Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

FY17 Annual Review

Robert Sakahara
Project Manager (Acting)

Davis Hackenberg
Deputy Project Manager (Acting)

William Johnson
Chief Engineer

24 October 2017
Agenda

8:30–8:45 Welcome, Opening Remarks, Integrated Aviation Systems Program (IASP) Overview
   Dr. Edgar Waggoner

8:45–9:45 UAS-NAS Overview
   Davis Hackenberg

9:45–10:15 Technical Challenge Performance
   Davis Hackenberg

10:15–10:30 Break

10:30–11:30 Technical Challenge Performance (continued)
   Systems Integration and Operationalization (SIO) Status
   Davis Hackenberg

11:30–12:30 Project Level Performance & Fiscal Year (FY) 18 Look Ahead
   Review Summary
   Short Video of Future Flight Central at Ames
   Davis Hackenberg

12:30 Lunch

1:00–3:00 Caucus
   IRP and PRP separately

3:00–4:00 Initial Feedback
   IRP and PRP

4:00 Adjourn
Annual Review Overview

• Purpose - Conduct an assessment of the Project’s quality and performance

• Approach - The Project will provide a programmatic review addressing the following:
  – Project’s Goal and Technical Challenges (TC) and their alignment to NASA and Aeronautics Research Mission Directorate (ARMD) Strategy
  – Project background and alignment with community efforts
  – Key highlights and accomplishments for the Project’s technical challenges
  – Project performance of the past year through examination of:
    ▪ Cost/Resource, Schedule, and Technical Management
    ▪ Progress in establishing partnerships/collaborations and their current status
  – Key activities, milestones, and “storm clouds” for FY18
  – Specific Topics:
    ▪ Summarize final Command and Control (C2) work package scope
    ▪ Describe current status of the Systems Integration and Operationalization work package
Outline

• UAS Integration in the NAS (UAS-NAS) Overview
  – FY17 Summary
  – UAS-NAS Project Background
• Technical Challenge Performance
• SIO Status
• Project Level Performance & FY18 Look Ahead
• Review Summary
FY17 Summary

• Established Project Phase 2 Detect and Avoid (DAA) and Command and Control Community Technical Challenges - ARMD approved

• Established Project Phase 2 Baseline - ARMD approved

• Successful on-time completion of multiple Project Research Activities

• Defined executable framework for Systems Integration and Operationalization Demonstration

• Provided significant contributions to the UAS Community

• Continued effective Project and Subproject management
# UAS-NAS Project Lifecycle

## Timeframe for impact: 2025

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<th>Prior</th>
<th>Phase 1 [FY11 - FY16]</th>
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### Formulation

**System Analysis:**
- Concept of Operations (ConOps), Community Progress, etc.
- Technical input from Project technical elements, NASA Research Announcements, Industry, Academia, Other Government Agencies, Project Annual Reviews, ARMD UAS Cohesive Strategy

### Early investment Activities

- Flight Validated Research Findings to Inform Federal Aviation Administration (FAA) Decision Making
  - KDP-C
  - KDP-A

### Project Start, May 2011

- Integrated Modeling, Simulation & Flight Testing
- Project Start, May 2011

### Key Decision Points

- **SC-228 Deliverables**, i.e. Minimum Operational Performance Standards (MOPS) Complete
- P1 MOPS
- P2 MOPS
- SIO Demo Close-out

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**Note:** Key Decision Points are marked with a triangle (△) symbol.
UAS Integration in the NAS Organizational Structure

Host Center
- AFRC Director of Programs: Joel Sitz (Acting)
- Deputy Director: Laurie Grindle (Acting)
- Deputy Director: Lauri Grindle (Acting)

Program Office
- IASP Program Director: Dr. Ed Waggoner
- Deputy Program Director: Lee Noble

Project Office
- Project Manager (PM): Robert Sakahara (Acting), AFRC
- Deputy PM: Davis Hackenberg (Acting), AFRC
- Deputy PM, Integration: TBD, AFRC
- Chief Engineer: William Johnson, LaRC
- Deputy Chief Engineer: Clint St. John, AFRC
- Staff Engineer: Dan Roth, AFRC
- Senior Advisor for UAS Integration: Chuck Johnson

Subprojects
- Command and Control (C2) SPM: Mike Jarrell, GRC
- C2 Subproject Technical Lead: Jim Griner, GRC
- Detect and Avoid (DAA) SPM: Jay Shively, ARC
- DAA Subproject Technical Leads: Gilbert Wu, ARC (Acting); Lisa Fern, ARC; Tod Lewis, LaRC
- Integrated Test and Evaluation (IT&E) Co-SPMs: Jim Murphy, ARC (Acting); Mauricio Rivas, AFRC (Acting)
- IT&E Subproject Technical Lead: Sam Kim, AFRC; Ty Hoang, ARC (Acting)

Program External Interfaces
- ExCom, RTCA Steering Committee, UAS Aviation Rulemaking Committee
- FAA, DoD, RTCA SC-228, Industry, etc.

Aero Centers
- Brad Flick – ARD, AFRC
- Huy Tran – ARD, ARC
- Ruben Del Rosario – ARD, GRC
- George Finelli – ARD, LaRC

ARD: Aeronautics Research Director, PM: Project Manager, SPM: Subproject Manager
### STRATEGIC GOAL

2: Advance understanding of Earth and develop technologies to improve the quality of life on our home planet

### OBJECTIVE

2.1: Enable a revolutionary transformation for safe and sustainable U.S. and global aviation by advancing aeronautics research

### PERFORMANCE GOAL UAS-NAS

2.1.6: Support transformation of civil aircraft operations and air traffic management through the development, application, and validation of advanced autonomy and automation technologies, including addressing critical barriers to future routine access of Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS), through the development and maturation of technologies and validation of data

### Project GOAL UAS-NAS

Provide research findings, utilizing simulation and flight tests, to support the development and validation of DAA and C2 technologies necessary for integrating Unmanned Aircraft Systems into the National Airspace System.
ARMD Strategic Plan Flow Down to UAS-NAS Project

**Thrust 1:** Safe Efficient Growth in Global Operations

**Outcome (2025):** ATM+1 Improved NextGen operational performance in individual domains, with some integration between domains

**Thrust 6:** Assured Autonomy for Aviation Transformation

**Outcome (2025):** Initial Introduction of aviation systems with bounded autonomy, capable of carrying out function-level goals

