UAS Integration in the NAS Project
FY15 Annual Review

Laurie Grindle
Project Manager

Debra Randall
Chief Systems Engineer

Davis Hackenberg
Deputy Project Manager, Integration

October 27, 2015
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Presenter</th>
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<tr>
<td>8:00 – 8:30</td>
<td>Welcome, Opening Remarks</td>
<td>Ed Waggoner</td>
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<tr>
<td>8:30 – 9:15</td>
<td>UAS-NAS Overview</td>
<td>Laurie Grindle</td>
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<td>9:15 – 10:30</td>
<td>Technical Challenge Performance</td>
<td>Debra Randall</td>
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<td>10:30 – 10:45</td>
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<td>10:45 – 11:50</td>
<td>Non-Technical Challenge Work</td>
<td>Davis Hackenberg</td>
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<td>Project Processes Implementation</td>
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<td>11:50 – 12:30</td>
<td>Project Level Performance &amp; FY16 Look Ahead</td>
<td>Laurie Grindle</td>
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<td>Review Summary</td>
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<td>12:30</td>
<td>Lunch</td>
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<td>1:00 – 3:00</td>
<td>IRP/PRP Caucus</td>
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<td>3:00 – 4:00</td>
<td>IRP/PRP Initial Feedback</td>
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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 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 FY16
  – Specific Topics; for each of the following describe:
    • Assessment of programmatic rigor and the balance with quality and performance
    • LVC-DE state of the art capability, FY15 work towards enhancements, and future benefit
    • Resources necessary to complete planning for potential additional Project phase
    • FY15 progress towards assessment of UAS full integration and near term next steps
Outline

• UAS Integration in the NAS (UAS-NAS) Overview
  – FY15 Summary
  – UAS-NAS Project Background
• Technical Challenge Performance
• Non-Technical Challenge Work
• Project Processes Implementation
• Project Level Performance & FY16 Look Ahead
• Review Summary
FY15 Summary

• Successful execution of Project Phase 2 Portfolio
  – Executed multiple ground tests, simulations, and flight tests
  – FY15 Annual Performance Indicator (API)

• Balanced rigor with timely and effective project management
  – Incorporating process lessons learned

• Enhanced LVC distributed test environment with augmentation spending

• Integral member of RTCA SC-228

Delivered research findings and subject matter expertise integral to DAA and C2 Preliminary MOPS
NASA Strategic Plan Flow Down to UAS-NAS Project

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

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

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, through the development and maturation of technologies and validation of data.

AR-15-7: Deliver data, analysis, and recommendations based on integrated simulations and flight tests to the RTCA Special Committee on Minimum Operational Performance Standards (MOPS) for UAS to support preliminary MOPS development.

* AR-16-8: Deliver data, analysis, and recommendations based on integrated simulation and flight test series with simulated traffic or live vehicles to the RTCA Special Committee on MOPS for UAS to support development of the final MOPS.

* Revised based on current OCFO submission
ARMD Strategic Plan Flow Down to UAS-NAS Project

**AERONAUTICS STRATEGIC THRUST**

**AERONAUTICS OUTCOME**

**UAS-NAS Project Goal**

**UAS-NAS Research Themes**

**UAS-NAS Technical Challenges**

Thrust 6: Assured Autonomy for Aviation Transformation

Outcome (2015 – 2025): Initial Autonomy Applications with Integration of UAS into the NAS

Goal: Provide research findings to reduce technical barriers associated with integrating Unmanned Aircraft Systems into the National Airspace System utilizing integrated system level tests in a relevant environment

Research Theme 1: UAS Integration - Airspace integration procedures and performance standards to enable UAS integration in the air transportation system

Research Theme 2: Test Infrastructure - Test infrastructure to enable development and validation of airspace integration procedures and performance standards

TC-C2: Command & Control Performance Standards

TC-SAA: Sense and Avoid Performance Standards

TC-HSI: Human Systems Integration

TC-ITE: Integrated Test & Evaluation
UAS Integration in the NAS Organizational Structure

**Host Center**
- AFRC Director of Programs
  - Dennis Hines
  - Deputy Director: Joel Sitz

**Program Office**
- IASP Program Director
  - Dr. Ed Waggoner
  - Deputy PD: Lee Noble (acting)

**Project Support**
- Lead Resource Analyst – Cindy Brandvig - AFRC
- Lead Procurement Officer – R. Toberman - AFRC
- Lead Scheduler – John Percy - AFRC
- Mgmt Support Specialist – Jamie Turner - AFRC
- Administrative Support – Giovanna Bowen - AFRC
- Bus. Sys. Coordinator – Stacey Jenkins - AFRC

**Project Office**
- Project Manager - Laurie Grindle - AFRC
- Deputy Project Manager – Robert Sakahara – AFRC
- Deputy Project Manager, Integration – Davis Hackenberg - AFRC
- Chief Systems Engineer – Debra Randall – AFRC
- Deputy Chief Systems Engineer – Peggy Hayes - AFRC
- Staff Systems Engineer – Dan Roth – AFRC

