NOAA and AeroVironment Puma AE Research and Development in the Santa Barbara Channel Region

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NOAA

AUVSI Channel Islands

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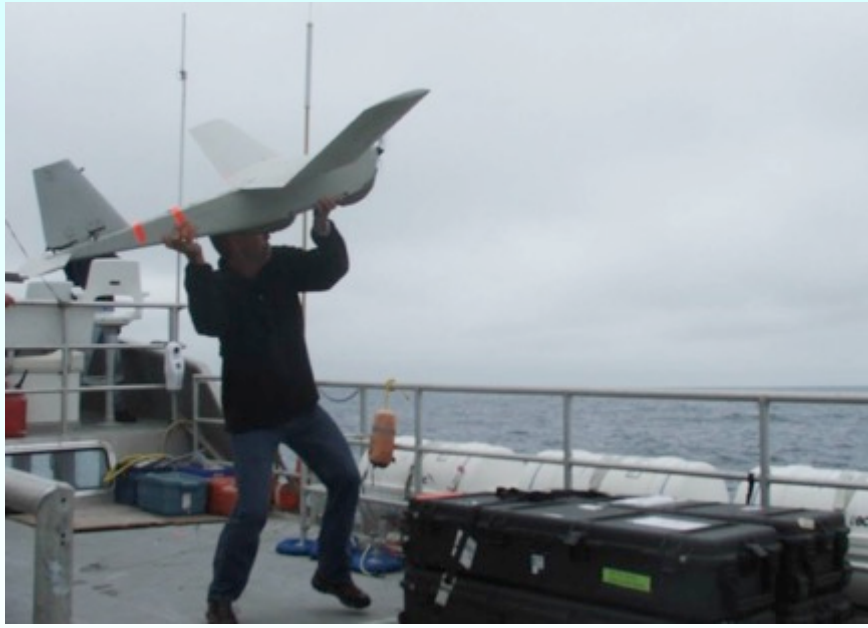
NOAA Small UAS Experience

- 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
- Signed CRADA with AeroVironment
- Worked with AeroVironment to modify and optimize equipment for NOAA Missions
- Performed Missions:
  - Living marine resource surveys
  - Habitat mapping and characterization
  - Enforcement
  - Emergency response
  - Marine Debris
  - USCG Arctic support
  - USCG Antarctic support



