Overview of the NOAA Unmanned Aircraft Systems (UAS) Program

Robbie Hood
Director, NOAA UAS Program
8 March 2017
BACKGROUND
## Motivating Factors for Using Unmanned Aircraft Systems (UAS)

### What Missions?
- Dull
- Dirty
- Dangerous
- Remote

### What Benefits?
- Very high and low altitudes
- Vertical profiling
- Long endurance
- Long range
- Quiet
- Rapid response

### Why Now?
- Improving flight performance
- Increasing payload options
- Improving affordability
- Increasing access to airspace
Relationship of UAS Program to NOAA Goals and Enterprise Objective

Environmental Data Enterprise Goal

High Impact Weather Observations
- Weather-ready Nation Goal

Marine Observations
- Healthy Ocean Goal
- Resilient Coastal Communities Goal

Polar Observations
- Climate Adaptation and Mitigation Goal
- Weather-Ready Nation Goal
- Healthy Ocean Goal
- Resilient Coastal Communities Goal
NOAA UAS Strategic Vision and Goals (FY09 – FY15)

• **Vision**
  – UAS will revolutionize NOAA observing strategies by 2015 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 observations*
    • *Marine observations*
    • *Polar observations*
  – Goal 3: Transition cost-effective, operationally feasible UAS solutions into routine operations
External Panel Membership and Expertise

**Panel Members**

- **High Impact Weather Observations**
  - Dr. Linnea Avallone, Chair
  - Dr. Gary Jedlovec
  - Dr. Daniel Eleuterio

- **Marine Observations**
  - Mr. Robert Winokur
  - Mr. Mark Bathrick
  - Dr. Bruce Quirk

- **Polar Observations**
  - Dr. Peter Milne
  - Dr. Scott Harper
  - Dr. Sally McFarlane

**Expertise**

- Management of science or aviation programs
- Development or evaluation of Earth science observing applications
- Funding or leading scientific aircraft field experiments
- Transition of observing strategies to routine application or operations
- Developing UAS technology, policy, or operational procedures
Long Endurance UAS

High Altitude Long Endurance
- Maximum Altitude: 60,000 ft
- Maximum Endurance: 24 hrs
- Maximum Payload Weight: 1200 lbs

Medium Altitude Long Endurance
- Maximum Altitude: 40,000 ft
- Maximum Endurance: 24 hrs
- Maximum Payload Weight: 400 lbs (internal) – 2000 lbs (external)

Low Altitude Long Endurance
- Maximum Altitude: 20,000 ft
- Maximum Endurance: 24 hrs
- Maximum Payload Weight: 13.5 lbs

Hybrid Fixed and Rotary Wing
- Maximum Altitude: 24,000 ft
- Maximum Endurance: 15 hrs
- Maximum Payload Weight: 42 lbs
Short Endurance UAS

- **Maximum Altitude**: 1000 ft
- **Maximum Endurance**: 2 hrs
- **Maximum Payload Weight**: 2 lbs

Low Altitude
Short Endurance

- **Maximum Altitude**: 3280 ft
- **Maximum Endurance**: 1.4 hrs
- **Maximum Payload Weight**: 1.7 lb

Vertical Takeoff
and Landing

- **Maximum Altitude**: 20,000 ft
- **Maximum Endurance**: 2 hrs
- **Maximum Payload Weight**: 0.9 lbs

Aircraft-Launched

- **Maximum Altitude**: 100,000 ft
- **Maximum Endurance**: 0.5 hrs
- **Maximum Payload Weight**: 3 lbs

Balloon-Launched
UAS PROGRAM BASICS
NOAA UAS Program Staff

**Program Management**
*Manages the activities, staff and budget of the program; leads the development of strategic direction and priorities for the program*

- Robbie Hood – Federal, OAR Headquarters (100% FTE)
- Dr. Justyna Nicinska – Federal, OAR Headquarters (100% FTE)

**Scientific Assessment Team**
*Interacts with science stakeholders to understand observing requirements, evaluate data impact, assess science benefit, and coordinates projects*

