# Overview of the NOAA Unmanned Aircraft Systems (UAS) Program

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Director, NOAA UAS Program

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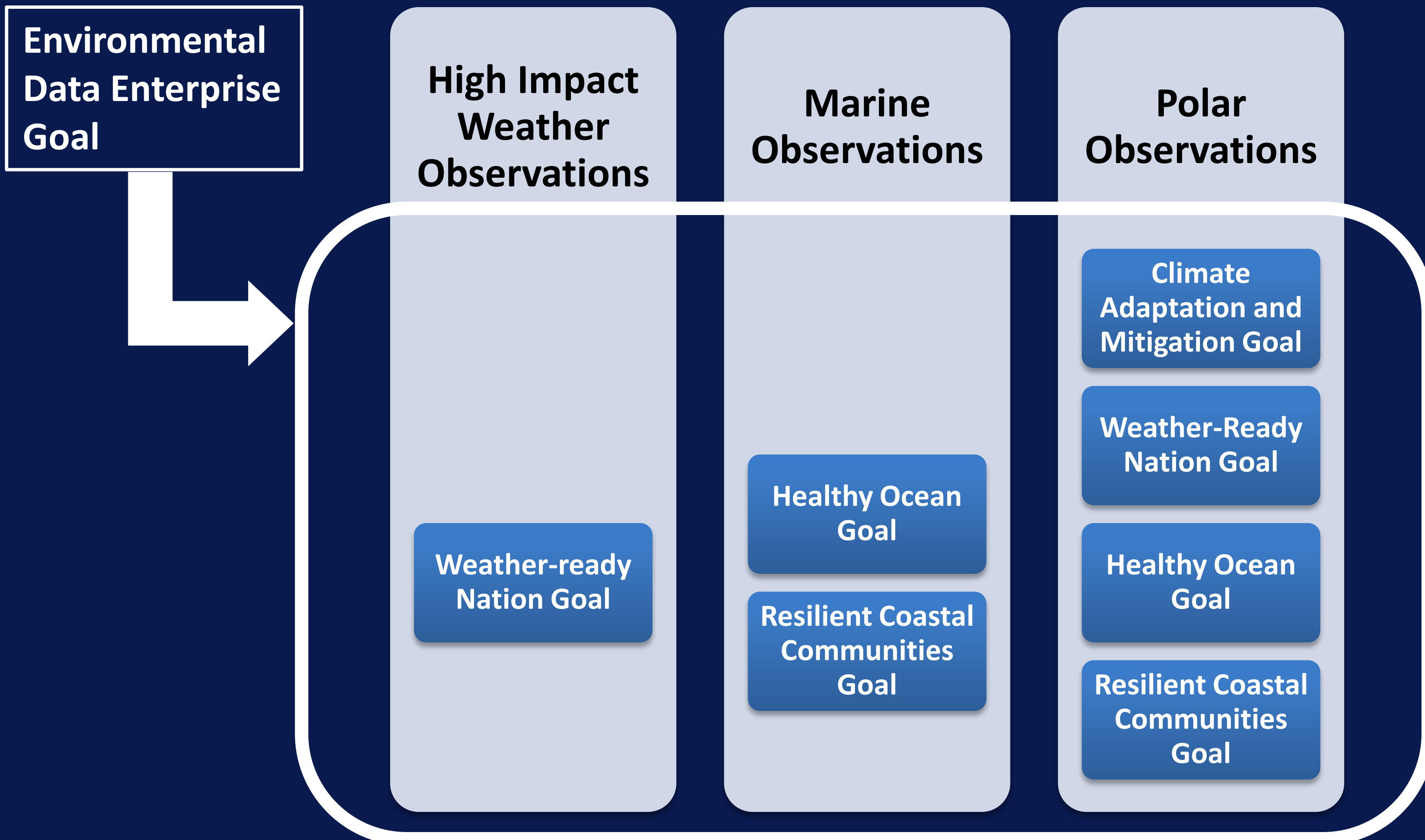
# BACKGROUND

# Motivating Factors for Using Unmanned Aircraft Systems (UAS)

| What Missions? | What Benefits? | Why Now? |
| --- | --- | --- |
| • *Dull*<br>• *Dirty*<br>• *Dangerous*<br>• *Remote* | • *Very high and low altitudes*<br>• *Vertical profiling*<br>• *Long endurance*<br>• *Long range*<br>• *Quiet*<br>• *Rapid response* | • *Improving flight performance*<br>• *Increasing payload options*<br>• *Improving affordability*<br>• *Increasing access to airspace* |

# Relationship of UAS Program to NOAA Goals and Enterprise Objective



# 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

# UAS PRIMER

# Long Endurance UAS

- Maximum Altitude *60,000 ft*
- Maximum Endurance *24 hrs*
- Maximum Payload Weight *1200 lbs*

**High Altitude Long Endurance**

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

**Medium Altitude Long Endurance**

- Maximum Altitude *20,000 ft*
- Maximum Endurance *24 hrs*
- Maximum Payload Weight *13.5 lbs*