The “holy grail”: Launching and recovering at sea

Marine Resource Monitoring

Blue Whale Tagging Support

Marine Resource Monitoring

Living Marine Resource Surveys

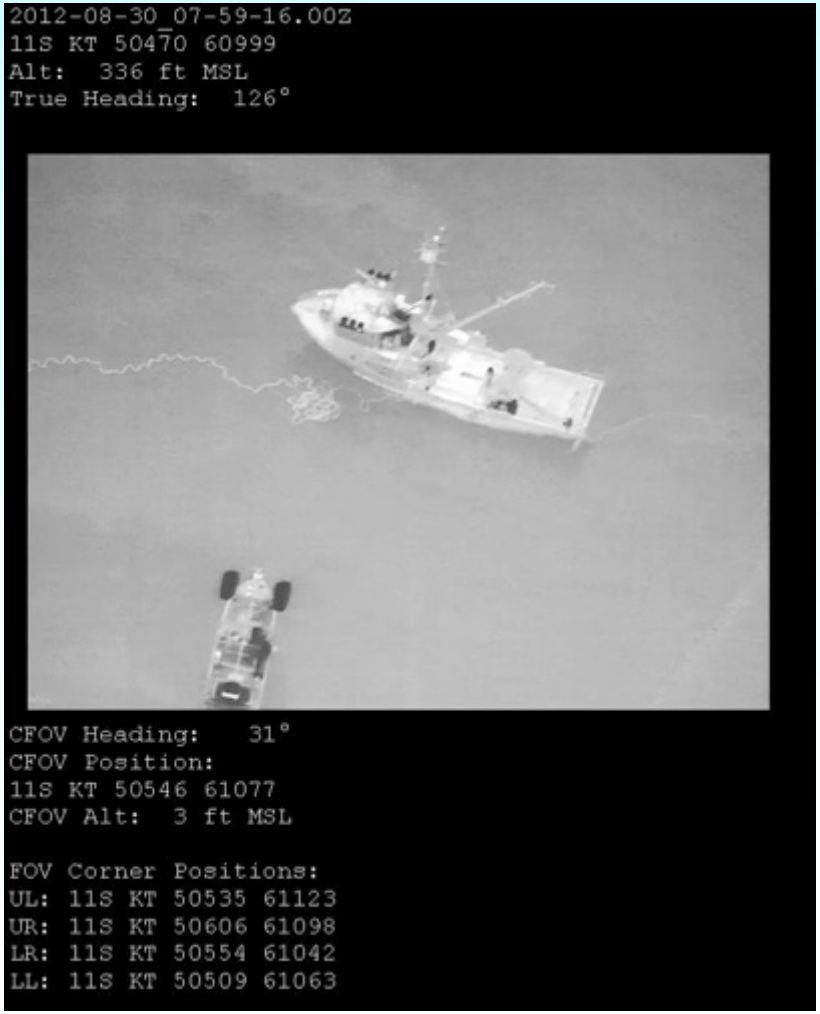
- Pinnipeds

Marine Resource Monitoring

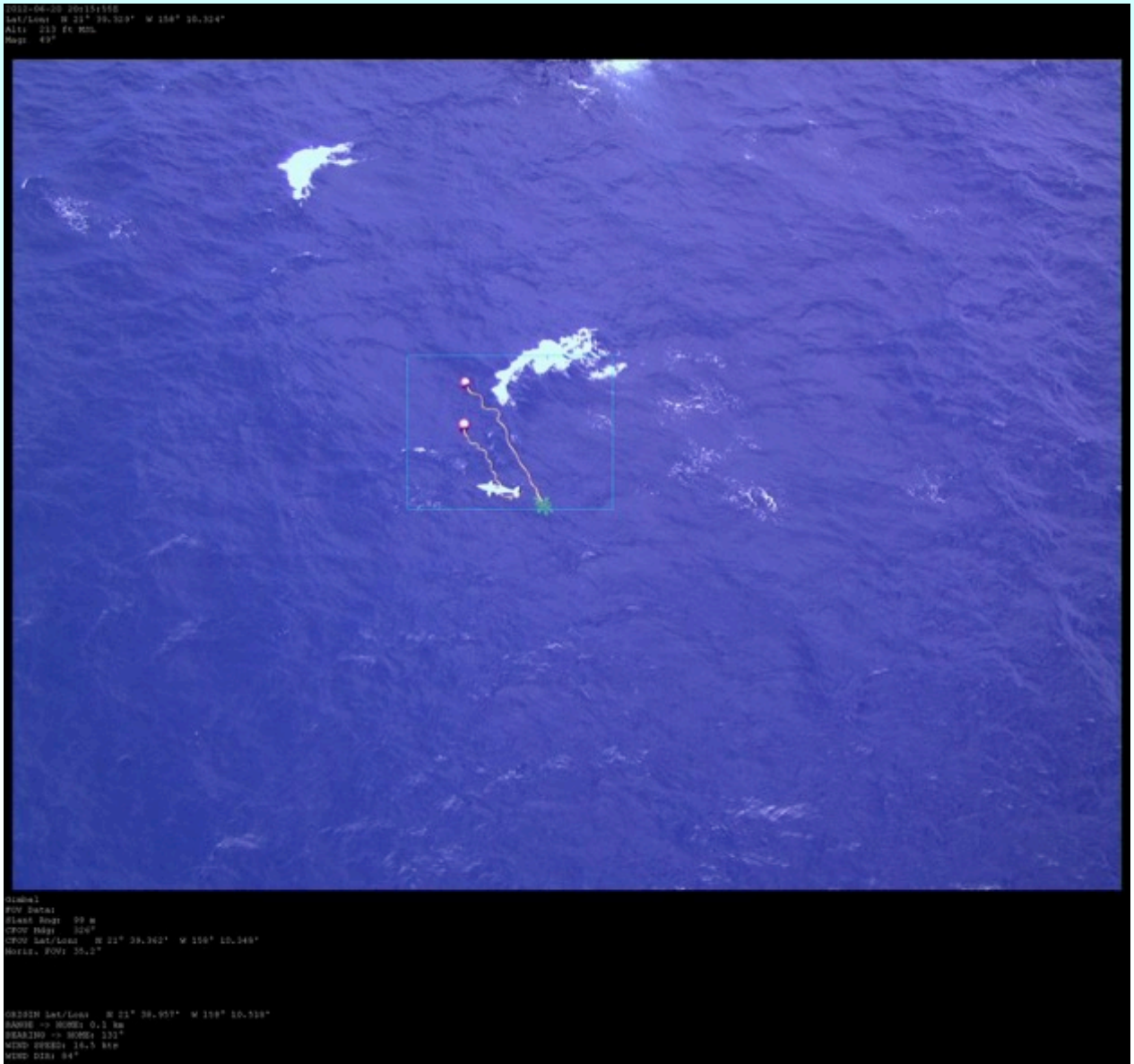
Habitat Mapping

Marine Resource Monitoring

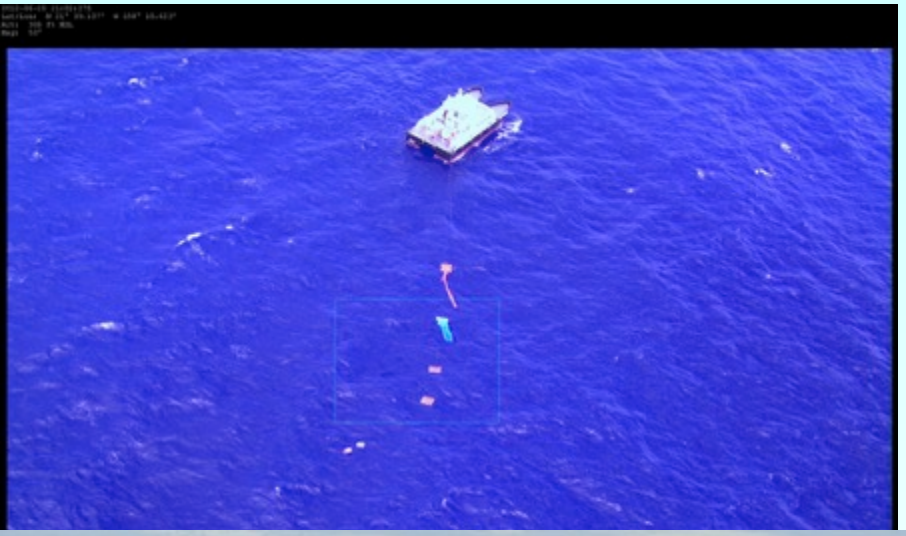
Enforcement



