Agenda

8:30– 8:45  Welcome, Opening Remarks, Integrated Aviation Systems Program (IASP) Overview  Dr. Edgar Waggoner
8:45 – 9:30  UAS-NAS Overview  Davis Hackenberg
9:30 – 10:15  Technical Performance  William Johnson
10:15 – 10:30  Break
10:30 – 11:00  Technical Performance  William Johnson
11:00 – 12:00  Project Level Performance & Fiscal Year (FY) 19 Look Ahead Review Summary  Laurie Grindle
12:00  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 FY19
Outline

- UAS Integration in the NAS (UAS-NAS) Overview
  - FY18 Summary
  - UAS-NAS Project Background
- Technical Performance
- Project Level Performance & FY19 Look Ahead
- Review Summary
FY18 Summary

• Successful completion of multiple Project Research Activities (simulations and flight tests) in support of Phase 2 Detect and Avoid (DAA) and Command and Control (C2) Technical Challenges (TC)

• Successfully advanced the Systems Integration and Operationalization (SIO) Demonstration through Cooperative Agreements (CA) with selected Industry Partners

• Established Research Transition Team (RTT) formally with the Federal Aviation Administration (FAA)

• Successful continuous risk management
  – Flight Test (FT) 5 and 6

• Effective Schedule and Milestone management
## UAS-NAS Project Lifecycle

**Timeframe for impact: 2025**

<table>
<thead>
<tr>
<th>Prior</th>
<th>Phase 1 [FY11 - FY16]</th>
<th>Phase 2 [FY17]</th>
<th>Phase 2 [FY18]</th>
<th>Phase 2 [FY19]</th>
<th>Phase 2 [FY20]</th>
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</thead>
<tbody>
<tr>
<td>Formulation Review</td>
<td>Project Start, May 2011</td>
<td>KDP ▲ KDP-A ▲</td>
<td>KDP-C</td>
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<td>Project Closeout △</td>
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<td>Concept of Operations (ConOps), Community Progress, etc.</td>
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<td>Flight Validated Research Findings to Inform Federal Aviation Administration (FAA) Decision Making</td>
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<td>Formulation</td>
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<td>Technology Development to Address Technical Challenges</td>
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<td>External Input</td>
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</table>

**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
Personnel Changes

- Data Redacted
**NASA Strategic Plan Flow Down to UAS-NAS Project**

**STRATEGIC GOAL**

3: Address national challenges and catalyze economic growth

**OBJECTIVE**

3.2: Transform aviation through revolutionary technology research, development, and transfer

**PERFORMANCE GOAL**

3.2.6: 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 UAS in the NAS, through the development and maturation of technologies and validation of data

**Annual Performance Indicators (APIs)**

**UAS-NAS**

AR-18-10: Complete the data collection, analysis, and reporting for DAA well clear / alerting requirements, foundational terminal operations, HITL simulation; and complete the initial test asset for the C2 Version 6 (V6) terrestrial communication system test

AR-19-10: Complete the data collection, analysis, and reporting for the DAA and IT&E FT5 and for the C2 V6 terrestrial communication system flight test

**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 UAS into the NAS
ARMD Strategic Plan Flow Down to UAS-NAS Project

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

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

**Critical Commitment:**
Deliver validated flight data to RTCA for MOPS enabling persistent UAS flight in Class E airspace

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

**TC-DAA:**
Detect and Avoid

**SIO:**
Systems Integration and Operationalization

*Note: UAS-NAS is also related to Thrust 1 through the Thrust TC - Develop Operational Standards for UAS in NAS*
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.
Commercial Operating Environments (OE)

- **High Altitude**
  - FL 600
  - IFR-Like
  - 18K' MSL
  - 10K' MSL
  - VFR-Like
  - Top of Class G

- **Low Altitude**
  - Urban Passenger Transport
  - URBAN URBAN
  - 500' AGL
  - Low Altitude Rural
  - Top of URBAN AIRSPACE

- **Cooperative Traffic**
  - Hot air Balloon
  - Helicopters

- **Non-Cooperative Traffic**
  - GA Aircraft

- **Commercial Operating Environments (OE)**

- **TOP OF URBAN AIRSPACE**
  - 500' AGL

- **VLOS**
  - Airport
  - Terminal Airspace
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

---

The UAS Airspace Integration Pillars enable achievement of the 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.
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
  - Low Cost SWaP sensors
  - Well Clear
  - Collision Avoidance
- Develop DAA Performance & Interoperability Requirements

**Integrated Test & Evaluation**
- Develop DAA Prototype System
- Live Virtual Constructive (LVC) Test Infrastructure
  - Conduct Technology and ConOps testing
  - 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
- Conduct Demo

**Key Products**
- C2 Performance Requirements to inform C2 MOPS
- DAA Performance Requirements to inform DAA MOPS
- Re-usable Test Infrastructure
- Progress Toward Certification

**Resultant Outcomes**
- C2 Technical Standard Order (TSO)
- DAA Technical Standard Order (TSO)
- Generic Certification and Airworthiness Approaches
# Phase 2 Flight and Simulation Overview

<table>
<thead>
<tr>
<th>Flight / Sims Series</th>
<th>FY2017</th>
<th>FY2018</th>
<th>FY2019</th>
<th>FY2020</th>
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<td>Ku-Band SatCom</td>
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<td>Alternative Surveillance</td>
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<td>Human Automation Teaming</td>
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<td>SIO/FAA Test Site Tasks</td>
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**Red Status Line Date 9/30/18**
Progress Indicator Definition

- Technical Challenge progress is tracked by means of Progress Indicators (PI)
  - Schedule Package (SP) L2 milestones are the data points for these plots
- Progress Indicators, i.e. lower portion of the plot, represent execution/data collection of Project SP activities
- Tech Transfer (i.e. upper portion of the plot), plotted to coincide with execution, represents the data analysis and reporting of SP Activities
- Assessed individual contribution towards achieving the overall technical challenge
  - High = 2, i.e. Integrated Tests
  - Moderate = 1, i.e. multiple subproject technologies
  - Low = 0, i.e. foundational activities
- Results normalized and placed on a 10 point maturity scale represents meeting the content of the TC
- Progress is tracked against all the tasks in the schedule package using a color indicator
Outline

• UAS-NAS Overview

• Technical Performance
  – TC-DAA
  – TC-C2
  – SIO

• Project Level Performance & FY19 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)

UAS Detect and Avoid (DAA) Operating Environments (OE)

DAA System for Operational Altitudes (> 500ft AGL)