**Technical Challenges (TC)/Subprojects**
- TC-C2: C2 Performance Standards
  - Communications
  - PE
  - Jim Griner - GRC
- TC-SAA: SAA Performance Standards
  - Separation Assurance/Sense and Avoid Interoperability (SSI)
  - Co-PEs
  - Confesor Santiago - ARC
  - Keith Arthur - LaRC
- TC-HSI: Human Systems Integration (HSI)
  - HSI
  - PE
  - Jay Shively - ARC
- TC-ITE: Integrated Test and Evaluation (IT&E)
  - IT&E
  - Co-PEs
  - Sam Kim - AFRC
  - Jim Murphy - ARC
- Certification
  - PE
  - Kelly Hayhurst - LaRC

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

**AFRC ARD**
- ARC ARD
- GRC ARD
- LaRC ARD
## UAS-NAS Project Lifecycle

### Phase 1 (P1)
- Initial Modeling, Simulation, & Flight Testing

### Phase 2 (P2)
- Integrated Modeling, Simulation, & Flight Testing

### Prior Activities
- Formulation
- Early investment Activities

### Technology Development to address Technical Challenges

### Prior

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<tr>
<th>Year</th>
<th>Activity</th>
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<tr>
<td>FY11/12</td>
<td>Prior Activities</td>
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<tr>
<td>FY13</td>
<td>P2 Portfolio Developed</td>
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<td>FY14</td>
<td>Key Decision Point (KDP)</td>
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<td>FY15</td>
<td>Flight Validated Research Findings to Inform FAA Decision Making</td>
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<td>FY16</td>
<td>Project Closeout</td>
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### External Input
- Sys Analysis: ConOps, Community Progress, etc.
- Technical input from Project technical elements, NASA Research Announcements (NRA)s, Industry, Academia, Other Government Agencies, Project Annual Reviews

### Timeframe for impact: 2015 - 2025
Community Needs Influence on Project Phase 2 Portfolio and Technical Challenges

- Phase 2 Content Decision Process (CDP) included an evaluation of the technical needs of the UAS Community
- Resultant prioritized list, and Community Progress Assessment, of Focus Area Bins served as the foundation for Phase 2 Portfolio and Technical Challenges
- Technical Challenges, Technical Work Packages, and detailed executable Schedule Packages were evaluated using a cost/benefit/risk process to determine the final portfolio
The FAA is using several domestic forums, in conjunction with several international forums to lay out the pathway for their priorities and investments.

- RTCA
- FAA UAS Executive Committee (ExCom)
- FAA UAS Center of Excellence & Test Sites
- FAA UAS Aviation Rulemaking Committee (ARC)
- NASA
- Office of Secretary of Defense (OSD)
- SARP

**World Radio Conference (WRC) and International Civil Aviation Organization (ICAO)**

UAS Study Group are addressing UAS access from an international perspective.

**SC-228** chartered to develop Detect and Avoid (DAA) and Command and Control (C2) MOPS.

**UAS Executive Committee (ExCom):** Senior gov’t steering group focused on streamlining public UAS access.

**UAS Aviation Rulemaking Committee (ARC):** Developed civil UAS Implementation Plan based on the FAA UAS Concept of Operations (CONOPs) & Roadmap.

**Office of Secretary of Defense (OSD) Sense and Avoid (SAA) Science and Research Panel (SARP):** Chartered by OSD to identify SAA Research Gaps.
RTCA SC-228 Influence on Project Phase 2 Portfolio

RTCA SC-228 Terms of Reference (ToR) has defined a path forward to develop Minimum Operational Performance Standards (MOPS)

- Phase 1 MOPS are addressed by UAS-NAS Current (FY14 – FY16) Portfolio
  - Command and Control (C2) Data Link MOPS – Performance Standards for the C2 Data Link using L-Band Terrestrial and C-Band Terrestrial data links
  - Detect and Avoid (DAA) MOPS – Performance standards for transitioning of a UAS to and from Class A or special use airspace, traversing Class D and E, and perhaps Class G airspace

- SC-228 Deliverables
  - C2 & DAA White Papers (Dec 2013) - Assumptions, approach, and core requirements for UAS DAA and C2 Equipment
  - C2 & DAA MOPS for Verification and Validation (July 2015) – Preliminary MOPS including recommendations for a Verification and Validation test program
  - C2 & DAA MOPS (July 2016) – Final MOPS
UAS Integration in the NAS Project
Phase 1 MOPS Value Proposition Flow Diagram

**NASA UAS-NAS Project Activities**

**C2 Performance Standards**
- Develop C2 Prototype System
  - Conduct C2 Flight Test and MS&A
    - Data Link
    - CNPC Spectrum
    - CNPC Security
    - LOS
    - BLOS
    - ATC Interoperability
- Develop C2 Requirements

**SAA Performance Standards**
- Develop SAA Performance Testbed
  - Conduct SAA Flight Test and MS&A
    - Performance Trade-offs
    - Interoperability
    - Self Separation
    - CONOPS
    - Well Clear
    - Collision Avoidance
- Develop SAA Performance & Interoperability Requirements

**Human Systems Integration**
- Develop Prototype GCS
  - Conduct Human Factors (HF) Flight Test and MS&A
    - Contingency Management
    - SAA
    - Pilot Response
    - C2
    - Autonomy
    - Displays
- Develop HF Guidelines for SAA, C2 & GCS