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°

AV GCS/RVT on R/V Shearwater

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,

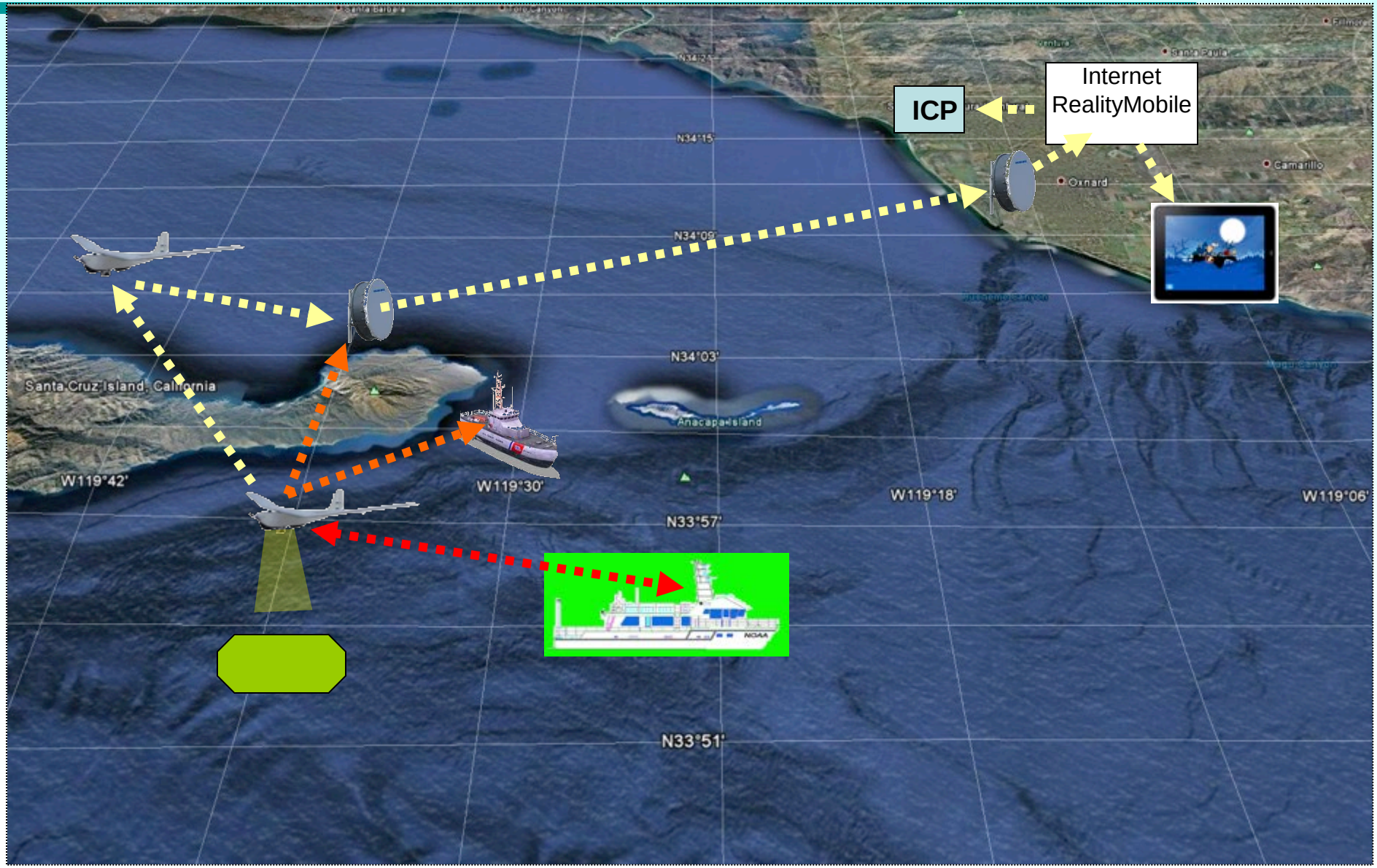
•Operated BVLOS (SUA provided by Point Mugu)

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:

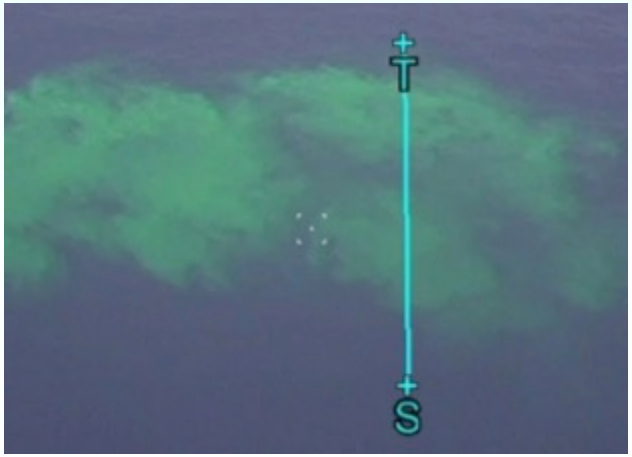
Someone needs to document how to effectively apply fluorescein dye!