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

Cooperative Traffic
ACAS Xu
ADS-B & TCAS–II
Airborne Radar

Non-cooperative Aircraft

"VFR-like" UAS

Altarative DAA Sensors

C2 Datalink

UAS Ground Control Station

GBDAA Data

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.
**Research Objective:**

- Explore pilot performance and operational suitability issues associated with Class D terminal area operations
  - Implement two candidates for a terminal area DAA well clear (DWC) definition
  - Further investigate the efficacy of the DAA Corrective alert in the terminal area
  - Compare pilot and system performance to previous studies

**DWC Candidate (Within-Subjects):**

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<th>DWC Candidate</th>
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<th>Tau</th>
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<td>Vertical Threshold</td>
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<tr>
<td>modTau</td>
<td>N/A</td>
<td>15sec</td>
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</tbody>
</table>

*HMD in Tau definition

**Status:**

- Experiment design completed December 2017
- Data collection completed February 2018
- Results dissemination completed May 2018
- Technical Baseline Element completed May 2018

**Results support definition of Terminal Area Well Clear**

Technical Baseline Element Number: TBEN-024 (SP D.2.90)
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 an 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
- NCC Approval received March 2018
- NCC Demonstration Flights completed June 2018
- NCC Flight Test Report completed August 2018

FAA (AJT): “…successful event ... no different than a manned flight…”

Technical Baseline Element Number: TBEN-023 (SP T.8.20)
DAA Flight Test 5 (FT5) - Original

Flight Test ConOps

- NASA Sensor Integrated Environment Remote Research Aircraft (SIERRA-B) Group 3 UAS equipped with Low size, weight, and power (SWaP) air to air (A/A) sensors performing unmitigated DAA encounters with manned intruder(s)
  - A/A sensor tracks downlinked to the Ground Control Station (GCS) for processing by DAA algorithm
    - NASA SIERRA-B equipped with non-cooperative and cooperative (Automatic Dependent Surveillance-Broadcast (ADS-B) In) sensors and a tracker to correlate multiple sensor tracks
  - DWC alerts and maneuver guidance provided on standalone DAA display
  - UAS pilot employs DAA display to meet encounter test objectives
DAA Flight Test 5 (FT5) - New

Flight Test ConOps

- NASA SIERRA-B Group 3 UAS - Honeywell AStar manned helicopter equipped with Low SWaP A/A sensors performing unmitigated DAA encounters with manned intruder(s)
  - A/A sensor tracks downlinked to the GCS stored onboard the aircraft for post-processing by DAA algorithm
  - NASA SIERRA-B Helicopter equipped with non-cooperative and cooperative (ADS-B In) sensors and a tracker to correlate multiple sensor tracks
  - DWC alerts and maneuver guidance provided on standalone DAA display
  - UAS pilot employs DAA display to meet encounter test objectives

Addressed by analysis and post-processing of flight data

Successful Technology Readiness for FT6
Original FT6 Operational Plans

Flight Test ConOps

- NASA SIERRA-B Group 3 UAS equipped with Low SWaP A/A sensors performing unmitigated and mitigated DAA encounters with manned intruder(s)
  - A/A sensor tracks downlinked to the GCS for processing by DAA algorithm
    - NASA SIERRA-B equipped with non-cooperative and cooperative (ADS-B In) sensors and a tracker to correlate multiple sensor tracks
  - DWC alerts and maneuver guidance provided on Vigilant Spirit Control System GCS
  - UAS pilot employs DAA display to meet encounter test objectives
  - Full mission operations with pilot performance data to validate Human in the Loop (HITL) results

Note: Blue font represents changes from FT5
New FT6 Operational Plans

Picture removed

NASC TigerShark XP

NASA AFRC Test Range

DAA Unmitigated and Mitigated Encounters with Intruders

Successful Data Collection for DAA Standards Development

Flight Test ConOps

- NASA SIERRA-B Navmar Applied Sciences Corporation (NASC) TigerShark XP Group 3 UAS equipped with Low SWaP A/A sensors performing unmitigated and mitigated DAA encounters with manned intruder(s)
  - A/A sensor tracks downlinked to the GCS for processing by DAA algorithm
  - NASA SIERRA-B NASC TigerShark XP equipped with non-cooperative and cooperative sensors and a tracker to correlate multiple sensor tracks
  - DWC alerts and maneuver guidance provided on Vigilant Spirit Control System GCS
  - UAS pilot employs DAA display to meet encounter test objectives
  - Full mission operations with pilot performance data to validate HITL results

Picture removed

Nose section to be modified to accommodate the DAPA-Lite sensor and radome
FAA Test Site Ground Based Detect and Avoid Demonstration

• **Goal:** Implement a GBDAA system with long term strategic value to NASA, FAA, and industry partners
  – 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 a means for industry to evaluate technologies and procedures for low level BVLOS use cases
  – Provide a foundation for future commercial waivers seeking operational capability for industry applications

• **Status:**
  – Two of three flight campaigns using General Aviation (GA) aircraft have been completed
    ▪ Campaign 1 completed July 10-12. 29 test instances flown with 1 GA aircraft using 3 radar sites
    ▪ Campaign 2 completed August 1-2. 11 test instances flown with 2 GA aircraft using 3 radar sites
  – Sensor model development is ongoing

• **Next Steps**
  – Complete Campaign 3 flight test October 22-26
  – Sensor models and final report to be provided to NASA December 2018

Not included in Project Technical Baseline
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)

SatCom C2 Data Link

Terrestrial C2 Data Link

FL-600

18K’ MSL

10K’ MSL

Top of Class G

SatCom/BLOS Link

Non-cooperative Traffic

“VFR-like” UAS

Urban Air Mobility (UAM) C2 Data Link Study

Terrestrial C2 Data Link

“IFR-like” UAS

SatCom Link

Cooperative Traffic

Communications Satellite

CNPC Ground Stations

SatCom Transmitter

UAS Ground Control Station

Land Line

Urban Air Mobility (UAM) C2 Data Link Study

SatCom Link

CNPC Network

Phase 1 Research Areas (FY14 – FY16)
Phase 2 Research Areas (FY17 – FY20)
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.
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 (V6) Preliminary Design Review (PDR) completed July 2017
  - V6 Critical Design Review (CDR) completed October 2017
  - V6 Flight Test started July 2018

- **Next Steps:**
  - Terrestrial-Based V6 Flight Test to be completed October 2018
  - Terrestrial-Based Version 7 (V7) Flight Test to be completed July 2019
  - Terrestrial-Based UAS Command & Control Final Report to be completed July 2020
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 Notional Demonstration Strategy

<table>
<thead>
<tr>
<th>SIO Goals</th>
<th>SIO Partnership Strategy</th>
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<tbody>
<tr>
<td>Goal: Work toward routine commercial UAS operations in the NAS</td>
<td>Industry Partnership Strategy</td>
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<tr>
<td>• Obtain approval to operate in the NAS for a FY20 flight demonstration</td>
<td>• Agreements established to conduct industry centric SIO demonstrations in FY20</td>
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<tr>
<td>• Demonstrate integrated DAA and C2 technologies</td>
<td>• Leverage NASA expertise to inform UAS development and integration of DAA, C2, and other technologies required for commercial missions</td>
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<tr>
<td>• Progress toward Type Certification</td>
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Industry Partnership Strategy
- Agreements established to conduct industry centric SIO demonstrations in FY20
- Leverage NASA expertise to inform UAS development and integration of DAA, C2, and other technologies required for commercial missions