**Research Theme:**
Airspace Operations Performance Enablers

**Research Themes:**
Implementation and Integration of Autonomous Airspace and Vehicle Systems
Testing and Evaluation of Autonomous Systems

**Develop Operational Standards for UAS in NAS**

**Select, develop, and implement autonomy applications compatible with existing systems**

**Develop policies, standards, & regulations framework of increasingly autonomous systems**

**Test, evaluate & demonstrate selected small-scale applications of autonomy**

**TC-C2:** UAS Command & Control

**TC-DAA:** Detect and Avoid operational concepts and technologies

**SIO:** System Integration & Operationalization

**Overarching Technical Challenges**

**UAS-NAS Technical Content**
UAS-NAS Technical Challenge Autonomy Contributions

**Thrust 6: Assured Autonomy for Aviation Transformation**

**Outcome (2015 – 2025):** Initial Introduction of aviation systems with bounded autonomy, capable of carrying out function-level goals

**Implementation and Integration of Autonomous Airspace and Vehicle Systems**

**4B.** Select, develop, and implement applications of autonomy that are compatible with existing systems

**4C.** Develop framework for co-development of policies, standards, and regulations with development and deployment of increasingly autonomous systems

**TC-DAA Alignment:**
- Development of requirements that can be leveraged for autonomous DAA guidance algorithm and alerting display
- Examples: removing the operator from the system and meeting the same requirements

**TC-C2 Alignment:**
- Development of requirements that support automatic and/or autonomous unmanned aircraft communication systems
- Examples: system wide removal of communication delays in time sensitive situations

**SIO Alignment:**
- Implement, test, evaluate and demonstrate selected applications of increasingly autonomous systems
UAS-NAS Technical Challenge Autonomy Contributions

**Aeronautics Strategic Thrust**

**Aeronautics Outcome**

**Aeronautics Research Theme**

**Aeronautics Overarching Technical Challenge**

**UAS-NAS Technical Content**

**Thrust 6: Assured Autonomy for Aviation Transformation**

**Outcome (2015 – 2025):** Initial Introduction of aviation systems with bounded autonomy, capable of carrying out function-level goals

**Testing and Evaluation of Autonomous Systems**

5B. Test, evaluate & demonstrate selected small-scale applications of autonomy

**UAS-NAS Portfolio:**

- Development of unmanned aircraft flight test methods and operational procedures relevant to small-scale applications of autonomy
  - Flight test of automatic and/or autonomous systems such as Airborne Collision Avoidance System (ACAS Xu)
  - Flight test of Detect and Avoid systems
  - Flight test of command and control radios
- Leverage NASA airworthiness safety processes to provide operational assessments for automatic and autonomous systems
Full UAS Integration Vision of the Future

Manned and unmanned aircraft will be able to routinely operate through all phases of flight in the NAS, based on airspace requirements and system performance capabilities.
Emerging Commercial UAS Operating Environments (OE)

IFR-LIKE

UAS will be expected to meet certification standards and operate safely with traditional air traffic and ATM services. (Example Use Case: Communication Relay / Cargo Transport)

VFR-LIKE

These UAS will operate at altitudes below critical NAS infrastructure and will need to routinely integrate with both cooperative and non-cooperative aircraft. (Example Use Case: Infrastructure Surveillance)

BVLOS RURAL

Low risk BVLOS rural operations with or without aviation services. (Example Use Case: Agriculture)

BVLOS URBAN

Must interface with dense controlled air traffic environments as well as operate safely amongst the traffic in uncontrolled airspace. (Example Use Case: Traffic Monitoring / Package Delivery)
UAS Airspace Integration Pillars and Enablers

**UAS Technologies:**
- T01 - Airport Operations Technologies
- T02 - Airworthiness Standards
- T03 – Command, Control, Communications (C3)
- T04 - Detect & Avoid (DAA)
- T05 - Flight & Health Mngmt Systems
- T06 - GCS Technologies
- T07 - Hazard Avoidance
- T08 - Highly Automated Architectures
- T09 – Navigation
- T10 - Power & Propulsion
- T11 - Weather

**ATM Services & Infrastructure:**
- I01 - Airport Infrastructure
- I02 - ATM Infrastructure
- I03 - Non-FAA Managed Airspace Infrastructure
- I04 - RF Spectrum Availability
- I05 - Test Ranges & M&S Facilities

**Operational Regulations, Policies & Guidelines:**
- P01 - ATM Regulations / Policies / Procedures
- P02 - Airworthiness Regulations / Policies / Guidelines
- P03 - Operating Rules / Regulations / Procedures
- P04 - Safety Risk Mngmt & Methods of Compliance

**Public Acceptance & Trust:**
- A01 - Cybersecurity Criteria & Methods of Compliance
- A02 - Legal & Privacy Rules / Guidelines
- A03 – Noise Reductions
- A04 - Physical Security Criteria & Methods of Compliance
- A05 - Public Safety Confidence

**UAS Airspace Access Vision:**
Manned and unmanned aircraft will be able to routinely operate through all phases of flight in the NAS, based on airspace requirements and system performance capabilities.

**The UAS Airspace Integration Pillars enable achievement of the Vision**
UAS Integration / Project Background

• Each Operating Environment (OE) has unique considerations with respect to each Pillar

• Program and Project core competencies focus on Integrated Vehicle technologies

• “IFR-Like” and “VFR-Like” OEs became the project focus due to considerations such as core competencies, Technology Readiness Level (TRL), other ARMD portfolio work, and community benefit

• Project Phase 2 TCs, i.e. detect and avoid (DAA) and command and control (C2), do not cover the broad needs for all Operating Environments or UAS Vehicle Technologies

• Systems Integration and Operationalization (SIO) Demonstration effort developed around integration of DAA and C2 while including efforts towards closing UAS Vehicle technology gaps for project relevant OEs

• Project currently does not support other Program/Project TCs
UAS Integration / Project Background

- NASA and FAA have determined DAA and C2 are highly significant barriers to UAS integration

- Project wrote TC statements that address the full barrier for DAA and C2 in the “VFR-Like” and “IFR-Like” Operating Environments

- Project identified the work required to complete the TCs and which aspects NASA should lead

- Project assessed and prioritized research to provide the greatest benefit to address the community barriers within resource allocations
Project Phase 2 Formulation Review Background

