NOAA Unmanned Aircraft Systems (UAS) Program Activities

“Alaska is our aircraft carrier in the Arctic!”

John “JC” Coffey
September 2014
NOAA UAS Program
2nd UAS Arctic and River Forecast Workshop Agenda

0730: Welcome

0740: NOAA NWS River Forecasting Center Update: Robert Moorhead & John “JC” Coffey
  • Brief last report, summarize range of UASs, discuss progress, discuss plans

0820: Break

0830: North Central RFC: Mike Deweese

0850: Lower Mississippi RFC: Suzanne van Cooten (remote)

0920: Missouri Basin RFC: Kevin Low

0940: Southeast RFC: Regina Cabrera

1000: Alaska Pacific RFC: Scott Lindsey

1030: Summarize needs: Robert Moorhead

1100: Discuss next steps and discuss coordinating with other federal agencies: John “JC” Coffey

1200: Lunch

1300: Discuss “Other NWS UAS Applications” – (Carven Scott)

1400: NOAA UAS Flight Operations – (Phil Hall)

1420: NOAA Wildlife Observations – (Robyn Angliss, NMFS)

1440: NOAA Air Chemistry Observations – PMEL Manta Missions (Dr. Timothy Bates)

1500: NOAA UAS Oil Spill and Marine Domain Awareness Observations– Arctic Shield (Todd Jacobs)

1520: NOAA Weather and Sea Ice Observations – MIZOPEX and SHOUT (Robbie Hood, remote)

1540: Wrap-Up (JC Coffey)

1800: No Host Dinner at the Snowgoose Restaurant and Brewpub (JC Coffey)
### National Strategy for the Arctic Region

- Advance U.S. security interests
- Pursue responsible Arctic region stewardship
- Strengthen international cooperation

### NOAA’s Arctic Vision and Strategy

- Forecast sea ice
- Improve weather and water forecasts and warnings
- Strengthen foundational science to understand and detect Arctic climate and ecosystem changes
- Improve stewardship and management of ocean and coastal resources in the Arctic
- Advance resilient and healthy Arctic communities and economies
- Enhance international and national partnerships
NOAA UAS Program Strategic Vision and Goals

• **Vision**
  – UAS will revolutionize NOAA observing strategies comparable to the introduction of satellite and radar assets decades earlier

• **Goals**
  – Goal 1: Increase UAS observing capacity
  – Goal 2: Develop high science-return UAS missions
    • *High impact weather monitoring*,
    • *Polar monitoring*
    • *Marine monitoring*
  – Goal 3: Transition cost-effective, operationally feasible UAS solutions into routine operations
Conducted UAS market survey and developed data base of UAS performance capabilities and costs

Developed UAS Analysis of Alternatives & Strategy:

- High altitude long endurance – Global Hawk
- Medium altitude long endurance – Predator or Ikhana
- Low altitude long endurance – ScanEagle
- Low altitude short endurance – Puma or Vertical Take Off and Landing (VTOL)
- Air-Launched – Coyote, Cutlass, GALE, SBIR
- USV – EMILY

Developed technology review process for funded projects

Supported operator training / initial concept of operations
Key Accomplishments

- Observations of oceanic weather systems in Atlantic, Arctic, and Pacific using NASA Global Hawk
- Development of Global Hawk dropsonde system with NSF
- Lower Mississippi River Forecast Center demonstration with Puma and Aircraft-launched UAS development through SBIR Phase I
- Development of Fire Weather UAS through NSF collaboration
- Development of EMILY unmanned surface marine vehicle
- Two peer-reviewed journal articles published in 2014
Environment Observations
- Profiles of temperature, humidity, wind, and pressure
- Cloud top height
- Cloud top temperature and profiles of temperature and humidity

Hurricane Edouard 9/14/14
- St Croix
- Buoy Drops Highlighted
- NOAA’s P-3s, GIV and GH Flying this week
- Watch our flights: http://airbornescience.nasa.gov/tracker/
**Key Accomplishments**

- Peer-reviewed journal article based on black carbon mission using Manta in Norway
- Deployment of three different UAS during Marginal Ice Zone Experiment in partnership with NASA
- Puma UAS deployed from US Coast Guard Healy Ice Cutter ship for marine monitoring and oil spill detection with ONR, AeroVironment
- Development of partnership with UAF, US Navy, USCG, Conoco Philips for ScanEagle flights in the Arctic
- Other platform coordination Aerosonde, Flexrotor...
NOAA USCG Healy Deployment, Operational and Scientific Goals

- Conduct Puma AE "due regard" operations from USCG (Icebreaker) Healy
  - Water and Ice Landings
  - Deck Landing
  - Net Capture System

- Conduct Intelligence, Surveillance, and Reconnaissance (ISR) Operations Stream Full Motion Video (FMV), EO and IR 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 (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 sUAS

- Utilize the Environmental Response Management Application (ERMA)

- Coordinate with ONR Marginal Ice Zone Experiment (MIZOPEX) FY14

- Coordinate with the UAF for ScanEagle flight operations coordination and data exchange
Puma “Due Regard” Ops & Recovery Testing

- Due Regard Operations
- Water and Ice Landings
- Deck Landing
- Net Capture System
ISR Missions including Oil Spill & SAR

- Sea ice ridge detection/monitoring
- Marine and marine mammal monitoring
- Usefulness in search and rescue scenarios
- Detection and monitoring of oil spilled from ship
- Detection and monitoring of marine debris from ship
ERMA Coordination

- 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.
- Second year participations through the UAS Program.