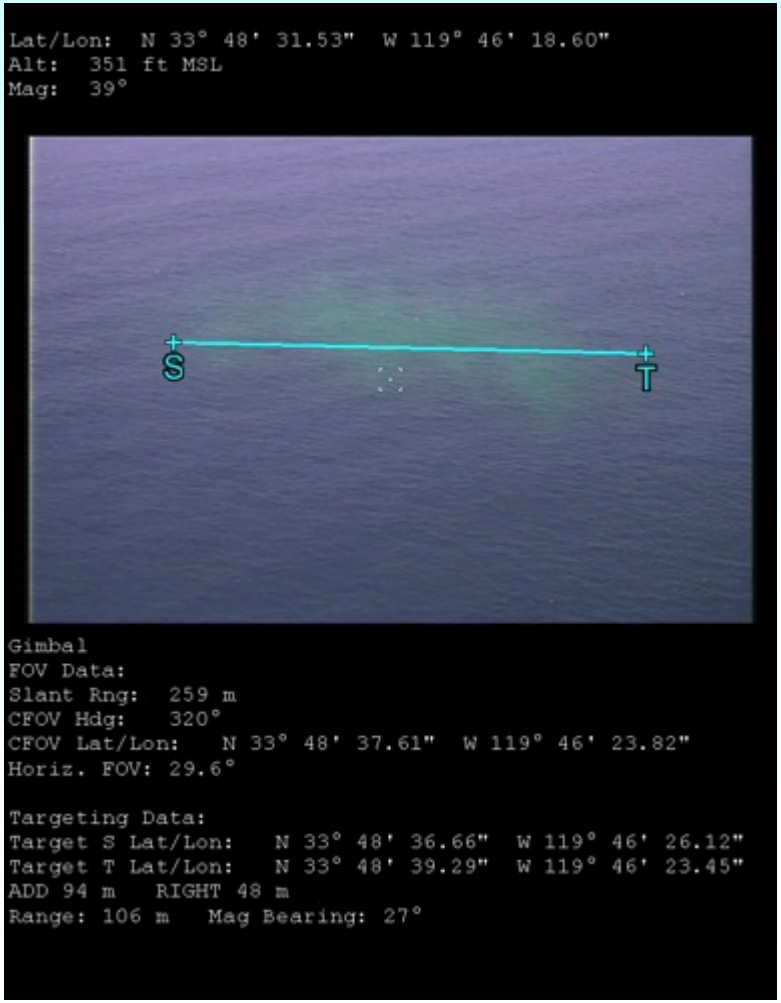
Data distribution architecture



Emergency Response & Oil Spill Simulation

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





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

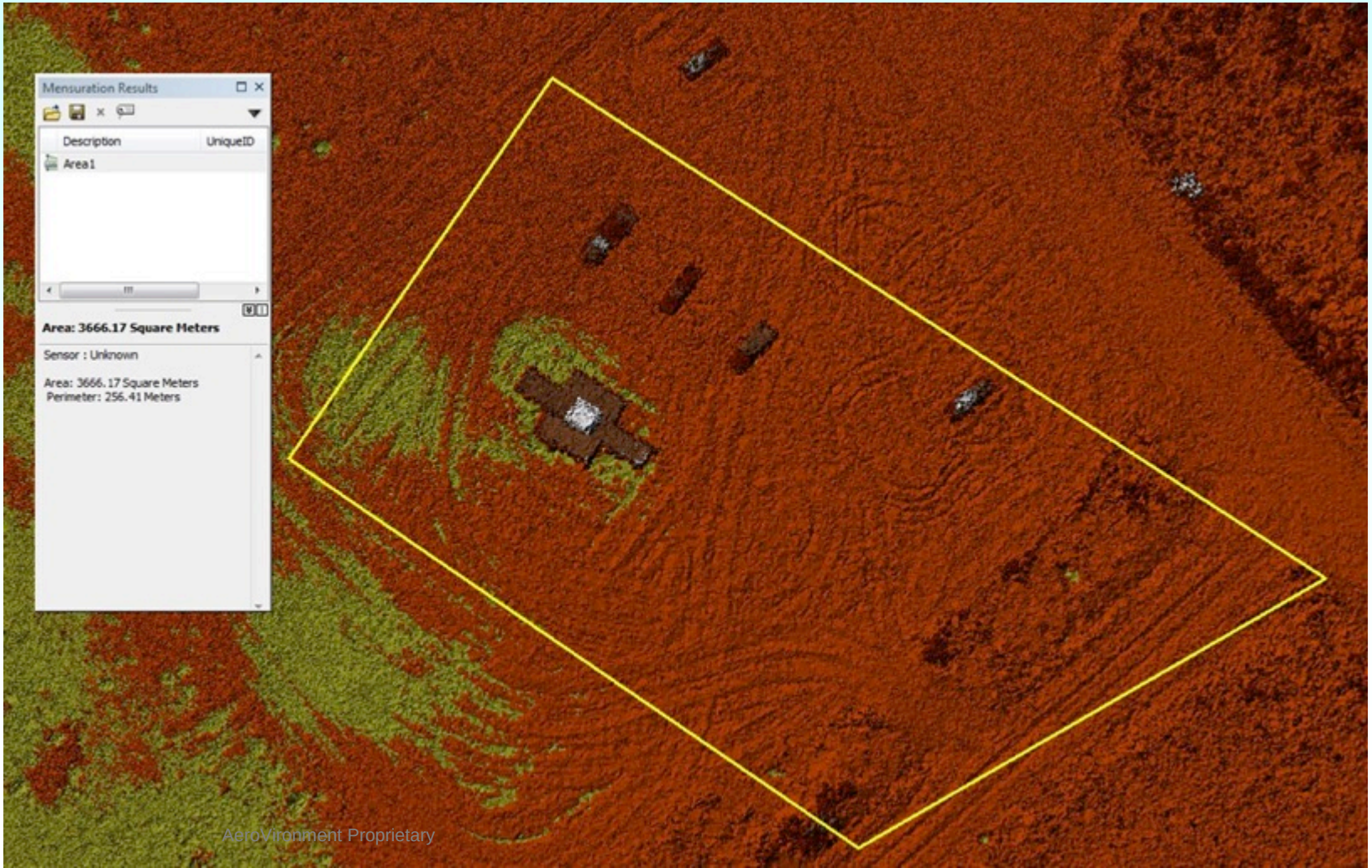
Dye Release (color enhanced)