• Key Decision Point (KDP)-A, Authorization to Proceed (ATP) with Formulation
  – Approved to proceed with the TC-C2 partnerships, ACAS Xu Flight Test 2 Partnership
  – Primary actions were to assess and add clarity to Technical Challenges, including descriptions of the portion of the industry that would benefit, and demand for the research in the next 5 years

• KDP-C, ATP for Implementation
  – Approved baseline of DAA and terrestrial C2 content, with considerations to broader aviation markets
  – Primary actions included re-assessing SatCom portfolio, including SIO in the project portfolio, and providing clarity on several miscellaneous items

• Post KDP-C
  – Responded to all ARMD actions
  – Baselined all technical content that was approved at KDP-C
  – Began study of UAS demand and economic benefit

Project Phase 2 formulation process leveraged to maximize NASA’s contributions to the UAS community
UAS-NAS Project Value Proposition

**NASA UAS-NAS Project Activities**

### C2 Performance Standards
- Research C2 SatCom Systems
- Develop C2 Prototype Terrestrial System

#### Conduct C2 Flight Test and MS&A
- Data Link
- CNPC Spectrum
- CNPC Security
- BVLOS/BRLOS
- ATC Interoperability

#### Develop C2 Requirements

### DAA Performance Standards
- Develop DAA Test beds

#### Conduct DAA Flight Test and MS&A
- Human Factors
- Performance Trade-offs
- CONOPs
- Interoperability
- Collision Avoidance
- Self Separation
- Low Cost SWaP sensors

#### Develop DAA Performance & Interoperability Requirements

### Integrated Test & Evaluation
- Develop DAA Prototype System

#### Live Virtual Constructive (LVC) Test Infrastructure

- ACAS Xu FT2
- No Chase COA
- Conduct FT5 Test Scenarios
- Conduct FT6 Test Scenarios

### Systems Integration and Operationalization
- Develop Robust NASA/Industry Partnership

#### Document certification and airworthiness approaches

#### Integrate Essential Technologies

### Key Products

#### C2 Performance Requirements to inform C2 MOPS
- RTCA Terrestrial MOPS
- C2 Technical Standard Order (TSO)

#### DAA Performance Requirements to inform DAA MOPS
- RTCA Non-Coop Sensor MOPS
- GBDAA MOPS
- DAA Technical Standard Order (TSO)

### Resultant Outcomes

#### Re-usable Test Infrastructure

- Substantiated path to certification

- Generic Certification Airworthiness Approaches
### Phase 2 Flight and Simulation Overview

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<th>Flight / Sims Series</th>
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**Integration** | **Flights / Sims** | **Analysis** | **Reporting** | **API Element** | **Level 1** | **Level 2**

*Red Status Line Date 9/30/17*
Progress Indicator Definition

- Technical Challenge (TC) progress is tracked by means of Progress Indicators
  - TC completion represented by both UAS-NAS Progress and Community Outcome sections

- UAS-NAS Progress
  - Represents the execution/data collection of milestones for Project Schedule Packages (SP)

- Assessed maturity of Project research portfolio related to the technical challenge
  - High = 2, i.e. L1 Milestones and Flight Tests
  - Moderate = 1, i.e. Human in the Loop (HITLs), System Development Complete, and Demonstrations
  - Low = 0, Foundational activities, i.e. the rest

- Research portfolio maturity normalized on a 10 point scale represents Project progress towards TC completion

- Tech Transfer
  - Represents the data analysis and reporting milestones for Project SP

- Progress is tracked against all SP tasks and UAS Community Outcomes using a color indicator
Outline

• UAS-NAS Overview
• Technical Challenge Performance
  – TC-DAA
  – TC-C2
• SIO Status
• Project Level Performance & FY18 Look Ahead
• Review Summary
Develop Detect and Avoid (DAA) operational concepts and technologies in support of standards to enable a broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to detect and avoid manned and unmanned air traffic.
UAS Detect and Avoid (DAA) Operating Environments (OE)

Legend
Phase 1 Research Areas (FY14 – FY16)
Phase 2 Research Areas (FY17 – FY20)

DAA System for Transition to Operational Altitude

HALE aircraft

FL-600

18K' MSL

10K' MSL

Top of Class G

DAA System for Operational Altitudes (> 500ft AGL)

“VFR-like” UAS

“VFR-like” UAS

DAA Sensors

ADS-B & ACAS Xu

ADS-B & TCAS-II

ACAS Xu

C2 Datalink

Cooperative Traffic

Cooperative Traffic

Non-cooperative Aircraft

Ground Based Radar

Ground Based Radar

Terminal Area Ops

Terminal Area Ops

UAS Ground Control Station

GBDAA Data

GBDAA Data
TC-DAA: Develop Detect and Avoid (DAA) operational concepts and technologies in support of standards to enable a broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to detect and avoid manned and unmanned air traffic.
Integrated Flight Test: ACAS-Xu Flight Test 2

• Research Objectives:
  – Continue collaboration with the FAA TCAS Program Office-led partnership to mature the ACAS Xu software in support of ACAS Xu MOPS development (draft FY18, final FY20)
  – Demonstrate system behavior integrated on prototype avionics and UAS
  – Collect flight test data for performance evaluations and future Research and Development (R&D)
  – Validate modeling and simulations

• Status:
  – Flight test completed August 2017
    ▪ 12 flight tests / 56 flight hours
    ▪ 6.5 weeks (13 June – 1 Aug) duration
    ▪ 241 flight cards / test points flown
    ▪ All priority 1 test points (114 flight cards) completed
  – Flight test data made available to FAA and contractor team following each flight
  – Flight test report (internal distribution only) completed September 2017

• Next Steps:
  – Public release of Flight test report to be completed October 2017

Schedule Package T.8.10
Alternative Surveillance: Foundational Fast-time Simulation (FY17)

- **Research Objective:**
  - Estimate the target performance of alternative surveillance within Phase 2 MOPS UAS operations in order to provide acceptable DAA alerting and guidance

- **Status:**
  - Experiment review completed July 2017
  - Data collection completed August 2017

- **Next Steps:**
  - Data analysis to be completed October 2017
  - Report to be completed December 2017
Research Objective:

- Explore pilot performance and operational suitability issues associated with Class D terminal area operations

Status:

- Experimental design, including Stakeholder/Partner Workshop, completed July 2017
- Traffic scenarios completed August 2017
- Shakedown completed September 2017

Next Steps:

- Data collection to be completed October 2017
- Reports to be completed December 2017
• **Research Objective:**
  – Conduct unmanned aircraft flight demonstration as described in an FAA approved No Chase Certificate of Waiver or Authorization (COA)
  – Transfer of technology proving the feasibility of integrating a UAS with and alternate means of compliance with FAA FAR Part 91.113 (see and avoid).