FAA Partnership Strategy
- Work through the UAS Integration RTT to obtain approvals, and impact policy, procedures, and regulations

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![Timeline Diagram](image)

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<thead>
<tr>
<th>SIO Goals</th>
<th>SIO Partnership Strategy</th>
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<tr>
<td>Initial SIO resources to Centers</td>
<td>Industry Partnership Strategy</td>
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<tr>
<td>SIO Industry Day and RFI</td>
<td>• Agreements established to conduct industry centric SIO demonstrations in FY20</td>
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<tr>
<td>Partners Selected</td>
<td>• Leverage NASA expertise to inform UAS development and integration of DAA, C2, and other technologies required for commercial missions</td>
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<tr>
<td>Technology Development and Integration</td>
<td>FAA Partnership Strategy</td>
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<tr>
<td>Conduct SIO Demonstrations</td>
<td>• Work through the UAS Integration RTT to obtain approvals, and impact policy, procedures, and regulations</td>
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| SIO Vehicle Task Award | SIO Vehicle Task Demo |

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<thead>
<tr>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
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Research Objective:
- Assess the state-of-the-art of individual UAS vehicle technologies for a Concept of Operations (ConOps) that is consistent with NASA’s UAS Operational Environments.

Status:
- Two UAS flight demonstrations completed
  - Demo 1: Completed May 14-16, focused on nominal UAS operations
  - Demo 2: Completed July 16-19, focused on demonstration of technologies for lost link operations, including weather avoidance, an automated voice capability, and obstacle detection during taxi.
- An outreach day was held on July 19, and included representatives from NASA, Air Force Research Lab (AFRL), and industry.

Next Steps:
- Key data from the flight demonstrations will be analyzed to inform RTCA SC228 and future NASA research areas.
- A report will be provided to NASA by October 2018.
### Selected/Awarded SIO Partners

#### Bell

**Mission:** Cargo delivery in urban areas  
**Vehicle:** Autonomous Pod Transport - 70 (APT70) electric Vertical Take Off and Landing (VTOL) (240 to 500 lb, depending on configuration)  
**Test Locations:** Wrangler Field (remote area), and Arlington Municipal Airport (urban), Texas

#### General Atomics

**Mission:** Infrastructure inspection in Instrument Flight Rules (IFR)-Like airspace  
**Vehicle:** SkyGuardian (12,500 lb)  
**Test Location:** Southern California and Arizona

#### PAE ISR (Awarded September 25)

**Mission:** Pipeline inspection in Visual Flight Rules (VFR)-Like airspace  
**Vehicle:** Resolute Eagle (210 lb)  
**Test Location:** Pendleton Oregon UAS Range (part of Alaska FAA UAS test site)
### Systems Integration and Operationalization (SIO)

**Timeline Not To Scale**

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<th>Milestone</th>
<th>Type</th>
<th>Date</th>
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<tr>
<td>Cooperative agreements with Industry Partners signed</td>
<td>L2</td>
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<tr>
<td>Baseline Mission ConOps and Risk-Based Safety Assessment documents complete</td>
<td>L3</td>
<td>7/30/19</td>
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<tr>
<td>Airworthiness approvals for SIO demonstration</td>
<td>L2</td>
<td>7/30/20</td>
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<tr>
<td>Documentation of type certification lessons learned and guidelines provided to Project Office</td>
<td>L3</td>
<td>7/30/20</td>
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<tr>
<td>SIO demonstration complete</td>
<td>L2</td>
<td>8/31/20</td>
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<td>SIO Final Report provided to project office and submitted for review and export release</td>
<td>L3</td>
<td>9/18/20</td>
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- **L1 Milestone**
- **L2 Milestone**
- **L3 Milestone**
- **Significant Event**

### ConOps and Risk Based Safety Assessment
- **6/19**

### Project Specific Certification Plan
- **12/19**

### SIO Demo complete
- **8/20**

### All airworthiness artifacts provided
- **7/20**

### Type Certification Discussions with FAA

**SC-228 P1 MOPS and Draft Phase 2 MOPS**
Technical Performance Summary

- **TC-DAA**
  - Completed No Chase COA flights in the NAS
  - Completed experiment designs, infrastructure preparations, and/or data collection for multiple experiments
  - Delivered data from simulations

- **TC-C2**
  - Conducted terrestrial based Version 6 radio systems development
  - Completed C-Band Satellite Communications (SatCom) Payload & Earth Station Concept Design
  - ConOps for Urban Air Mobility (UAM) C2 Study delivered

- **SIO**
  - Three partners identified
  - ConOps presented at SIO RTT planning meeting
  - Detailed schedules in work and resources being assigned

**Conducting experiments critical to C2 & DAA MOPS; SIO execution underway**
Outline

• UAS-NAS Overview
• Technical Performance
• Project Level Performance & FY19 Look Ahead
  – Risk Summary
  – Resource Allocation and Utilization
  – Schedule Performance
  – Partnerships and Collaboration
  – FAA/NASA UAS Integration Research Transition Team
  – UAS-NAS and Urban Air Mobility (UAM)
  – International Participation and Collaboration
  – FY18 Accomplishments and FY19 Look Ahead
  – FY20 Closeout Planning
• Review Summary
• Data Redacted
FY18 Top Risks

• Data Redacted
Storm Clouds

• Data Redacted
Resource Allocation against Baseline Budget

• Data Redacted
Resource Utilization FY18
Budget vs. Actuals Summary

• Data Redacted
• Data Redacted
Schedule Performance

• Phase 2 Milestone Count
  – Completed 2 of 7 Level 1 Milestones
  – Completed 34 of 66 Level 2 Milestones
    ▪ Experienced some delays to L2 milestones

• Causes of Level 2 Milestone Delays
  – DAA and C2 technical scope changes implemented to better align with community requirements
  – C2 Version 6 radio performance issues impacted delivery
  – SIERRA-B airworthiness and envelope expansion tests
  – FAA Spectrum Office RF authorization for No Chase COA

• Utilize continuous risk management to identify schedule impacts

• L2 Milestone delays did not impact downstream Level 1 or 2 Milestones

Successful Milestone Management
## Current Active Collaborations/Partnerships Status (1 of 3)