Quadrat transects at VAFB

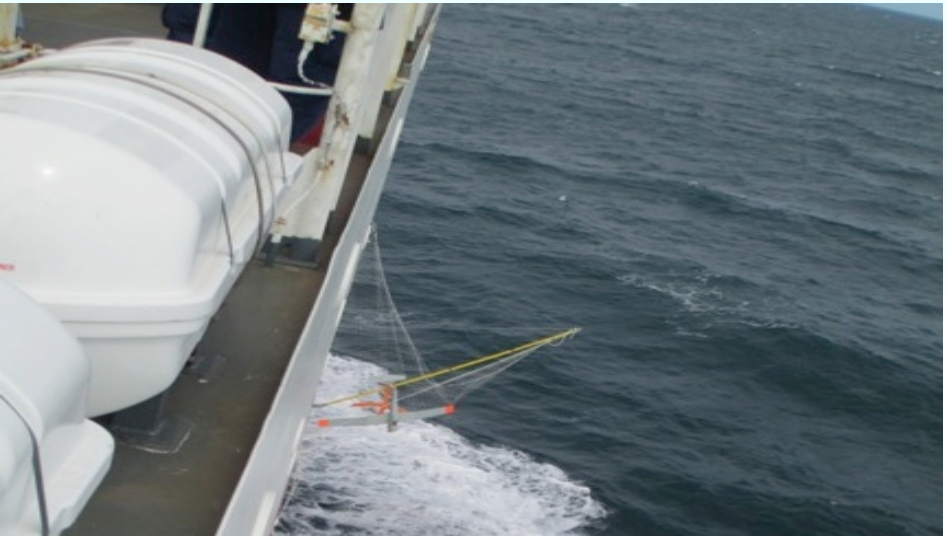
2d3 Super Resolution Enhancement

January 2014: Nadir mapping camera and lidar demo

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



“Holy Grail”: Launch and Recovery at Sea



Arctic Support of USCG

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**

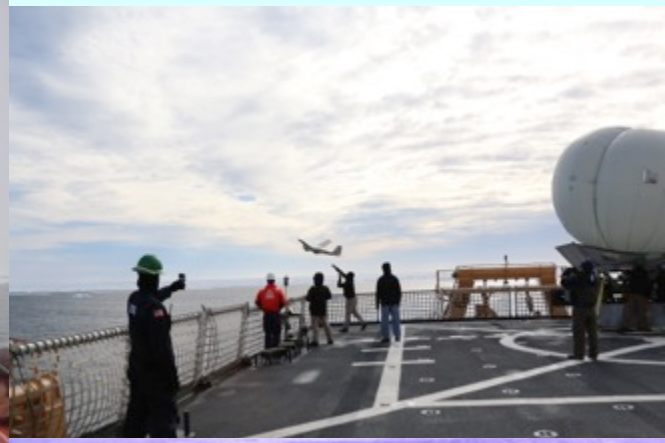
•Problems with accuracy of positioning when operating in areas without DTED (now solved by manufacturer)

•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

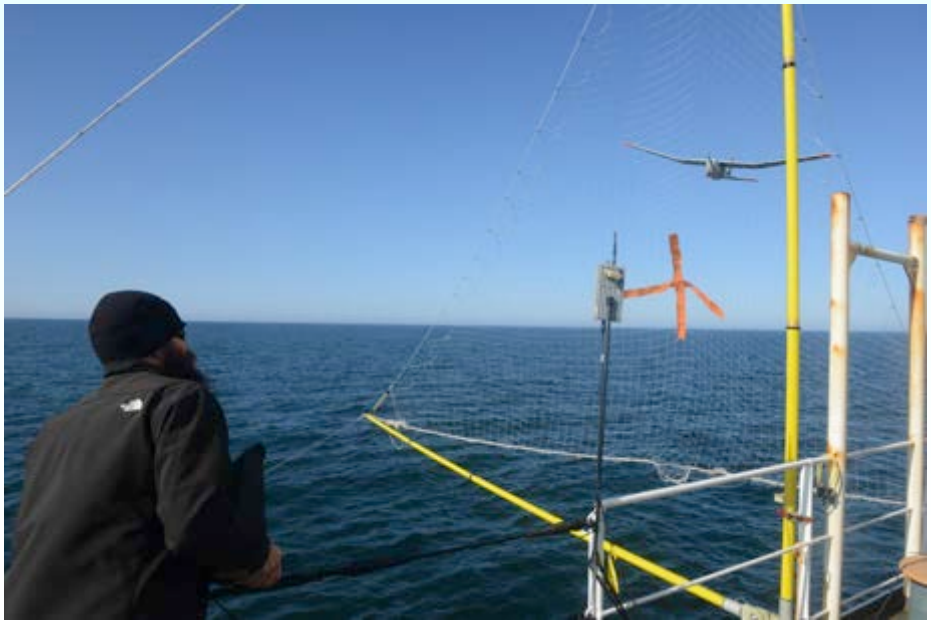
Arctic Shield Oil Spill Testing

2014 Detection and monitoring of simulated oil spilled from ship



2014 Puma “Due Regard” Ops & Recovery Testing in the Arctic

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



March 2015:
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 AS14 and set the stage for Arctic Shield 2015.

