



NOAA's experience over the past several years testing, evaluating and operating small Unmanned Aircraft Systems (sUAS) in remote and hostile environments and from ships at sea in support of marine resource surveys oil spills and simulations .

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NOAA

Prevention First

September 27, 2016

NOAA Small UAS Experience



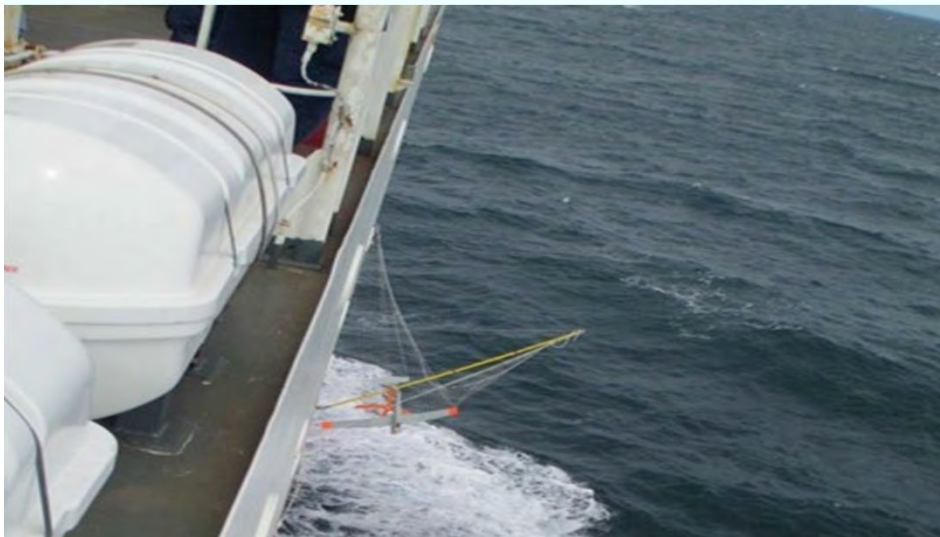
- Tested various systems
 - Aerosonde (2005 – 2007)
 - Silver Fox and Manta (2005 – 2012)
 - ScanEagle (2007, 2009 and 2016)
 - Multi-copters (2010 - present)
 - Puma (2008 - present)
- Developed protocols
- Performed Missions:
 - Living marine resource surveys
 - Habitat mapping and characterization
 - Enforcement
 - Emergency response
 - Marine Debris
 - USCG Arctic support
 - USCG Antarctic support



Launch and recovery at sea



“Holy Grail”: Launch and Recovery at Sea



Why AeroVironment Puma AE?



- Evaluated multiple systems for maritime operations
- Meets DoD, NOAA and USCG requirements
- Documented airworthiness and military flight clearances
- Professional training
- Extensive field testing
- Spare parts availability
- All Environment capable
- Self-contained – carry onto vessels of opportunity