**Low Altitude Long Endurance**

- Maximum Altitude *24,000 ft*
- Maximum Endurance *15 hrs*
- Maximum Payload Weight *42 lbs*

**Hybrid Fixed and Rotary Wing**

# 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

*Period of UAS Program Push of UAS Capabilities*

**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

*Period of Line Office Pull for UAS Capabilities*

**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

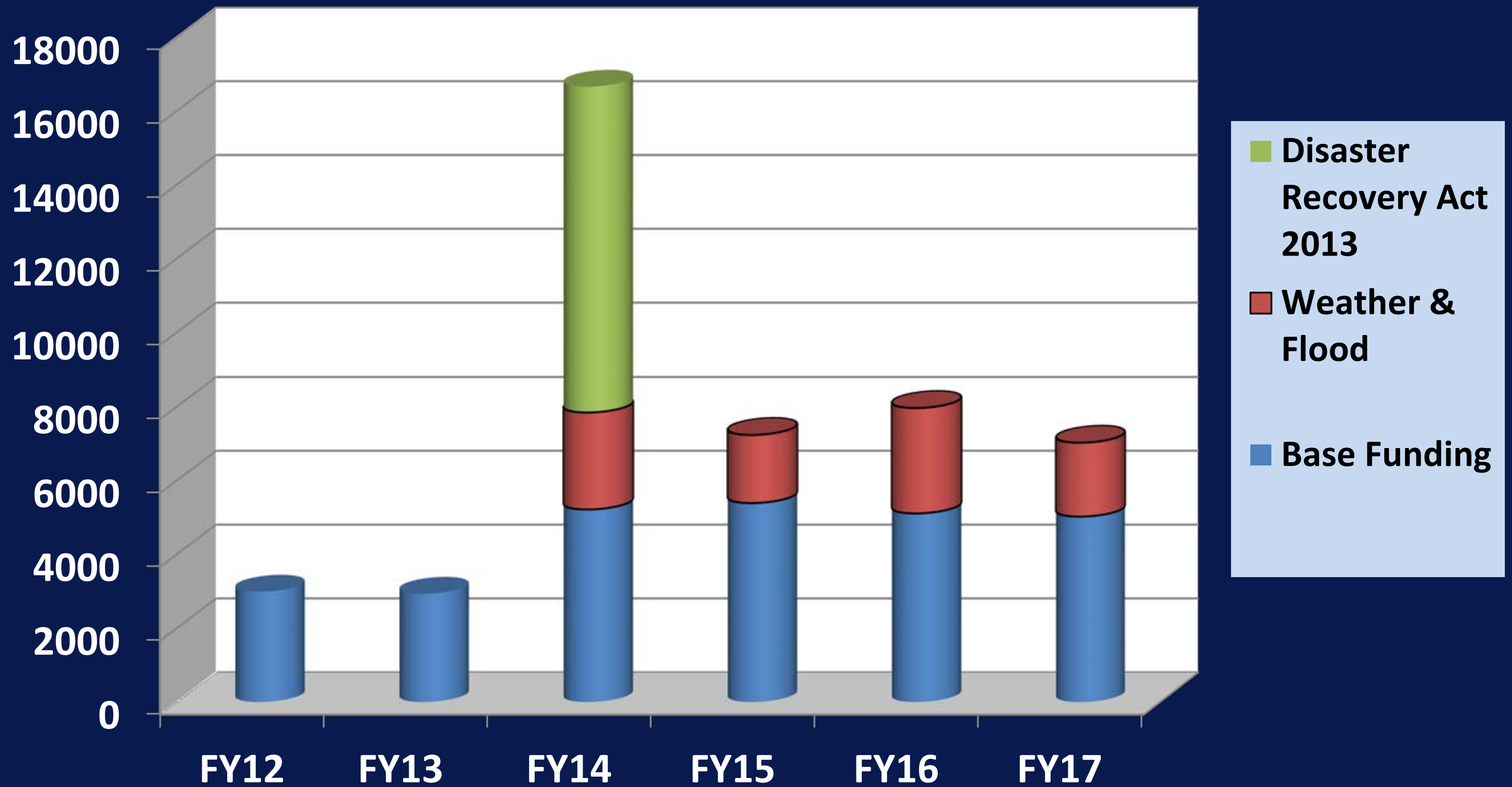
**FY16**

- 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**

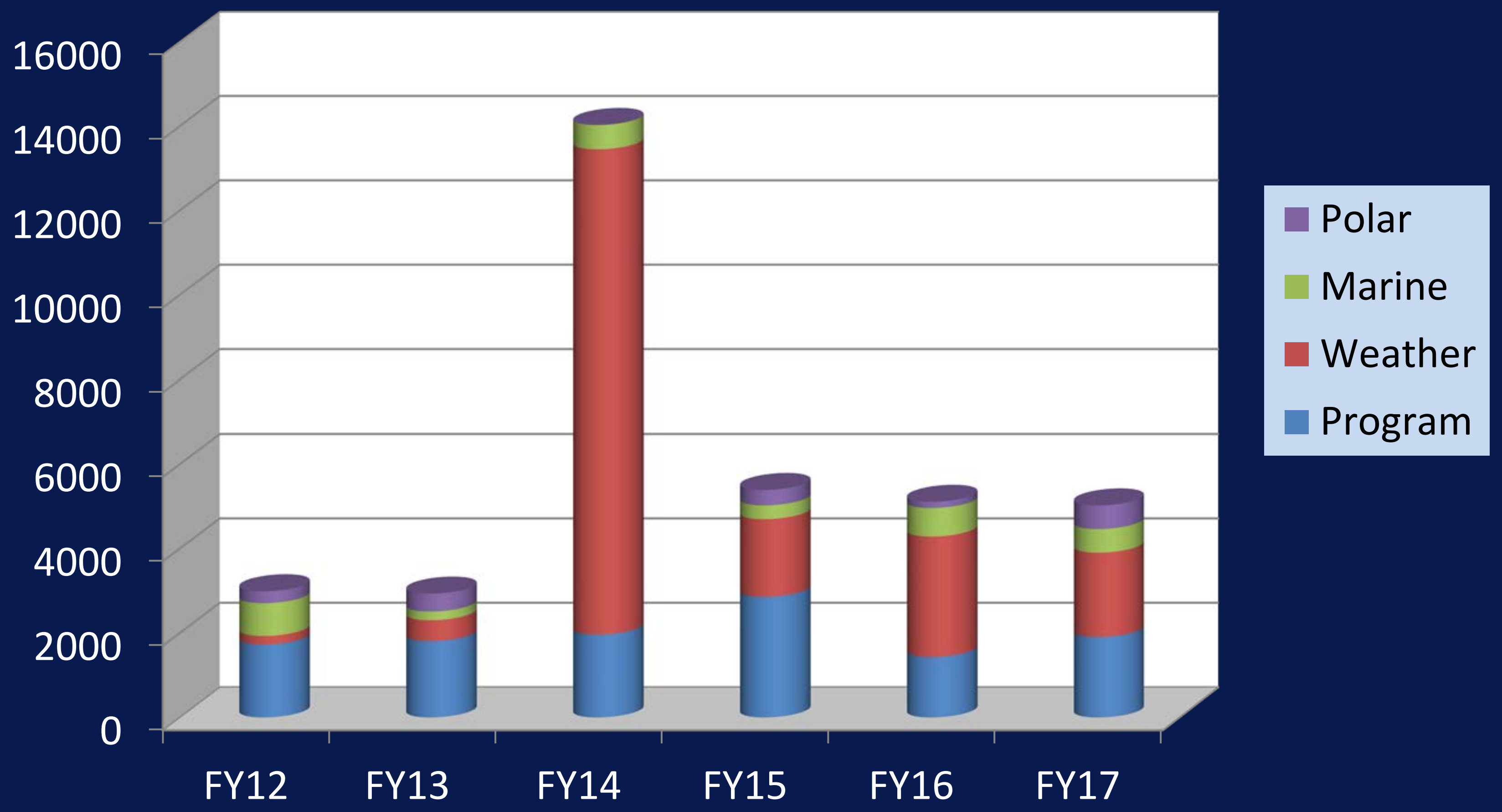
- Third Internal UAS Request for Proposal
- NAO 216-120 Operation of NOAA Arctic Program