• **Status:**
  – No Chase COA (NCC) Objectives defined May 2017
  – Conducted NCC Kick-Off meeting with FAA May 2017

• **Next Steps:**
  – NCC Demonstration Flights to be completed March 2018
  – NCC report to be completed June 2018

**No Chase COA Demonstration**

| Purpose | Obtain Certificate of Authorization (COA) from FAA to fly Ikhana UAS without safety chase in multiple Classes of air space, including Class A, D and E.
| Demonstrate UA transitioning to/from Class A or SUA to Class E and Class D employing the Phase 1 Deconflict and Avoid (DAA) and A/A Radar MOPS Systems as alternate compliance for 14 CFR 91.113a. |
| Approach | Complete gap analysis and safety case analysis justifying alternative method of compliance with FAR Part 91.113.
| Work in partnership with General Atomics – Aeronautical Systems, Inc. (GA-ASI) to secure use of GA-ASI's DAA System as primary airborne de-conflicting tool. |
| Test Duration | February, 2018 (2-3 flights) |
| Tech Transfer | Demonstrate the Phase 1 DAA and Radar MOPS research findings through a "Capstone" event. |
| Project Benefit | Demonstration of UAS-NAS Phase 1 DAA technologies. |

Technical Baseline Element Number: TBEN-023 (SP T.8.20)
Ground Based Detect and Avoid (GBDAA)
Virginia UAS Test Site

- [Redacted funding] Competed across all six test sites
- The goal of the proposed effort is to implement a GBDAA system that will have long term strategic value to NASA (i.e. TC-DAA), FAA, and industry partners. The proposed system will:
  - Provide a foundation and testbed for validation and iteration of RTCA standards
  - Provide a foundation for FAA Beyond Visual Line of Sight (BVLOS) rulemaking activities
  - Provide an effective means for industry to evaluate technologies and procedures for conducting low level BVLOS use cases
  - Provide a foundation for future commercial waivers seeking operational capability for industry applications
TC-DAA Risk Summary

- Data Redacted
TC-C2: UAS Command and Control

Develop Satellite (SatCom) and Terrestrial based Command and Control (C2) operational concepts and technologies in support of standards to enable the broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to leverage allocated protected spectrum.
UAS Command and Control
Operating Environments (OE)

Legend
Phase 1 Research Areas (FY14 – FY16)
Phase 2 Research Areas (FY17 – FY20)
TC-C2 Technical Work Scope

• Terrestrial C-Band
  – Develop and standardize Control and Non-Payload Communications (CNPC) radios with Rockwell Collins
  – Flight Testing over Urban environments
  – Low-Size, Weight and Power (L-SWaP) configuration, Cooperative Agreement modification in work

• SatCom C-Band Study
  – Trade studies

• SatCom Ku-Band
  – FY17 propagation/interference system development and testing

• SatCom Ka-Band
  – No project technical content

• Addressing Urban Air Mobility (UAM) Communications Technology Study
  – New activity that will evaluate C2 UAM ConOps, technical requirements, candidate implementations, etc
TC-C2: Develop Satellite (SatCom) and Terrestrial based Command and Control (C2) operational concepts and technologies in support of standards to enable the broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to leverage allocated protected spectrum.
Ku-Band Propagation Flights and Interference Analysis

**Research Objective:**
- Collect flight test data to validate earlier analysis of possible interference of Ku Unmanned Aircraft Systems (UAS) Command and Control (C2) SatCom radio systems with Ku fixed point-to-point ground stations in Europe needed for the development and validation of standards and spectrum allocation for a Ku-Band SatCom C2 data link.

**Status:**
- Ku interference flight test phase completed August 2017
  - Two final data collection flights
- Ku interference data analysis completed September 2017
- Ku interference final report completed September 2017
  - Provided to FAA
- Technical Baseline Element completed September 2017

*Ku-Band Spectrum Interference data provided to FAA Spectrum Office*
Terrestrial C2 Radio Evaluation System Development

• **Research Objective:**
  – Develop a Terrestrial C2 data link radio system and transfer technology and research data for the development and validation of standards for Terrestrial C2 data link

• **Status:**
  – Established Cooperative Agreement for C2 Terrestrial Extension radio January 2017
  – Version 6 Preliminary Design Review (PDR) completed July 2017

• **Next Steps:**
  – Version 6 Critical Design Review (CDR) to be completed October 2017
  – Terrestrial-Based Version 6 Flight Test to be completed July 2018
  – Terrestrial-Based Version 7 Flight Test to be completed July 2019
  – Terrestrial-based UAS C2 Final Report to be completed September 2020

Technical Baseline Element Number: TBEN-004 (SP C.6.10, SP C.6.11)
TC-C2 Risk Summary

• Data Redacted
Technical Performance Summary

- **SC-228 Support**
  - Provided input into C2 and DAA White Papers to further scope the RTCA SC228 Phase 2 efforts
  - Leading/co-leading several topical subgroups
  - Presented DAA experiment plans
  - Presented analyses results to support publication of errata for DO-362

- **TC-C2**
  - Completed Ku-Band Spectrum Interference ground and flight systems design, systems installation, and flight test
  - Provided FAA Spectrum Office Ku-Band Spectrum Interference data

- **SC-228 Support**
  - Provided input into C2 and DAA White Papers to further scope the RTCA SC228 Phase 2 efforts
  - Leading/co-leading several topical subgroups
  - Presented DAA experiment plans
  - Presented analyses results to support publication of errata for DO-362

- **TC-DAA**
  - Completed ACAS Xu Flight Test 2
  - Developed Alternative Surveillance and Well Clear/Alerting Requirements ConOps
  - Completed experiment designs, infrastructure preparations, and/or data collection for multiple experiments

---

Preparing and conducting experiments collecting data critical to C2 and DAA MOPS
Outline

• UAS-NAS Overview
• Technical Challenge Performance
• SIO Status
• Project Level Performance & FY17 Look Ahead
• Review Summary
Integrate state of the art DAA and C2 technologies into Unmanned Aircraft Systems (UAS) to ensure sufficient aircraft level functional and operational requirements, and perform demonstrations in the NAS to inform Federal Aviation Administration creation of policies for operating UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations.
SIO Overview