Software and Datasets
- **ADIOS**, oil weathering model.
- **ERMA®**, online mapping tool for environmental response data, adapted to a variety of regions.
- **GNOME**, oil spill trajectory model.
- **GOODS**, a tool that helps GNOME users access base maps, ocean currents, and winds.
- **NUCOS**, a unit converter that includes units unique to oil spill response.
- **Spill Tools**, a set of three programs: the Mechanical Equipment Calculator, the In Situ Burn Calculator, and the Dispersant Mission Planner.
- **Trajectory Analysis Planner**, oil spill contingency planning software.
- **Environmental Sensitivity Index (ESI) maps and data**, concise summaries of coastal resources that may be at risk in a spill incident.
Healy Planned Track, MIZOPEX, ScanEagle Op Areas

- ONR MIZOPEX BUOYS & Gliders (8/24)
- USCG (Icebreaker) Healy Track
- ScanEagle Operations Area

Rover - used to intercept UAS Platform Signals
Take Aways & Operational Assessment

• Arctic is a Challenging Environment
  – Platform flight envelope must be expanded
  – Platform recovery process and sensors must continue to be improved
  – “Due Regard” operations must be expanded

• Partnerships are crucial (Maritime Strategy)
  – People, property and platforms (data captured) are valuable
  – Must maximize operations and date sharing opportunities
ScanEagle Operational Assessments (2009-2014)

- (Goal) Fly a combination of different types of remote sensing instruments for atmospheric research, marginal ice zone, polar & marine monitoring
- (Outcomes) Operational Coordination and Operations
  - Maritime and Ice Seal Survey from MacArthur (2009)
  - Atmospheric Testing from NSWC Dahlgren (2012)
  - Atmospheric Research Deployment from R/V Revelle (2012)
  - Atmospheric Testing from NSWC Dahlgren (2013)
  - Atmospheric Research Deployment from R/V Knorr (2013)
  - Marginal Ice Zone Experiment (MIZOPEX) for Oliktock Pt (2013)
  - Data Management and Coordination with ERMA (2014)
  - Maritime survey Data Exchange with UAF & Conoco Philips (2013-2014)
  - Alaskan Wildfire Night / Beyond-Line-of-Sight Flights 2014
  - Government and Industry Platform Updates and Coordination (2014)

"Flux" payload

<table>
<thead>
<tr>
<th>Instrumentation</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-port turbulence/gust probe</td>
<td>Winds, momentum fluxes, other fluxes (vertical wind est., accuracy ±1 cm/s)</td>
</tr>
<tr>
<td>Laser altimeter</td>
<td>Surface waves, air control</td>
</tr>
<tr>
<td>Humidity/temperature</td>
<td>H/T profiles and bulk fluxes</td>
</tr>
<tr>
<td>SST sensor</td>
<td>SST, frontal proceeses</td>
</tr>
<tr>
<td>Fast response optical temp. sensor</td>
<td>T, sensible heat flux</td>
</tr>
<tr>
<td>Krypton hygrometer</td>
<td>H2O covariance fluxes</td>
</tr>
<tr>
<td>DAQ system</td>
<td>Data acquisition</td>
</tr>
<tr>
<td>DGPS</td>
<td>georeferencing, winds, air control</td>
</tr>
<tr>
<td>IMU - LN200</td>
<td>georeferencing, winds</td>
</tr>
</tbody>
</table>
Key Accomplishments

- Acquisition and deployment of two Puma UAS
- Two years of Puma missions in partnership with National Marine Sanctuaries Program
- Development of Puma Transition Plan in collaboration with OMAO and NOS
- Demonstration of NASA Ikhana and observing capabilities for long distance monitoring of Hawaiian marine monument
- Development of medium altitude UAS observing capabilities for gravity measurements and coastal mapping through SBIR Phase II study
Hawaii Activities

Papahanaumokuakea Marine National Monument

362,073 square kilometers of the Pacific Ocean

NOAA PUMA

NASA IKHANA
Marine Resource Monitoring
Issues & Barriers to Success

- Unmanned Systems have been “Wildly successful!”
- Plenty of issues but, “We have chosen to admire the problem.”
- Issues & Barriers to Success
  - Privacy
  - FAA Regulations & Access – Airspace, Airworthiness, Quals
  - Program Management
    - Engineering, Logistics, T&E, Operations, Contracting…
    - Cost, Schedule, Performance, Risk, Requirement Traceability, Commonality
  - Administrative hurdles to cooperation & asset pooling
    - MOUs & IAAs
    - Buying data or capability (assets, personnel, infrastructure)?
    - Understanding utilization rates and metrics
      - S&T… R&D… “Three months of install and ground test for 1 Flt-Hr
      - Flt Hours vs On-station Hours vs Sensor Hours vs Data Hours vs Used DH
Success!!!