AeroVironment Puma AE System Configuration



3 Air Vehicles (in soft packs)



3 Gimbal
EO/IR/Cameras



6 Aircraft Batteries (ISP)



1 Universal
Battery Charger
(ISP)



3 Field Repair Kits



2 Ground Control Stations

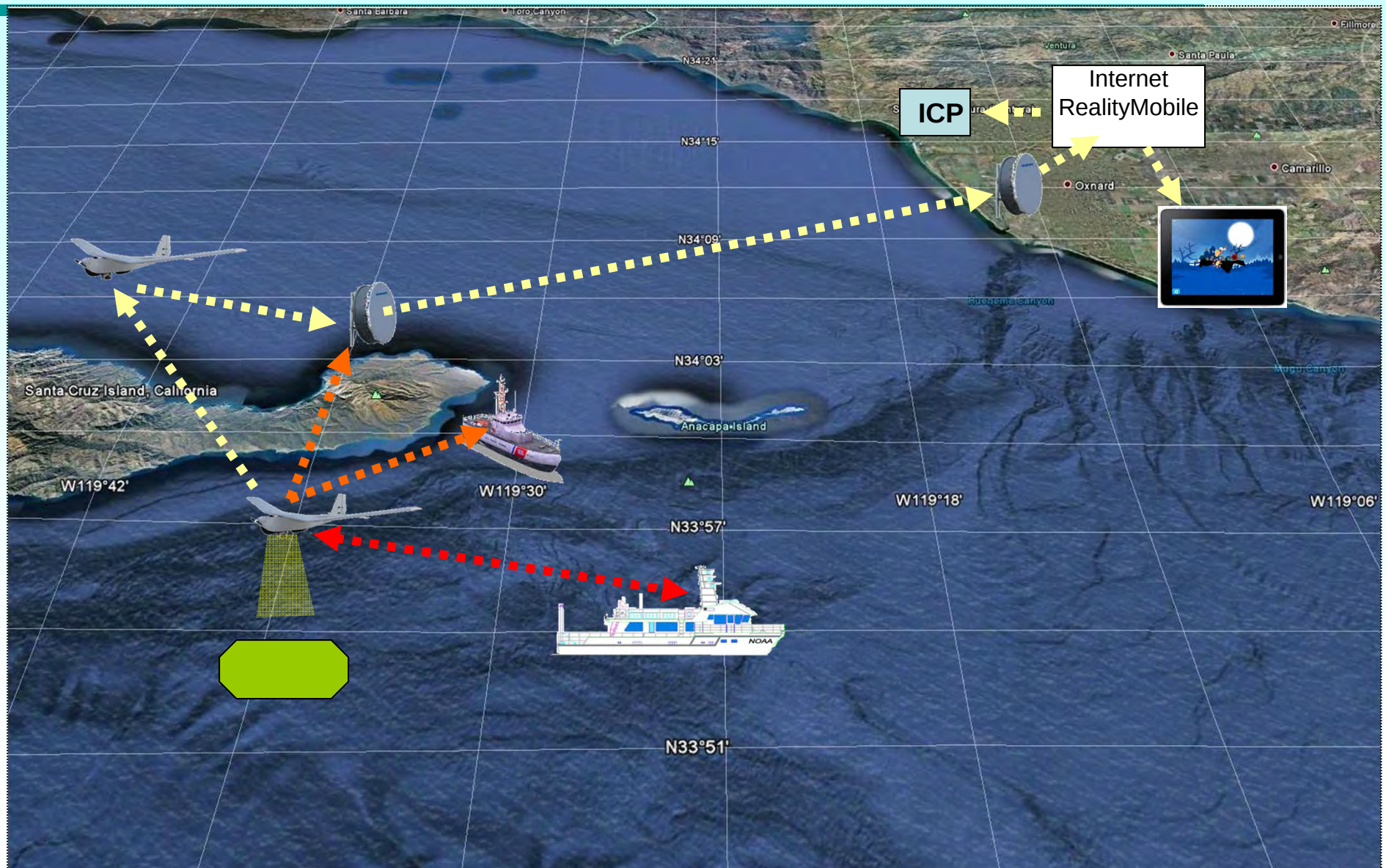
1 Toughbook



AV GCS/RVT on R/V Shearwater



Data distribution architecture



Marine Resource Monitoring



Blue Whale Tagging Support



Marine Resource Monitoring



Living Marine Resource Surveys

- Pinnipeds



Marine Resource Monitoring



Habitat Mapping



Marine Resource Monitoring



Enforcement



2012-08-30 07:59:16.00Z
11S KT 50470 60999
Alt: 336 ft MSL
True Heading: 126°



CFOV Heading: 31°
CFOV Position:
11S KT 50546 61077
CFOV Alt: 3 ft MSL

FOV Corner Positions:
UL: 11S KT 50535 61123
UR: 11S KT 50606 61098
LR: 11S KT 50554 61042
LL: 11S KT 50509 61063

Simulated seal and turtle



Hawaii Marine Debris testing 6/12



2012-06-20 21:06:10Z
Lat/Lon: N 21° 39.092' W 158° 10.676'
Alt: 344 ft MSL
Mag: 36°



Gimbal
FOV Data:
Slant Rng: 184 m
CFOV Hdg: 339°
CFOV Lat/Lon: N 21° 39.203' W 158° 10.720'
Horiz. FOV: 6.3°

ORIGIN Lat/Lon: N 21° 39.386' W 158° 10.509'
RANGE -> HOME: 0.1 km
BEARING -> HOME: 176°
WIND SPEED: 00.0 kts
WIND DIR: 68°

2008 aboard R/V Shearwater in Santa Barbara Channel.



Objectives included:

- Ability of the Puma system to operate at sea
- Coastal surveys for evaluation of the system's ability to determine the presence/absence of oil and survey to wildlife,
- Demonstrating the ability to function as a communications relay
 - Operated BVLOS (SUA provided by Point Mugu)

Partners included: AeroVironment, USCG (USCGC HALIBUT and R&D Center), CA Fish and Wildlife/OSPR, NPS & USWFS

2011 aboard R/V Shearwater in Santa Barbara Channel.



Objectives included:

- Microwave Internet data relay to Incident Command Center (FMV and still images with telemetry transmitted real-time to ICC over the Internet)
 - Imaging oil simulant (fluorescein dye),
 - Puma as communications relay
- Quantification of geographic scope of simulated spill over time
- Coastal surveys for evaluation of the system's ability to determine the presence/absence of oil,
 - Operated BVLOS (SUA provided by Point Mugu)

Partners included: AeroVironment, Chevron Shipping, Reality Mobile, USCG (Sector LA/LB USCGC BLACKTIP and R&D Center), NPS, USFWS, CA Fish and Wildlife/OSPR