**Integrated Test & Evaluation**
- Conduct TC Specific Testing
  - Conduct TC Specific Testing
  - Conduct LVC Test Infrastructure
    - Conduct IHITL
    - Conduct SAA Initial Flight Test Scenarios
    - Conduct FT3 Test Scenarios
    - Conduct FT4 Test Scenarios & Capstone

**Key Products**
- C2 Performance Requirements to inform C2 MOPS
- SAA Performance Requirements to inform MOPS
- HF Performance Requirements to inform MOPS and HF Guidelines

**Resultant Outcomes**
- C2 Technical Standard Order (TSO)
- DAA MOPS
- C2 MOPS
- Re-usable Test Infrastructure
- Test Data for MOPS Development
- DAA Technical Standard Order (TSO)
- RADAR MOPS
- C2 Technical Standard Order (TSO)
## Flight and Simulation Overview

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<tr>
<td>ACES Sim</td>
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### Flight and Simulation Overview Details:

- **IHITL Sim**:
  - 7/23
  - 9/29

- **SAA Initial FT**: 8/18, 9/15, 10/21, 12/19

- **FT3**: 9/9, 12/5, 3/11, 8/15

- **FT4**: FAA TIM, 9/11, 2/11, 4/19

- **Part Task Sim Series**: P15, PT6

- **CNPC Testing**: Review, Gen-4, 10/59, FT Radio Model - Gen2, ACES - Gen2, ACES - Gen5, SatCom

- **CAS Sim Series**: Alerting Times + CA-SS Integration Combined HTL, Sensor Model Stress Testing & Sensitivity Analysis HTL

- **ACES Sim**: Surveillance Requirements (Medium Fidelity), DAA Self-Separation Alerting Methods, Performance & Robust Sub-function Tradeoffs w/ UAS Performance, Effect of SAA Maneuvers with Procedures, Comprehensive Evaluation of Airspace Risk Threshold

**Red Status Line Date: 9/30/15**
UAS-NAS Project OV-1
IT&E Technical Challenge: Backbone for Integrated Testing
Outline

• UAS-NAS Overview
• Technical Challenge Performance – Debra Randall
  – TC-C2
  – TC-SAA
  – TC-HSI
  – TC-ITE
• Non-Technical Challenge Work
• Project Processes Implementation
• Project Level Performance & FY16 Look Ahead
• Review Summary
Progress Indicator Definition

- Technical Challenge progress is tracked by means of Progress Indicators
  - Schedule Package (SP) L2 milestones are the data points for these plots

- 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

- 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

- Progress is tracked against all the tasks in the schedule package using a red, yellow, green indicator
TC-C2: C2 Performance Standards

- **RT1**
  - UAS Integration
    - Airspace integration procedures and performance standards to enable UAS integration in the air transportation system

- **TC-C2**
  - Provide research findings to develop and validate UAS Minimum Operational Performance Standards (MOPS) for terrestrial command and control (C2) communication

**TC-ITE: Integrated Test & Evaluation**

**TC-HSI: Human Systems Integration**

**TC-SAA: Sense and Avoid Performance Standards**

**RTCA**

C2 MOPS

**TC-C2: Command & Control Performance Standards**
As of 9/30/15

TC-C2: Progress Indicator

As of 9/30/15

Maturity

Fiscal Year

2012 2013 2014 2015 2016 2017

SC-228 White Papers Dec 2013
Preliminary Phase 1 MOPS July 2015
Final Phase 1 MOPS July 2016
Final Phase 2 MOPS July 2018

RTCA MOPS
Tech Transfer

+FAA +ITU-R
+FAA +ITU-R
+ITU-R
+ITU-R

C-Band Planning & Standards Interim Report [C.3.20]
Comm System Per Impact Testing [C.4.40]
FT Radio Model Development & Regional Sims [C.4.10]
ACES Sim Operations w/FT Models w/Gen5 [C.4.20]
Recommendations for Integration of CNPC and ATC Comm Prelim [C.4.30]
Performance Validation of Security Mitigations [C.2.20]
ACES Sim Ops/FT Models w/Gen2 [C.4.20]
Recommendations for Integration of CNPC and ATC Comm Final [C.4.30]
Gen5 [C.1.30]
Gen2 Radio in Relevant Env., FT [C.1.10]
Completion of CNPC Radio Model
1st CNPC Radio Prototype Delivered/FT
Spectrum Allocation Terrestrial CNPC (WRC-12)
Develop & Test Security Prototype [C.2.10]
C-Band Planning & Standards Final Report [C.3.20]
Spectrum Compatibility Analysis (WRC-2015) [C.3.10]

L1/API Milestone
L2 Milestone

Complete
In Work / On Track
In Work / Late – No L1 Impact
In Work / Late – L1 Impact
Not Yet Started

Tech Transfer to RTCA (+other orgs)
Inputs from RTCA

As of 9/30/15
Verify Prototype Performance
Preliminary C2 MOPS Input

• **Research Objective:**
  – Analyze the performance of the fourth generation Control and Non-Payload Communication System prototype in a relevant flight environment

