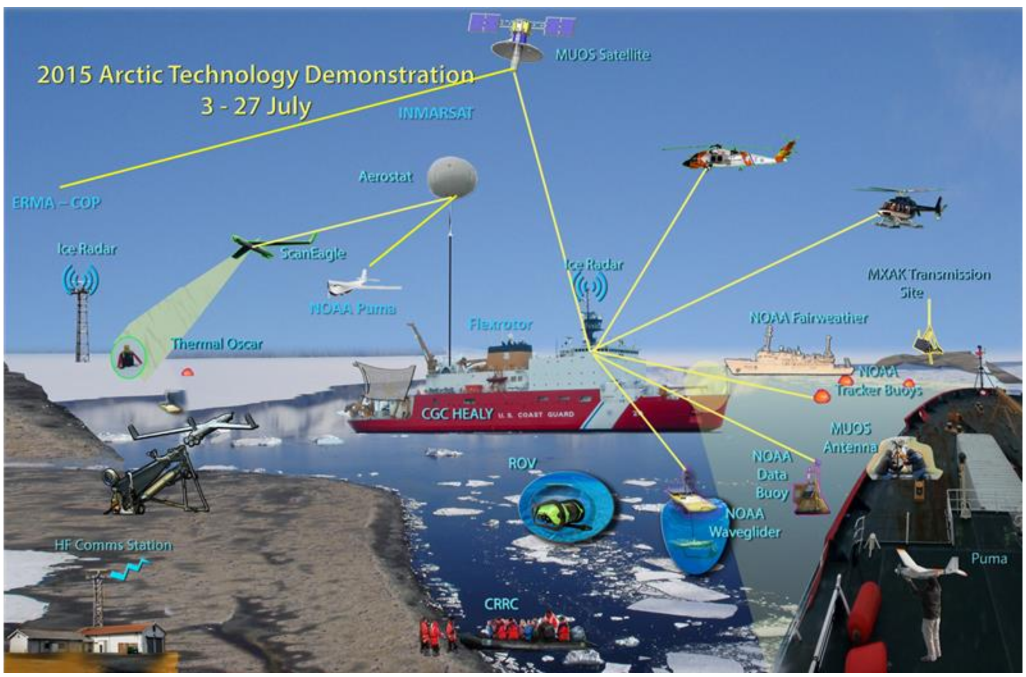

Figure 3. Arctic Shield 2015 SAREX Concept of Operations.

1.3 NOAA / USCG Healy Deployment, Operational and Scientific Objectives:
The science and operational objectives for the airborne systems include:

- Conduct Puma AE operations safely on/off board U.S. Icebreakers while underway in the Arctic in international, uncontrolled airspace including beyond line-of-site "due regard" operations.
- Conduct shipboard recoveries utilizing autonomous net capture procedures and develop/refine tactics, techniques, and procedures (TTPs).

- Demonstrate the ability to acquire, monitor, and reacquire marine debris, oil and/or distressed personnel over an extended period of time (Search and Rescue (SAR) Exercise objective).
- Conduct Intelligence, Surveillance, and Reconnaissance (ISR) and Maritime Domain Awareness (MDA) operations with the Puma AE to multi-agency science crew and Coast Guard/NOAA/Navy operational crew. Stream Full Motion Video (FMV), EO and IR including advanced payload(s) from Puma AE for:
    - Sea ice ridge detection/monitoring
    - Producing a Digital Elevation Map (DEM) of ice ridge and surrounding area
    - Marine and marine mammal monitoring
    - Usefulness in Search and Rescue (SAR) (emergency response) scenarios
    - Detection and monitoring of oil spilled from ship or oil exploration
    - Detection and monitoring of marine debris from ship
    - Preparation for future boundary layer research from UAS
- Utilize the Environmental Response Management Application (ERMA).
  ERMA® is an online mapping tool that integrates both static and real-time data, such as Environmental Sensitivity Index (ESI) maps, ship locations, weather, and ocean currents, in a centralized, easy-to-use format for environmental responders and decision makers. ERMA enables a user to quickly and securely upload, manipulate, export, and display spatial data in a Geographic Information System (GIS) map.
- Conduct Puma-AE Carbon Nano-Tube Anti-Ice System Flight and Ground Testing with NASA.
- Coordination with Inland-Gulf Maritime (IGM) Aerostat flight operations with advanced payloads.
- Coordinate with NOAA's Wave Glider Missions for Puma AE overflight of sensing equipment and operating area.
- Coordinate with the Conoco Phillips and Insitu for ScanEagle flight operations coordination, overflight and data exchange with possible operational hand-off.
- Coordinate with NASA, Aerovel and Precision Aviation for Flexrotor flight operations coordination and data exchange with possible operational hand-off.
- Coordinate with 2d3 for imagery data fusion.
- Coordinate with INMARSAT for data distribution.
- Conduct PEMDAS Ice Prediction System Ground Testing with ONR (prelude to ScanEagle mission).