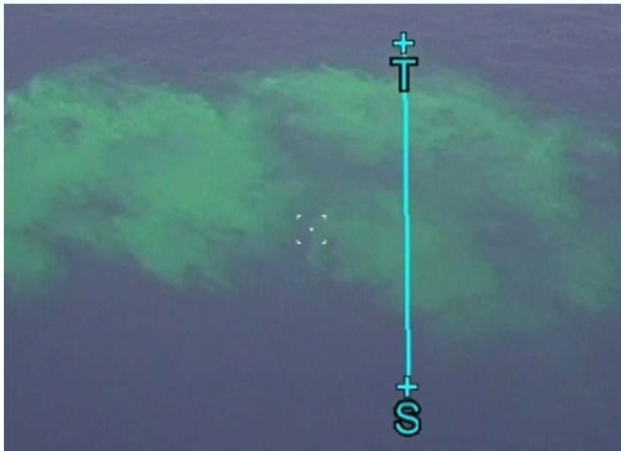
Take aways:

Someone needs to document how to effectively apply fluorescein dye!

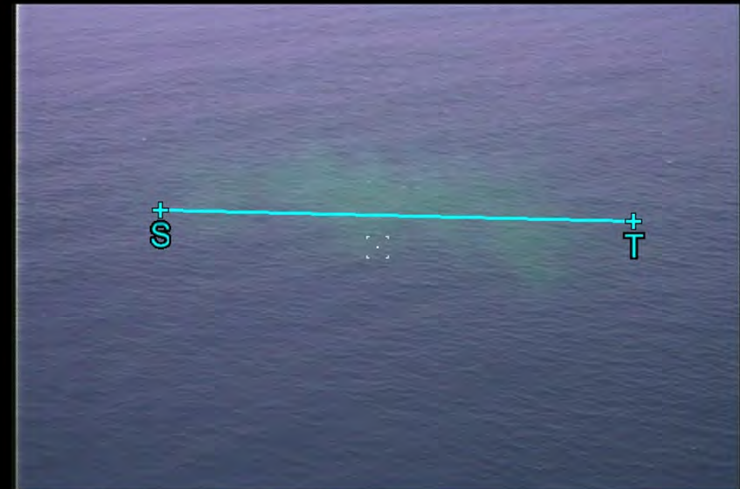
Emergency Response & Oil Spill Simulation



Coast Guard UAS partnership study of oil spill monitoring in Santa Barbara channel



Lat/Lon: N 33° 48' 31.53" W 119° 46' 18.60"
Alt: 351 ft MSL
Mag: 39°



Gimbal
FOV Data:
Slant Rng: 259 m
CFOV Hdg: 320°
CFOV Lat/Lon: N 33° 48' 37.61" W 119° 46' 23.82"
Horiz. FOV: 29.6°

Targeting Data:
Target S Lat/Lon: N 33° 48' 36.66" W 119° 46' 26.12"
Target T Lat/Lon: N 33° 48' 39.29" W 119° 46' 23.45"
ADD 94 m RIGHT 48 m
Range: 106 m Mag Bearing: 27°

2014 aboard Shearwater and along the coast of VAFB



Objectives included:

1. Shearwater:

- Fluorescein dye application procedure development and documentation
 - Imaging of dye and ability to use Puma UAS imagery to quantify spill
 - Testing of 2d3 image processing software
- Real-time processing (mosaic and image optimization) and transmission of data (with telemetry) over 4G and Ku band satellite to remote locations.

2. Vandenberg Air Force Base:

- Testing ability to use Puma UAS imagery to support SCAT surveys using stuffed animals and black plastic sheeting as oil and wildlife analog
 - Documentation of sensor resolution with calibrated targets
- Real-time processing (mosaic and image optimization) and transmission of data (with telemetry) over Ku band satellite to remote locations.

Partners included: NOAA HAZMAT & National Marine Fisheries Service, OSPR, Chevron Shipping, 2d3 and Ku satellite support by Ground Control.

Take aways: Need higher resolution optical sensor for SCAT and Damage Assessment

Dye Release (color enhanced)



Quadrat transects at VAFB



Tuesday-9.mpg

UNCLASSIFIED

Frame Center:

34.555°N 120.609°W



Scratch - Session Explorer

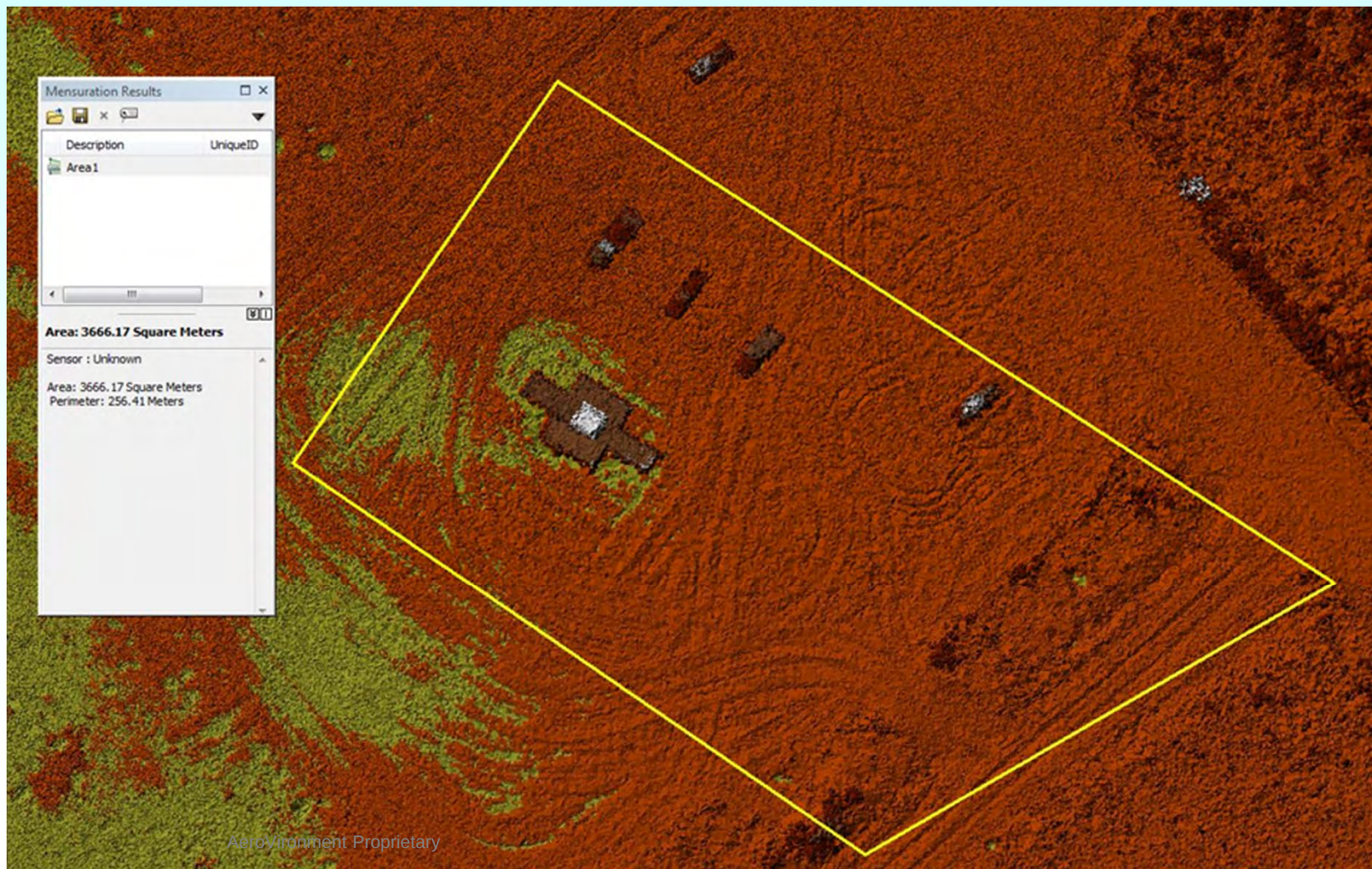
2d3 Super Resolution Enhancement



January 2014: Nadir mapping camera and lidar demo



- This brought the commercial services and advanced payloads to NOAA's attention.



Arctic Support



2013 aboard USCGC HEALY for Arctic Shield



Objectives included:

- Puma Data to ERMA
- System testing in Arctic environment
- First Arctic shipboard deployment of Puma

Take aways:

- Need ice sensing
- Need to simplify data ingest to ERMA
- Need autonomous shipboard recovery system
- Problems with accuracy of data when operating in areas without DTED
- Need more and better oil simulants for future testing

Partners included: USCGC HEALY & R&D Center, University of Alaska Fairbanks and Air Force Special Operations Command

2014 aboard USCGC HEALY for Arctic Shield



Objectives included:

- Imaging various oil simulants and ingesting Puma Data to ERMA
 - Testing 2d3 image processing software
- Testing of deck landing procedures and of beta Puma net capture system
- Exercising of NOAA's "Due Regard" policy in international airspace
 - Operating in conjunction with Aerostat

Partners included: USCGC HEALY & R&D Center, AeroVironment, IGM Aerostat & 2d3

Take aways:

- Need autonomous shipboard recovery system
- Problems with accuracy of positioning when operating in areas without DTED (now solved by manufacturer)
 - Need to fly BVLOS, change weather minimums and increase flight envelope
- Aerostat was great compliment to UAS by confirming the ceiling and providing truth for the imagery