• The SIO activity and associated FY20 demonstration will be a partnership between NASA and Industry in concert with the FAA to support the vision of UAS Integration in the NAS

• Primary Objectives are to:
  – Demonstrate UAS operations in the NAS by leveraging integrated DAA, C2, and other state of the art UAS technologies on an unmanned aircraft
  – Ensure relevant project research transitions into UAS stakeholder community
  – Accelerate certification basis for UAS new entrants
  – Advance the state of the art for UAS technologies

• Planning Considerations:
  – UAS Integration focused demonstration flight(s) with one or more partner provided UAS
  – Considers all ground and flight needs necessary to implement the proposed UAS mission (e.g. all phases of flight, take-off through landing, etc)
  – All UAS equipped with operationally relevant, DAA and C2 systems that have a pathway to certification (not necessarily SC-228 developed standards)
  – All vehicle technologies assessed to determine the most state of the art solution set that can meet airworthiness expectations for the demonstration
  – Operating Environment is MOPS-like, with primary operating altitude being above 500 feet above ground level (AGL) in controlled airspace
  – All Vehicles will be greater than 55 lbs (25 kg)

Obtain Industry partner(s) who demonstrate integrated DAA and C2 technologies in the NAS, leverage vehicle technologies that enable end-to-end mission performance without operational restrictions, and compile the necessary artifacts and data to support regulatory compliance
Potential SIO Operational View Representation

LEGEND
- Detect and Avoid (DAA) Technologies
- Air Traffic Control (ATC) Services
- Control and Non-Payload Communications (CNPC) Network
- Satellite Command and Control (C2) Links

ACRONYMS
- ACAS Xu: Airborne Collision Avoidance System, UAS Variant
- ADS–B: Automatic Dependent Surveillance—Broadcast
- BRLOS: Beyond Radio Line of Site
- BVLOS: Beyond Visual Line of Site
- TCAS–II: Traffic Alert and Collision Avoidance System
- UAS: Unmanned Aircraft Systems

Communications Satellite

IFR-Like Airspace Integration

Airborne Detect and Avoid

UAS test aircraft

Terrestrial C2

CNPC Ground Stations

Non-cooperative Aircraft

“mid-sized” test aircraft

VFR-Like Airspace Integration

UAS Ground Control Station

Alternative DAA Sensors

Cooperative Aircraft

ADS–B & TCAS–II / ACAS Xu

Non-cooperative Aircraft

DAA Sensors

Terrestrial C2 Link

ACRINERS

UAS Ground Control Station

ATC Interoperability

Ground Based Detect and Avoid

Ground Based Radar

IFR-Like Airspace Integration

Air Traffic Control (ATC) Services

Control and Non-Payload Communications (CNPC) Network

Satellite Command and Control (C2) Links

Acronyms
- ACAS Xu: Airborne Collision Avoidance System, UAS Variant
- ADS–B: Automatic Dependent Surveillance—Broadcast
- BRLOS: Beyond Radio Line of Site
- BVLOS: Beyond Visual Line of Site
- TCAS–II: Traffic Alert and Collision Avoidance System
- UAS: Unmanned Aircraft Systems

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NASA/FAA/Industry Relationship for SIO

**NASA**
- C2 and DAA Technologies
- UAS Airworthiness
- ARMD-wide Technologies
- Generic Type Cert Requirements

**FAA**
- Approval to fly in the NAS
- Type Cert guidance
- Procedural / policy / regulatory changes

**SIO**
- TSOs, Ops Approval

**DAA/C2, Airworthiness Criteria**
- Airworthy vehicle with integrated C2 and DAA equipage
- Other gap filling technologies required
- Specific Type Cert Basis

**Systems Integration and Operationalization (SIO) Partnership Venn**

- Maximum contribution from NASA
- Minimum contribution from Industry

- FAA role
### SIO Notional Demonstration Strategy

<table>
<thead>
<tr>
<th>SIO Potential Stakeholders</th>
<th>SIO Potential Partners</th>
<th>SIO Engagement Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>• RTCA SC-228</td>
<td>• Industry Aircraft OEMs</td>
<td>Industry Partnership Strategy</td>
</tr>
<tr>
<td>• FAA and Other Government Agencies</td>
<td>• Industry Sensor Manufacturers</td>
<td>• Develop agreements with substantial industry investments, and leveraging NASA SMEs, to conduct the SIO demonstration</td>
</tr>
<tr>
<td>• Industry</td>
<td>• Industry Communication Providers</td>
<td>• Industry to integrate C2 and DAA technologies in concert with essential vehicle technologies</td>
</tr>
<tr>
<td>• ICAO, EUROCAE</td>
<td>• FAA UAS Test Sites</td>
<td>• Conduct industry centric SIO demonstration</td>
</tr>
<tr>
<td></td>
<td>• AFRL, US Army</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Service Providers</td>
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</tbody>
</table>

**FAA Partnership Strategy**

• Work through the UAS Integration RTT to impact policy/procedural/regulatory/approval changes

---

**SIO Engagement Timeline**

- **SIO Vehicle Task Award**
- **SIO Vehicle Task Demo**
- **SIO Developing SIO Strategy**
- **SIO DAY and RFI SIO CONTRIB**
- **SIO Selected SIO PARTNERS**
- **SIO Technology Development**
- **SIO Demonstration**

---

**SIO Potential Partners**

- Industry Aircraft OEMs
- Industry Sensor Manufacturers
- Industry Communication Providers
- FAA UAS Test Sites
- AFRL, US Army
- Service Providers

---

**SIO Engagement Strategy**

- **Industry Partnership Strategy**
  - Develop agreements with substantial industry investments, and leveraging NASA SMEs, to conduct the SIO demonstration
  - Industry to integrate C2 and DAA technologies in concert with essential vehicle technologies
  - Conduct industry centric SIO demonstration

- **FAA Partnership Strategy**
  - Work through the UAS Integration RTT to impact policy/procedural/regulatory/approval changes
SIO Staffing Maturation

• Data Redacted
Initial SIO Demo  
New York UAS Test Site

- [Redacted funding] ; competed across all six test sites
- Demonstration task to assess individual UAS vehicle technology state of the art for a Concept of Operations (ConOps) that is consistent with NASA’s UAS Operational Environments
- The proposed effort is expected to inform planning efforts for the SIO FY20 demonstration and establish a foundation for future test platforms that are relevant to NASA ARMD initiatives