2. PUMA AE TEST PLAN AND OPERATIONAL ASSESSMENT

2.1 Puma AE Technology Description

The Puma AE is a small unmanned aircraft system designed for land based and maritime operations. Capable of landing in the water or on land, the PUMA AE (Figure 3.) is durable with a reinforce fuselage construction. It is man portable for ease of mobility and requires to auxiliary equipment for launch or recovery operations.

Figure 4. Puma AE.

Length: 5.9 ft
Wingspan: 8.5 ft
Weight: 9.9 lbs
Speed: Max – 60 mph; cruise - 15 to 31 mph
Ceiling: 12500 ft
Range: 9 miles
Endurance: Primary Battery - 4 h; Rechargeable battery - 3 h
Propulsion: Electric motor 600 W

2.2 Puma Payload Description

The standard configuration for the PUMA AE is a gimbaled payload, 360-degree continuous pan +10 to -90 degree tilt stabilized electro/optical infrared (EO/IR) camera and IR illuminator. Advanced payloads will be considered for this event which may include a 24 MP nadir camera, Lidar/14 MP system, and/or multi-spectral camera.

2.3 Ship's Coordination and Communications

The USCG/NOAA/NASA/USN UAS technology team will make every attempt to notify and coordinate with any potential manned and unmanned aerial activities that are in the vicinity of the Puma off the USCGC HEALY operations in the Beaufort and Chukchi Seas during the month of July. Currently, it is known that the USCG/NOAA and industry teams will be coordinating ScanEagle and Flexrotor remote operations from Oliktock Point, AK to supplement shipboard Puma AE operations in the operating area.

The National Marine Mammal Laboratory (NMML) will be conducting concurrent aviation activities in the northern Chukchi and Beaufort Seas for the month of August 2015. NMML will be conducting a survey known as the Aerial Surveys of Arctic Marine Mammals (ASAMM) and will be utilizing two manned survey aircraft. The USN will be flying ScanEagle UASs from Barrow, AK, in August 2015 for marine and ice monitoring. NOAA will coordinate with these events for real-time and post mission data exchange. The following communication protocol shall be in effect to ensure adequate separation and situational awareness for both teams.

Arctic UAS Communication Plan

UAS communications requirements are outlined in the Arctic UAS Communications Plan directs at the minimum:

- The night prior to any planned UAS operations, the NOAA/UAF PIC will contact any known aviation activity in the vicinity of HEALY operations to include at a minimum UAS team leads via e-mail, land line, or sat phone (in that order of preference). Details will include planned locations, times, and types of operations.
- Parties will immediately communicate significant changes in plans via the methods listed in step 2 or VHF 16 (121.5 secondary).
- If airborne and either party visually or audibly identifies the other, attempt hail via VHF 16 (121.5 secondary) and switch to a working channel.
- NOAA PUMA Shipboard SOPs dictate that blind calls will be made on CH16 and 121.5 prior to launch, on the half hour while airborne, and after landing. If the NMML aircraft receives the transmission, attempt to establish a line of communication to ensure adequate separation exists.

2.4 Ship Operations (UASs will be operated as per Flight Manuals)

2.4.1 **Launch Location**

The Puma AE should be launched from the upper deck space behind HEALY's pilothouse or helo deck. The area should be clear of any obstacles in the Puma's flight path. Suggested areas include the port/starboard beam of the bridge deck or from the ship's bow.

2.4.2 **Ship Positioning for Launch**

The OOD will reduce speed, position the ship with the designated launch location facing into the wind, and hold station. For example, if the port bridge deck is chosen as the launch location the OOD will place the wind on ship's port beam for launch. Holding station in this orientation will allow the wind to push the vessel away from the Puma AE in the event of a failed launch.