<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>Space Act Mar-17 to Sep-18</td>
<td>On-going collaboration with AFRL supporting use of Vigilant Spirit Control Station (VSCS) on DAA activities. AFRL has agreed to a NASA “leave behind” simulation capability after the agreement expires</td>
</tr>
<tr>
<td><strong>Bell (SIO Selectee)</strong></td>
<td>Cooperative Agreement In Process</td>
<td>Selectee for the SIO Demonstration. Mission is to conduct emergency medical supply delivery in Urban Areas with the Autonomous Pod Transport - 70 (APT70) electric VTOL</td>
</tr>
<tr>
<td>FAA UAS Integration (Project Office, TC-DAA, TC-C2)</td>
<td>RTT</td>
<td>Support by FAA leadership, management, and technical subject matter experts to validate work being done by the Project. On-going coordination of Research Transition Products (RTPs) within the UAS Integration RTT</td>
</tr>
<tr>
<td>FAA Aviation Safety (AVS) and NextGen (AUS) (Project Office, TC-DAA, TC-C2)</td>
<td>RTT</td>
<td>Coordination of RTPs within the UAS Integration RTT</td>
</tr>
<tr>
<td>FAA Air Traffic Organization (ATO) (Project Office, TC-DAA, TC-C2)</td>
<td>RTT / Controlled Airspace ARC</td>
<td>Primary organization managing the Controlled Airspace ARC where the project actively participates. Coordination of RTPs within the UAS Integration RTT</td>
</tr>
<tr>
<td>FAA UAS Test Sites (Project Office)</td>
<td>IDIQ Contract Aug-15 to Sep-20</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 (Griffiss International Airport with the following subcontractors: Aurora, MTSI, NUAIR, AX Enterprize, Gryphon Sensors, Navmar Applied Sciences Corp.) Activities with the test sites are ongoing</td>
</tr>
</tbody>
</table>

*Purple text indicates changes since FY17 Annual Review*
### Current Active Collaborations/Partnerships Status (2 of 3)

<table>
<thead>
<tr>
<th>Partner (Project Area)</th>
<th>Agreement In Place</th>
<th>Collaboration/Partnership Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Atomics (TC-DAA)</td>
<td>Space Act Sep-14 to Feb-20</td>
<td>Ikhana equipped with avionics and Proof of Concept DAA system directly supported by UAS-NAS Project. General Atomics supported the No Chase COA flight</td>
</tr>
<tr>
<td>General Atomics (SIO Awardee)</td>
<td>Cooperative Agreement In process</td>
<td>Selectee for the SIO Demonstration. Mission is to inspect infrastructure in IFR-like airspace with the SkyGuardian unmanned aircraft</td>
</tr>
<tr>
<td>Honeywell (TC-DAA)</td>
<td>Cooperative Agreement Oct-17 to Sep-20</td>
<td>Partner for the DAA low SWaP non-cooperative sensor in support of data-buy. Agreement modification processed to include data-buy in support of FT5</td>
</tr>
<tr>
<td>LinQuest (TC-C2)</td>
<td>Contract Oct-17 to Sep-20</td>
<td>Completed a conceptual system design study of the UAS C2 SatCom System, payload &amp; earth station conceptual design, and Hosted Payload Study Report</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</td>
</tr>
<tr>
<td>NASC (TC-DAA)</td>
<td>Contract Sep-18 to Oct-19</td>
<td>The NASC TigerShark is the test vehicle for FT6</td>
</tr>
<tr>
<td>PAE-ISR (SIO Awardee)</td>
<td>Cooperative Agreement Oct-18 to Aug-20</td>
<td>SIO Demonstration awardee. Mission is to inspect infrastructure in VFR-like airspace with the Resolute Eagle unmanned aircraft</td>
</tr>
</tbody>
</table>

*Purple text indicates changes since FY17 Annual Review*
<table>
<thead>
<tr>
<th>Partner (Project Area)</th>
<th>Agreement In Place</th>
<th>Collaboration/Partnership Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rockwell Collins (TC-C2)</td>
<td>Cooperative Agreement Nov-11 to Oct-20</td>
<td>Cost sharing agreement for CNPC radio development and flight test support for V6 radios in FY18 and V7 radios in FY19. FY20 support for final CNPC radio summary report</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. NASA C2 CNPC radio testing is coordinated with SC-228 to support the development and validation of the C2 Link Systems MASPS and the CNPC Link System MOPS (terrestrial) DO-362A</td>
</tr>
<tr>
<td>RTCA SC-147 (TC-DAA)</td>
<td>NA</td>
<td>Close coordination on DAA standards required for success of P2 MOPS. Hosting workshops to ensure success of both working groups. Ad Hoc FAA/NASA working group established to coordinate ACAS Xu research</td>
</tr>
<tr>
<td>Science And Research Panel (SARP) (TC-DAA)</td>
<td>NA</td>
<td>Multi-UAS HITL results presented at the SARP special meeting on multi-UAS control. This work investigated the scalability of the Phase 2 well clear definition to multi-UAS control with clear applicability to other domains, e.g., UAM</td>
</tr>
</tbody>
</table>

Purple text indicates changes since FY17 Annual Review
FAA/NASA UAS Integration Research Transition Team

- Phase 2 collaboration between NASA and the FAA is being coordinated through a RTT that includes all FAA Lines of Business

- There are currently five Working Groups (WGs) within the UAS Integration RTT each with their own focus:
  - C&TA WG: Developing commercial concepts of use for UAS Integration
  - DAA WG: Coordinating SC-228 related DAA research
  - C2 WG: Coordinating SC-228 related C2 research
  - NCC WG: Coordinating all aspects of the 2018 NCC Flight
  - SIO WG: Coordinating all aspects of the 2020 SIO demonstration

Collaboration Across RTT WGs
Accomplishments/Next Steps for the UAS Integration RTT

• 2018 Accomplishments
  – The Joint Management Plan (JMP) was signed February 5, 2018
  – All work under RTCA SC-228 for DAA and C2 were coordinated with the FAA lines of business
  – The NCC flight was successfully completed on June 12, 2018.
    ▪ The FAA played a significant role in helping NASA with COA, operational, and frequency approvals
  – The C&TA WG provided input to NASA on potential SIO ConOps to assist in the CAN review process
    ▪ The FAA provided three reviewers to assist in the SIO selection process.
  – A new SIO WG was established which will operate in a similar manner to the NCC WG as the 2020 demonstration approaches

• Next steps for the UAS Integration RTT
  – The NCC WG will be sunset at the next Executive Meeting
  – Continuation of Research Transition Product (RTP) delivery will occur throughout the duration of the Project
  – The FAA briefing of UAS Implementation Research Plan on September 27, 2018 may lead to future joint planning to help shape the ARMD UAS/autonomy research portfolio
UAS-NAS and Urban Air Mobility (UAM) Partnerships and Technology Transitions