- Key Characteristics
  - Griffiss Airport in upstate NY
  - Tremendous airspace enables full missions
  - Several technology demonstrations including DAA, C2, and many others
  - Vehicle Partner: Aurora Flight Sciences – Centaur
  - Collaboration on dissemination of outcomes to community
  - Demonstration in July
SIO Path Forward

• Address SIO Concerns (Storm Clouds)
  – Define acquisition/partnership strategy
  – Identification of an Industry partner willing to provide adequate resources
  – Staffing to support SIO within subprojects, filling open positions, and addressing potential need for certification expertise
  – Increased tasks due to FY20 SIO demonstration (Project resources reduced for closeout in N2 Budget)

• SIO Demonstration Request for Information (RFI) for Industry ConOps, Technology Maturation, and Rough Orders of Magnitude
  – Communicate NASA expectations for the NASA partnership development process at industry day
  – Industry Day Announcement released in FedBizOps on October 4
    ▪ [https://www.fbo.gov/index?s=opportunity&mode=form&id=7b629912df70effbb2a7a97c5918623b&tab=core&_cview=1](https://www.fbo.gov/index?s=opportunity&mode=form&id=7b629912df70effbb2a7a97c5918623b&tab=core&_cview=1)
  – RFI to be released by October 25
  – Industry day to be held on November 30 in San Diego, CA
  – RFI responses due December 15
  – RFI evaluation complete by end of January

• Project plans to release request for proposal to Industry by February 2018
Outline

- UAS-NAS Overview
- Technical Challenge Performance
- SIO Status
- Project Level Performance & FY18 Look Ahead
  - Risk Status
  - Resource Allocation and Utilization
  - Schedule Performance
  - Technical Baseline Summary
  - Partnerships and Collaboration
  - FY17 Accomplishments and FY18 Look Ahead
- Review Summary
Risk Status

• Data Redacted
Resource Allocation against Baseline Budget

- Data Redacted
• Data Redacted
UAS FY17 Project Funding

- Data Redacted
FY17 Schedule Performance

• **Milestone Count**
  – Total of 8 Level 1 milestones, 2 completed to date, 6 remain open
  – Total of 56 Level 2 milestones, 15 completed to date, 41 are incomplete

• **Causes of Milestone Delays**
  – Level 1 Milestone
    • Delay in one Level 1 milestone due to Federal Registry delays
  – Level 2 Milestones
    • Alternative Surveillance Cooperative Agreement delayed longer than expected
    • Technical scope changes implemented to better align with community requirements

• **Impacts of Milestone Delays**
  – Alternative Surveillance CAN delays has slipped the start of FT 5 to October 2018
  – Acceptable impacts to downstream test and simulation activities

**Successful Milestone Management**
<table>
<thead>
<tr>
<th>Partner (Project Area)</th>
<th>Agreement In Place</th>
<th>Collaboration/Partnership Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Force Research Lab (TC-DAA)</td>
<td>Ames Space Act</td>
<td>Coordinate activities on Vigilant Spirit Control Station. On-going collaboration with AFRL supporting use of Visual Spirit Control Station (VSCS) on DAA activities</td>
</tr>
<tr>
<td>FAA Office of UAS Integration (Project Office)</td>
<td>RTT</td>
<td>Support by FAA leadership, management, and technical subject matter experts (SME)s to validate work being done by the Project. On-going coordination of Project deliverables. Research Transition Team participation</td>
</tr>
<tr>
<td>FAA R&amp;D Integration (Project Office)</td>
<td>RTT</td>
<td>Primary organization on RTT collaborations, on-going coordination of Project deliverables</td>
</tr>
<tr>
<td>FAA Air Traffic Organization (Project Office)</td>
<td>RTT / Controlled Airspace ARC</td>
<td>Primary organization managing the Controlled Airspace ARC for which the project will actively participate. Research Transition Team participation</td>
</tr>
<tr>
<td>FAA TCAS Program Office (ACAS Xu) (TC-DAA)</td>
<td>Software</td>
<td>Coordinating on collaboration for ACAS-Xu FT2 software and associated flight tests</td>
</tr>
<tr>
<td>FAA UAS Test Sites (Project Office)</td>
<td>IDIQ Contract</td>
<td>Awarded Task 4 GBDAA (Gryphon Sensors LLC, Textron, UAVPro, FirebirdSE, Sunhillo, Dominion Energy, and Aviation Systems Engineering Company) and Task 5 Vehicle Task (Aurora, MTSI, NUAir, Griffiss International Airport, AX Enterprize, Gryphon Sensors, Navmar Applied Sciences Corp.)</td>
</tr>
<tr>
<td>General Atomics (TC-DAA)</td>
<td>Space Act</td>
<td>Ikhana equipped with avionics and Proof of Concept DAA system directly supported by UAS-NAS Project and supported FT4. General Atomics supported ACAS-Xu FT2 and is currently collaborating to support the No Chase COA flight</td>
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Purple text indicates changes since FY16 AR
<table>
<thead>
<tr>
<th>Partner (Project Area)</th>
<th>Agreement In Place</th>
<th>Collaboration/Partnership Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honeywell (TC-DAA)</td>
<td>Cooperative Agreement</td>
<td>Selectee for DAA subproject cooperative agreement</td>
</tr>
<tr>
<td>Honeywell (TC-C2)</td>
<td>Cooperative Agreement</td>
<td>Selectee for C2 subproject cooperative agreement for SatCom Ka-band development. Agreement was canceled.</td>
</tr>
<tr>
<td>NASA AOSP (Project Office)</td>
<td>NA</td>
<td>Coordination with Airspace Operations and Safety Program (AOSP) on UAS Traffic Management (UTM), SMART NAS, autonomy roadmapping, and other activities including collaborative effort on UAS integration strategies and LVC development. Full UAS Cohesive Strategy currently being worked</td>
</tr>
<tr>
<td>Rockwell Collins (TC-C2)</td>
<td>Cooperative Agreement</td>
<td>CNPC radio development and flight test. Cost sharing with Rockwell Collins concentrated in FY11-13, totaling $3M contribution from Rockwell. Rockwell Collins delivered Gen-5 radios</td>
</tr>
<tr>
<td>RTCA SC-228 (TC-C2, TC-DAA)</td>
<td>NA</td>
<td>On-going support to DAA and C2 working groups</td>
</tr>
<tr>
<td>RTCA SC-147 (TC-DAA)</td>
<td>NA</td>
<td>Close coordination between ACAS Xu and DAA standards required for success of P2 MOPS Hosting workshops and performing flight test to ensure success of both working groups</td>
</tr>
</tbody>
</table>