• **Results, Conclusions, and Recommendations:**
  – Demonstrated use of multiple ground stations and multiple aircraft during Gen-3 flight testing at Rockwell Collins in Cedar Rapids, IA
  – Completed development and testing of GRC T-34C surrogate aircraft using Gen-3 CNPC radios
  – Completed flight test of Gen-4 CNPC radios, using Rockwell Collins developed small-form-factor 1W radio hardware
  – Results of Gen-3&4 CNPC radio development and testing were delivered to RTCA SC-228 C2 working group for incorporation into Draft C2 MOPS

CNPC Radio for Development and V&V of C2 MOPS
Performance Validation of Security Mitigations - Relevant Flight Environment

- **Research Objective:**
  - Determine Control and Non-Payload Communication security recommendations for civil UAS operations based on analysis of flight test results

- **Results, Conclusions, and Recommendations:**
  - Completed flight test of CNPC system security controls
    - Demonstrated strong mutual authentication between the end nodes
    - Demonstrated end-to-end confidentiality and integrity protection
    - Demonstrated seamless system functions to the end users and will dynamically create security associations as required to protect network flows
  - Flight test report was completed and released
  - Security requirements validated in this flight test were incorporated into the C2 Preliminary MOPS

CNPC System Security Requirements for C2 MOPS

Schedule Package: C.2.20
TC-C2: C2 MOPS Contributions

**NASA UAS-NAS Project Activities**

- Develop C2 Prototype System
- Conduct C2 Flight Test and MS&A
- Develop C2 Requirements

**Key Products**

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

**Resultant Outcomes**

- Data and text to Preliminary MOPS sections and appendices
- Designed, developed, and tested (laboratory & flight) a prototype radio
- Provided prototype radio performance from laboratory and flight tests to C2 Working Group for Preliminary MOPS development
- Developed a NAS-wide CNPC system simulation validated with flight test data
- Technical report for ITU-R Working Party 5B to support Fixed Satellite Service (FSS, i.e. commercial satellite services) BLOS CNPC capability decisions
TC-SAA: SAA Performance Standards

RT1 - UAS Integration
  • Airspace integration procedures and performance standards to enable UAS integration in the air transportation system

TC-SAA - Provide research findings to develop and validate UAS Minimum Operational Performance Standards (MOPS) for sense and avoid (SAA) performance and interoperability

TC-ITE: Integrated Test & Evaluation

TC-HSI: Human Systems Integration

TC-C2: Command & Control Performance Standards
SAA Traffic Display Evaluation HITL1  
(Joint w/HSI Part Task Sim 4)

• Research Objective:
  – Evaluate integrated SAA system under perfect sensor conditions
  – Evaluate the pilot’s ability to remain clear as a function of self separation threshold
  – Evaluate the pilot’s acceptability of recommended Autoresolver maneuvers to avoid loss of Well Clear
  – Evaluate the utility of two different trial planner capabilities that aid an UAS in remaining Well Clear of other traffic

• Results, Conclusions, and Recommendations:
  – No significant difference in remaining Well Clear given self-separation alerts at 80 vs. 110 seconds
  – Pilots were almost never able to remain Well Clear when first alerted at 55 seconds to CPA or less
  – Incorporation of ‘Advanced’ DAA information and tools significantly reduced the proportion of Loss of Well Clear when compared to the ‘Basic’ configuration
  – Integration of DAA traffic information and tools with the pilot’s ground control station did not significantly improve the pilots ability to remain well clear
    • Other human systems integration research reveals difference in response time and workload

GCS Display & Well Clear Separation Requirements for DAA MOPS

Schedule Package: S.2.10
GA-FAA (SAA Initial Flight Tests)  
Flight Test Participation w/IT&E

• **Research Objective:**
  – Perform collaborative flight tests and demonstrations to evaluate, validate and refine simulation-tested SAA concepts in an actual flight environment with prototype airborne sensors, prototype C2 radio links, and prototype ground station information displays

• **Interim Results, Conclusions, and Recommendations:**
  – Self-separation guidance from Stratway+ was effective, stable, understandable, and usable
  – Matured data collection capability
  – Applied lessons learned to Flight Test Series 3 and Collision Avoidance Self-separation Alerting Times human-in-the-loop simulation

**Pilot Maneuvers Using DAIDALUS Self-Separation Guidance**

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<th>Deviation from Guidance (degrees)</th>
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<td>90</td>
<td>40</td>
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<td>135</td>
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**Mean Aircraft Separation Distance at Time of Maneuver**

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<th>Encounter Geometry (degrees)</th>
<th>Separation Distance (nautical miles)</th>
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**DAA System Maturation for Development and V&V of DAA MOPS**

Schedule Package: S.6.10
**NASA UAS-NAS Project Activities**

**Key Products**

- SAA Performance Requirements to inform DAA and RADAR MOPS

**Resultant Outcomes**

- Develop SAA Performance Testbed
- Develop SAA Interoperability Testbed
- Conduct SAA Flight Test and MS&A
  - Performance Trade-offs
  - Interoperability
  - CONOPS
  - Well Clear
  - Self Separation
  - Collision Avoidance
- Develop SAA Performance & Interoperability Requirements

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- **Data and text to Preliminary MOPS sections and appendices**
- **Further assessment of Well Clear definition**
- **Further development of maneuver guidance algorithms**
- **Data collection contributing to DAA alerting requirements and performance**
- **Assessment of airborne radar intruder frequency and detection range sensitivity on Preliminary MOPS alerting requirements**
- **Analysis of surveillance errors and other representative uncertainties in flight test and calibration of simulation models**
- **Provide sample DAA algorithm**
TC-HSI: Human Systems Integration