- R&D to Operations
  - Optimized existing infrastructure
  - Airspace Access
    - Dangerous, Dirty, Dull, Denied
    - Efficient, Effective, Economical and Environmentally Friendly
  - Common and Pooled Assets & Operators
    - Logistic, Configuration Management, Training
    - Data Standardization, Quality, Storage and Cataloging
- Affordable & Environmentally Friendly
  - Autonomous
    - Multiple platforms controlled by single operator
  - Uses 10% of the fuel or “new fuels” or “no fuel”
UAS Web Site: http://uas.noaa.gov/

Questions should be directed to:

Robbie Hood - NOAA UAS Program Director
(robbie.hood@noaa.gov / 303-905-3411)

John “JC” Coffey - NOAA UAS Program Office
(john.j.coffey@noaa.gov / 904-923-1709)
Sensing Hazards Using Operational Unmanned Technology (SHOUT)

Overall Goal

• Demonstrate and test prototype UAS concept of operations that could be used to mitigate the risk of diminished high impact weather forecasts and warnings in the case of polar-orbiting satellite observing gaps

Objective 1

• Conduct data impact studies
  • Observing System Experiments (OSE) using data from UAS field missions
  • Observing System Simulation Experiments (OSSE) using simulated UAS data

Objective 2

• Evaluate cost and operational benefit through detailed analysis of life-cycle operational costs and constraints
SHOUT General Plan

**FY14**
- OSE with previous HS3 data underway
- OSSE with simulated data starting soon for Atlantic / Gulf of Mexico tropical cyclones and Pacific / Arctic weather systems
- 5 extra missions added to HS3
- NOAA aviation personnel supporting NASA and NOAA Global Hawk missions

**FY15**
- Continued OSE and OSSE studies
- 10 NOAA-dedicated Global Hawk missions
- NOAA aviation personnel supporting NASA and NOAA Global Hawk missions

**FY16**
- 10-15 NOAA-dedicated Global Hawk missions and/or possible partnership with NASA Earth Venture experiment
- NOAA aviation personnel supporting NASA and NOAA Global Hawk missions
- Finalize data impact studies and analysis of cost and operational benefits
NOAA UAS Oil Spill and Marine Domain Awareness Observations

Operation Arctic Shield 2013 & 2014
Some basic principles

• No need to secure the global commons
  - Threat to global sea lanes likely lower than at any time since 1890

• Need to identify threats moving over the commons
  - Maritime Domain Awareness
  - Global Maritime Partnerships

• Need to be able to act quickly to potential threats or disruptions
  - Operate forward
  - Global Maritime Partnerships

• Need to assure access to commons in localized theaters, locations
  - Peacetime, for trade
  - Wartime, for the Joint Force
In peacetime, assuring access will increasingly involve solving access disputes

- Internal Waters
  - Landward of the low-water mark or within straight baselines
  - Sovereignty as on land
  - Possible right of innocent passage
- Territorial Sea
  - 12 nm
  - Nearly-full sovereignty; right of innocent passage
- Exclusive Economic Zone (EEZ)
  - 200 nm
  - Exclusive rights to all resources in the water and seabed
  - Passage as on high seas
- Extended Continental Shelf (ECS)
  - 350 nm; or 2500M isobath + 100NM
  - Exclusive rights to all resources in the seabed
- International Straits
  - Innocent/transit passage through otherwise restricted waters

Ilulissat Declaration
- May 2008 commitment by Arctic Ocean littoral states to apply existing legal frameworks to delimitation in Arctic

Arctic delimitation and disputes

Russia-U.S./Others Northern Sea Route Sovereignty Dispute
Russia claims historic internal waters at Kara, Vilkitskiy, and Laptev Straits; U.S. and others claim international straits

Canada-U.S./Others Northwest Passage Sovereignty Dispute
Canada claims historic internal waters throughout Arctic Archipelago; U.S. and others claim straits used for international navigation

Canada-Denmark Hans Island Sovereignty Dispute
Canada and Denmark each claim sovereignty of 1.3 sq km island; maritime boundary agreement did not include island

Canada-Denmark Lincoln Sea Maritime Boundary Dispute
65 sq nm disputed; Denmark claims EEZ based on small island/rock, Canada claims island/rock does not generate EEZ

Canada-Denmark Maritime Boundary Dispute
Canada claims western line on treaty and sector basis; U.S. claims eastern line based on equidistance principle

Canada-Denmark Eskimo Island EEZ Dispute
Denmark claims EEZ based on small island/rock, Canada claims island/rock does not generate EEZ

Canada-Canada EEZ Disputed EEZ

United States EEZ

Arctic delimitation and disputes
**NOAA Mission Needs:**

- Operate in Arctic Environment specifically in the Chukchi Sea area
- Shipboard Operations specifically utilizing NOAA assets (100’-250’ ships)
- Sensor Packages to obtain Whale Density Information with specific resolution
- Conduct UAS Operations with no risk to manned aircraft in area and FAA approval
- Minimize logistics footprint and setup for flight readiness to minimize costs
- Maximize Safety for Operations personnel
For highest ranked proposals...

- OAR-02 PMEL Saildrone - 3 DAS added to FOCI cruise (Apr/May) on *Oscar Dyson* if project can start early
- NOS-01 fish vocalization glider - 2 DAS swap on Batista EFHMA project (Mar/Apr) on *Nancy Foster* (or piggy-back on *Pisces* MPA or SEFIS project if space available in Jun/Jul)

For other proposals...