- Complex UAS technology testing and standards verification and validation (V&V) experience
  - Vehicle and airspace interfaces and test techniques for emerging technologies such as DAA and C2
  - Experience in scenario development for UAM HITLs and Grand Challenge
  - Experience on standards V&V and FAA approvals

- Live Virtual Constructive Development
  - Development of LVC-DE environment that supports varying test infrastructure needs
  - Adaptable to external test ranges and future UAM partners
  - UAMPort (i.e. vertiport) visualizations and demonstrations

- Partnerships lessons learned
  - SIO implemented and baselined; “mini-Grand Challenge”
  - Explores unique NASA/industry partnership models

Leveraging UAS-NAS technologies to assess the UAM concept and support research
International Participation and Accomplishments

• International Civil Aviation Organization (ICAO)
  – Accomplishments:
    ▪ The Human In The System (HITS) outline was complete
    ▪ Writing assignments were agreed upon and distributed
  – Next Steps:
    ▪ The HITS team will write a chapter for the Remotely Piloted Aircraft Systems (RPAS) Panel’s Remote Pilot Station (RPS) manual
      • Drafts are due March 1, 2019, Final to secretariat due July 1, 2020
      • The next HITS meeting will be at Ames

• European Organization for Civil Aviation Equipment (EUROCAE)
  – Accomplishments:
    ▪ Participated in the development of the Operational Services Environment Description (OSED) for DAA related to European Classes A-C, D-G, and Very Low Level (VLL)
      • The OSEDs are an incremental step to creating international standards
      • The OSEDs for A-C and D-G are out for review
  – Next Steps:
    ▪ OSED for VLL will be completed by the end of calendar 2018
    ▪ Develop Minimum Aviation System Performance Standards (MASPS) and Minimum Operational Performance Standards (MOPS) to be submitted to ICAO for the development of global Standards and Recommended Practices (SARPS)

International standards organizations accepting US standards accelerates the time to market for UAS manufacturers
FY18 Accomplishments

- Rania Ghatas: won best paper and received publication in their bound volume for her paper on “The Effects of Alert Scoring and Alert Jitter on a MOPS UAS DAA System” at the 5th ENRI International Workshop on ATM/CNS (EIWAC)

- Dr. Lisa Fern: former DAA Tech Lead was recognized by RTCA for her contributions to DO-365, “DAA MOPS Phase 1 and DO-365, MOPS for Air-to-Air Radar DAA Systems Phase 1”

- DAA team: NASA Group Achievement Award for their work that formed the basis of national standard, “DO-365: MOPS for DAA Systems”

- Laurie Grindle: NASA Outstanding Leadership Medal

- Robert Sakahara: NASA Exceptional Achievement Medal

- Cesar Munoz: won the best in session and best in track awards for his paper on Sensor Uncertainty Mitigation and Well Clear Volumes In Detect and Avoid Alerting Logic for Unmanned Systems (DAIDALUS), at the Digital Avionics Systems Conference 2018
FY18 Accomplishments & FY19 Look Ahead

FY18 Accomplishments
• TC: Detect and Avoid
  – Simulations: Terminal Ops HITL 1B; Multi-UAS HITL Simulation
  – Flight Tests: No Chase COA Flight Demonstration; Flight Test 5/6 Planning
• TC: Command and Control
  – C-band SatCom: Hosted Payload Study Report
  – UAM Study: UAS C2 System ConOps
• Systems Integration and Operationalization
  – Industry coordination and CAN release
  – Industry Partner selection and award
• FAA Test Sites
  – GBDAA task order 4 test activities
  – Vehicle and ConOps task order 5 test activities
• Project
  – Establishment of Research Transition Team

FY19 Look Ahead
• DAA Simulations: ACAS Xu HITL, Terminal Area HITL, Fast Time Simulation
• Flight Tests: Data Collection for FT5 & FT6; CNPC Radio V6 & V7
• Submit Consolidated Input for DAA MOPS Rev A to RTCA
FY20 Closeout Planning

• Project Completion date set for September 30, 2020
  – Two years left on Project; ramping down personnel in FY20 for DAA, IT&E and C2

• Notional Closeout requirements/content
  – Transition of technologies and relationships to appropriate ARMD projects/programs
  – Final project plan to address:
    ▪ Description of research and/or technology advancement
    ▪ Performance relative to goals and threshold requirements
    ▪ Lessons learned
    ▪ Dissemination and/or storage/archival approach utilized, and
    ▪ Results of any independent assessments
    ▪ Continuation of contract mechanisms and partner agreements
  – AFRC Project closeout checklist (additional items)
    ▪ Systems decommissioning/disposal
    ▪ Risk status
    ▪ Funding/budget

• Schedule:
  – Update Project Plan (new section) – November 2018
  – IASP Terms of Reference – December 2019
  – Closeout Review Meeting – July 2020
  – Project Final Report – September 2020
Outline

- UAS-NAS Overview
- Technical Performance
- Project Level Performance & FY19 Look Ahead
- Review Summary
FY18 Summary

✓ Successful completion of multiple Project Research Activities (simulations and flight tests) in support of Phase 2 Detect and Avoid (DAA) and Command and Control (C2) Technical Challenges (TC)

✓ Successfully advanced the Systems Integration and Operationalization (SIO) Demonstration through Cooperative Agreements (CA) with selected Industry Partners

✓ Established Research Transition Team (RTT) formally with the Federal Aviation Administration (FAA)

✓ Successful continuous risk management
  ✓ Flight Test (FT) 5 and 6

✓ Effective Schedule and Milestone management

Successfully executing technical portfolio
UAS-NAS Technical Performance
Backup Slides
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 Traffic**
  - Non-cooperative Aircraft

- **Cooperative Traffic**
  - Cooperative Aircraft

- **Terminal Airspace**
  - Airport

- **FL-600**
  - 18K' MSL

- **Agricultural Aircraft**
  - Helicopters

- **VLOS**
  - Restricted Access

- **Routine Access**
  - TIME (Notional)
UAS-NAS Technical Challenge Autonomy Contributions

Thrust 6: Assured Autonomy for Aviation Transformation

Outcome (2015 – 2025):
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

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

**Outcome (2015 – 2025):**
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

**UAS-NAS Technical Content**

**AERONAUTICS STRATEGIC THRUST**

**AERONAUTICS OUTCOME**

**AERONAUTICS Research Theme**

**AERONAUTICS Overarching Technical Challenge**
UAS Integration / Project Background

- Each 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 for DAA and C2 do not cover the broad needs for all OEs or UAS Vehicle Technologies
- 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
## TC-DAA Technical Baseline Elements (1/4)