Purple text indicates changes since FY16 AR
Project Related UAS Integration Progress

• Phase 1 Technical Challenge Community Outcomes
  – FAA published TSO for DO-362 is under review within the FAA
  – No Chase COA is driving the community towards the first flight of an UAS in the NAS with a technology solution for “see and avoid” rules (i.e. Part 91)

• Phase 2 Technical Content Progress
  – Project baseline portfolio (M&S, HITLS, and Flight Tests) used to set aggressive goals for DAA and C2 within the community
  – Significant input to SC-228 white papers scoping upcoming standards
  – NASA challenging the community to demonstrate critical technologies and accelerate commercial operational approvals

• Phase 2 partnerships with the FAA are being coordinated though a Research Transition Team (RTT) that includes all Lines of Business
FY17 Accomplishments

- Detect and Avoid Subproject
  - Phase 1 MOPS Published
  - SC-228 DAA White Paper
- Integrated Test and Evaluation Subproject
  - ACAS Xu Flight Test 2
  - No Chase COA Planning
  - Flight Test 5 Planning
- Project Office
  - ICAO/VIP Day
  - Key Decision Point – C (Baseline Review)
  - ARMD UAS Cohesive Strategy and FAA Research Transition Team

FY18 Look Ahead

- Command and Control Subproject
  - Phase 1 MOPS Published
  - Ku-Band interference testing
  - Ka-Band cooperative agreement award and subsequent deletion
  - SC-228 C2 White Paper
- Awards
  - ARMD Associate Administrator (AA) Group award for technology and innovation for IT&Es work on Flight Test Series 4
  - Joseph J. Jacobs Master Builder Award for UAS in the NAS Fight Test 4 project

FY18 Look Ahead

- DAA HITL Simulation
- No Chase COA Flight Demonstration
- SIO Demo Industry Day and Partner Collaboration
- CNPC Radio Version 6 Flight Test
Summary

✔ Established Project Phase 2 Detect and Avoid and Command and Control Community Technical Challenges

✔ Established Project Phase 2 Baseline

✔ Successful On-time Completion of Multiple Project Research Activities

✔ Defined Executable Framework for SIO

✔ Provided Significant Contributions to the UAS Community

✔ Continued Effective Project and Subproject Management

*Project continues to provide positive impacts towards the Integration of UAS into the NAS*
UAS-NAS Technical Challenge Performance
Backup Slides
<table>
<thead>
<tr>
<th>Technical Baseline Element Number</th>
<th>Technical Baseline Element Title</th>
<th>Reference Schedule Package Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBEN-005</td>
<td>Alternative Surveillance and Well Clear/Alerting Requirements ConOps</td>
<td>SP D.1.30, SP D.2.10</td>
</tr>
<tr>
<td>TBEN-006</td>
<td>Alternative Surveillance: Foundational Fast-time Simulation (FY17)</td>
<td>SP D.1.40</td>
</tr>
<tr>
<td>* TBEN-007</td>
<td>Alternative Surveillance: Display Requirements</td>
<td>SP D.1.50</td>
</tr>
<tr>
<td>* TBEN-008</td>
<td>Alternative Surveillance: Unmitigated Fast-time Simulation (FY18)</td>
<td>SP D.1.60</td>
</tr>
<tr>
<td>* TBEN-009</td>
<td>Alternative Surveillance: HITL Simulation 1</td>
<td>SP D.1.70, SP T.7.20</td>
</tr>
<tr>
<td>* TBEN-010</td>
<td>Alternative Surveillance: Unmitigated/Mitigated Fast-time Simulation (FY19)</td>
<td>SP D.1.80</td>
</tr>
<tr>
<td>* TBEN-011</td>
<td>DELETED September 2017 MRB: Alternative Surveillance: HITL Simulation 2</td>
<td>SP D.1.90, SP T.7.40</td>
</tr>
</tbody>
</table>

* Accomplishment chart not included
## TC-DAA Technical Baseline Elements (2/3)

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<th>Technical Baseline Element Number</th>
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<tr>
<td>TBEN-012</td>
<td>Well Clear/Alerting Requirements: Foundational Terminal Operations HITL Simulation 1</td>
<td>SP D.2.30, T.7.10</td>
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<tr>
<td>TBEN-013</td>
<td>Well Clear/Alerting Requirements: Foundational Terminal Operations Fast-time Simulation 1</td>
<td>SP D.2.40</td>
</tr>
<tr>
<td>TBEN-014</td>
<td>Well Clear/Alerting Requirements: Fast-time Simulation 2</td>
<td>SP D.2.50</td>
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<td>* TBEN-019</td>
<td>ACAS-Xu: HITL Simulation 1</td>
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* Accomplishment chart not included
Research Objective:
- Develop a ConOps describing the scope of DAA alternative surveillance and Well Clear Definition research to support the development of DAA Phase 2 MOPS and Non-Cooperative Sensor MOPS

Status:
- Alternative Surveillance ConOps completed June 2017
  - Internal Project document
- Well Clear/Alerting Requirements ConOps completed August 2017

Next Steps:
- Public release of Well Clear/Alerting Requirements ConOps to be completed October 2017

Alternative Surveillance and Well Clear/Alerting Requirements ConOps available to shape future Project research
Well Clear/Alerting Requirements: Foundational Terminal Operations Fast-time Simulation 1

**Research Objective:**
- Collect empirical data to address well clear issues

**Status:**
- Experiment design, shakedown, and data collection completed August 2017
  - Phase 1 Well clear Definition

**Next Steps:**
- Report to be completed November 2017
• **Research Objective:**
  – Collect empirical data to address well clear issues

• **Status:**
  – Experiment design, shakedown, and data collection completed August 2017
    • Independent variables: Well Clear Definition parameters

• **Next Steps:**
  – Report to be completed October 2017
ACAS-Xu: Mini HITL Simulation

- **Research Objective:**
  - 1) Determine that the Ames Research Centers Human Autonomy Teaming Laboratory components are installed properly and up to date for Project Phase 2 research (Primary) and 2) provide data on alerting, display and/or guidance Phase 1 DAA MOPS (Secondary)