# Annual UAS Program Budget
## *(In Millions of Dollars)*



# Annual UAS Program Investments

## *(In Millions of Dollars)*

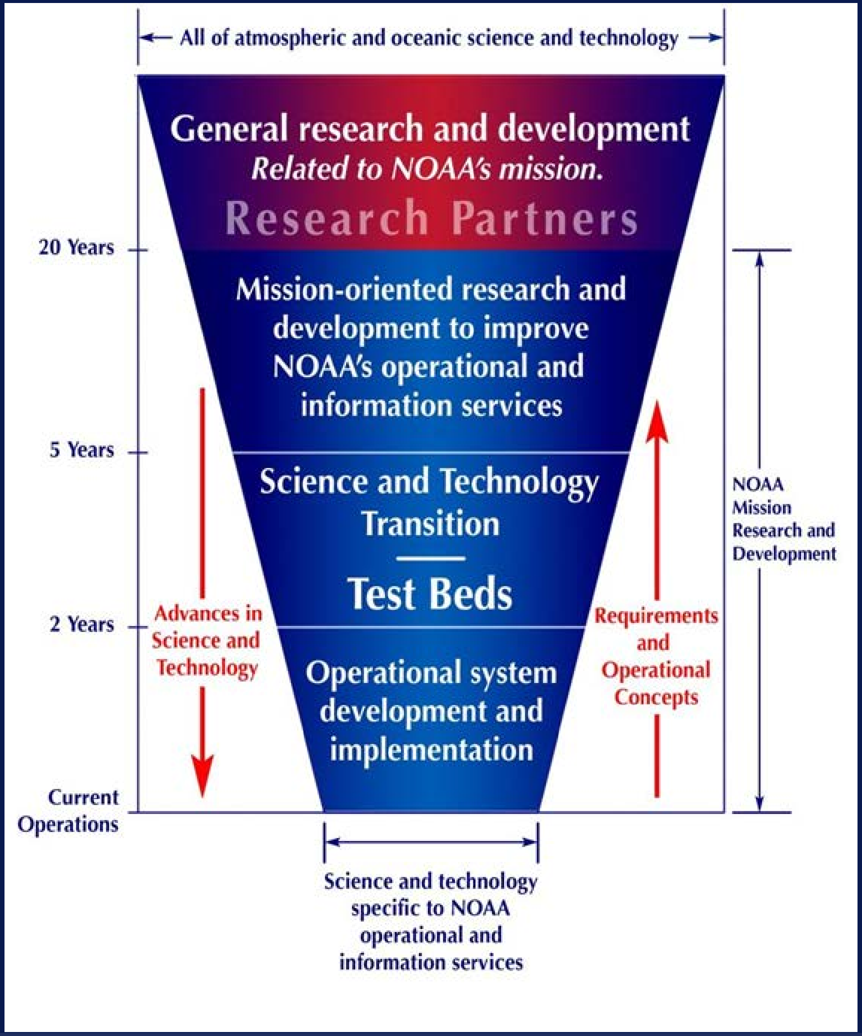


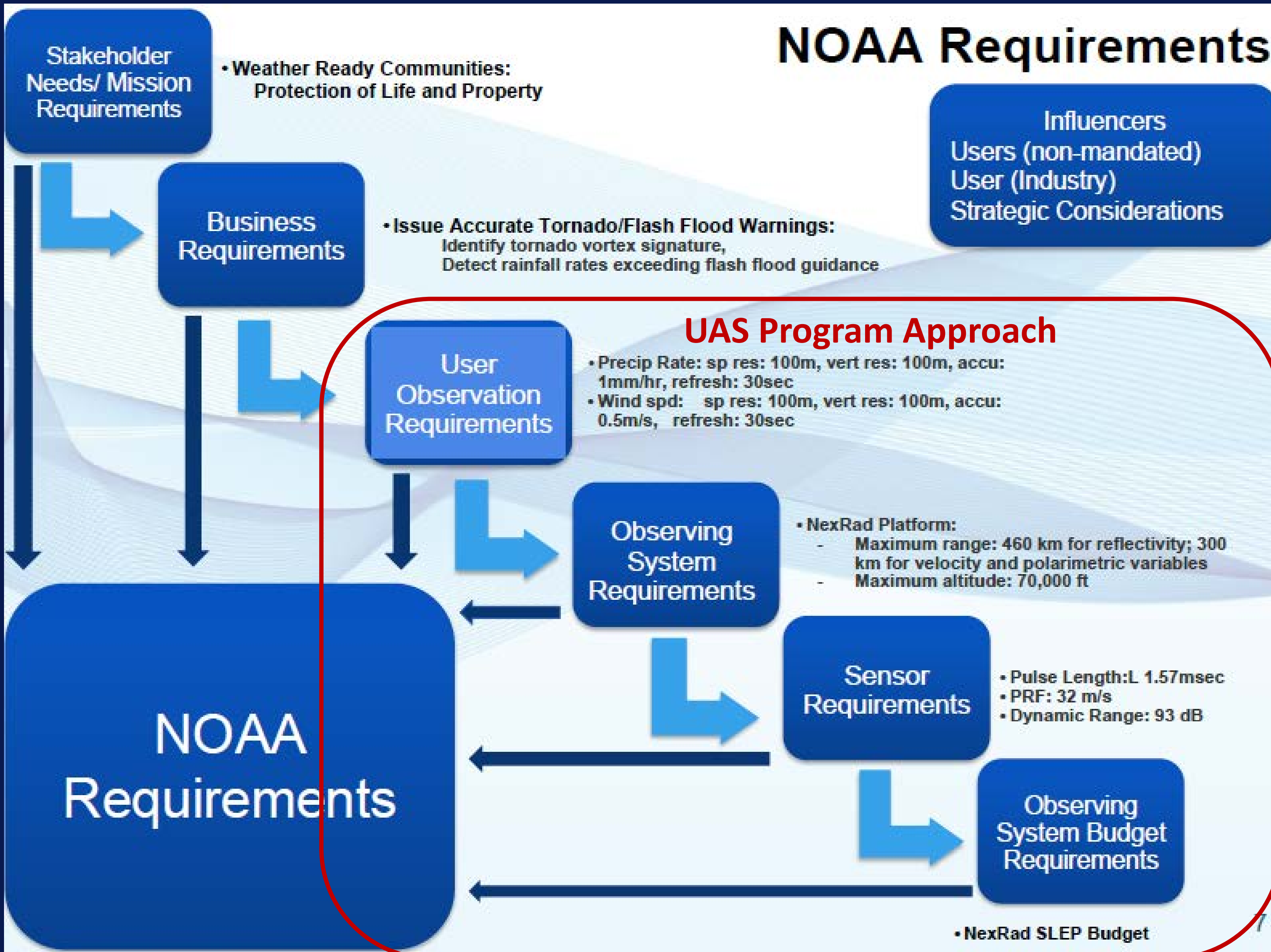
# READINESS FOR TRANSITION TO RESEARCH OR OPERATIONAL APPLICATION

# 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





NOAA Requirements
Stakeholder Needs/ Mission Requirements
• Weather Ready Communities: Protection of Life and Property
Influencers
Users (non-mandated)
User (Industry)
Strategic Considerations
Business Requirements
• Issue Accurate Tornado/Flash Flood Warnings:
Identify tornado vortex signature,
Detect rainfall rates exceeding flash flood guidance
UAS Program Approach
User Observation Requirements
• 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