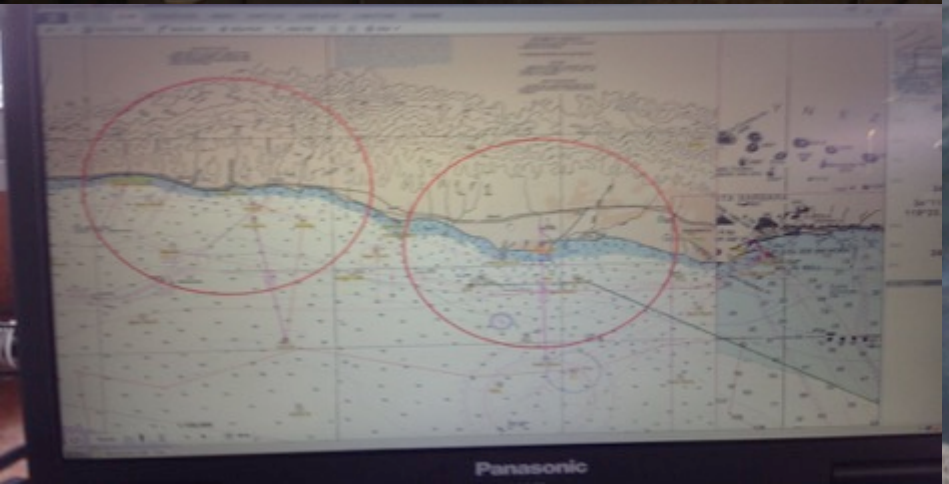
Refugio Oil Spill

Refugio Oil Spill

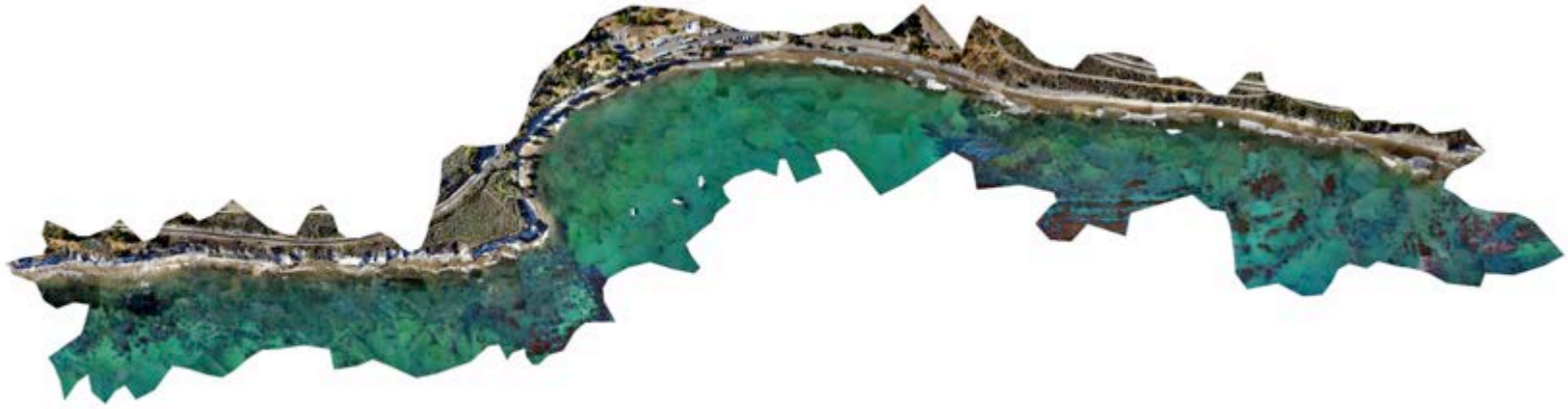
May 2015:
Refugio oil spill

- 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

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”

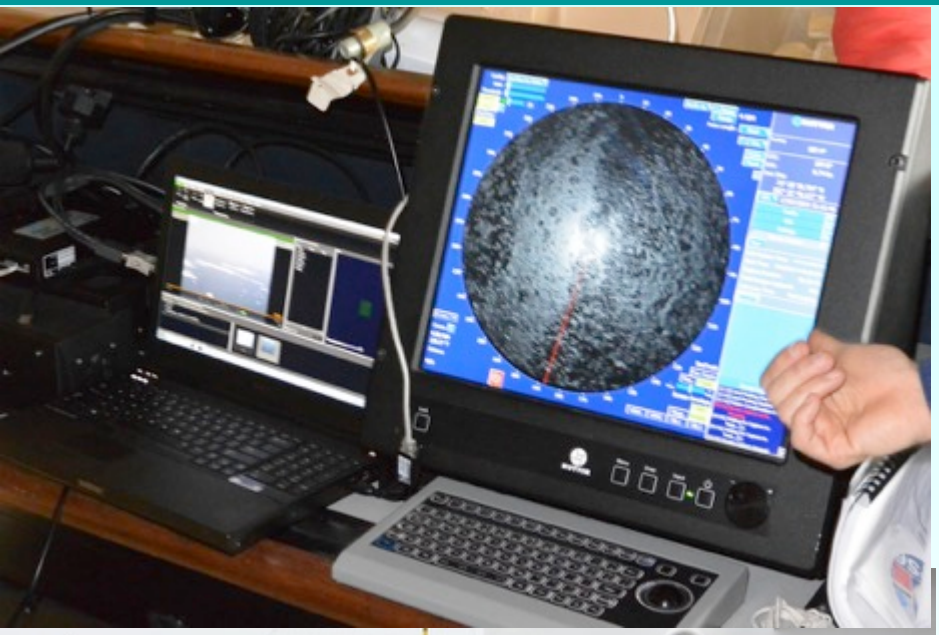
Arctic Shield July 2015 aboard the USCGC (Polar Icebreaker) HEALY.