Arctic Shield Oil Spill Testing



2014 Detection and monitoring of simulated oil spilled from ship

Lat/Lon: N 73° 58' 14.84" W 155° 03' 20.64"
Alt: 266 ft MSL
Mag: 241°



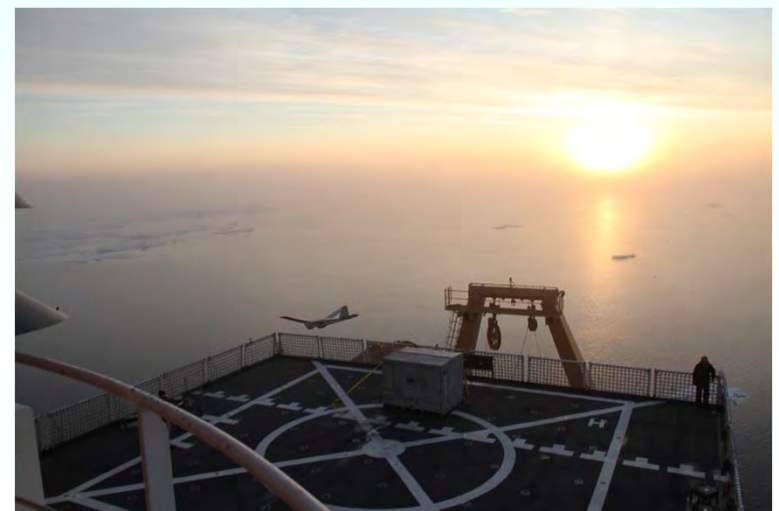
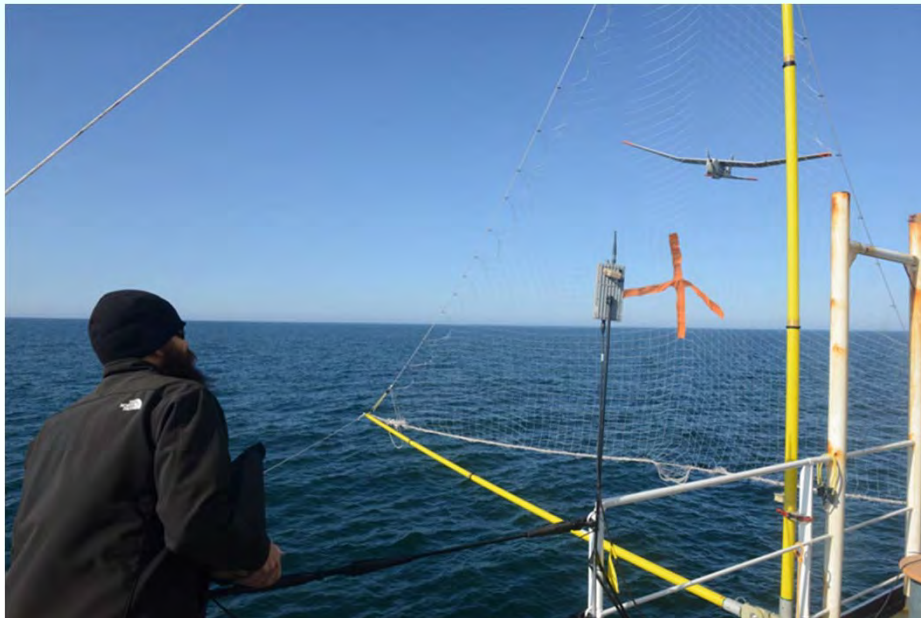
Gimbal
FOV Data:
Slant Rng: 159 m
CFOV Hdg: 181°
CFOV Lat/Lon: N 73° 58' 13.34" W 155° 03' 20.81"
Horiz. FOV: 29.6°



Puma “Due Regard” Ops & Recovery Testing



- ✓ Due Regard Operations
- ✓ Water and Ice Landings
 - ✓ Deck Landing
 - ✓ Net Capture System



Focus over the past year



sUAS capacity building focus in the following areas:

- Responding to natural resource emergencies and events (Oil spill)
- Operating BVLOS
- Integration with manned aviation in controlled environments
- Polar work in support of USCG and NOAA
- Supporting development of new capabilities through partnerships and CRADAS:
 - High-resolution sensor
 - Autonomous recovery system
 - Ice sensing and deicing
- Data products and dissemination from remote locations.
- Follow on missions in promising areas
- Collaborating with other agencies to share knowledge and experience:
 - USCG
 - NASA
 - US Navy

Significant events during the past year or so



Significant events in chronological order:

- May 2015: **Refugio Oil Spill** & Scheduled SB Channel Study of Natural Oil Seeps
- June 2015: **Sea turtle capture** (and tagging) support aboard the NOAA Ship Thomas B. Bigelow in the Gulf Stream in Canadian waters off of Newport, RI
- July 2015: **Arctic Shield** 2015 aboard the USCGC (Icebreaker) HEALY
- August 2015: **Northwestern Hawaiian Islands** High-resolution Mapping, Monk Seal and Marine Debris surveys aboard NOAA Ship Oscar Elton Sette with new high-resolution sensors
- November 2015: **Testing and documentation** of systems aboard the NOAA R/V Shearwater in the Santa Barbara Channel in preparation for Operation Deep Freeze 2016 (ODF-16) in support of NOAA and USCG.
 - Autonomous Net Capture System
 - Long range telemetry antennas
- Late December 2016 – February 2016: **ODF-16 2015** aboard the USCGC Polar Star (Heavy Icebreaker) in support of NOAA and USCG.