- *Oscar Dyson* piggy-back with OAR-02
  - NMFS-03 marine mammal glider
  - OAR-04 op assessment (Puma, ScanEagle & Emily)
- Fairweather piggy-back on proposed 25 DAS UAS Project (Aug)
  - OAR-03 Ecosystem/Carbon Waveglider
NMFS/NOAA Mission Needs:

- Operate in Arctic Environment specifically in the Chukchi Sea area
- Shipboard Operations specifically utilizing NOAA assets (100’-250’ ships)
- Sensor Packages to obtain Whale Density Information with specific resolution
- Conduct UAS Operations with no risk to manned aircraft in area and FAA approval
- Minimize logistics footprint and setup for flight readiness to minimize costs
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# UAV Specifications

<table>
<thead>
<tr>
<th>UAV Name</th>
<th>Aerosonde</th>
<th>T-16</th>
<th>T-20</th>
<th>FlexRotor</th>
<th>Heron</th>
<th>Scan Eagle / Nanook</th>
<th>TD100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>AAI</td>
<td>Arcturus- UAV</td>
<td>Arcturus- UAV</td>
<td>Aerovel</td>
<td>IAI</td>
<td>Insitu</td>
<td>Brican Flight Systems</td>
</tr>
<tr>
<td>Ship-Based Operation</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>In Works</td>
</tr>
<tr>
<td>Land-Based Operation</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ceiling (ft)</td>
<td>15000</td>
<td>15000</td>
<td>15000</td>
<td>24,600</td>
<td>30000+</td>
<td>19500</td>
<td>14763</td>
</tr>
<tr>
<td>Endurance (hr)</td>
<td>30</td>
<td>16 (24 on XL)</td>
<td>16 (8 w/ VTOL)</td>
<td>40+</td>
<td>20-45</td>
<td>24/22</td>
<td>4 (Battery)/30 (with Bio Fuel)</td>
</tr>
<tr>
<td>Max Speed (Knots)</td>
<td>80</td>
<td>75</td>
<td>75</td>
<td>79</td>
<td>80</td>
<td>80</td>
<td>104</td>
</tr>
<tr>
<td>Range (nm)</td>
<td>1620</td>
<td>600</td>
<td>1000</td>
<td>2000</td>
<td>2520</td>
<td>922</td>
<td>300 /1950 Est</td>
</tr>
<tr>
<td>Payload Capacity (lb)</td>
<td>10</td>
<td>30</td>
<td>75</td>
<td>1.98</td>
<td>550</td>
<td>13.2</td>
<td>18</td>
</tr>
<tr>
<td>Payload Dimensions (In)</td>
<td>12 x 9.5 x 9.5</td>
<td>25 x 8 x 8</td>
<td>36 x 12 x 12</td>
<td>5.9 dia. Sphere</td>
<td>No Data</td>
<td>No Data</td>
<td>No Data</td>
</tr>
<tr>
<td>Available Sensors</td>
<td>Electro-Optic (EO), Infrared (IR), Laser Pointer (LP)</td>
<td>TASE 200 (EO/IR), Applanix DMS</td>
<td>TASE 400 (EO/IR), Applanix DMS</td>
<td>ALTICAM (EO/IR)</td>
<td>EO/IR</td>
<td>NEX7 (In Dev) (EO/MWIR)</td>
<td>GoPro, Nikon D300, Nikon D3X, Applanix DMS</td>
</tr>
<tr>
<td>Operational Temp. (F)</td>
<td>*Down to 5°F</td>
<td>*Down to 5°F</td>
<td>Down to -30°F</td>
<td>Down to 3°F</td>
<td>*Down to -48°F</td>
<td>Down to 3°F</td>
<td>~40F to 113F (In Spec)</td>
</tr>
<tr>
<td>Fuel Injected</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>TBD</td>
<td>No/Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Arctic Operation</td>
<td>Yes</td>
<td>T-20 Tested</td>
<td>*Yes WY Tested</td>
<td>#Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Operational Temp. Estimated by Altitude  # Not demonstrated
## Endurance Comparison

<table>
<thead>
<tr>
<th>Rank</th>
<th>Platform</th>
<th>Endurance (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Heron</td>
<td>45 (with Heavy Fuel)</td>
</tr>
<tr>
<td>2</td>
<td>FlexRotor</td>
<td>40+</td>
</tr>
<tr>
<td>3</td>
<td>Aerosonde</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>TD100</td>
<td>30 (with Bio Fuel)</td>
</tr>
<tr>
<td>5</td>
<td>ScanEagle / Nanook</td>
<td>24/22</td>
</tr>
<tr>
<td>6</td>
<td>T-20</td>
<td>16/8 VTOL</td>
</tr>
<tr>
<td>7</td>
<td>T-16</td>
<td>16</td>
</tr>
</tbody>
</table>