- Dr. Gary Wick – Federal, OAR Earth System Research Laboratory (75% FTE)
- John Walker – Contractor, Cherokee Nation Technologies (100% FTE)
- Dr. Peter Black – Contractor, Cherokee Nation Technologies (100% FTE)

**Performance Assessment Team**
*Conducts market surveys, monitors readiness to meet requirements, evaluates cost and operational feasibility, and coordinates projects*

- Phil Kenul – Contractor, TriVector Services (100% FTE)
- JC Coffey – Contractor, Cherokee Nation Technologies (100% FTE)
History of Key Events

FY12
- Puma Acquisition
- First internal UAS Request for Proposal
- NASA Polar Monitoring Collaboration

FY13
- Start of 4-year USCG Collaboration
- Start of Observing System Simulation Experiment Development

FY14
- Budget increase for Weather and Flood Studies leading to SHOUT and SHOUT4Rivers projects
- NASA Ikhana Marine Monitoring Collaboration

FY15
- NMFS Polar Collaboration with BOEM and ONR
- Establishment of NOAA UxS Executive Oversight Board
- NAO 216-014-A Management and Utilization of Aircraft
- Presidential Memorandum on UAS Privacy

FY16
- Second internal UAS Request for Proposal
- FAA Release of small UAS Rule (Part 107)
- NAO 216-105-B Policy on Research and Development Transitions

FY17
- Third Internal UAS Request for Proposal
- NAO 216-120 Operation of NOAA Arctic Program
Annual UAS Program Budget
(In Millions of Dollars)

- FY12
- FY13
- FY14
- FY15
- FY16
- FY17

Disaster Recovery Act 2013
Weather & Flood
Base Funding
Annual UAS Program Investments
(In Millions of Dollars)
READINESS FOR TRANSITION TO RESEARCH OR OPERATIONAL APPLICATION
OAR Strategic Plan

❖ Aims

- Climate Adaption and Mitigation
- Weather-Ready Nation
- Healthy Oceans
- Resilient Coastal Communities and Economies
- Across the Enterprise-Observing, Modeling, and Engaging for All Goals

❖ Activities

- Research – *Yields ideas, knowledge, and understanding of systems*
- Development – *Yields inventions, techniques, and engineering of systems*
- Transition – *Yields outcomes for stakeholder, either within NOAA or in the broader community*
Relationship of Research, Development, and Transition to Operational Mission Goals

Diagram showing the relationship between general research and development, mission-oriented research and development, science and technology transition, and operational system development and implementation.
UAS Program Approach

NOAA Requirements

Stakeholder Needs/ Mission Requirements

Business Requirements

User Observation Requirements

Observing System Requirements

Sensor Requirements

Observing System Budget Requirements

Influencers
Users (non-mandated)
User (Industry)
Strategic Considerations

Weather Ready Communities: Protection of Life and Property

Issue Accurate Tornado/Flash FloodWarnings:
Identify tornado vortex signature,
Detect rainfall rates exceeding flash flood guidance

Precip Rate: sp res: 100m, vert res: 100m, accu: 1mm/hr, refresh: 30sec
Wind spd: sp res: 100m, vert res: 100m, accu: 0.5m/s, refresh: 30sec

NexRad Platform:
- Maximum range: 460 km for reflectivity; 300 km for velocity and polarimetric variables
- Maximum altitude: 70,000 ft

NexRad SLEP Budget

Pulse Length: L 1.57msec
PRF: 32 m/s
Dynamic Range: 93 dB
UAS Program Definitions

• **Unmanned Observing Platform** – *unmanned aircraft or marine system with launch, recovery, communication, and ground control packages*

• **Payload Sensor** – *instrument capable of collecting observation from an observing platform*

• **Observing System** - *Payload, platform, data storage components working as a system to acquire an observation*

• **Observing Strategy** – *application of a process or plan to use an observing system to acquire an observation*
## UAS Readiness Level