2015: UAS Rapid Response for Emergency Operations



Deploying UAS in response to disasters: *Developing the capacity for UAS to respond to disasters and provide useful/actionable data to decision makers in the formats and resolutions that they require in a timeframe that is relevant.*

At this point in time, there is nothing "rapid" about deploying UAS.

We are working on reducing planning and deployment time from weeks or months to hours... Working with NOAA HAZMAT to find and develop the right spill drill to exercise all of the elements necessary to truly respond to an oil spill or other disaster event.

- Contracts in place for surge capacity
 - Emergency COAs and TFRs?
 - Data accuracy and resolution
 - Real-time data dissemination

Refugio Oil Spill



Refugio Oil Spill



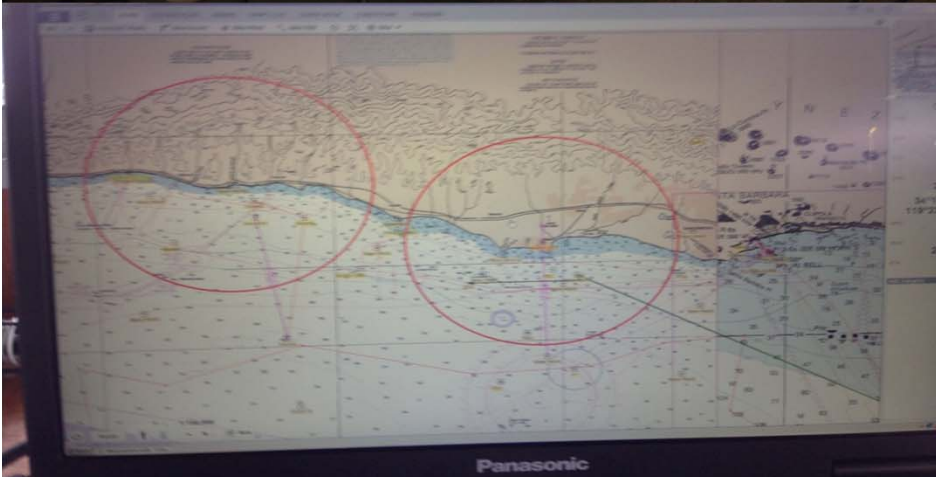
May 2015: Refugio oil spill



- Requested by NOAA Damage Assessment Program
- Tasked by Incident command
- Supported NRDA data collection.
- Safe integration and concurrent operations with two manned helicopters
- Flew standard payload from shore and from NOAA R/V Shearwater.
- Collected high-resolution data from shore with nadir mapping camera.
- Produced stitched ortho-rectified image of Refugio bay at 2.5 cm per pixel.
- Learned quite a bit about how to integrate into Incident Command and oil spills.
- Data ingested into ERMA



Refugio Oil Spill



Refugio Oil Spill



Refugio Oil Spill



Refugio Oil Spill



Refugio take aways:



1. TFRs may be the way to go for controlled and rapid integration of sUAS into oil spills:
2. The roll of the Air Boss is critical.
3. Differentiation of sanctioned sUAS operation from hobby/amateur operators:
 - Professional grade equipment vs toys
 - Transponders to aid in deconfliction/coordination
 - Pilots vs operators
 - Good comms for real-time coordination

Future recommendations



1. Drill baby drill - to familiarize incident commanders with sUAS capabilities and deployment considerations.
2. Support of skimming/clean up operations as well as damage assessment
Night operations?
3. Fly under weather (fog, low ceilings) when manned assets are grounded.
4. sUAS included in OSRV standard equipment and routinely supporting skimming operations.

2015: Arctic Shield aboard USCGC HEALY



Objectives:

- Oil spill support of USCG and NOAA HAZMAT:
- Working with industry to increase capacity by optimizing equipment
- Working with regulators and decision makers to develop rules & policies that allow the technology to be deployed and utilized in safe, relevant and useful ways
 - Testing new autonomous net capture system on Puma,
- High-speed communications and data relay through aerostat
 - Hand-off and/or data downlink with ScanEagle
 - Operating BVLOS under “due regard”