![Endurance Graph](image_url)
## Altitude Comparison

<table>
<thead>
<tr>
<th>Rank</th>
<th>Platform</th>
<th>Ceiling (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Heron</td>
<td>30,000</td>
</tr>
<tr>
<td>2</td>
<td>FlexRotor</td>
<td>24,600</td>
</tr>
<tr>
<td>3</td>
<td>ScanEagle/ Nanook</td>
<td>19,500</td>
</tr>
<tr>
<td>4</td>
<td>Aerosonde</td>
<td>15,000</td>
</tr>
<tr>
<td>5</td>
<td>T-20</td>
<td>15,000</td>
</tr>
<tr>
<td>6</td>
<td>T-16</td>
<td>15,000</td>
</tr>
<tr>
<td>7</td>
<td>TD100</td>
<td>14,763</td>
</tr>
</tbody>
</table>
## Max Gross Takeoff Weight Comparison

<table>
<thead>
<tr>
<th>Rank</th>
<th>Platform</th>
<th>MGTOW (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Heron</td>
<td>2530</td>
</tr>
<tr>
<td>2</td>
<td>T-20</td>
<td>175</td>
</tr>
<tr>
<td>3</td>
<td>T-16</td>
<td>85</td>
</tr>
<tr>
<td>4</td>
<td>Aerosonde</td>
<td>55</td>
</tr>
<tr>
<td>5</td>
<td>TD100</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>ScanEagle/Nanook</td>
<td>48.5</td>
</tr>
<tr>
<td>7</td>
<td>FlexRotor</td>
<td>42.5</td>
</tr>
</tbody>
</table>

Heron MGTOW is a significant order of magnitude heavier than other UAVs compared.

![MGTOW Graph](image.png)
### AAI AEROSONDE Mark 4.7

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length / Wingspan</td>
<td>5.8 / 9.2 ft</td>
</tr>
<tr>
<td>MGTOW</td>
<td>38.6 or 55 lbs (Depending on engine)</td>
</tr>
<tr>
<td>Ceiling</td>
<td>15,000 ft</td>
</tr>
<tr>
<td>Endurance</td>
<td>30 (Up to 38) Hrs</td>
</tr>
<tr>
<td>Range</td>
<td>1,620 nm</td>
</tr>
<tr>
<td>Max / Cruise Speed</td>
<td>80 / 60 kts</td>
</tr>
<tr>
<td>Launch / Recovery</td>
<td>Catapult / Belly or Net</td>
</tr>
<tr>
<td>Payload Weight / Dim.</td>
<td>10 lb / 12x9.5x9.5 in</td>
</tr>
<tr>
<td>Sensors</td>
<td>EO/IR</td>
</tr>
</tbody>
</table>

- Integrated launch and recovery system (Ship Ready)
- Precision GPS
- Successful shipboard launch and recovery in 2009
- Flew into eye of a hurricane in 2007 with NOAA
### ARCTURUS-UAV™ T-16XL

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length / Wingspan</strong></td>
<td>6.8 / 12.9 ft</td>
</tr>
<tr>
<td><strong>MGTOW</strong></td>
<td>85 lbs</td>
</tr>
<tr>
<td><strong>Ceiling</strong></td>
<td>15,000 ft</td>
</tr>
<tr>
<td><strong>Endurance</strong></td>
<td>16 hrs (8 w/ VTOL)</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>600 nm</td>
</tr>
<tr>
<td><strong>Max Speed</strong></td>
<td>75 kts</td>
</tr>
<tr>
<td><strong>Launch / Recovery</strong></td>
<td>Catapult / Belly or Capture</td>
</tr>
<tr>
<td><strong>Payload Weight / Dim.</strong></td>
<td>30 lbs / 24 x 8 x 8</td>
</tr>
<tr>
<td><strong>Sensors</strong></td>
<td>TASE 200 (EO/IR)</td>
</tr>
</tbody>
</table>

- First Generation Model
- Smaller payload capacity than T-20
- Smaller Engine (Honda 60cc)
- Sensor platform gimbaling
- Piccolo autopilot
- Modular internal payload
- Waypoint navigation
- Onboard GPS & INS
- Mobile Video Viewer
### ARCTURUS-UAV™ T-20

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length / Wingspan</td>
<td>9.8 x 17.25 ft</td>
</tr>
<tr>
<td>MGTOW</td>
<td>175 lbs</td>
</tr>
<tr>
<td>Ceiling</td>
<td>15,000 ft (Flown to 20,000)</td>
</tr>
<tr>
<td>Endurance</td>
<td>16 hrs (8 with VTOL)</td>
</tr>
<tr>
<td>Range</td>
<td>1,000 nm</td>
</tr>
<tr>
<td>Max / Cruise Speed</td>
<td>75 / 55 kts</td>
</tr>
<tr>
<td>Launch / Recovery</td>
<td>Catapult / Belly or Capture</td>
</tr>
<tr>
<td>Payload Weight / Dim.</td>
<td>75 lbs / 12x12x36 in</td>
</tr>
<tr>
<td>Sensors</td>
<td>TASE 400 (EO/IR Gimbal)</td>
</tr>
</tbody>
</table>

- Most current T-series
- Fuel injected (2lb fuel burn/hour w/ 35lb capacity)
- Sensor platform gimbalng
- Piccolo autopilot
- Two 20lb wing hard mounts (w/ drop capability)
- Modular internal payload
- Waypoint navigation
- Onboard GPS & INS
- Mobile Video Viewer
ARCTURUS T-Series

- ARTURUS-UAV created the JUMP vertical takeoff and landing system for the T-20 and T-16 UAV’s.
- The vertical lift motors shut off for winged flight. This transition is achieved by the Piccolo autopilot.
- T-Series has shown ship capability with the Marines and used a Inflatable retrieval system.
  - Revised on advice of ship captain to VTOL “Jump" system
  - Elegant solution from the autopilot (PICCOLO) could easily handle the flight transition
  - VTOL did impact negatively the endurance due to the added wt.

