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

Successfully transitioned from Formulation to Implementation
# UAS-NAS Project Lifecycle

**Timeframe for impact: 2025**

| Prior | Phase 1  
|       | [FY11 - FY16] | Phase 2  
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<td>Early investment Activities</td>
<td>System Analysis: Concept of Operations (ConOps), Community Progress, etc.</td>
<td>Flight Validated Research Findings to Inform Federal Aviation Administration (FAA) Decision Making</td>
<td>P1 MOPS</td>
<td>P2 MOPS</td>
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Technical input from Project technical elements, NASA Research Announcements, Industry, Academia, Other Government Agencies, Project Annual Reviews, ARMD UAS Cohesive Strategy

⚠️ Key Decision Points  ⚠️ SC-228 Deliverables, i.e. Minimum Operational Performance Standards (MOPS) Complete
UAS Integration in the NAS Organizational Structure

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

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

Project Support
- Lead Resource Analyst – April Jungers, AFRC
- Lead Proc Officer – Rosalia Toberman, AFRC
- Scheduler – Irma Ruiz, AFRC
- Risk and Outreach Lead – Jamie Turner, AFRC
- Doc and Change Mgmt – Lexie Brown, AFRC
- Admin Support – Sarah Strahan, AFRC
- Resource Analyst – Amber Gregory, AFRC
- Resource Analyst – Warcquel Frieson, ARC
- Resource Analyst – Julie Blackett, GRC
- Resource Analyst – Pat O’Neal, LaRC

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 Manger
NASA Strategic Plan Flow Down to UAS-NAS Project

**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

Research Theme: Airspace Operations Performance Enablers

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

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


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
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 Content

TC-C2
TC-DAA
SIO
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)*

Non-Cooperative Aircraft
The 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 Mgmt 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 Mgmt & 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
- I“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
• 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
- Well Clear
- Self Separation
- Collision Avoidance
- 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 Technology and CONOPS testing
- 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

#### Conduct Demo

### 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 MOPS Rev A/B

### Resultant Outcomes

#### Substantiated path to certification
- Generic Certification Airworthiness Approaches

#### Re-usable Test Infrastructure
- RTCA DAA Technical Standard Order (TSO)

#### Resultant Outcomes
- NASA UAS-NAS Project Activities
- Resultant Outcomes
- Key Products
- C2 Performance to inform C2 MOPS
- Non-Coop Sensor MOPS
- DAA MOPS Rev A/B
- Substantiated path to certification
# Phase 2 Flight and Simulation Overview

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- **Integration**
- **Flights / Sims**
- **Analysis**
- **Reporting**
- **API Element**
- **Level 1**
- **Level 2**
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.
DAA System for Transition to Operational Altitude

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

HALE aircraft
FL-600
18K’ MSL
10K’ MSL
Top of Class G

DAA System for Operational Altitudes (> 500ft AGL)

“VFR-like” UAS
ADS-B & ACAS Xu
ADS–B & TCAS–II
ACAS Xu
Non-cooperative Aircraft
Airborne Radar
C2 Datalink

UAS Ground Control Station
GBDAA Data

Terminal Area Ops

Cooperative Traffic
Ground Based Radar

Cooperative Traffic
Non-cooperative Aircraft

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

Technical Baseline Element Number: TBEN-006 (SP D.1.40)
Well Clear/Alerting Requirements: Foundational Terminal Operations HITL Simulation 1

- **Research Objective:**
  - Explore pilot performance and operational suitability issues associated with Class D terminal area operations

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<th>Ownship Scenario</th>
<th>Description</th>
<th>Route Variations</th>
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| Instrument Approach | • RNAV (GPS) Rwy 14 approach  
  • Non-precision approach, flown via GPS avionics | 1. Start point NW of CABEX  
2. Start point NE of FIPUM |
| Visual Approach | • Approach conducted under IFR but through ATC-approved visual clearance  
  • Pilot must report either airport or a lead aircraft detected to start procedure | 1. Start point NW of KSTS  
2. Start point NE of KSTS |
| Traffic Pattern | • Used to sequence (typically VFR) arrivals and departures  
  • Prop pattern=1150ft | 1. 45° entry into the downwind  
2. Mid-field entry |

- **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

Technical Baseline Element Number: TBEN-012 (SP D.2.30, T.7.10)
No Chase Certificate of Waiver or Authorization Flight Demonstration