Observing System Requirements
• NexRad Platform:
- Maximum range: 460 km for reflectivity; 300 km for velocity and polarimetric variables
- Maximum altitude: 70,000 ft
Sensor Requirements
• Pulse Length:L 1.57msec
• PRF: 32 m/s
• Dynamic Range: 93 dB
Observing System Budget Requirements
• NexRad SLEP Budget
NOAA Requirements
7

# UAS Program Definitions

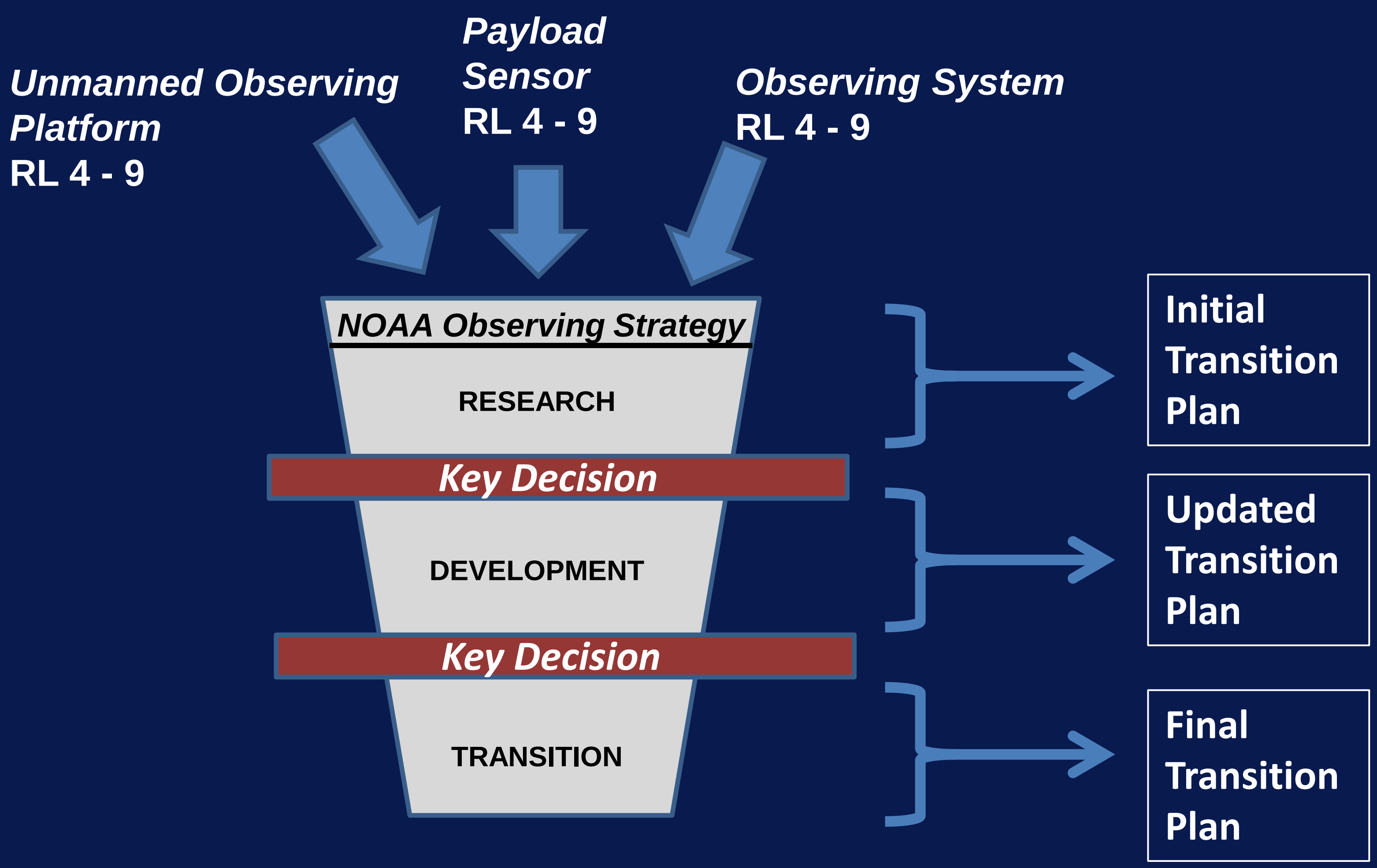
- **Unmanned Observing Platform** – ***unmanned aircraft or marine system with launch, recovery, communication, and ground control packages***
- **Payload Sensor** – ***instrument capable of collecting observation from an observing platform***
- **Observing System** - ***Payload, platform, data storage 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