2.4.3 **Ship Operations While Puma AE is Deployed**

The OOD and Puma AE operators will follow the mission plan established at the pre-operations briefing. This may entail sailing an assigned route, altering course and speed as requested, holding station, or any other action the OOD deems necessary.

2.4.4 **Recovery Following Failed Launch**

In the event of a failed launch the OOD will keep the ship clear of the downed Puma, mark the position, notify the CB to deploy the small boat for Puma AE recovery, and position the ship for small boat deployment. The small boat team will recover the Puma AE and return to the ship.

2.4.5 UAS Recovery

The OOD will reduce speed, position the ship with the designated recovery location facing into the wind, and hold station. The crew will execute a net recovery using approved recovery procedures.

3. METHOD

3.1 Demonstration Schedule

The demonstration schedule will have to remain very flexible depending on weather conditions and other technology deployment schedules. Below is a tentative demonstration schedule, including general locations of flights. The ASB crew and HEALY command staff will need to be notified well in advance of all planned test activities.

3.2 Technology Demonstration Procedures

The Puma shall be hand launched from the USCGC HEALY. The HEALY will be equipped with passive RVT, which will allow personnel aboard to observe real video/data feed streaming from UAS. At the conclusion of each HEALY flight, the aircraft will complete a net recovery or water landing.

Mission flight profiles:

A hand-launched Puma will be flown from the USCGC HEALY within five nautical miles (nm) of the cutter and outside of 12 nm of the coast of Alaska. These operations will adhere to the PUMA Shipboard Operations Plan as well as Appendix A of NOAA AOC UAS Policy 220-1-5 UAS regarding NOAA Small UAS Operations in Uncontrolled International Airspace. The Puma will fly between 100 and 2000 feet Above Ground Level (AGL) in a suitable systematic search pattern in an effort to search for signs of marine debris and/or simulated oil spill. Once the Puma successfully detects marine debris or the simulated oil spill, attempts will be made to provide quantifiable assessments of location, size and potential characteristics such as thickness and proximity to ice. Optical and infrared payloads will provide real time data feed via RVT to onboard personnel.

In the event that weather or sea conditions are not suitable for UAS operations, as determined by the NOAA Pilot-in-Command (PIC), operations will be cancelled or suspended for the day or night.

Notional unmanned flight operations demonstration scenario:

- The Puma will conduct systematic ISR/MDA search of assigned area and may respond to for signs of marine debris, oil and/or SAR when required.

Roles/Responsibilities/Qualifications:

Clear roles and responsibilities, as outlined below, will be maintained for all UAS operations. For vessel-based UAS operations, the ship's command, in consultation with the UAS PIC will determine if weather, sea, vessel, aircraft, and human factors are such that safe UAS operations can be conducted in accordance with documented criteria.

The **Pilot in Command (PIC)** is tasked with overall responsibility for safe execution of the mission. It is the PIC's responsibility to ensure that all crewmembers understand and can properly perform their specific roles for the flight. The PIC is additionally responsible for ensuring all documentation, including pre and post-flight briefs are conducted. The PIC is charged with ensuring adherence to all SOP and checklist requirements. The PIC is responsible for communicating with the authorities that control airspace and maintaining communication with the appropriate Air Traffic Control Authority. While conducting air operations, the PIC is the final authority to the safe operation of the aircraft. The PIC will have responsibility for aircraft system preparation, launch, airborne operations, landing, and preventative maintenance.

The **UAS Mission Operator (MO)** is the individual responsible for the control of the mission laptop/moving map display. Typically the aircraft will be mechanically or hand-launched under remote manual control. When at survey altitude, the PIC may cede control of the aircraft to the autopilot, which the MO will have programed to follow a pre-determined survey path. If flying on autopilot, the PIC shall always be ready to take over manual control and the MO shall always be monitoring the system health. This individual is also responsible for recording all operations and associated flight logs

External Observer (EO): There shall be at all times an external observer for "see and avoid" purposes.

At a minimum, there must be three individuals at all times present during operations to fulfill specified ground control system (GCS), operation of the UAS, and "see and avoid" roles/responsibilities.