<table>
<thead>
<tr>
<th>Readiness Level (RL)</th>
<th>UAS Platform</th>
<th>UAS Payload</th>
<th>UAS Observing System</th>
<th>UAS Observing Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>RL 1  Basic research with no particular application planned</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RL 2  Applied research directed toward specific application</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RL 3  Proof-of concept system or process developed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RL 4  Successful proof-of-concept system or process validated in laboratory or experimental environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RL 5  Successful proof-of-concept system or process validated in relevant environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RL 6  Successful prototype system or process demonstration in relevant or test environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RL 7  Successful prototype system process demonstration in operational environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RL 8  Finalized system or process operating as expected in user environment; user training completed; user acceptance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RL 9  Finalized system or process operated routinely by user</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Critical Elements Needed to Mature a Complete Observing Strategy

- Payload Selection
- Platform Selection
- Concept of Operations
- Information Management Plan
- Life-Cycle Management Plan
- Staffing, Safety, Training & Proficiency Plans

Complete Observing Strategy
Maturing the Readiness of a UAS Observing Strategy

Unmanned Observing Platform RL 4 - 9

Payload Sensor RL 4 - 9

Observing System RL 4 - 9

NOAA Observing Strategy

Key Decision

RESEARCH

DEVELOPMENT

TRANSITION

Key Decision

Initial Transition Plan

Updated Transition Plan

Final Transition Plan
### Observing Strategies

**Maturity versus Science Focus Area**

<table>
<thead>
<tr>
<th>Readiness</th>
<th>High Impact Weather</th>
<th>Marine Monitoring</th>
<th>Polar Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Demonstrating UAS Capabilities in the Rim of the Pacific Exercise - Todd Jacobs/ NOS</td>
<td>3. Researching UAS capabilities during the Marginal Ice Zone Experiment (Partnership) - Tom Wagner / NASA</td>
</tr>
<tr>
<td><strong>Development</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Lower Mississippi River Forecast Center and NERR Habitat Mapping and Restoration using fixed and rotary wing UAS – Robert Moorhead</td>
<td>1. Demonstrating small UAS for Oil Spill Simulations and Environmental Response Management Application (ERMA) – Robb Wright</td>
<td>1. Developing UAS capabilities for Polar Applications (Partnership) US Coast Guard and AeroVironment collaboration – Jason Story/USCG and Brian Walsh/AeroVironment</td>
</tr>
<tr>
<td></td>
<td>3. SHOUT Cost and Operational Feasibility Study – Phil Kenul</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. SHOUT Data Impact Study– Gary Wick</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Transition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Assimilation of Global Hawk/AVAPS data into EMC operational models - Vijay Tallapragada/ NWS</td>
<td>1. National Marine Sanctuaries UAS applications –Todd Jacobs and Brendan Bray/NOS</td>
<td>1. UAS Observations for Soot Transport, Absorption, and Decomposition Study (STADS) - Trish Quinn / OAR</td>
</tr>
<tr>
<td></td>
<td>4. UAS Observations for Rapid Response Post Storm Damage Assessment (Partnership) – Michael Sporer/ NWS</td>
<td>4. Protected Resources Research with small UAS APH-22 for Large Whale Health Assessment: John Durban / NMFS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. UAS Observations for Satellite Calibration: GOES-R Calibration (Partnership) - Frank Padula / NESDIS</td>
<td>5. Protected Species Research- Advancing APH-22 rotary wing applications for pinniped surveys- Kimberly Murray/NMFS</td>
<td></td>
</tr>
</tbody>
</table>
QUALITY
Awards and Interagency Memberships

• Awards
  – Robbie Hood (2013), Executive Excellence Award / American Indian Science and Engineering Society
  – JC Coffey (2015), Member of the Year / Association for Unmanned Vehicle Systems International

• Memberships
  – Federal Advisory Board for Alliance for System Safety of UAS through Research (ASSURE) / FAA Center of Excellence for UAS Research
  – NSF Center for Unmanned Aircraft Systems
  – Interagency Coordinating Committee for Airborne Geoscience Research and Applications
Selected List of Invited Speaking Engagements