| Readiness Level (RL) | UAS Platform | UAS Payload | UAS Observing System | UAS Observing Strategy |
|---|---|---|---|---|
| RL 1 Basic research with no particular application planned | | | | |
| RL 2 Applied research directed toward specific application | | | | |
| RL 3 Proof-of concept system or process developed | | | | |
| RL 4 Successful proof-of-concept system or process validated in laboratory or experimental environment | | | | |
| RL 5 Successful proof-of concept system or process validated in relevant environment | | | | |
| RL 6 Successful prototype system or process demonstration in relevant or test environment | | | | |
| RL 7 Successful prototype system process demonstration in operational environment | | | | |
| RL 8 Finalized system or process operating as expected in user environment; user training completed; user acceptance | | | | |
| RL 9 Finalized system or process operated routinely by user | | | | |

# Critical Elements Needed to Mature a Complete Observing Strategy

# Maturing the Readiness of a UAS Observing Strategy



# Observing Strategies

## *Maturity versus Science Focus Area*

| Readiness | High Impact Weather | Marine Monitoring | Polar Monitoring |
|---|---|---|---|
| Research | 1. Researching UAS Capabilities for Three Dimensional Profiling of the Severe-Weather – John Walker<br>2. Validating UAS Weather Observations (Partnership) – Bruce Baker, ARL/OAR | 1. National Estuarine Research Reserve Ecosystem Assessments with small UAS- Kirk waters/Nina Garfield/NOS<br>2. Juvenile Salmon Habitat Characterization using small UAS- Curtis Roegner/NMFS<br>3. Demonstrating UAS Capabilities in the Rim of the Pacific Exercise - Todd Jacobs/ NOS | 1. Assessing UAS Capabilities during the Arctic Aerial Calibration Experiment: Cetacean and Pinniped Population Assessments – Robyn Angliss<br>2. Researching UAS Shipboard Capabilities for Future Polar Applications– Trish Quinn<br>3. Researching UAS capabilities during the Marginal Ice Zone Experiment (Partnership) - Tom Wagner / NASA<br>4. |
| Development | 1. Lower Mississippi River Forecast Center and NERR Habitat Mapping and Restoration using fixed and rotary wing UAS – Robert Moorhead<br>2. Sensing Hazards with Operational Unmanned Technology (SHOUT) Mission Concept – Jason Dunion<br>3. SHOUT Cost and Operational Feasibility Study – Phil Kenul<br>4. SHOUT Data Impact Study– Gary Wick | 1. Demonstrating small UAS for Oil Spill Simulations and Environmental Response Management Application (ERMA) – Robb Wright | 1. Developing UAS capabilities for Polar Applications (Partnership) US Coast Guard and AeroVironment collaboration – Jason Story/USCG and Brian Walsh/AeroVironment<br>2. Balloon-Launched Glider UAS for Measuring Trace Gases - Jim Elkins |
| Transition | 1. Assimilation of Global Hawk/AVAPS data into EMC operational models - Vijay Tallapragada/ NWS<br>2. Development of the Global Hawk Turbulence Sensor for Aircraft Safety – Ru-Shan Gao / OAR<br>3. Observing System Simulation Experiment Analysis for Evaluating Impact of HALE Observations: Altug Aksoy/ OAR<br>4. UAS Observations for Rapid Response Post Storm Damage Assessment (Partnership) – Michael Sporer/ NWS<br>5. UAS Observations for Satellite Calibration: GOES-R Calibration (Partnership) - Frank Padula / NESDIS | 1. National Marine Sanctuaries UAS applications –Todd Jacobs and Brendan Bray/NOS<br>2. Optionally Piloted Aircraft for the GRAV-D Gravimetry Mission–Monica Youngman<br>3. Coastal Mapping using small UAS – Mike Aslaksen/NOS<br>4. Protected Resources Research with small UAS APH-22 for Large Whale Health Assessment: John Durban /NMFS<br>5. Protected Species Research- Advancing APH-22 rotary wing applications for pinniped surveys- Kimberly Murray/NMFS | 1. UAS Observations for Soot Transport, Absorption, and Decomposition Study (STADS) - Trish Quinn / OAR |

# 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*
- **January, 2016 –** *NASA/NOAA Press Event for El Nino Rapid Response Experiment*
- **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)

| Project | Collaborator | Year | Focus | Remarks |
|---|---|---|---|---|
| Puma-AE Spiral Development | AeroVironment | 2012-17 | Marine and Polar | Arctic and Antarctic Demonstrations |
| Multi-Mission Survey | Aurora Flight Sciences | 2013-17 | Marine | Medium Altitude Remote Sensing |
| NWS Multi-Mission | Prioria | 2015-17 | Weather | Low Altitude Observations |
| Shipboard Operations | Latitude Engineering | 2016-17 | Marine and Polar | Arctic Observations |
| Shipboard Operations | Precision | 2015-17 | Marine and Polar | Arctic Observations |
| Platform and Payload Integration | UAVSolutions | 2015-17 | Weather | Prototype Demonstrations |