3.3 Operating Limitations

The following procedures and operational restrictions shall be complied with during all Puma UAS operations conducted off the USCGC HEALY:

a) The Ground Control Station (GCS) and UAS shall remain within uncontrolled airspace at all times.

b) The GCS and UAS shall remain greater than 12 NM (i.e. international waters) from the U.S. coastline or U.S. territory during all phases of flight. (Note: for UAS operations conducted off another country's coastline, please consult with the U.S. Department of State for minimum standoff, which may be greater than 12 NM due to diplomatic concerns).

c) The UAS shall be operated at or below 2,000 feet MSL.

d) The UAS shall remain within 5 NM of the GCS at all times.

e) The UAS shall be operated in VMC conditions only. If IMC conditions are unintentionally encountered, return to VMC conditions by the safest and most expeditious means possibly.

f) Day or night operations are permitted, but associated risks and mitigation measures shall be addressed in each project-specific Operational Risk Management (ORM) document.

g) Flight operations shall be selected so as not to interfere with established air routes and ocean shipping lanes.

h) UAS operations shall not be conducted under the veil of Class B or C airspace.

i) Notices to Airmen (NOTAMs) and Notices to Mariners (NOTMARs) shall be issued for the affected airspace / body of water.

j) Radio "calls in the blind" shall be made on marine Channel 16 and on aviation band 121.5 prior to launch and at no greater interval than every 30 minutes.

k) The launch vessel should conduct a surface search using its radar 10-30 minutes prior to the launch of the UAS in order to identify other vessels within the operational area. A qualified radar operator should monitor the ship's radar display at all times the UAS is airborne. If another vessel is identified within the 5 NM UAS operational range, the UAS shall remain at least 2 NM from that vessel at all times unless identification of vessels is a requirement of the mission flight specifics shall be addressed in each project-specific ORM.

l) At least one observer shall be posted during all UAS operations to assist with separation from other aircraft. The observer shall be provided binoculars, or other visual enhancement device, and shall have the means to be able to clearly communicate with the PIC.

Mission Plans:

Prior to each day's operation, a mission briefing shall be developed by USCG/NOAA/USN and industry partners with input and review from the participating agencies. The Mission Coordinator will conduct this briefing, it will include:

a) Weather

b) Safety

c) Status of equipment and personnel

d) Communications plan

e) Objectives

f) Other relevant information as necessary.

Missions will typically consist of launch, ingress to target area, perform data collection, egress from target area and recover.

Personnel Requirements

3.4 Contingency Planning

For contingency planning purposes, HEALY may deployed a small boat for Puma AE operations and/or retrievals.

3.5 Data Requirements

The NOAA requirements/desired attributes for unmanned systems (Puma, Aerostat, ScanEagle, Flexrotor) sensor optimized conducting ISR, MDA for marine surveys, ice surveys, marine debris and oil detection/identification and SAR include:

a) **Number of Cameras and Resolution** - Two to three digital video cameras would be optimal, one high resolution with a narrow field of view with a resolution of 1-2 cm (from the chosen flight altitude) pointed at nadir, and one or two wide field of view cameras with a lower resolution of about 10 cm. Two wide field of view cameras obliquely pointed and overlapping at nadir would be optimal. For HD video cameras, 1080p is preferred to 1080i. Ground viewing swath of wide field of view cameras would be about 300 m, with the high resolution camera having a swath of 60-120m.

b) **Object size to be detected** – Be able to detect and identify a fishing float of 8 inches diameter (thus the requirement for a resolution of 1-2 cm). This includes detection/identification of SAR victim (Thermal Oscar)

c) **Object discrimination** – Be able to discriminate between a debris object and natural floating material like kelp. Individual objects, not collections of objects need to be detected.

d) **Spectral bands** – Red-Green-Blue (RGB) video is preferred, but will test the usefulness of infrared cameras.

e) **Dynamic Range** – 8 bits per channel.

f) **Polarization/filters** - polarization should be possible – at least for oblique views, but usefulness needs to be tested. The optical port needs to permit polarization. One way to accomplish this is with polarized coatings on the optical ports.

g) **Sampling frame rate** (overlapped or non-overlapped) – variable frame rate is preferred.

h) **Downlink/record** – Be able to downlink at least the output of one camera in real time to the ship. Record output of all cameras. Be able to downlink from 5-20 miles away.