- T-Series is rated for operations in a .25in/hr of rain/moisture.
  - All Weather/ Cold Climate operations demonstrated (https://www.dropbox.com/s/gq6ghb3ybj4gge/auvsin2014.m4v)
  - Jump variant not demonstrated
- Line of sight 77 miles
- Carries 35lbs of fuel and only burns 2 lbs per hour (Cruise at 3HP)
- Two hard points on each wing with 20lbs each side of wing pod payload capacity.
  - Buoy drop capability
- $32000 a week operations cost to include crew, fuel, sensors etc.
- Wyoming Field test at -30F at ground level for a 12hr acceptance test at 21,000ft
  - https://www.youtube.com/watch?v=omkay1cJmXI
AEROVEL FlexRotor

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<th>Feature</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Length / Wingspan</td>
<td>5.25 / 9.85 ft</td>
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<tr>
<td>MGTOW</td>
<td>42.5 lbs</td>
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<tr>
<td>Ceiling</td>
<td>24,600 ft</td>
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<tr>
<td>Endurance</td>
<td>40 Hrs (w/ typical payload)</td>
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<td>Range (nm)</td>
<td>2,000 nm</td>
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<tr>
<td>Max / Cruise Speed</td>
<td>79 / 44 kts</td>
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<tr>
<td>Launch / Recovery</td>
<td>Vertical / Vertical</td>
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<tr>
<td>Payload Weight / Dim.</td>
<td>1.98 lbs / 150 mm diameter sphere</td>
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</table>

- VTOL to Fixed Wing flight
- 28cc 2 stroke Engine (not fuel injected)
- Very Small Payload Weight
- No current data on Arctic environment operating temps
- VTOL launch and recovery from ship
## IAI HERON

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<th>Details</th>
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<td><strong>Length / Wingspan</strong></td>
<td>27.8 / 54.4 ft</td>
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<td><strong>MGTOW</strong></td>
<td>2,530 lbs</td>
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<tr>
<td><strong>Ceiling</strong></td>
<td>30,000 ft</td>
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<td><strong>Endurance</strong></td>
<td>20-45 hrs</td>
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<td><strong>Range</strong></td>
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<td><strong>Max / Cruise Speed</strong></td>
<td>120 / 80 kts</td>
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<td><strong>Launch / Recovery</strong></td>
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<tr>
<td><strong>Payload Weight</strong></td>
<td>550 lbs</td>
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- SATCOM for extended range
- Proven in extreme weather (Cold, icy, snowy, hot, humid, and high altitude.
- Multi-sensor capability (Up to 6 simultaneously)
- Automatic Takeoff and Landing System
- Launch from aircraft carrier
## INSITU ScanEagle

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<td>Length / Wingspan</td>
<td>4.5 / 10.2 ft</td>
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<td>MGTOW</td>
<td>48.5 lbs</td>
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<tr>
<td>Ceiling</td>
<td>19,500 ft</td>
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<td>Endurance</td>
<td>24 hrs</td>
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<tr>
<td>Range</td>
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<td>Max Speed</td>
<td>80 / 48 kts</td>
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<td>Catapult / Cable</td>
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<tr>
<td>Payload Weight</td>
<td>13.2 lbs</td>
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<tr>
<td>Sensors</td>
<td>NEX7 3-Camera System (In Development)</td>
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<tr>
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<td>EO and MWIR</td>
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- Fly EO and MWIR Imagers at the same time
- Continuously deployed on land since 2004 and in maritime environment 2005.
- Arctic flight in 2011
- Shipboard launch and recovery
BRICAN TD100

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<th>Description</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Length / Wingspan</td>
<td>6.7 / 16.3 ft</td>
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<td>MGTOW</td>
<td>50 lbs</td>
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<tr>
<td>Ceiling</td>
<td>14,763 ft</td>
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<tr>
<td>Endurance</td>
<td>2.5 hrs (Electric) or 30 hrs (with BioFuel)</td>
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<td>Range</td>
<td>300/1950 nm</td>
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<tr>
<td>Max Speed</td>
<td>104 / 65 kts</td>
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<tr>
<td>Launch / Recovery</td>
<td>Catapult / Belly</td>
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<tr>
<td>Payload Weight</td>
<td>18 lbs</td>
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<tr>
<td>Sensors</td>
<td>Nikon D800, Nikon D3X, Applanix DMS</td>
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</tbody>
</table>

- Deployed in Arctic for whale mission
- Highly Customizable
- Electric and Diesel Model
- Integrated Inertially-aided GPS
- Ship based launch planned for October 2014
- [https://www.youtube.com/watch?v=uWx3KnCMTEA](https://www.youtube.com/watch?v=uWx3KnCMTEA) Whale Video
Technology Readiness Levels

TRLs are a standard tool for assessing the readiness of an emerging technology for production or incorporation into an existing technology or system.