# Small Business Innovation Research

| SBIR | Focus | Status |
|---|---|---|
| Phase I-III SBIR: Gravimetry | Grav-D capture using UAS<br>(Researcher –Aurora Flight Sciences) | Phase III - Commercialized |
| Phase I-II SBIR: Atmospheric and SST from Air-launched UAS | Atmospheric and SST from Air-launched UAS<br>(Researcher: Piasecki Aircraft) | No Cost Extended for Phase II flight testing |
| Phase I FY17 NOAA UAS SBIR: Maritime and Arctic (MAS) Observations + VTOL (Proposed) | Targeted Autonomous In-situ Sensing and Rapid Response | Submissions due Jan 2017 pending selection |

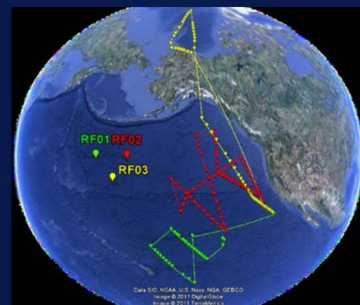
# Advancing Operational Readiness of High Altitude Dropsonde

## 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

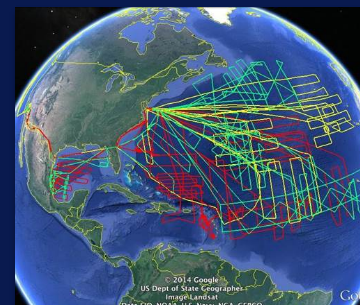
First Arctic Global Hawk flight

First dropsonde intercomparsion with NOAA G-IV

Results were published in peer-reviewed publication

Prototype in relevant environment

## 2012 - 2014




NASA Hurricane and Severe Storm Sentinel (HS3) /2011 - 2015

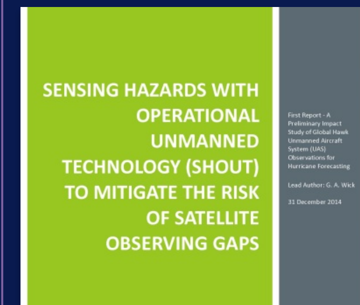
Dropsonde and remote sensing payload

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

# RELEVANCE

# 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

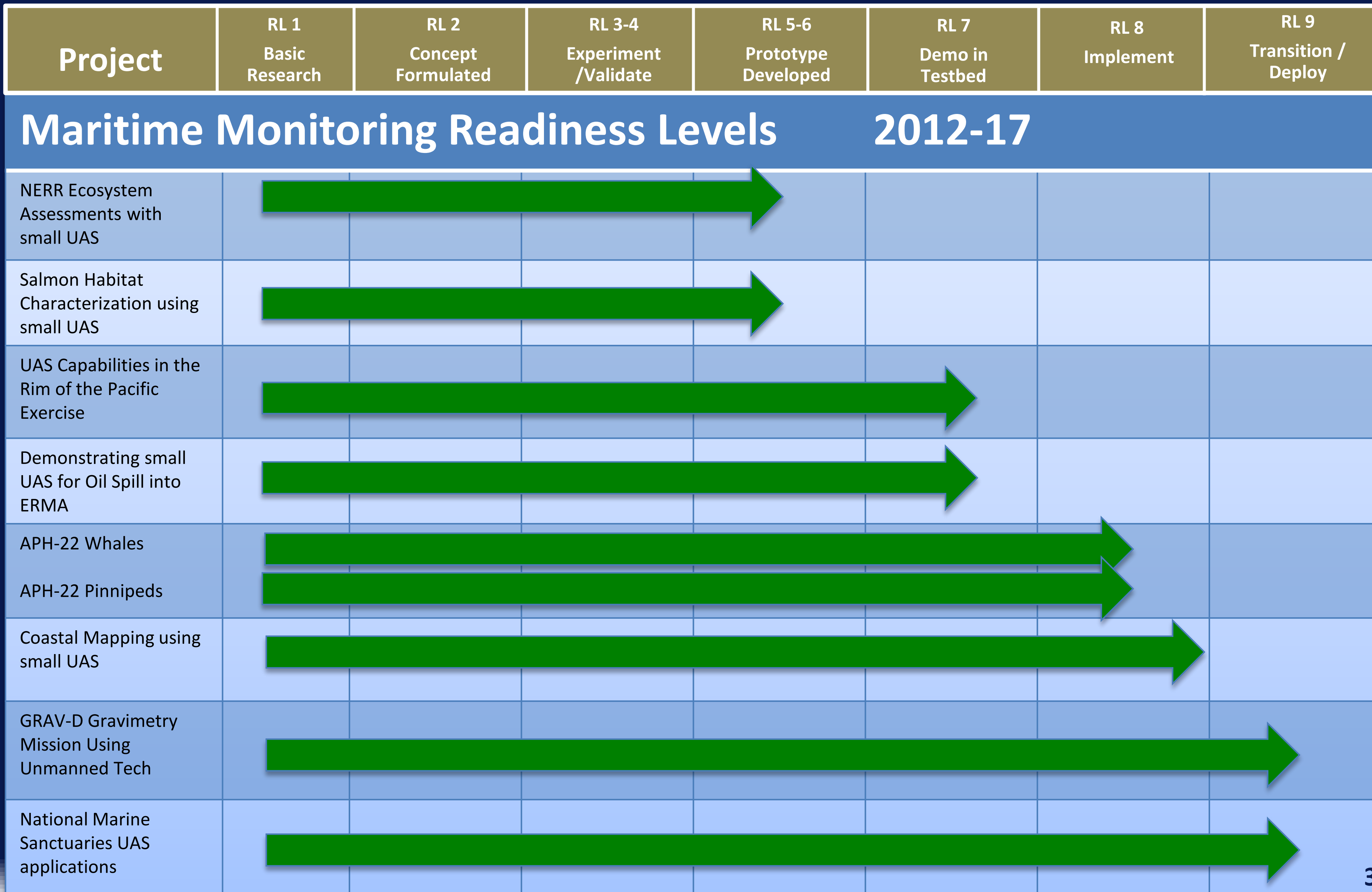
# Project Management of Field Missions

- 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

| Project | RL 1 Basic Research | RL 2 Concept Formulated | RL 3-4 Experiment /Validate | RL 5-6 Prototype Developed | RL 7 Demo in Testbed | RL 8 Implement | RL 9 Transition / Deploy |
|---|---|---|---|---|---|---|---|
| **High Impact Weather Readiness Levels 2012-2017** | | | | | | | |
| 3-D Profiling of the Severe Weather Environment | | | | | | | |
| Role of UAS for Boundary Layer Measurements | | | | | | | |
| RFC, NERR & Restoration Monitoring Using UAS | | | | | | | |