i) **Fixed or steerable camera** – Fixed swath with multiple cameras, or gimbal - mounted steerable camera

j) **Global shutter versus rolling shutte**r – global shutter; i.e., all charge coupled device (CCD) detectors exposed at same time, is preferred for sharper images (this however is a cost/weight trade off since rolling shutter cameras are cheaper and lighter).

k) **Interface with airframe** – optical aperture design and material – aperture material would most likely plexiglass – which could be polarized. If polarized filter is used instead, this may present a problem since looking through plexiglass affects polarization. Each camera should have its own aperture.

l) **Documentation of Sensor Selection** - specify ideal sensor and contrast with practical sensor selected and document the tradeoffs made.

m) **Metadata file or metadata on image** – Store GPS location and time, altitude, and aircraft attitude and gimbal angle (if exists) in metadata with each image. Do not implant information in the image itself.

n) **Anomaly software and algorithm** – Detect anomalies on-board the UAS and send GPS positions of anomalies to the ship

o) **How to mark areas of interest** – Mark by image and by coordinates. For purposes of this survey, it is expected that the aircraft location/coordinates will be sufficiently accurate (will not require slant-range post-processing for object location)

p) **Quantify or classify or both** - Both. Project will ideally quantify debris objects or other targets, and differentiate/identify them.

q) **How to record and archive ISR missions including marine surveys, debris, oil and SAR** – Archive format and archive organization needs to be determined. There are options for archival at the Northern Gulf Institute (NGI), the NOAA Oceanographic Data Center, and the NOAA UAS Program. Previous manned aircraft surveys have recorded debris locations in an Excel file containing time, lat, long, item identification, and comments. This information should be recorded by the USCG, as well. The NOAA UAS Program has coordinated with the ERMA Program and the USCG for real-time data distribution for the Common Operating Picture (COP), and data archiving with NGI.

4. OTHER AIRBORNE SYSTEMS OPERATIONAL ASSESSMENTS

4.1 Aerostat

Inland-Gulf Maritime LLC (IGM) was selected to participate in the Arctic Shield 2014 and will rejoin our team for this year's OA. The IGM Aerostat-IC was deployed to support the USCG during the oil spill response exercise which was held on Lake Michigan in February 2013. The system provided the USCG with aerial video of the various exercises and proved to be a great asset during a man overboard exercise using the IR capability. As a follow on, the Aerostat-IC deployed on the USCG Healy for Arctic Shield 2014 Technology and Arctic Oil Spill Evaluation. The system was tested for its capability to support both oil spill tracking and other emergency response scenarios in arctic conditions which proved the value of utilizing an Aerostat for remote surveillance during an oil spill scenario. The team provided an aerial view both in EO and IR to prove the value to the operators to receive an overview of operating situation to enable work crews to attack the heaviest oil and increase encounter rate so that the oil spill can be efficiently and effectively cleaned up. This video can also be transmitted to a command center to enable pre-planning for the NOP. Arctic Shield 2015 will further assess this technology with advance payloads in support of ISR, MDA and SAR missions.

Figure 5. IGM Aerostat onboard USCGC Healy 2014.

Mission Planning and Operational Assessment:

The primary objectives for the Aerostat team will be:

a) Icebreaker Familiarization and Fit Checking

b) Polar Observation Requirement Familiarization

c) Aerostat data distribution onboard icebreaker using real or simulated data

d) Aerostat data relay (Wave Relay) with Puma AE

4.2 NOAA Buoy and Wave Glider

Testing will be conducted as per the Mission Planning Document HYL-1501. UAS fly-overs and surveys will be coordinated onboard Healy.

4.3 Insitu ScanEagle

Testing will be conducted as per the Mission Planning Document HYL-1501. UAS fly-overs and surveys will be coordinated onboard Healy.

4.4 Aerovel Flexrotor

The Flexrotor unmanned aircraft is designed to operate over oceans and remote areas while sending high-quality imagery to its control vessel. Endurance is more than 40 hours, and the operations cycle is automatic through flight, retrieval, servicing in a lightweight handling apparatus, and re-launch. The aircraft stows and quickly assembles for flight in a 2 m/6 ft handling box. Small footprint and ability to hover allow Flexrotor to be based on a small open skiff or in spaces of opportunity on larger private or commercial vessels.