- **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

**Flight Profile**

**Description**

- **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 Detect and Avoid (DAA) and A/A Radar MOPS Systems as alternate compliance for 14 CFR 91.113.b.
  - **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 IAS-NAS Phase 1 DAA technologies.
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
As of 9/30/17

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

Technical Baseline Element Number: TBEN-002 (SP C.5.11)
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)
• 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

- **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

Terrestrial C2

VFR-Like Airspace Integration

Ground Based Detect and Avoid
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

**Industry**
- Airworthy vehicle with integrated C2 and DAA equipage
- Other gap filling technologies required
- Specific Type Cert Basis

**Minimum contribution from Industry**

**Maximum contribution from NASA**

**FAA role**

Systems Integration and Operationalization (SIO) Partnership Venn
### SIO Notional Demonstration Strategy

**SIO Potential Stakeholders**
- RTCA SC-228
- FAA and Other Government Agencies
- Industry
- ICAO, EUROCAE

**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

---

**Timeline**

1. **Initial SIO resources to Centers**
2. **SIO Industry Day and RFI**
3. **Develop SIO CONOPs**
4. **Partners Selected**
5. **Technology Development**
6. **Conduct SIO Demonstration**

**Contribution**
- NASA DAA
- NASA C2
- Test Site Task

**SIO Vehicle Task Award**

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<tr>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
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</table>
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
• 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
<table>
<thead>
<tr>
<th>Partner (Project Area)</th>
<th>Agreement In Place</th>
<th>Collaboration/Partnership Role</th>
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</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>
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<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>
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<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>
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<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>
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<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>
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<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>
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<th>Partner (Project Area)</th>
<th>Agreement In Place</th>
<th>Collaboration/Partnership Role</th>
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<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>
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<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>
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<tr>
<td>RTCA SC-228 (TC-C2, TC-DAA)</td>
<td>NA</td>
<td>On-going support to DAA and C2 working groups</td>
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<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 Technical Standard Order (TSO)-C211 Detect and Avoid and TSO-C212 ATAR for Traffic Surveillance
  - 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 through a Research Transition Team (RTT) that includes all Lines of Business**
FY17 Accomplishments & FY18 Look Ahead

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
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<th>Technical Baseline Element Title</th>
<th>Reference Schedule Package Numbers</th>
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<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>
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<td>TBEN-006</td>
<td>Alternative Surveillance: Foundational Fast-time Simulation (FY17)</td>
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<td>* TBEN-007</td>
<td>Alternative Surveillance: Display Requirements</td>
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<td>* TBEN-008</td>
<td>Alternative Surveillance: Unmitigated Fast-time Simulation (FY18)</td>
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<td>* TBEN-009</td>
<td>Alternative Surveillance: HITL Simulation 1</td>
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<td>* TBEN-010</td>
<td>Alternative Surveillance: Unmitigated/Mitigated Fast-time Simulation (FY19)</td>
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<tr>
<td>* TBEN-011</td>
<td>DELETED September 2017 MRB: Alternative Surveillance: HITL Simulation 2</td>
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* Accomplishment chart not included
## TC-DAA Technical Baseline Elements (2/3)

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<td>Well Clear/Alerting Requirements: Foundational Terminal Operations HITL Simulation 1</td>
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<td>Well Clear/Alerting Requirements: Fast-time Simulation 2</td>
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<td>TBEN-018</td>
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<td>Integrated Event: Flight Test 5</td>
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</table>

* Accomplishment chart not included
**Alternative Surveillance and Well Clear/Alerting Requirements ConOps**

- **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
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
Well Clear/Alerting Requirements: Fast-time Simulation 2

**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

Technical Baseline Element Number: TBEN-014 (SP D.2.50)
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
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

Technical Baseline Element Number: TBEN-021 (SP D.5.20, SP T.8.30)
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**Legend:**
- ★ L1 Program (IASP)
- ✨ L2 Project
- 🔺 API Element

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

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TC-DAA Risk

- Data Redacted
TC-DAA Risk

- 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>Ku-Band Propagation Flights and Interference Analysis</td>
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<td>C-Band Design Study, Verification &amp; Validation Planning</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

Technical Baseline Element Number: TBEN-001 (SP C.5.10)
• **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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Green Status Line Date 9/30/17
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
Project Office Risk Summary

- 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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# Phase 2 Milestone Summary

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**Legend:**
- Level 1
- Level 2
- API Element

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**Legend:**
- ★ L1 Program (IASP)
- ★★ L2 Project

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