<table>
<thead>
<tr>
<th>Technical Baseline Element Number</th>
<th>Technical Baseline Title</th>
<th>Reference SP Numbers</th>
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<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 (Complete 2/13/18)</td>
<td>SP D.1.50</td>
</tr>
<tr>
<td>TBEN-008</td>
<td>Alternative Surveillance: Unmitigated Fast-time Simulation for Low SWaP Sensors Using Surveillance Volume and Uncertainties with Updated DAA Well Clear Definition (FY18)</td>
<td>SP D.1.60</td>
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<td>TBEN-009</td>
<td>Alternative Surveillance: HITL Simulation 1</td>
<td>SP D.1.70, SP T.7.20</td>
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<tr>
<td>TBEN-010</td>
<td>Alternative Surveillance: Unmitigated/Mitigated Fast-time Simulation (FY19)</td>
<td>SP D.1.80</td>
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<td>Technical Baseline Element Number</td>
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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>
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<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-015</td>
<td>Deleted September 28 2017 MRB, CR178: Well Clear/Alerting Requirements: Fast-time Simulation 3</td>
<td>SP D.2.60</td>
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<tr>
<td>TBEN-016</td>
<td>Well Clear/Alerting Requirements: HITL Simulation 2</td>
<td>SP D.2.70</td>
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<td>TBEN-017</td>
<td>Well Clear/Alerting Requirements: HITL Simulation 3</td>
<td>SP D.2.80</td>
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<tr>
<td>TBEN-018</td>
<td>ACAS-Xu: Mini HITL Simulation</td>
<td>SP D.3.20</td>
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<tr>
<td>TBEN-019</td>
<td>ACAS-Xu: HITL Simulation 1</td>
<td>SP D.3.50, SP D.7.30</td>
</tr>
<tr>
<td>TBEN-020</td>
<td>Integrated Event: ACAS-Xu Flight Test 2 (Complete 10/23/17)</td>
<td>SP D.5.10, SP T.8.10</td>
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<tr>
<td>TBEN-021</td>
<td>Integrated Event: Flight Test 5</td>
<td>SP D.5.20</td>
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<td>TBEN-022</td>
<td>Integrated Event: Flight Test 6</td>
<td>SP D.5.30, SP T.8.40</td>
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<td>TBEN-023</td>
<td>No-Chase Certificate of Waiver or Authorization Flight Demonstration</td>
<td>SP T.8.20</td>
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<tr>
<td>TBEN-024</td>
<td>Well Clear/Alerting Requirements: Foundational Terminal Ops HITL Simulation 1B</td>
<td>SP D.2.90, T.7.50</td>
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<tr>
<td>TBEN-025</td>
<td>Deleted February 22, 2018 MRB, CR185: External Coordination: DAA-C2 Latency Sensitivity HITL Simulation</td>
<td>SP-D.4.60, T.7.60</td>
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<td>Technical Baseline Element Number</td>
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<tr>
<td>TBEN-026</td>
<td>Human Automation Teaming: Multi UAS HITL</td>
<td>SP D.6.10</td>
</tr>
<tr>
<td>TBEN-027</td>
<td>Human Automation Teaming: Automatic Execution of CA and Return to Course Analysis</td>
<td>SP D.6.20</td>
</tr>
</tbody>
</table>
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

---

<table>
<thead>
<tr>
<th>Ownership Scenario</th>
<th>Description</th>
<th>Route Variations</th>
</tr>
</thead>
</table>
| Instrument Approach | • RNAV (GPS) Ryw 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 patterns 1100ft | 1. 45° entry into the downwind  
2. Mid-field entry |

---

• Status:
  – Experimental design, including Stakeholder/Partner Workshop, completed July 2017
  – Data collection completed October 2017
  – Results dissemination completed December 2017
  – Technical Baseline Element completed December 2017

Results accepted by SC-228; Shaping DAA MOPS development

Technical Baseline Element Number: TBEN-012 (SP D.2.30, T.7.10)
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 November 2017
- Well Clear/Alerting Requirements ConOps completed January 2018
- Technical Baseline Element completed January 2018
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
- Final results dissemination to SC-228 completed February 2018
- Technical Baseline Element completed February 2018

Results accepted by SC-228; Shaping Alternative Surveillance MOPS Requirements

Technical Baseline Element Number: TBEN-006 (SP D.1.40)
Alternative Surveillance: Display Requirements

✓ Research Objective:

– Define DAA system display requirements for UAS with alternative surveillance systems within UAS operations associated with Phase 2 MOPS

• Status:

  – Definition of human factors issues completed February 2018
  – Definition of requirements completed February 2018
  – Definition of display options, as a list of display recommendations, completed February 2018
  – Technical Baseline Element completed February 2018

Display recommendations support future human-in-the-loop simulation
Alternative Surveillance: Unmitigated Fast-time Simulation (FY18)

✓ Research Objective:
  – Verify DAA alerting and surveillance performance with surveillance volume and uncertainties and updated DAA Well Clear definition within UAS operations associated with Phase 2 MOPS

• Status:
  – Experiment Review completed March 2018
  – Data Collection completed June 2018
  – Data analysis completed August 2018
  – Results disseminated September 2018
Alternative Surveillance: HITL Simulation 1

- **Research Objective:**
  - Verify 1) UAS pilot performance of an DAA system with low size, weight, and power sensors, 2) interoperability of low size, weight, and power sensor requirements with DAA alerting, guidance, and display requirements, and identify modifications to alerting, guidance and display requirements for low size, weight, and power sensors as needed

- **Status:**
  - Experiment design started April 2018
  - Experiment design completed September 2018

- **Next Steps:**
  - Data collection to be completed November 2018
  - Results dissemination to be completed January 2019
Research Objective:
- Inform and verify draft for final DAA and Non-cooperative Sensor Phase 2 MOPS

Next Steps:
- Experiment plan to be completed March 2019
- Data collection to be completed April 2019
- Results dissemination to be completed August 2019
Well Clear/Alerting Requirements: Foundational Terminal Operations Fast-time Simulation 1

✓ Research Objective:
  – Collect empirical data to address well clear issues

• Status:
  – Experiment design and shakedown completed July 2017
  – Data collection completed August 2017
  – Results dissemination completed December 2017
  – Technical Baseline Element completed December 2017

Results accepted by SC-228; Shaping future simulations and DAA MOPS development

Technical Baseline Element Number: TBEN-013 (SP D.2.40)
Well Clear/Alerting Requirements: Fast-time Simulation 2

✓ Research Objective:
  – Collect empirical data to address well clear issues

• Status:
  – Experiment design and shakedown completed July 2017
  – Data collection completed August 2017
  – Results dissemination completed March 2018
  – Technical Baseline Element completed March 2018

Results accepted by SC-228; Shaping future simulations and DAA MOPS development

Technical Baseline Element Number: TBEN-014 (SP D.2.50)
Well Clear/Alerting Requirements: Well Clear/Alerting Requirements: HITL Simulation 2