The steerable, zoomable imaging turret performs search and target tracking with a daylight or infrared camera. Its real-time, georeferenced video can be merged with data from other shipboard equipment such as radar and AIS, and distributed to multiple displays. NTSC/PAL-quality video can be downlinked from 100 km radius to a 2 m shipboard antenna, and more compact antennas can be used where less video range is required. If desired, multiple aircraft can be managed from a single control station so that several sectors can be monitored simultaneously.

Flexrotor's range, endurance, economy, basing flexibility, and ease-of-use will enable ships to have an extended ISR and survey capability. Land-based launches will be conducted from Oliktok Point, AK, and ISR missions flown in the vicinity of the Healy. A Flexrotor Ground Control Station (GCS) and operators will be onboard Healy. Mission monitoring will be conducted testing the ISR capabilities using real-time or simulated data with recoveries (if flight is executed) being conducted at the land-site. UAS fly-overs and surveys will be coordinated onboard Healy.

Mission Planning and Operational Assessment:
The primary objectives for the Flexrotor team will be:
a) Icebreaker Familiarization and Fit Checking
b) Polar Observation Requirement Familiarization
c) Flexrotor data distribution onboard icebreaker using real or simulated data
d) Flexrotor flight from Oliktok Point (if able)

FLEXROTOR SUMMARY SPECIFICATIONS

Endurance	More than 40 hrs with typical payload
Range @ endurance speed	More than 3400 km/1800 nm
Range @ maximum speed	More than 900 km/500 nm
Endurance speed	85 km/h – 46 kt
Maximum level speed	158 km/h – 86 kt
Wing-borne ceiling @ max wgt	7,500 m – 24,000 ft
Hover ceiling (OGE) @ max wgt	900 m – 3,000 ft
Length	2 m
Wingspan	3 m
Maximum launch weight	20.5 kg at sea level, ISA
Engine	28 cc 2 stroke
Fuel	Unleaded automotive gasoline
Communication range	100 km – 55 nm
Storage	205 x 57 x 38 cm box with integral assembly stand
Assembly time	10 minutes
Imaging	Stabilized turret with optical or LWIR video camera
Video downlink	Digital; NTSC equivalent resolution

SPECIFICATIONS FOR IMAGING TURRET (WITH VISIBLE-LIGHT CAMERA)

Wavelength	400 – 900 mm
Horizontal field of view	1.1° – 31.5°
Image size	640 x 480 downlinked; HD stored onboard
Analog video output	Composite NTSC
Digital video output	Standard formats
Pan about aircraft roll axis	Endless 360°
Tilt about turret pan axis	30° up; 90° down
Slew rate	50°/sec

Specifications subject to change without notice.

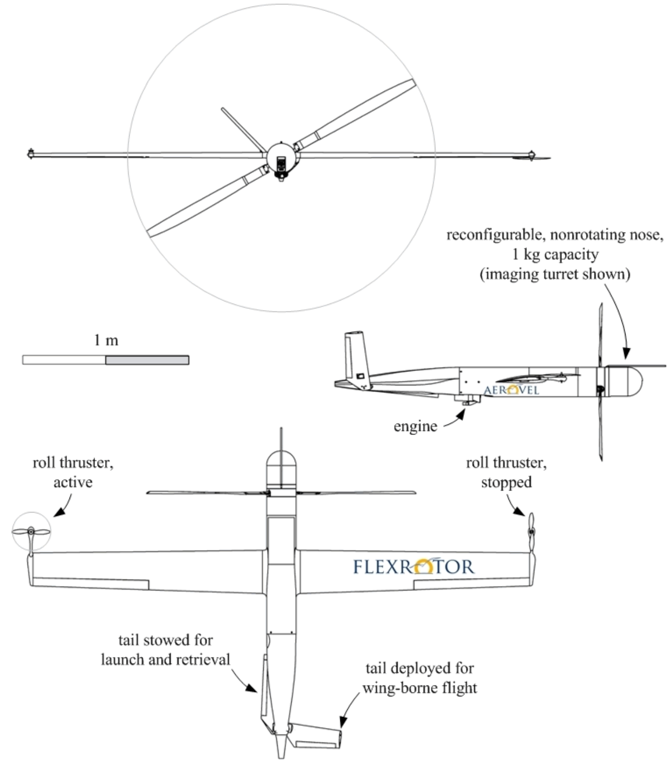

Figure 6. Aerovel Flexrotor Specification & Diagram.