- UAS Integration
  - Airspace integration procedures and performance standards to enable UAS integration in the air transportation system

- Provide research findings to develop and validate human systems integration (HSI) ground control station (GCS) guidelines enabling implementation of the SAA and C2 performance standards

TC-C2: Command & Control Performance Standards

TC-SAA: Sense and Avoid Performance Standards

TC-ITE: Integrated Test & Evaluation

TC-HSI: Human Systems Integration
Part-task Simulation 4: SAA Pilot Guidance

• **Research Objective:**
  – Evaluate efficacy of minimum information SAA displays, potential improvements for advanced information features and pilot guidance, and integrated vs stand-alone GCS SAA displays

• **Results, Conclusions, and Recommendations:**
  – Consistent advantage seen for Advanced over Basic displays
    • Faster Total Response Times compared to Basic
  – No significant differences between the Standalone and Integrated condition

GCS Display Minimum Information Guidelines/Requirements for DAA and C2 MOPS

Schedule Package: H.1.40
HSI IHITL Participation & Data Collection

• **Research Objective:**
  – Evaluate an instantiation of the prototype GCS in relevant environment

• **Interim Results, Conclusions, and Recommendations:**
  – Integration of guidance and auto pilot in the *auto-resolver* and *auto resolver + vector planner* conditions led to significantly faster pilot ‘edits’
  – No other significant differences in pilot response times

GCS Information Guidelines/Requirements for DAA and C2 MOPS

Schedule Package: H.1.10
TC-HSI: DAA and C2 MOPS Contributions

**NASA UAS-NAS Project Activities**

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<th>Human Systems Integration</th>
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<tr>
<td>Develop Prototype GCS</td>
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<td>Conduct Human Factors (HF) Flight Test and MS&amp;A</td>
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<tr>
<td>Contingency Management</td>
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<td>Pilot Response</td>
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<td>C2</td>
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<td>Displays</td>
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**Key Products**

HF Performance Requirements to inform MOPS and HF Guidelines

**Resultant Outcomes**

- Data and text to Preliminary MOPS sections

**DAA MOPS**

- Further development of alerting timeline and GCS display
- Further development of maneuver guidance display
- Evaluation of the effects of sensor uncertainty
- Development assessment of TCAS/DAA interoperability

**C2 MOPS**

- Defined C2-related GCS information requirements enabling pilot management and monitoring of the C2 Link
- Examined video considerations for UAS C2 in civil airspace
TC-ITE: Integrated Test and Evaluation

- Test Infrastructure
  - Test infrastructure to enable development and validation of airspace integration procedures and performance standards

- Develop a relevant test environment for use in generating research findings to develop and validate HSI Guidelines, SAA and C2 MOPS with test scenarios supporting integration of UAS into the NAS

RTCA

DAA MOPS

TC-ITE: Integrated Test & Evaluation

RTCA

RADAR MOPS

TC-C2: Command & Control Performance Standards

TC-SAA: Sense and Avoid Performance Standards

TC-HSI: Human Systems Integration
TC-ITE: Progress Indicator

As of 9/30/15

Fiscal Year

2012 2013 2014 2015 2016 2017

Maturity

0 1 2 3 4 5 6 7 8 9 10

Established LVC Infrastructure
Established Connection to FAA Tech Ctr
Initiate Flight Test Series 2
IHTIL Sim Test Plan [T.2.50]
IHTIL [T.2.50]
SAA Initial FT [T.3.40]
FT3 Test Plan [T.4.20]
FT3 Relevant Env. Eval. Report [T.4.60]
FT Series 3 [T.4.50]
FT Series 4 [T.5.60]
Capstone Flight Test [T.5.60]
Stakeholder Feedback Report [T.5.70]
Comprehensive Relevant Env. Eval. [P.1.10]
FT4 Relevant Env. Eval. Report [T.5.70]
LVC Leave Behind Doc [T.1.20]
FT4/Capstone Flight Test Plan [T.5.50]

L1/API Milestone
L2 Milestone

Complete
In Work / On Track
In Work / Late – No L1 Impact
In Work / Late – L1 Impact
Not Yet Started

Tech Transfer to RTCA (+other orgs)
Inputs from RTCA

As of 9/30/15
IHITL Relevant Environment Analysis

• **Objective:**

• **Results, Conclusions, and Recommendations:**
  – IHITL successfully utilized the LVC connections to distribute simulation activities between ARC/AFRC and ARC/LaRC
    • Emulation of actual Oakland and Dallas Ft. Worth airspaces
    • DAA algorithms performance evaluated with UAS pilots and ATC controllers
    • Latencies measured among distributed participating assets
    • UAS Pilot and ATC controller subjects provided feedback on the test environment and traffic scenario realism

Test Environment for V&V of DAA and C2 MOPS
SAA Initial Flight Tests Execution

**Research Objectives:**
- Conduct SAA Initial Flight Test using the Live, Virtual, Constructive test environment
- Document the performance of the test infrastructure in meeting the flight test requirements