- **January, 2016** – American Meteorological Society 6th Conference on Transition of Research to Operations and 18th Symposium on Meteorological Observations and Measurements
- **February, 2016** – Drones for Scientific Research Session of American Association for the Advancement of Science Annual Meeting
- **March 2016** – Office of the Federal Coordinator for Meteorology - Tropical Cyclone Operations and Research Forum
- **May, 2016** – Women in Robotics, XPONENTIAL / Association for Unmanned Vehicle Systems International
- **August, 2016** – White House Office of Science and Technology Workshop on Drones and the Future of Aviation
- **November, 2016** – Women in Drones Panel of Commercial Unmanned Aircraft Vehicle Symposium
- **December, 2016** – UAS in Geosciences Session of American Geophysical Union Fall Meeting
## Cooperative Research and Development Agreements (CRADAs)

<table>
<thead>
<tr>
<th>Project</th>
<th>Collaborator</th>
<th>Year</th>
<th>Focus</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puma-AE Spiral Development</td>
<td>AeroVironment</td>
<td>2012-17</td>
<td>Marine and Polar</td>
<td>Arctic and Antarctic Demonstrations</td>
</tr>
<tr>
<td>Multi-Mission Survey</td>
<td>Aurora Flight Sciences</td>
<td>2013-17</td>
<td>Marine</td>
<td>Medium Altitude Remote Sensing</td>
</tr>
<tr>
<td>NWS Multi-Mission</td>
<td>Prioria</td>
<td>2015-17</td>
<td>Weather</td>
<td>Low Altitude Observations</td>
</tr>
<tr>
<td>Shipboard Operations</td>
<td>Latitude Engineering</td>
<td>2016-17</td>
<td>Marine and Polar</td>
<td>Arctic Observations</td>
</tr>
<tr>
<td>Shipboard Operations</td>
<td>Precision</td>
<td>2015-17</td>
<td>Marine and Polar</td>
<td>Arctic Observations</td>
</tr>
<tr>
<td>Platform and Payload Integration</td>
<td>UAVSolutions</td>
<td>2015-17</td>
<td>Weather</td>
<td>Prototype Demonstrations</td>
</tr>
</tbody>
</table>
## Small Business Innovation Research

<table>
<thead>
<tr>
<th>SBIR</th>
<th>Focus</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I-III SBIR: Gravimetry</td>
<td>Grav-D capture using UAS (Researcher – Aurora Flight Sciences)</td>
<td>Phase III - Commercialized</td>
</tr>
<tr>
<td>Phase I-II SBIR: Atmospheric and SST from Air-launched UAS</td>
<td>Atmospheric and SST from Air-launched UAS (Researcher: Piasecki Aircraft)</td>
<td>No Cost Extended for Phase II flight testing</td>
</tr>
<tr>
<td>Phase I FY17 NOAA UAS SBIR: Maritime and Arctic (MAS) Observations + VTOL (Proposed)</td>
<td>Targeted Autonomous In-situ Sensing and Rapid Response</td>
<td>Submissions due Jan 2017 pending selection</td>
</tr>
</tbody>
</table>
Advancing Operational Readiness of High Altitude Dropsonde

**2009-2010**
- NOAA/NSF develop Global Hawk dropsonde system
- Concept in laboratory / relevant environment

**2011**
- NOAA Winter Storms and Pacific Atmospheric Rivers (WISPAR)
- First Global Hawk flights with dropsonde system
- First Arctic Global Hawk flight
- First dropsonde intercomparsion with NOAA G-IV
- Prototype in relevant environment

**2012-2014**
- NASA Hurricane and Severe Storm Sentinel (HS3) /2011 - 2015
- Dropsonde and remote sensing payload
- Real-time dropsonde delivery to NOAA Global Forecast System and National Hurricane Center
- Second dropsonde intercomparsion with NOAA G-IV
- Prototype in relevant / operational environment

**2014 – 2017**
- NOAA Sensing Hazards with Operational Unmanned Technology (SHOUT)
- Flights over Atlantic, Gulf of Mexico, Pacific storms
- 12 missions, 288 flight hours, 738 dropsondes in 2016
- Real-time dropsonde and remote sensing data delivery assimilate into NOAA Hurricane Weather Research Forecast Model
- Prototype / System in operational environment
Linkage of UAS Program Activities to NOAA Environmental Data Enterprise Goal

Environmental Data

Key question – What is the best observing system to meet NOAA’s mission?