4.5 NASA Carbon Nano-tube Anti-/De-Icing Coating (Ground and Flight Testing)

Unmanned systems anti-/de-icing is a known hazard that has not been properly mitigated especially for small vehicles that lack the power and weight capacity to carry large, energy depleting systems. The Norwegian University of Science and Technology (NTSU) In Collaboration with NASA Ames Research Center have invented an innovative of-the-shelf electrically conductive coating (nanotube-based paint) together with a power management system to control temperatures of exposed surfaces. This system is primed by on-board humidity sensors and ambient temperature sensors, as well as model based ice accretion estimation, which have been developed using nonlinear estimation theory and/or fault diagnosis theory.

The coating temperature is controlled using a feedback controller, with temperature sensors, measuring the surface temperature of the aircraft (these will be embedded in the coating itself), and humidity sensors (icing usually only forms when the ambient humidity is greater than 85%). This system has been successfully integrated onto NASA's Dragon Eye UAS and AeroVironment's Puma, and will be ground and flight tested onboard the Puma AE to mitigate icing hazards. This will be the first shipboard anti-/de-icing testing for small UASs.

Figure 7. Nano-tube integrated onto airfoil leading edge.

Mission Planning and Operational Assessment:

The primary objectives for the nano-tube team will be:

a) Icebreaker Familiarization, Fit Checking and Ground Test Element Placement
b) Polar Observation Requirement Familiarization
c) Nano-tube ground testing in know icing conditions
d) Nano-tube flight testing onboard the Puma AE as a risk mititgator for icing conditions

4.6 PEMDAS Ice Prediction System (Ground Testing)

An important mitigation to the aircraft icing hazard, PEMDAS Inc. has developed an ice prediction system that has been tested on several manned and unmanned aircraft. Integration of this system has been completed by PEMDAS on the AV Raven, Insitu ScanEagle and our team is investigating the integration onto the AV Puma. The payload data relayed to ground station over command & control (C2) radio link, and icing data sent from ground station to separate computer running software to display risk of icing & meteorological data. Ground testing will include the fixing of a sensor set with exposure to the elements.

Figure 8. PEMDAS ASAP Metrological & Icing Sensor.

Mission Planning and Operational Assessment:
The primary objectives for the ice prediction system team will be:
a) Icebreaker Familiarization, Fit Checking and Ground Test Element Placement
b) Polar Observation Requirement Familiarization
c) Ice Prediction System ground testing in know icing conditions

4.7 INMARSAT Hughes 9211-HDR Land Portable Satellite Terminal

The rugged and lightweight Hughes 9211-HDR is an affordable High Data Rate terminal, ideal for media, governments, NGOs, mobile healthcare providers and possibly for shipboard operations in the Polar regions. The 9211-HDR has a hardened and compact design— currently the world's smallest and lightest HDR-capable BGAN. Users can connect at streaming broadband speeds of over 650 kbps with features such as built-in, multi-user WiFi access.

Figure 9. INMARSAT Hughes 9211-HDR.

An external powered antenna is available to support long RF cable runs for temporary or permanent fixed-site installations. The Hughes 9211-HDR enables users to send and receive IP traffic via Ethernet and/or 802.11 b/g/n WiFi, including voice or fax via a standard telephone connection. It is all IP-based and offers Class 1 background IP or selectable, dedicated Quality of Service (QoS) levels.

Inmarsat's BGAN HDR service network now offers new and higher streaming rates. The Hughes 9211-HDR supports the highest streaming rates available (above 650 kbps) for transmitting video and other critical data from the field. Asymmetric streaming rates are supported, enabling users to better tailor the service to their individual preferences and minimize cost.

Main Features

- Rugged and durable IP65 rating
- User-friendly LCD display with four-button control
- 802.11 b/g/n WiFi supporting multiple user access
- Advanced Web user interface
- Automatic context activation
- XL-band supported
- External antenna options
- HDR streaming above 650 kbps

Interfaces

- Ethernet connection (RJ45)
- POTS connection for voice and fax (RJ11)
- External antenna connector

Mission Planning and Operational Assessment:

The primary objectives for the INMARSAT Hughes 9211 team will be:

a) Icebreaker Familiarization and Fit Checking

b) Polar Observation Requirement and Regional Satellite Familiarization

c) Real-time data distribution from the icebreaker using real and/or simulated data

d) Real-time data distribution for fusion and infusion into ERMA

-