**Results, Conclusions, and Recommendations:**
- Flight tests conducted in December 2014
- 3 unmanned vs. manned flights and 55 encounters completed
- Successful risk reduction activities completed to include SAA algorithm refinements, sensor noise modeling, sensor noise filtering, data collection and dissemination efficiencies, and flight test operations

Test Environment for V&V of DAA and C2 MOPS
TC-ITE: DAA and Air-to-Air RADAR MOPS Contributions

**NASA UAS-NAS Project Activities**

- Develop LVC Test Infrastructure
- Conduct TC Specific Testing
- Conduct IHITL
- Conduct SAA Initial Flight Test Scenarios
- Conduct FT3 Test Scenarios
- Conduct FT4 Test Scenarios & Capstone

**Key Products**

- Test Data for MOPS Development
- Re-usable Test Infrastructure
- DAA MOPS
- RADAR MOPS
- DAA Technical Standard Order (TSO)
- RADAR Technical Standard Order (TSO)

**Resultant Outcomes**

- Data provided to PEs and Partners for DAA and Radar MOPS development
- Further development of live, virtual, constructive distributed test environment
- Designed and developed a data archive scheme for integrated events
- IHITL Relevant Environment Analysis
- Completion of PT5
- Completion of SAA Initial Flight Test Execution
- Completion of FT3 Execution
Flight Test 3 Baseline Plan

Top Level Research Goals:

- Validate results previously collected during project simulation testing with live data
  - Sensor performance, uncertainty
  - State data uncertainty
  - Wind compensation
  - Inform final DAA MOPS

- Test fully integrated system in a relevant live test environment
  - HSI Proof of Concept GCS and pilot guidance displays
  - CNPC performance
  - Inform final DAA and C2 MOPS

- Reduce risk for Flight Test Series 4
  - More complex multi-vehicle scenarios

Configuration 1 - Scripted Encounters
- Live Ownship with Cooperative and Non-Cooperative Sensors
- Live Intruder(s)

Configuration 2 - Full Mission Evaluations
- Live Ownship (Surrogate UA)
- Live and Virtual Intruders
- Representative Operational Mission
- UAS Pilot Participants
FT3 Lessons Learned and FT4 Path Forward

• Lessons Learned
  – Multiple integration deficiencies
    • Surrogate UA: Improper RGCS display of information; intermittent INS data dropouts; latency of aircraft response to pilot command (unrelated to CNPC performance; due to surrogate implementation)
    • LVC/RGCS: MACS display clutter and fidelity
  – Multiple causes
    • Requirement definition
    • Multi-Center end-to-end test planning
    • Shakedown, integration, and combined system checkout schedule and success criteria
    • Communication and Technical discussions

• FT4 Path Forward
  – Post-FT3/FT4 Path Forward Meetings
    • #1 (8/24-25/2015): Technical and non-technical issue identification and discussion; Short-term actions identified and assigned
    • #2 (9/9-10/2015): Identified (single) FT4 Lead; first set of full mission ownership options
  – Decision Gate 1 (10/8/2015)
    • Triage full mission ownership options based on technical, development, or partnering/contracting risk
  – Decision Gate 2 (11/13/2016)
    • Select the best option (technical, cost, and schedule)
    • Identify actions for or approve changes to research portfolio
Technical Performance Summary

• World Radio Conference
  – Fixed Satellite Service BLOS CNPC capability analysis

• NATO and ICAO
  – Human Autonomy Teaming support
  – Provide HF leadership and expertise

• Preliminary MOPS
  – Expertise influencing deliberations
  – Timely and valuable research findings from simulation, flight test, and integrated flight test
  – Narrative text to multiple sections and appendices

• Future Research Portfolio shaping
  – Continuous involvement with SC-228 and FAA

Poised to provide timely, valuable input to Final MOPS and international community
Outline

- UAS-NAS Overview
- Technical Challenge Performance
- **Non-Technical Challenge Work – Davis Hackenberg**
  - FY15 Non-TC Performance
    - Certification
    - sUAS
    - Augmentation
  - FY16 Look Ahead
    - Capstone
    - Future Project Planning

- Project Processes Implementation
- Project Level Performance & FY16 Look Ahead
- Review Summary
Non-Technical Challenge Work

• Non-Technical challenge work is technical work outside the core project focus areas
  – Includes far-reaching/higher risk activities with an emphasis on future (post-project) capabilities
  – Utilizes project management rigor, but to a lesser extent (i.e. No Progress Indicators)
  – Content is not required for min-success of the project
  – Does not have L1 milestones

• Source for resources should TC work encounter unknown risks requiring additional resources for mitigation

• Long term activities have pre-defined off-ramps/on-ramps to facilitate potential TC work needs
  – Off-ramps: Clearly defined breakpoints/stopping places within scheduled activities
  – On-Ramps: New proposed activities that are aligned with the intent of Non-TC work

• Non-TC Work on UAS-NAS Project
  – Certification
  – sUAS

• Activities with on-ramp implications (being book kept as Non-TC work)
  – Augmentation used for LVC-DE Enhancements
  – Capstone Development and exemption
  – Future Project Planning and Full UAS Integration Analysis
The FAA is using several domestic forums, in conjunction with several international forums to lay out the pathway for their priorities and investments.