R&D Objective – Quantitative methodologies for assessing impacts of current and candidate observing systems to NOAA mission?

R&D Objective – Improved accuracy, coverage, resolution and effectiveness and cost of observation systems

UAS Program – Data impact, cost effectiveness, and operational feasibilities studies

Environmental Data

Key Question – How can we best use current and emerging environmental data?

R&D Objective – Exploit emerging data types and observing capabilities to satisfy NOAA’s observing requirement

5-year Aim – Transition UAS and autonomous underwater vehicles into NOAA’S operational observing system

UAS Program – Research, development, and transition activities
Linkage of UAS Program Activities to NOAA to Weather, Ocean, Coastal Goals

**Weather Ready Nation**

**Key Question** – How can we improve forecasts, warnings, and decision support for high impact weather event?

**R&D Objective** – Improved Observations

**5-year Aim** – Develop Global Hawk UAS configurations supporting multi-mission sensors

**UAS Program** – Sensing Hazards with Operational Unmanned Technology (SHOUT)

---

**Healthy Oceans**

**Key Question** – How can emerging technologies improve eco-system-based management?

**R&D Objective** – Improve survey capabilities to provide more accurate, precise, and synoptic information of key marine populations

**5-year Aim** – Enhance UAS camera systems for marine mammal surveys

**UAS Program** – Partnership with NMFS, BOEM, and ONR to demonstrate UAS camera system on low altitude UAS

---

**Resilient Coastal Communities and Economies**

**Key Question** – How is the Arctic affected by expanding Industry and commerce?

**R&D Objective** – Strengthen oil-spill response capabilities

**5-year Aim** – Document movement of crude oil and its likely effects of coastal ecosystems

**R&D Objective** – Improved impact assessments of changing sea ice

**5-year Aim** – Document changes in size and persistence of sea ice habitats

**UAS Program** – Partnership with NOS, NESDIS, OMAO, USCG, and Aerovironment
PERFORMANCE
Updated NOAA UAS Strategic Vision and Roles (FY15 – FY17)

Vision

UAS observations will become an essential component of the NOAA observing system by augmenting critical observations from satellites, ships, aircraft, balloons, and surface-based sensors to contribute to the environmental intelligence needed by our Nation and the world.

Program Roles

Serve as the NOAA subject matter experts for UAS technology and observations to provide a resource to support effective NOAA UAS investments and applications

Assist with the research, development, demonstration, evaluation, and transition to application of selected UAS observing strategies that can provide significantly improved or more efficient observing capabilities or safer observing operations for the NOAA observing system.
Project Selection

**Project Sources**

- Internal solicited or unsolicited proposals from NOAA scientists and cooperative institutes
- Federal agency partnership opportunities
- Cost sharing commitments to projects proposed to other federal agencies
- Small Business Innovation Research (SBIR) program
- Private industry Cooperative Research and Development Agreements (CRADAs)
- Specific congressional directives (e.g. Disaster Recovery Act of 2013)

**Selection Criteria**

- Importance and relevance to NOAA mission
- Scientific merit
- Technology readiness and likelihood for transition
- Qualifications of project team
- Cost and cost sharing
- Project risk and mitigation plan
- Partnership opportunities
Project Management of Field Missions

- Project Plan, Initial Transition Plan, Mission Concept Review
- Monthly Reports and Annual Quad Charts
- Engineering Reviews, as needed
- Mission Readiness Review and Flight Safety Review (Aircraft Operations Center)
- Post-Mission Review, Final Project Report, and Final Transition Plan
## Observing Strategies
### Advancements to High Impact Weather