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<th>Technology Readiness Level</th>
<th>Description</th>
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<tbody>
<tr>
<td>TRL 1</td>
<td>Basic or fundamental research</td>
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<tr>
<td>TRL 2</td>
<td>Technology concept and/or application</td>
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<tr>
<td>TRL 3</td>
<td>Proof-of-concept</td>
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<tr>
<td>TRL 4</td>
<td>Concept validated in laboratory</td>
</tr>
<tr>
<td>TRL 5</td>
<td>Concept validated in relevant environment</td>
</tr>
<tr>
<td>TRL 6</td>
<td>Prototype demonstration in relevant environment</td>
</tr>
<tr>
<td>TRL 7</td>
<td>Prototype demonstration in operational environment</td>
</tr>
<tr>
<td>TRL 8</td>
<td>System demonstration in an operational environment</td>
</tr>
<tr>
<td>TRL 9</td>
<td>System totally operational</td>
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# UAS TRL’s

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<tr>
<th>PLATFORM</th>
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<tr>
<td>Aerosonde</td>
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<tr>
<td>Arcturus T-16</td>
<td>9</td>
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<tr>
<td>Arcturus T-20</td>
<td>9</td>
</tr>
<tr>
<td>Arcturus T-16/20 Jump</td>
<td>6 Est</td>
</tr>
<tr>
<td>Flexrotor</td>
<td>6 Est</td>
</tr>
<tr>
<td>Brican</td>
<td>7-8 Est</td>
</tr>
<tr>
<td>Heron</td>
<td>9</td>
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<tr>
<td>Scaneagle/Nanook</td>
<td>9</td>
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</table>
Discussion, Next Steps

- Ship Based Options
  - All advertised as ship compatible except Heron
- Fit Check Ship Deck Space
  - Wing span issues
  - Very little margin for VTOL Options (Flexrotor, Arcturus - 16,20)
  - Net Capture Options (Aerosonde, Brican?)
- Arctic/All Weather Options
  - Successfully Demonstrated?
- Sensor Compatibility
- Refine Cost Data
- Land Based Options
  - All Compatible
- Determine Measure of Effectiveness (MOE’s)/Analysis Of Alternatives
ALTICAM VISION™ 05EO1

<table>
<thead>
<tr>
<th>Platform</th>
<th>Aerovel FlexRotor</th>
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<tr>
<td>Weight</td>
<td>1 lb</td>
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<tr>
<td>Horizontal Field of View</td>
<td>1.1°-31.5°</td>
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<tr>
<td>Pixels</td>
<td>640 x 480</td>
</tr>
<tr>
<td>Video Output</td>
<td>Composite NTSC</td>
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</table>

- Electro-Optical (EO) Imaging
- Gyro-Stabilized gimbal system with coordinate hold mode
- Embedded video stabilization
ALTICAM VISION™ LWIR 6000 SS

<table>
<thead>
<tr>
<th>Platform</th>
<th>Aerovel FlexRotor</th>
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</thead>
<tbody>
<tr>
<td>Weight</td>
<td>2 lbs</td>
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<tr>
<td>Field of View</td>
<td>15°</td>
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<td>Pixels</td>
<td>640 x 480</td>
</tr>
<tr>
<td>Video Output</td>
<td>NTSC</td>
</tr>
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</table>

- Super-stable long-wavelength, high-resolution infrared imaging
- Gyro-Stabilized
- Designed for small UAV’s
Cloud Cap Technology TASE 200

<table>
<thead>
<tr>
<th>Platform</th>
<th>Arcturus T-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>2.3 lbs</td>
</tr>
<tr>
<td>Horizontal Field of View</td>
<td>1.5°</td>
</tr>
<tr>
<td>Pixels</td>
<td>640 x 480</td>
</tr>
<tr>
<td>Video Output</td>
<td>NTSC or PAL</td>
</tr>
</tbody>
</table>

- Compact, light-weight, low cost daylight and IR imaging
- Camera bay environmentally sealed
- Onboard GPS/INS
Cloud Cap Technology TASE 400

<table>
<thead>
<tr>
<th>Platform</th>
<th>Arcturus T-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>7.5 lbs</td>
</tr>
<tr>
<td>HFOV (IR)</td>
<td>22° - 2°</td>
</tr>
<tr>
<td>HFOV (Daylight)</td>
<td>55.7° - 1.94°</td>
</tr>
<tr>
<td>Pixels</td>
<td>640 x 480</td>
</tr>
<tr>
<td>Video Output</td>
<td>NTSC or PAL</td>
</tr>
</tbody>
</table>

- Full motion EO imager and continuous zoom MWIR camera
- Day and Night Imaging
- Onboard GPS/INS
- Fiber Optic Stabilization
- Environmentally sealed
### Northern Embedded Nex7

<table>
<thead>
<tr>
<th>Platform</th>
<th>ScanEagle Nanook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>TBD lbs</td>
</tr>
<tr>
<td>Pixels</td>
<td>High Resolution</td>
</tr>
</tbody>
</table>

Three 24 MP cameras, aligned in the x-axis

- Embedded Linux controller
  - ++ Simultaneous triggering of cameras
  - ++ Configurable camera trigger rates
  - ++ Geofencing
  - ++ Record meta data separately to geotag photos in post processing

- <10 cm GSD obtainable at altitude of 305 m
- Swath width of 700-1000 m depending on altitude and lens choice
- Break-away SD card block and base station for pulling data post-mission
- Data collection times up to 10-11 hours depending on trigger rates

This payload may or may not fly on stock ScanEagles because of weight issues. NES is developing it for Piccolo modified ScanEagles which can handle a wider range of CG.