- RTCA
- FAA UAS ExCom
- FAA UAS ARC
- UAS UAS Executive Committee (ExCom): Senior gov’t steering group focused on streamlining public UAS access
- UAS Aviation Rulemaking Committee (ARC) Developed civil UAS Implementation Plan based on the FAA UAS Concept of Operations (CONOPs) & Roadmap
- SC-228 chartered to develop Detect and Avoid (DAA) and Command and Control (C2) MOPS
- FAA UAS Center of Excellence performs strategic research to guide the FAA, while the test sites contribute essential inputs through UAS testing
- World Radio Conference (WRC) and International Civil Aviation Organization (ICAO) UAS Study Group are addressing UAS access from an international perspective
- Office of Secretary of Defense (OSD) Sense and Avoid (SAA) Science and Research Panel (SARP): Chartered by OSD to identify SAA Research Gaps

**NASA has a leadership role within many domestic forums and participates in the international forums**
Certification Usage and Highlights

Leveraged operational evaluation approach (agriculture sprayer) and FAA FARs (part 21 &27) to develop a Mock Type Certification Basis

- A general approach to determining a type certification basis for UAS (leveraging a limited ConOps)

- An example concept of operations document with data needed to support airworthiness certification, and artifacts to help inform the UAS industry about civil certification

- Design and performance criteria derived from hazard analysis and current regulations used to establish
  - Airworthiness requirements for unmanned rotorcraft intended for “low-risk” operations
  - Requirements for new systems and equipment (e.g., a containment system for UAS)

- Recognition that applying current airworthiness standards to UAS is challenging
  - Tailoring will be difficult for many UAS vendors/operators
  - Even for UAS operating in low-risk environments

Applicability of Part 27 regulations to an unmanned ag rotorcraft

- Geospatially constrained
- Farmland (rural area)
- < 400 ft altitude
- Line of sight and low visibility conditions
## Hazard-Based Approach

### Research Tasks

1. Define ConOps and determine UAS platform
2. Identify hazards (Operational & Functional Hazard Assessment)
3. Evaluate existing regulations against the primary hazards (Part 27 for rotorcraft)
4. Create preliminary requirements for hazards not covered by existing regulation

### Intermediate Research Products

- ConOps Document
- Primary UAS Hazard List
- Hazard Severity Definitions
- Part 27 paragraphs that apply as is
- Part 27 paragraphs that apply with simple edits
- Part 27 paragraphs to be distilled and elaborated
  - Evaluation Rationale
- Draft requirements for UAS-unique functions

### Products used in the Mock Type Certification Basis

- G-1U Background

### FY15 Work

- G-1U Type certification basis
  - New Information Issue Papers
    - U-1 Controllability, Maneuverability, & Stability
    - U-2 Structural Integrity
    - U-3 Powerplant and Supporting Systems
  - New Information Issue Papers
    - U-4 Containment
    - U-5 DAA Intruder Aircraft
    - U-6 DAA Persons and Objects within Containment Area
    - U-7 Safety Critical Command and Control Datalinks

### Follow-on work: examine affects of different vehicle characteristics and operational modes certification basis
Cert Relationship to FAA Integration Initiatives

- FAA Pathfinders
  - Visual line-of-sight operations in urban areas
    - CNN will look at how UAS might be safely used for news gathering in populated areas.
  - Extended visual line-of-sight operations in rural areas
    - PrecisionHawk will explore how UAS flights outside the pilot's direct vision might allow greater UAS use for crop monitoring in precision agriculture operations.
  - Beyond visual line-of-sight in rural/isolated areas
    - BNSF Railroad will explore command-and-control challenges of using UAS to inspect rail system infrastructure.

- UAS ARC
  - “Pathfinders” concept as was part of FAA ARC Implementation Plan
  - “Pathfinders” also relevant to ARC BVLOS Working Group use cases

- RTCA SC-288
  - Use case, CONOPS, and vehicle size relevant to P2 MOPS
**sUAS Mission Support Technologies**

- **Top Level Research Goal**
  - Developing specific data relevant to partner Agencies while conducting high-value sUAS missions utilizing increasing levels of automation and sUAS technologies

- **Objectives**
  - Assess the state-of-the-art in sUAS Sense-and-Avoid capabilities
  - Develop and test one instantiation of an sUAS SAA system
  - Assess feasibility of BVLOS operation at GDS in Class G airspace

- **FY15 Accomplishments**
  - A series of test conducted to obtain video and telemetry data for various encounters of sUAS platforms
  - Flight tests leveraged an Electro-Optic (EO) cameras
  - 11 single UAS buildup flights, and 12 multi-UAS encounter flights
  - Diverse weather conditions
  - Initial indications seem to show we were getting good data, with internal and partner analysis happening in the coming weeks

**FY15 Work**

- Great Dismal Swamp Missions
- Sensor Rqmts Report
- FY15 sUAS Proposal & Scope Decision
- DAA Hardware Integration
- Partnerships
- Flight Test and Evaluation

- Mig CC Pattern 1
- Scaled SR-22 approaches, Turns away
- Mig CC Pattern 2
- Y-6 Hovers in place

*RFI Sensor Rqmts Report
Autonomy Tech Assessment Report*
sUAS Relationship to FAA Integration Initiatives