<table>
<thead>
<tr>
<th>Project</th>
<th>RL 1 Basic Research</th>
<th>RL 2 Concept Formulated</th>
<th>RL 3-4 Experiment /Validate</th>
<th>RL 5-6 Prototype Developed</th>
<th>RL 7 Demo in Testbed</th>
<th>RL 8 Implement</th>
<th>RL 9 Transition / Deploy</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-D Profiling of the Severe Weather Environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Role of UAS for Boundary Layer Measurements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RFC, NERR &amp; Restoration Monitoring Using UAS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• SHOUT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• AVAPS (NCEP Op Models)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• GH Turbulence Sensor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAS to Obtain Aerial Storm Damage Imagery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GOES-R Near Surface UAS Feasibility Study</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Observing Strategies
## Advancements to Maritime Monitoring

<table>
<thead>
<tr>
<th>Project</th>
<th>RL 1 Basic Research</th>
<th>RL 2 Concept Formulated</th>
<th>RL 3-4 Experiment/Validate</th>
<th>RL 5-6 Prototype Developed</th>
<th>RL 7 Demo in Testbed</th>
<th>RL 8 Implement</th>
<th>RL 9 Transition/Deploy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maritime Monitoring Readiness Levels 2012-17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NERR Ecosystem Assessments with small UAS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salmon Habitat Characterization using small UAS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAS Capabilities in the Rim of the Pacific Exercise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demonstrating small UAS for Oil Spill into ERMA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APH-22 Whales</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APH-22 Pinnipeds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal Mapping using small UAS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRAV-D Gravimetry Mission Using Unmanned Tech</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Marine Sanctuaries UAS applications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

38
### Observing Strategies
**Advancements to Polar Monitoring**

<table>
<thead>
<tr>
<th>Project</th>
<th>RL 1 Basic Research</th>
<th>RL 2 Concept Formulated</th>
<th>RL 3-4 Experiment/Validate</th>
<th>RL 5-6 Prototype Developed</th>
<th>RL 7 Demo in Testbed</th>
<th>RL 8 Implement</th>
<th>RL 9 Transition/Deploy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polar Monitoring Readiness Levels 2012-17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessing UAS Capabilities during the Arctic ACE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Researching UAS Shipboard Capabilities -Future Polar Applications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Researching UAS Capabilities during the Marginal Ice Zone Experiment (Partnership)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balloon-Launched Glider UAS -Measuring Trace Gases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Developing UAS capabilities for Polar Applications with USCG and AeroVironment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAS Observations for Soot Transport, Absorption, and Decomposition Study (STADS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
BACKUP SLIDES
UAS Program Science Focus Areas

High Impact Weather
- Can UAS observations enable improved forecasts, scientific understanding and decision support?

Marine
- Can UAS observations provide reliable, timely and affordable environmental intelligence information for resilient coastal communities and healthy oceans?

Polar
- Can UAS observations contribute to NOAA’S Arctic vision and strategy?
Maturing Technology Readiness of High Impact Weather UAS Observing Strategies

Research (TRL 1-2) – *identifying and assessing promising technologies and capabilities*

Development (TRL 3-5) – *concepts tested in laboratory or relevant environment*

Demonstration (TRL 6-8) – *prototype or system testing in relevant or operational environment in partnership with stakeholders*

Transition (TRL 9) – *observing strategy put into operational applications by stakeholders*
Maturing Technology Readiness of Marine Rapid Response UAS Observing Strategies

Research (TRL 1-2)

Development (TRL 3-5)

Demonstration (TRL 6-8)

Transition (TRL 9)
Maturing Technology Readiness of Polar UAS Observing Strategies

Research (TRL 1-2)

Development (TRL 3-5)

Demonstration (TRL 6-8)

Transition (TRL 9)

Arctic Applications
- Sea Ice
- Weather
- Air Chemistry
- Marine Hazards
- Wildlife