• **Research Objective:**
  – Verify 1) pilot performance of Class D and E terminal area operations and 2) DAA algorithm configurable parameters for Class D and E terminal area operations

• **Status**
  – Preliminary Experiment Review completed May 2018
  – Final Experiment Plan completed September 2018

• **Next Steps:**
  – Data collection to be completed November 2018
  – Results dissemination to be completed January 2019

Technical Baseline Element Number: TBEN-016 (SP D.2.70)
Well Clear/Alerting Requirements: HITL Simulation 3

- **Research Objective:**
  - Verify 1) pilot performance of Class E and G terminal area operations with no operating Airport Traffic Control Tower and 2) DAA algorithm configurable parameters for Class E and G terminal area operations with no operating Airport Traffic Control Tower

- **Next Steps:**
  - Experiment Design to be completed March 2019
  - Data collection to be completed July 2019
  - Results dissemination to be completed October 2019

Technical Baseline Element Number: TBEN-017 (SP D.2.80)
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
- Results dissemination completed February 2018
- Technical Baseline Element completed February 2018

Laboratory components installation acceptable; DAA results accepted by SC-228
ACAS-Xu: HITL Simulation 1

• **Research Objective:**
  – Investigate highest priority interoperability issues related to the impact of ACAS Xu integrated DAA Remain Well Clear and collision avoidance alerting and guidance on pilot performance

• **Next Steps:**
  – Experimental design including Stakeholder input to be completed January 2019
  – Data Collection to be completed May 2019
  – Results dissemination to be completed July 2019
  – Technical Baseline Element to be completed July 2019

Technical Baseline Element Number: TBEN-019 (SP D.3.50, T.7.30)
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
- Compare DAA alerts and guidance between ACAS Xu and NASA algorithms
- Evaluate interoperability between ACAS Xu and NASA’s DAA algorithms alerting and guidance

**Status:**
- Flight test completed August 2017 (12 flight tests / 56 flight hours, 241 flight cards / test points)
- Flight test data made available to FAA and contractor team following each flight
- Comparison of ACAS-Xu and DAIDALUS Detect and Avoid Systems briefing completed November 2017
- Public release of Flight test report completed October 23, 2017

**Flight Test Data Supported ACAS Xu MOPS Development**

Technical Baseline Element Number: TBEN-019 (SP D.5.10, T.8.10)
Integrated Event: Flight Test 5

• **Research Objective:**
  – Collect data to characterize the performance of the low size, weight, and power radar and to support development of the sensor model

• **Status:**
  – Contract modification with Honeywell completed September 2018

• **Next Steps:**
  – Data Collection to start October 2018
  – Data Delivery from Honeywell to be completed December 2018
  – Results to be disseminated March 2019

Technical Baseline Element Number: TBEN-021 (SP D.5.20, SP T.8.30)
Integrated Event: Flight Test 6

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

• **Status:**
  – Navmar Applied Sciences Corp awarded contract September 2018

• **Next Steps:**
  – Phase 2 CDR to be completed November 2018
  – System Checkout flights to be conducted May 2019
  – Radar Characterization flights to be conducted June 2019
  – FT6 Mission Flights to be conducted July 2019
  – Results to be disseminated March 2020

Technical Baseline Element Number: TBEN-022 (SP D.5.30, SP T.8.40)
Well Clear/Alerting Requirements: Foundational Terminal Ops HITL Simulation 1B

✓ Research Objective:
  – Explore pilot performance and operational suitability issues associated with Class D terminal area operations
    • Implement two candidates for a terminal area DAA well clear (DWC) definition
    • Further investigate the efficacy of the DAA Corrective alert in the terminal area
    • Compare pilot and system performance to previous studies

DWC Candidate (Within-Subjects):

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*HMD in Tau definition

• Status:
  – Experiment design completed December 2017
  – Data collection completed February 2018
  – Results dissemination completed May 2018
  – Technical Baseline Element completed May 2018

Results support definition of Terminal Area Well Clear
Human Automation Teaming: Multi UAS HITL

- **Research Objective:**
  - Investigate highest priority issues related to integration of the DAA system with multi-UAS control operations; Examine viability of 1:N and M:N operations with DAA

- **Status:**
  - Experiment design review complete June 2018
  - Data collection complete June 2018

- **Next Steps**
  - Results dissemination to be completed October 2018

Technical Baseline Element Number: TBEN-026 (SP D.6.10, T.7.70)
Human Automation Teaming: Automatic Execution of CA and Return to Course Analysis

• **Research Objective:**
  – Initial implementation of a Human Machine Interface to support effective auto-RA execution and return to course to inform SC-228 MOPS requirements development; Risk reduction for HITL testing of auto-RA and return to course in FY19

• **Status:**
  – Automation Workshop 2 complete May 2018

• **Next Steps**
  – Pilot-in-the-loop Engineering analysis to be completed January 2019
  – Recommendations for automation collision avoidance execution and return to course requirements presentation to be completed March 2019
## TC-DAA (1 of 3)

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### TC - Detect and Avoid (DAA); DAA Subproject

#### [TWP D.1] Alternative Surveillance Requirements
- [SP D.1.10] Tiger Team
- [SP D.1.20] Partnerships
- [SP D.1.30] CONOPS
- [SP D.1.40] Foundational Fast-Time Simulation for Low SWaP Sensors
- [SP D.1.50] Display Requirements
- [SP D.1.60] Unmitigated Fast-Time Simulation (FY18)
- [SP D.1.70] HITL Simulation 1
- [SP D.1.80] Unmitigated/Mitigated Fast-Time Simulation (FY19)
- [SP D.1.100] Alternative Surveillance: GBDAA Trade Space Survey

#### [TWP D.2] Well Clear/Alerting Requirements
- [SP D.2.10] CONOPS
- [SP D.2.20] Definition
- [SP D.2.30] Foundational Terminal Ops HITL 1
- [SP D.2.40] Foundational Terminal Ops Fast-Time Simulation 1
- [SP D.2.50] Fast-Time Simulation 2
- [SP D.2.70] HITL Simulation 2
- [SP D.2.80] HITL Simulation 3
- [SP D.2.90] Foundational Terminal Ops HITL 1B

#### [TWP D.3] ACAS-Xu Interoperability
- [SP D.3.10] Stakeholder Meeting
- [SP D.3.20] Mini HITL

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* L1 Program (IASP)  ● L2 Project  ● API Element

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**Green Status Line Date 9/30/18**
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L1 Program (IASP) | L2 Project | API Element
## TC-DAA (3 of 3)

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### [TWP T.6] Integration of Technologies into LVC

- [SP T.6.10] Systems Engineering & Management
- [SP T.6.20] ACAS Xu Integration
- [SP T.6.30] DAA MOPS Integration
- [SP T.6.40] Low SWaP Integration
- [SP T.6.50] Improvements & Maintenance