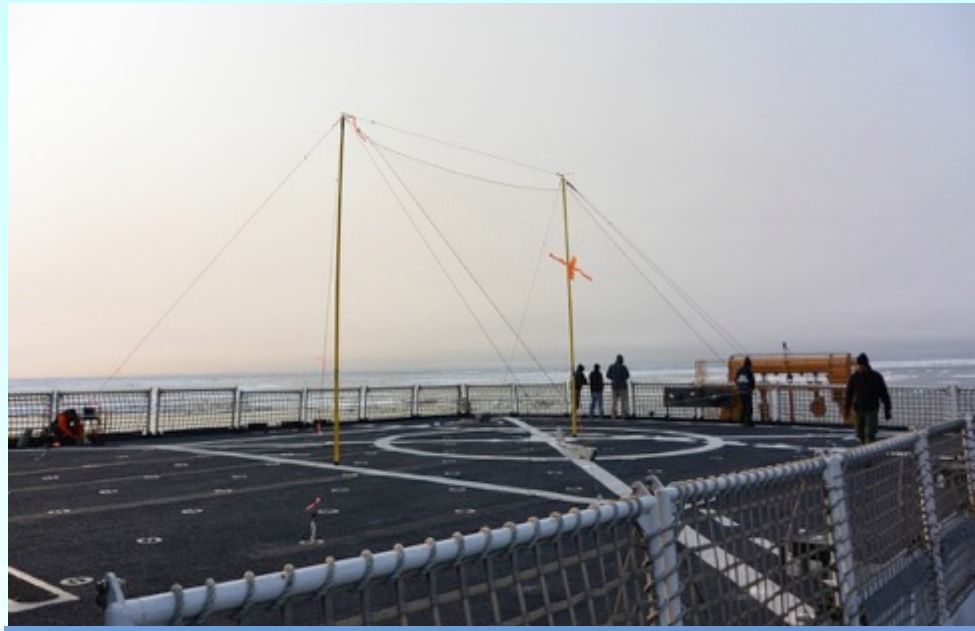
Milestones included:

- **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**.