| • SHOUT<br>• AVAPS (NCEP Op Models)<br>• GH Turbulence Sensor | | | | | | | |
| UAS to Obtain Aerial Storm Damage Imagery | | | | | | | |
| GOES-R Near Surface UAS Feasibility Study | | | | | | | |

# Observing Strategies
# Advancements to Maritime Monitoring



# Observing Strategies
# Advancements to Polar Monitoring

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

# BACKUP SLIDES

# UAS Program Science Focus Areas

## High Impact Weather

- ***Can UAS observations enable improved forecasts, scientific understanding and decision support?***

## Marine

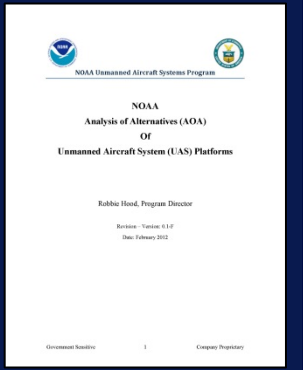
- ***Can UAS observations provide reliable, timely and affordable environmental intelligence information for resilient coastal communities and healthy oceans?***

## 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***


NOAA Unmanned Aircraft Systems Program

NOAA
Analysis of Alternatives (AOA)
Of
Unmanned Aircraft System (UAS) Platforms

Robbie Hood, Program Director

Revision – Version: 0.1-F
Date: February 2012

Government Sensitive 1 Company Proprietary

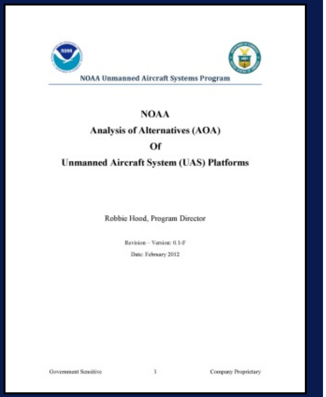
**Development (TRL 3-5) –** ***concepts tested in laboratory or relevant environment***

**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)**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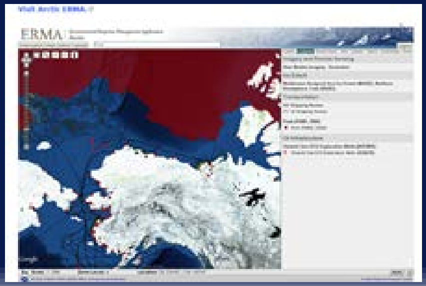
**Development (TRL 3-5)**


***Low Altitude UAS***

**Demonstration (TRL 6-8)**

***Low Altitude UAS***

**Transition (TRL 9)**

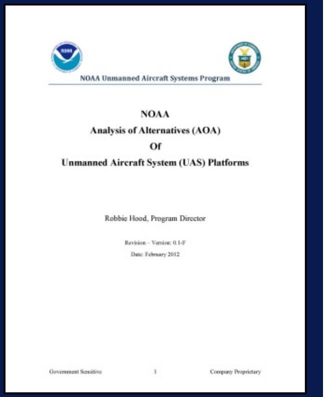



***Marine Disasters***

***Land Disasters***

# Maturing Technology Readiness of Polar UAS Observing Strategies

**Research (TRL 1-2)**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**Development (TRL 3-5)**

**Demonstration (TRL 6-8)**

**Transition (TRL 9)**

***Arctic Applications***

- ***Sea Ice***
- ***Weather***
- ***Air Chemistry***
- ***Marine Hazards***
- ***Wildlife***