- **Status:**
  - Experimental Design including Stakeholder input completed January 2017
  - Data Collection completed August 2017

- **Next Steps:**
  - Report to be completed December 2017

### Test Matrix

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### Integrated Display
Integrated Event: Flight Test 5

• **Research Objective:**
  – Conduct a flight test providing data to support development of the RTCA SC-228 Phase 2 Detect and Avoid and Alternative Surveillance MOPS

• **Status:**
  – ConOps and System Requirements Review completed August 2017

• **Next Steps:**
  – Flight Test 5 to be completed December 2018
  – Flight Test 5 reports to be completed February 2019
## TC-DAA (1 of 3)

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**Legend:**
- L1 Program (IASP)
- L2 Project
- API Element

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Green Status Line Date 9/30/17
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**Legend:**
- L1 Program (IASP)
- L2 Project
- API Element

*Green Status Line Date 9/30/17*
• Data Redacted
TC-DAA Risk

- Data Redacted
TC-DAA Risk

- Data Redacted
• Data Redacted
## TC-C2 Technical Baseline Elements

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<td>Ku-Band Spectrum Interference Evaluation System Development</td>
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<td>TBEN-002</td>
<td>Ku-Band Propagation Flights and Interference Analysis</td>
<td>SP C.5.11</td>
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<td>TBEN-003</td>
<td>C-Band Design Study, Verification &amp; Validation Planning</td>
<td>SP C.5.40, SP C.5.41</td>
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Ku-Band Spectrum Interference Evaluation System Development

- **Research Objective:**
  - Develop the Ku-Band interference evaluation system

- **Status:**
  - System design, installation, and integration completed July 2017
  - Technical Baseline Element completed July 2017

*Ku-Band Spectrum Interference Evaluation System ready for flight test and evaluation*
Research Objective:
- Transfer research data for the development and validation of standards for C-Band SatCom C2 data link

Status:
- Contract awarded and Kickoff meeting completed June 2017

Next Steps:
- Review with contractor to be completed October 2017
- Earth station design to be completed April 2019
- Verification and Validation Plan to be completed July 2019
- C-Band SatCom final report to be completed April 2020
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* L1 Program (IASP)  
* L2 Project  
* API Element  

Green Status Line Date 9/30/17
TC-C2 Risk

- Data Redacted
UAS-NAS SIO Status
Backup Slides
Systems Integration and Operationalization from the Technology perspective:

- **[All OEs]** Integrated Testing of Systems: Development of vehicle technologies (i.e. DAA, C2, and others) is insufficient to close complex integrated system gaps. Technologies must be integrated into vehicle systems and systematically tested in a relevant operational environment.

- **[IFR/VFR-Like]** Creation of standards typically leverage RTCA guidance for drafting performance standards that include expectations for meeting aircraft level functional and operational requirements. Other essential vehicle technologies are not being address by RTCA.

---

**Technology Benefits of SIO**

NASA’s leadership in vehicle technology development through performance of high profile integrated tests can push the industries state of the art UAS development, while ensuring aircraft level functional and operational performance criteria are included in standards activities.
Systems Integration and Operationalization from the Policy perspective

• **[All OEs]** UAS Operationalization: Integration of UAS is a broad multi-faceted problem that requires a systems level approach for implementation of technologies into the NAS, with a focus on ensuring FAA policy is created in a timely manner.

• **[IFR/VFR-Like]** Creation of standards largely benefits the Aviation Safety line of business at the FAA, but does not ensure broad FAA policy for operational approvals will follow
  – Risks of inconsistent operational approval policies are significantly reduced by standards, but in order for policies to be created in time for industry operations the FAA needs ongoing efforts consistent with those that were leveraged to develop the standards.
  – The high risk nature of system implementation without policy guidance creates an environment of opportunity for federal entities to assume some of this risk.

---

**Policy Benefits of SIO**

*Increasing confidence in the maturity of integrated C2, DAA, and other vehicle technologies an SIO demonstration will provide FAA the opportunity to stress/modify the approval process, leading to a playbook for industry to gain access for IFR/VFR-Like missions for extended operations within Classes D,E, and G Airspace.*
Project Level Performance
Backup Slides
• Data Redacted
• Data Redacted
Project Office Risk

• Data Redacted
FY17 Closed Risks

• Data Redacted
• Data Redacted
Resource Allocation FY17 Budget

- Data Redacted
Technical Baseline FY17 Summary

- Twenty-three Technical Baseline Elements approved 24 August 2017
- Twenty remain open at end of FY17
- One deleted
  - TBEN-011 (SP D.1.90, SP T.7.40)
    - Verify and Validate 1) UAS pilot performance of a DAA system with low size, weight, and power sensor, 2) interoperability of low size, weight, and power sensor requirements with DAA alerting, guidance, and display requirements, and 3) the final DAA and Non-cooperative sensor Phase 2 MOPS
- Two completed
  - TBEN-001 (SP C.5.10)
    - Ku-Band Spectrum Interference Evaluation System Development
  - TBEN-002 (SP C.5.11)
    - Transfer technology and interference research data for the development and validation of standards for Ku-Band SatCom C2 data link

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As of 8/30/2017 IMS
## FY17 Project Deliverables

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<td>TC-DAA</td>
<td>Feb-17</td>
<td>Briefing</td>
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<td>Cohesive Full UAS Integration Strategy</td>
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<td>Tech Activity Update US (NASA) HAT-MAPP Models, Agents Principles and Patterns (MAPP)</td>
<td>TC-DAA</td>
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<td>Ikhana UAS Overview</td>
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<td>Unmanned Aircraft Systems Detect and Avoid System: End-to-End Verification and Validation Simulation Study of Minimum Operational Performance Standards for Integrating Unmanned Aircraft into the National Airspace System Briefing</td>
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Phase 2 Milestone Summary

Milestones

- **Project Comments to MOPS**
  - [TC-C2]
    - Satellite-Based UAS Command & Control
    - Terrestrial-Based UAS Command & Control
  - [TC-DAA]
    - Alternative Surveillance Requirements
    - Well Clear/Alerting Requirements
    - ACAS Xu Interoperability
    - External Coordination
    - DAA Flight Tests
    - Subprojects DAA / IT&E

Red Status Line Date 9/30/17
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- ★ L1 Program (IASP)
- ★★ L2 Project

**Green Status Line Date 9/30/17**
### Acronyms

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# Acronyms

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