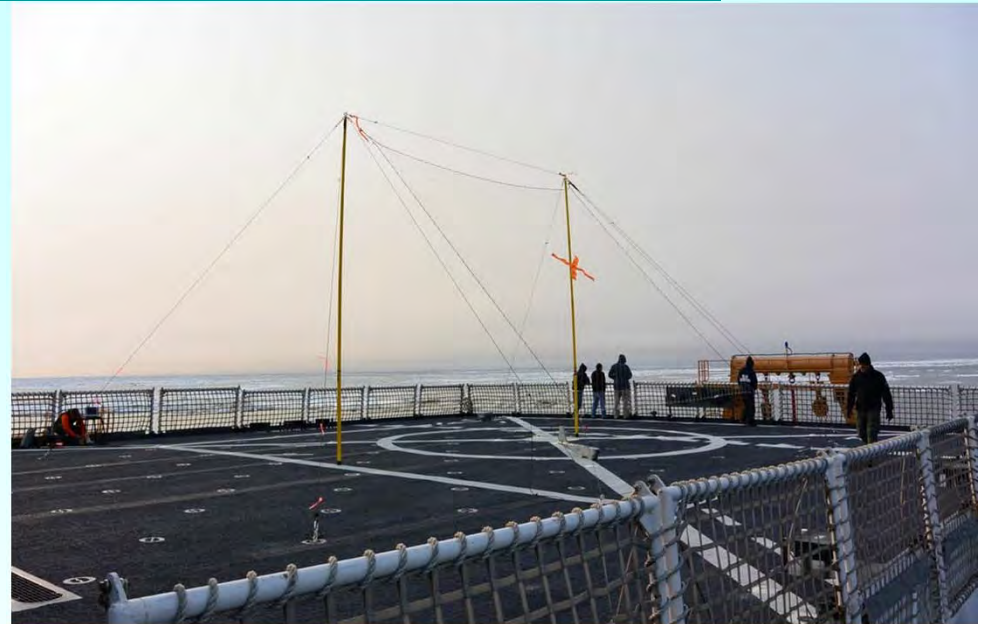
Arctic Shield July 2015 aboard the USCGC (Polar Icebreaker) HEALY.



Milestones included:

- Autonomous net recovery in rail-mounted triangular net and square net on helicopter deck
- BVLOS (5nm) operations by exercising "Due Regard"
- Real-time operations coordinated with two manned helicopters
- Testing of long range communications for C2
- Integration and testing of ice-sensing and deicing system
- Data transmission through aerostat with support from IGM Aerostatic and real-time to the Internet through satellite link with support from 2d3 and Inmarsat
- Success from this trip lead to AV and NOAA supporting ODF-16 to Antarctica.

Arctic Shield 2015



August 2015: NWHI Monk Sea and Marine Debris surveys aboard NOAA Ship Sette



Papahānaumokuākea Marine National Monument



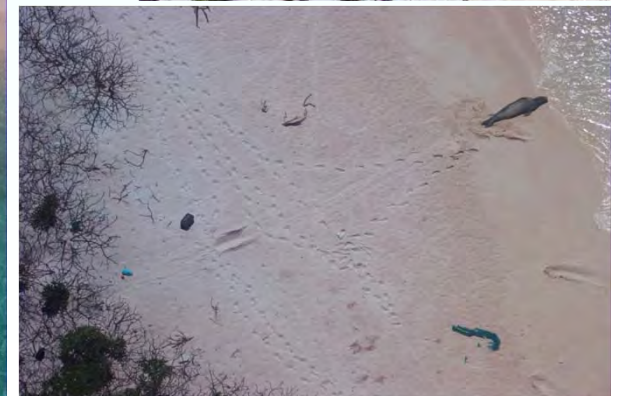
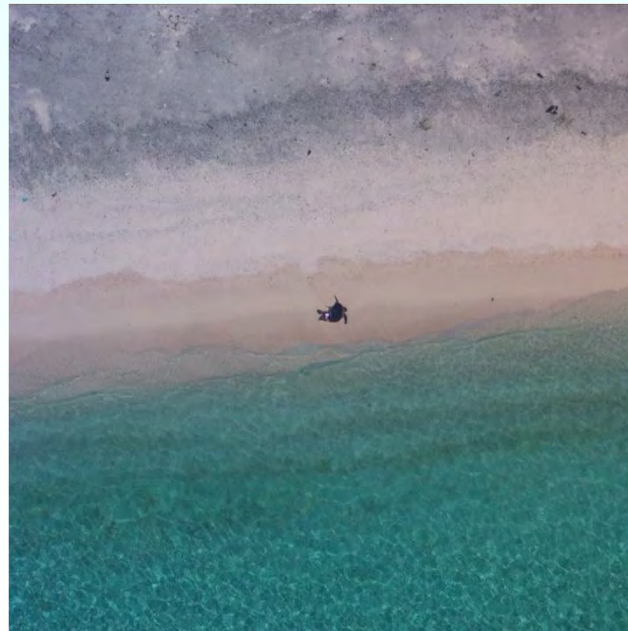
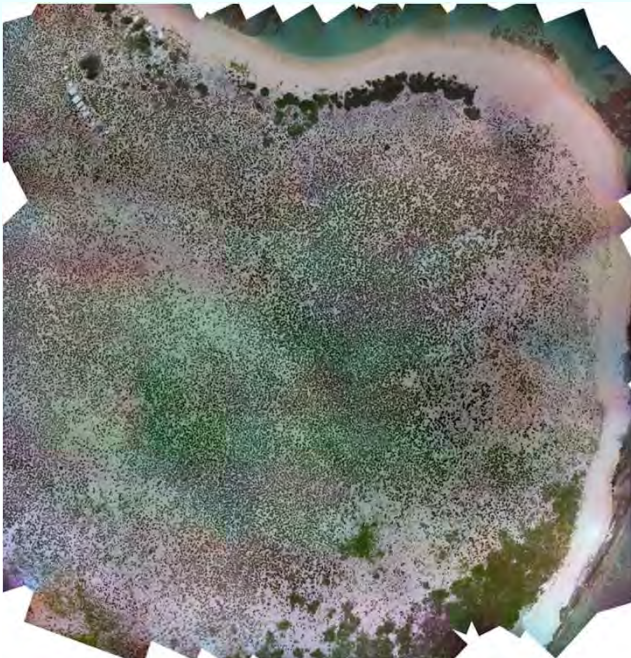
362,073 square kilometers of the Pacific Ocean