### [TWP T.7] Simulation Planning & Integration

- [SP T.7.10] Foundational Terminal Ops HITL 1
- [SP T.7.20] Alternative Surveillance HITL Simulation 1
- [SP T.7.30] ACAS Xu HITL Simulation 1
- [SP T.7.50] Foundational Terminal Ops HITL 1B
- [SP T.7.70] Multi UAS Control HITL

### [TWP T.8] Integrated Flight Test

- [SP T.8.01] SC-228 Support
- [SP T.8.02] External Coordination: RTT NCC
- [SP T.8.10] ACAS Xu Flight Test 2
- [SP T.8.20] No Chase COA
- [SP T.8.30] Flight Test 5
- [SP T.8.40] Flight Test 6

* L1 Program (IASP)  
* L2 Project  
* API Element

**Green Status Line Date 9/30/18**
## TC-C2 Technical Baseline Elements

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<td>TBEN-001</td>
<td>Ku-Band Spectrum Interference Evaluation System Development (Completed 7/25/17)</td>
<td>SP C.5.10</td>
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<td>TBEN-002</td>
<td>Ku-Band Propagation Flights and Interference Analysis (Completed 9/20/17)</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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<td>TBEN-028</td>
<td>UAS Urban Air Mobility C2 Study</td>
<td>SP C.7.10</td>
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TC-C2: Progress Indicator

Community Outcomes

- White Paper for Phase 2: September, 2017
- C2 Data Link MOPS (SatCom): January, 2019
- C2 Data Link MOPS (Terrestrial) Rev A: July, 2020

Tech Transfer

- C-Band SatCom Design Study [C.5.40, C.5.41]
- UAM C2 Technology Study Standards & Policy Gap Assessments Complete [C.7.10]

UAS-NAS Progress

- Ku-Band Propagation Flights and Interference Analysis [C.5.11]
- Comments for C2 White Paper to RTCA [P.7.01]
- Comments for C2 Terrestrial Data Link MOPS [P.7.01]

Maturity

- 2017
- 2018
- 2019
- 2020

Fiscal Year

Technical Transfer Recipients: RTCA SC-228 C2 Working Group, FAA Spectrum Office and ICAO
C-Band Design Study, Verification & Validation Planning

• **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
  – Conceptual System Design Study completed January 2018
  – Hosted Satellite Payload Study completed July 2018

• **Next Steps:**
  – Satellite payload design to be completed November 2018
  – 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
• **Research Objective:**
  - Study the unique C2 challenges related to UAS to satisfy the perceived needs of the Urban Air Mobility emerging market

• **Status**
  - Baseline ConOps completed September 2018

• **Next Steps:**
  - Final Candidate Technologies for Study Criteria to be completed March 2019
  - Final Standards & Policies for Study Criteria to be completed March 2019
  - Baseline UAM C2 Seed Requirements to be delivered March 2019
  - UAM UAS C2 Technology Study to be completed September 2019
  - UAS C2 Standards & Policies Gap Assessment to be completed June 2020
## TC-C2

### TC - Command and Control (C2)

- **TWP C.5** Satellite-Based UAS Command & Control
  - [SP C.5.01] External Coordination: RTT C2 SatCom
  - [SP C.5.05] Establish NASA/Industry Cooperative Agreement
  - [SP C.5.10] Ku-Band Spectrum Interference Evaluation System Development
  - [SP C.5.11] Ku-Band Propagation Flights and Interference Analysis
  - [SP C.5.40] C-Band Design Study
  - [SP C.5.41] C-Band Verification and Validation Planning

- **TWP C.6** Terrestrial-Based UAS Command & Control
  - [SP C.6.01] External Coordination: RTT C2 Terrestrial

- **TWP C.7** Urban Air Mobility Communications Technology Study
  - [SP C.7.10] UAS UAM C2 Study
  - [SP C.7.10] UAS UAM C2 System ConOps
  - [SP C.7.10] Candidate Technologies Activity
  - [SP C.7.10] UAS C2 Standards & Policy Activity
  - [SP C.7.10] UAM UAS C2 Seed Requirements
  - [SP C.7.10] UAM UAS C2 Technology Study
  - [SP C.7.10] UAM C2 System Conceptual Design

### Legend
- ⭐️ L1 Program (IASP)
- ♦️ L2 Project
- 🔫 API Element

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*Green Status Line Date 9/30/18*
NASA, FAA, and Industry Relationship for SIO

**NASA**
- Command and Control (C2) and Detect and Avoid (DAA)
- UAS Airworthiness
- Subject matter expertise
- Type certification lessons learned

**FAA**
- Approval to fly in the NAS
- Type Certification guidance
- Procedural, policy, and regulatory changes

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

**SIO**
- Certification, Operational Approval

**UAS-NAS RTT (SC-228)**
- DAA/C2, Airworthiness Criteria

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

Maximum contribution from NASA

Minimum contribution from Industry

FAA role
Project Level Performance
Backup Slides
Active Risk Status

• Data Redacted
Top Risk

• Data Redacted
Active Risks

- Data Redacted
FY18 Closed Risks

- Data Redacted
UAS-NAS Risk Summary Card

- Data Redacted
• Data Redacted
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August 23, 2018 MRB
- TBEN-021 modified for FT5 re-plan

Technical Baseline Elements Completed Since August 23, 2018 MRB
- [SP D.1.60] Results Dissemination for Unmitigated Fast-time Simulation Study of Surveillance Volume and Alerting Timelines for Low SWaP Sensors to SC-228

Technical Baseline Element Summary
- 25 Approved
- 13 Completed
- 12 Open
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<th>Type of Deliverable</th>
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<td>ACAS Xu Flight Test 2 Flight Test Report</td>
<td>TC-DAA</td>
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<td>Report</td>
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<tr>
<td>Foundational Terminal Ops Fast-Time Batch Simulation 1 Data Analysis</td>
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<td>Nov-17</td>
<td>Briefing</td>
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<td>C-Band Cost/Benefit Assessment</td>
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<td>UAS-NAS Terminal Operations Human in the Loop 1 Test Report</td>
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<td>Concept of Operations for UAS Detect-and-Avoid in Terminal Operations</td>
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<td>LinQuest Conceptual System Design Study of UAS C2 SatCom</td>
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<td>Comparative Analysis of ACAS-Xu and DAIDALUS Detect-and-Avoid Systems</td>
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<td>Terminal Area DAA Well-Clear Definition Results</td>
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<td>Payload &amp; Earth Station Conceptual Design</td>
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<td>An Interoperability Concept for Detect and Avoid and Collision Avoidance Systems: Results from a Human-in-the-Loop Simulation</td>
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Red Status Line Date 9/30/18
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### Key:
- ☆ L1 Program (IASP)
- ♦ L2 Project

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