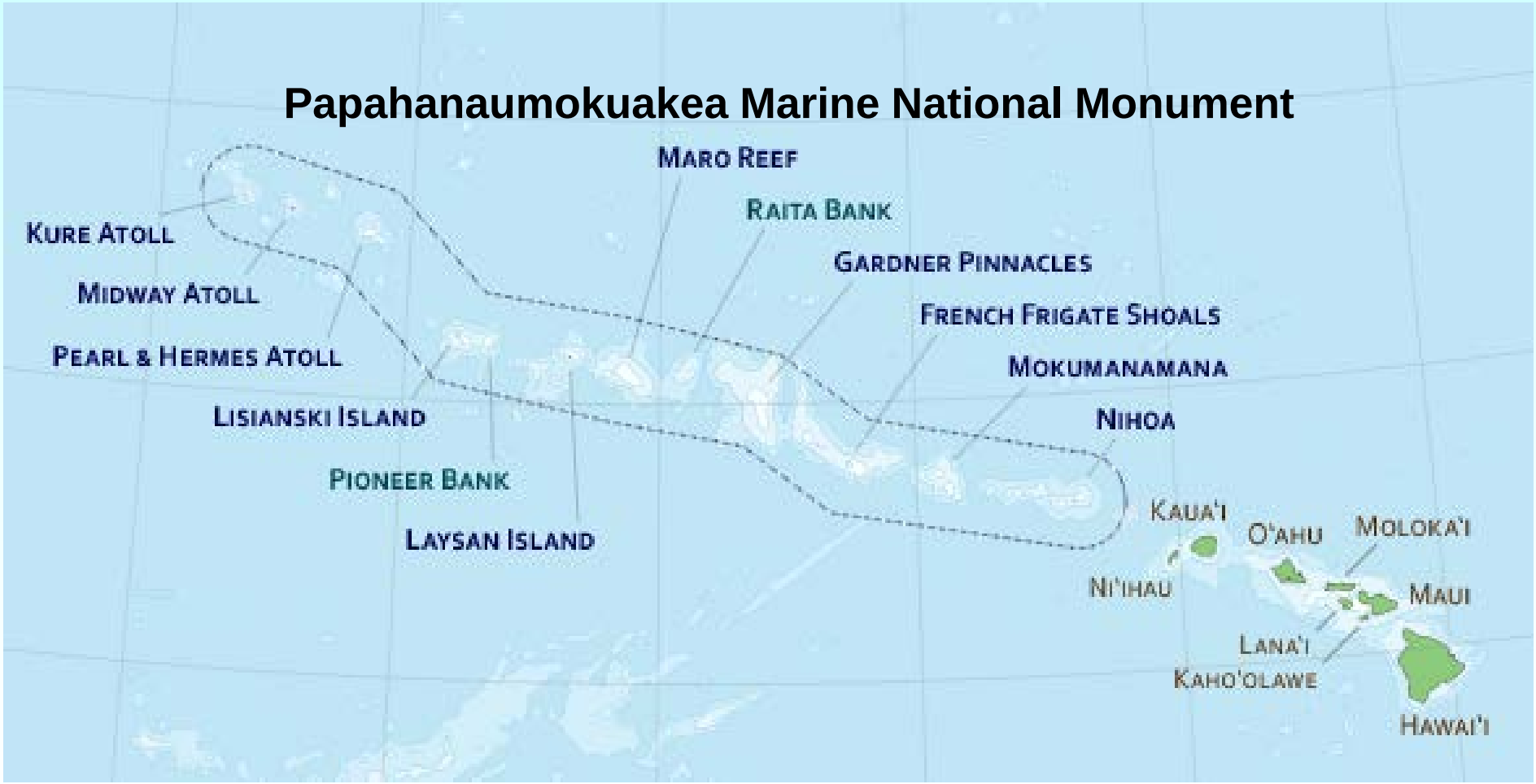
Arctic Shield Testing and integration

Arctic Shield 2015





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

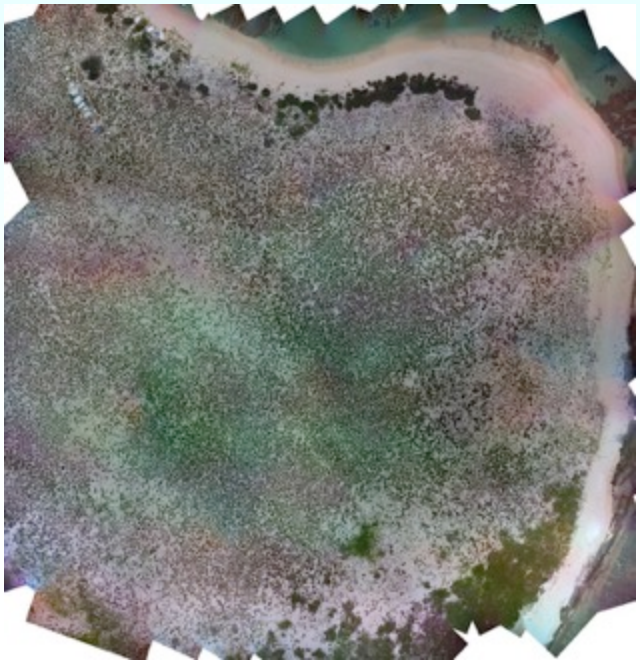


362,073 square kilometers of the Pacific Ocean

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

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 ll 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.

Antarctica

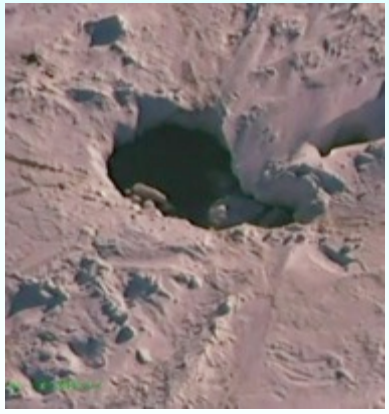
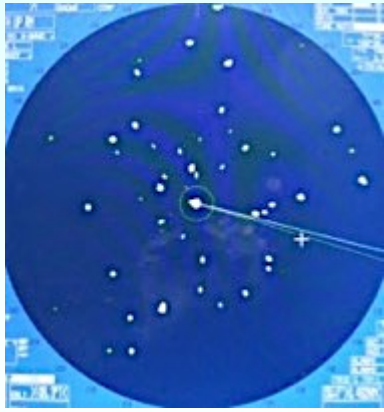
Operation Deep Freeze 2016

- NOAA and USCG
- **Annual resupply mission to US National Science Foundation's McMurdo base in Antarctica**
- Coordination between National Science Foundation, Department of Defense and US Coast Guard
- Physical and environmental challenges:
- Interesting/impressive statistics:
- Administrative and regulatory challenges: number of organizations involved in planning, review and execution of UAS operations

Deep Freeze Mission Objectives

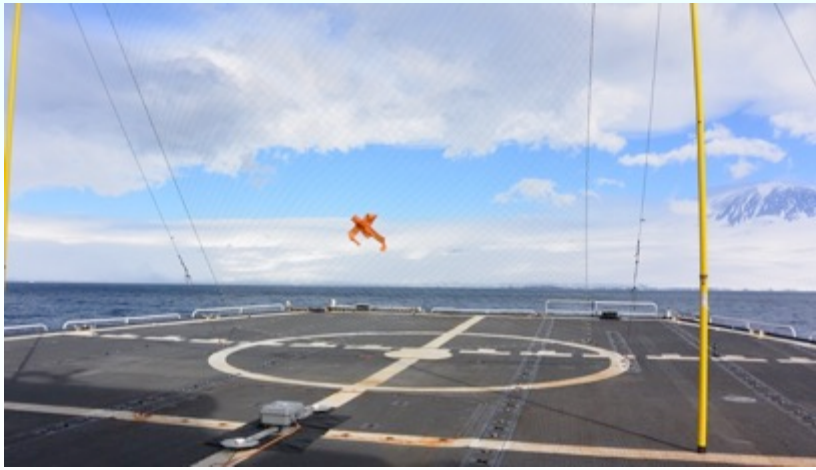
- Forward scouting for icebreaking
- Collect ice data (images) to validate satellite-based forecasts
- Continue development of shipboard TTPs for small UAS operations in Antarctic and Arctic environments
- **Demonstrate effective deployment of small UAS in extreme maritime operations**
- **Test new Puma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



Take aways

• Operating sUAS BVLOS is still a challenge even in the most remote areas due to airspace and de-confliction issues.
•There is still little to no spontaneity in operating UAS - the real returns will come when they can truly be used to respond to emergencies and events in real time.
•The more remote and/or hazardous of an area you are, the more UAS make sense to consider for data gathering
•More equipment is coming to market. Batteries and payloads are getting better (longer range/duration flights) and higher resolution imagery.
•Transponder equipped (Mode C/ADS-B) sUAS may be an interim step.
•Still waiting to find a VTOL that is designed to operate from boats that can survive landing in the water…