August 2015: NWHI Monk Seal and Marine Debris survey testing and high-resolution mapping



Objectives:

- Surveys for Hawaiian Monk Seal
- High resolution mapping of remote atolls for baseline
- Surveys for marine debris removal teams (lost fishing nets)
- Collecting example data for bird surveys
- Collecting example data for sea turtle surveys



Northwestern Hawaiian Islands



NWHI Monk Seal #207



NWHI Green Sea Turtle



SettePumaHighlights.mp4



November 2015 – February 2016



November 2015:

Testing and documentation of autonomous net solution resolution and range of high-gain patch antenna over water aboard Shearwater in the Santa Barbara Channel in preparation for Operation Deep Freeze 2016 (in support of NOAA and USCG.)

Late December 2016 – February 2016:

ODF-16.

- Flying Puma Block II BVLOS with long range antennas. Polar test of i45 Super Gimbal.
 - Flying Puma from USCGC Polar Star (Heavy Icebreaker) to provide data to the ship in support of safe and efficient navigation while it is breaking ice during it's mission to open up the ship channel to the McMurdo Research Station for its annual resupply.
 - Collecting of images to provide the National Ice Center (NIC) ground truth for validation of satellite-based forecasts.

November 2015: Long Range Telemetry & Autonomous net capture testing



Testing aboard NOAA
R/V Shearwater in the
Santa Barbara Channel:

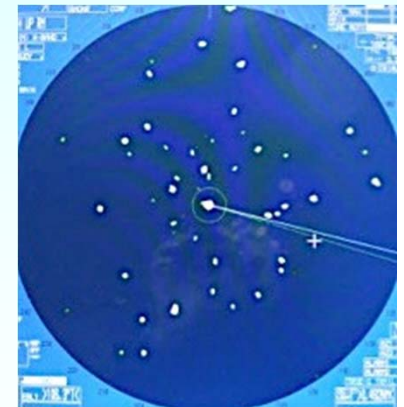
- Sea state 3
- 90+% Success Rate
- All Puma captures ended up in boat without significant damage to airframe or wings.
- This evolved from AS15 and set the stage for ODF-16.



Operation Deep Freeze 2016 Mission Objectives



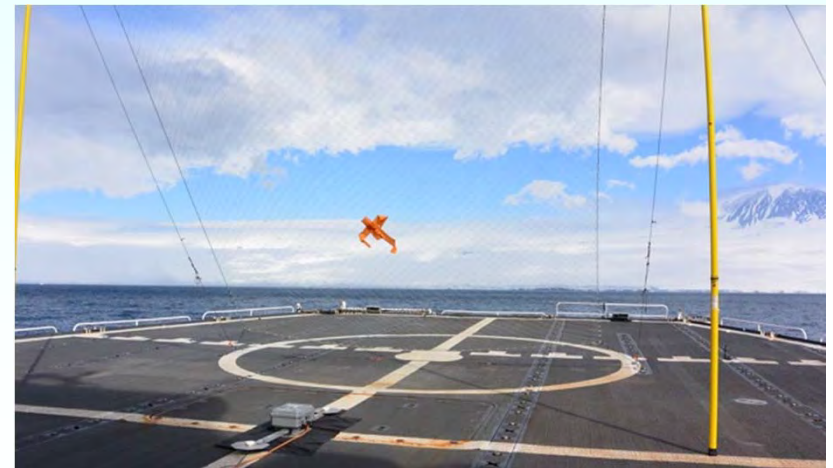
- Forward scouting for icebreaking
- Collect ice data (images) to validate satellite-based forecasts
- Continue development of shipboard TTPs for small UAS operations in Antarctic and Arctic environments
- Demonstrate effective deployment of small UAS in extreme maritime operations
- Test new Puma UAS i45 camera payload and autonomous net capture system



Deep Freeze Achievements



- 20 flights, including 46 kilometer flight (BVLOS)
 - “12”hours of video
 - i45 high resolution nadir images
- Autonomous shipboard landings
- Concepts of operation developed and tested
- Performed missions in conditions in which helicopters could not operate



Key Requirements for Future Maritime Small UAS Operations



- General maritime operations
 - Pre-programmed operations with more autonomous capabilities for data gathering and recovery
 - High wind capability (greater than 25 kts)
 - Range (BVLOS to 40+ kilometers)
 - Nadir mapping capability
 - Mode C or ADS-B transponder
- Polar maritime operations – most extreme conditions
 - Ice sensing and/or de-icing capability