- In Development for ScanEagle Nanook variant
- Single axis (roll) gimballed to keep payload nadir pointing
UAS Transition Process

Initial Operating Capability
- Optimizing Observing Strategies and Concept of Operations
- Reviewing Technology Readiness
- Finalize Life Cycle Planning

Final Operating Capability

Early Operating Capability
- Identifying Promising Technologies

Full Operations
- Implementing Operations to Address NOAA Goals

Key Decision Point
- Defer
- Cancel

Research Funding

Operational Funding

Milestone 1

Milestone 2
SHOUT General Plan

**FY14**
- OSE with previous HS3 data underway
- OSSE with simulated data starting soon for Atlantic / Gulf of Mexico tropical cyclones and Pacific / Arctic weather systems
- 5 extra missions added to HS3
- NOAA aviation personnel supporting NASA and NOAA Global Hawk missions

**FY15**
- Continued OSE and OSSE studies
- 10 – 16 NOAA-dedicated Global Hawk missions
- NOAA aviation personnel supporting NASA and NOAA Global Hawk missions

**FY16**
- NOAA-dedicated Global Hawk missions and possible partnership with NASA Earth Venture experiment
- NOAA aviation personnel supporting NASA and NOAA Global Hawk missions
- Finalize data impact studies and analysis of cost and operational benefits
GRAV-D Benefits From SBIR Program

- Vast areas remain to be surveyed in remote regions that are difficult to access
  - Aleutians, Pacific Islands
- Survey blocks are outside the range of our usual aircraft (King Air) and would require very expensive P-3 survey
  - Likely at least 50% cheaper with UAS
  - UAS much safer operation
- SBIR program hastens our move to the superior TAGS System 6 sensor
  - Relatively impervious to turbulence
  - Aurora will engineer this instrument onto their aircraft: we can use this effort to assist us in getting FAA/NAVAIR certification for this sensor
Some basic principles

• No need to *secure* the global commons
  - Threat to global sea lanes likely lower than at any time since 1890

• Need to identify threats moving over the commons
  - Maritime Domain Awareness
  - Global Maritime Partnerships

• Need to be able to act quickly to potential threats or disruptions
  - Operate forward
  - Global Maritime Partnerships

• Need to assure access to commons in localized theaters, locations
  - Peacetime, for trade
  - Wartime, for the Joint Force
In peacetime, assuring access will increasingly involve solving access disputes.

- **Internal Waters**
  - Landward of the low-water mark or within straight baselines
  - Sovereignty as on land
  - Possible right of innocent passage
- **Territorial Sea**
  - 12 nm
  - Nearly-full sovereignty; right of innocent passage
- **Exclusive Economic Zone (EEZ)**
  - 200 nm
  - Exclusive rights to all resources in the water and seabed
  - Passage as on high seas
- **Extended Continental Shelf (ECS)**
  - 350 nm; or
  - 2500M isobath + 100NM
  - Exclusive rights to all resources in the seabed
- **International Straits**
  - Innocent/transit passage through otherwise restricted waters

**Ilulissat Declaration**
- May 2008 commitment by Arctic Ocean littoral states to apply existing legal frameworks to delimitation in Arctic

**Arctic delimitation and disputes**

**U.S.-Canada Maritime Boundary Dispute**
Canada claims western line on treaty and sector basis; U.S. claims eastern line based on equidistance principle.

**Canada-U.S./Others Northwest Passage Sovereignty Dispute**
Canada claims historic internal waters throughout Arctic Archipelago; U.S. and others claim straits used for international navigation.

**Canada-Denmark Hans Island Sovereignty Dispute**
Canada and Denmark each claim sovereignty of 1.3 sq km island; maritime boundary agreement did not include island.

**Canada-Denmark Lincoln Sea Maritime Boundary Dispute**
65 sq nm disputed; Denmark claims EEZ based on small island/rock, Canada claims island/rock does not generate EEZ.

**Russia-U.S./Others Northern Sea Route Sovereignty Dispute**
Russia claims historic internal waters at Kara, Vilkitskiy, and Laptev Straits; U.S. and others claim international straits.

**Norway-Russia/Others Svalbard Maritime Sovereignty Dispute**
Norway claims 200 nm fisheries protection zone; Russia and others claim treaty-based open access.
NMFS/NOAA Mission Needs:
- Operate in Arctic Environment specifically in the Chukchi Sea area
- Shipboard Operations specifically utilizing NOAA assets (100’-250’ ships)
- Sensor Packages to obtain Whale Density Information with specific resolution
- Conduct UAS Operations with no risk to manned aircraft in area and FAA approval
### Strategic Plan

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<tr>
<th></th>
<th>FY11</th>
<th>FY12</th>
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