• UAS ARC
  – DAA necessary for many (if not all) ARC BVLOS use cases

• RTCA
  – Use case, CONOPS, and vehicle size may be relevant to Phase 2 MOPS
  – If technology development is successful, RTCA and NASA will have
    • Sensor characterization of a P2 MOPS relevant sensor
    • System capable of representing requirements that would relate to the expected SC-228 P2 TOR
UAS-NAS FY15 Augmentation Details

• Purpose
  – LVC Enhancements that would benefit the development of Phase 2 MOPS

• Overview
  – The Project began planning for an Augmentation (congressional add) as early as December 2014
  – Project developed multiple review packages to coordination scope of tasks across ARMD and multiple projects
  – Augmentation tasks have all been successful thus far
  – Financial summary: 99.99% Obligated, 43% Cost

• Augmentation task 3.3 completed, all other tasks are still in work

• Prototype connections to Test Sites was more expensive than anticipated due to late changes to the LVC Prototype Connection task, and the desire to fund all 6 Test Sites

<table>
<thead>
<tr>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Prototype connection equipment &amp; test site connections</td>
</tr>
<tr>
<td>3.2 LVC connection to scaled vehicles</td>
</tr>
<tr>
<td>3.3 Investigation of ideal middleware</td>
</tr>
<tr>
<td>4.1 VFR Traffic Model Development and Integration</td>
</tr>
<tr>
<td>6.1 Distributed Display Infrastructure Set-up</td>
</tr>
<tr>
<td>7.1 SatCom emulation capability on LVC</td>
</tr>
<tr>
<td>7.2 Adaptable SAA Architecture and LVC Connection</td>
</tr>
</tbody>
</table>
Outline

- UAS-NAS Overview
- Technical Challenge Performance
- Non-Technical Challenge Work – Davis Hackenberg
  - FY15 Non-TC Performance
    - Certification
    - sUAS
    - Augmentation
  - FY16 Look Ahead
    - Capstone
    - Future Project Planning
- Project Processes Implementation
- Project Level Performance & FY16 Look Ahead
- Review Summary
Capstone Overview

- Capstone is a mission-oriented demonstration subproject technologies, concepts, and procedures (rather than experimentally designed test series)
- The flight demonstrations will showcase the technologies developed by the Project, specifically related to RTCA Phase 1 MOPS
- A demonstration leveraging simultaneous flight of DAA and C2 systems utilizing the LVC-DE will be performed
  - DAA demonstration on Ikhana will include designed encounters integrated into a mission-oriented demonstration in R-2515 and will occur following FT4
  - C2 Terrestrial technologies will be demonstrated on the S-3B after Gen-5 radio Flight Tests
  - LVC will be leveraged to receive data from the Ikhana aircraft, provide that data to the algorithms and displays, provide a distributed video streaming capability, and “co-locate” Ikhana and S-3B
    - All four Centers and Technical Challenges will participate
- Capstone is being coordinated with FT4 planning activity; date of execution will be chosen with consideration for all project related activities
Capstone ConOps

- Fly live aircraft out of AFRC and GRC, translated into a virtual airspace
  - Virtual background traffic from LaRC
  - ATC from ARC
  - Stream video across all 4 centers
- Conduct checkout flights and full rehearsal in conjunction with FT4 and C2 testing
Future Project Planning

• Background: Project Baseline
  – The Phase 1 MOPS UAS-NAS Project baseline incorporated a roll-off of personnel Q4 FY16, and then leveraged Q1 FY17 to complete the project and required reporting

• Current FY16 plans
  – The project must burden current resources in FY16 to transition into P2 MOPS due to current cost/risk/schedule
    • FY16 reserves are being allocated to support FT4
    • FY16 resources are being adjusted to transition for effective execution of P2 MOPS support
    • P2 MOPS RFI/RFP development for partnerships (primarily C2 and DAA)
    • Content Decision Process planning leverages Full UAS Integration Analysis

• Activity may synchronize with planning for other UAS Full Integration Projects
Full UAS Integration Update

• Full UAS Integration Analysis is intended to provide a systematic means for ARMD to evaluate UAS research areas and assist in portfolio decisions

• FY15 analysis updates include
  – Source documentation updated to reflect current industry needs
  – Developed “100% complete” definition for all sub bins
  – Gap analysis performed for all bins
  – Opportunity/Risk/Benefit process for all Gaps refined through ARMD meetings
  – Lead, Collaborate, Leverage ground work laid

• Initial familiarization and coordination across NASA ARMD
  – ARMD Analysis Board
  – UTM Project Manager inputs

• MOE process (agenda, attendees, goals, etc) defined and ready to vet within NASA ARMD

ARMD UAS Full Integration
Portfolio Prioritization Process

1. DEFINE
   - Identify Supporting Evidence
   - Determine Evidence Types

2. ASSESS
   - Categorize Needs into Focus Areas
   - Identify Remaining Gaps
   - Define what it means to be filled in
   - Conduct Progress Assessment

3. PRIORITIZE
   - Define Weighting Criteria & Apply to Remaining Gaps
   - Determine Opportunity / Benefit / Risk to Achieving Outcome
   - Prioritize Remaining Gaps

As of 8/30/15
Future Project Planning Resources

• Planning Resources

• Risk to Potential early investment activities due to Project reserve availability
  – RFI/RFP develop and execution
  – DAA/C2 trade studies
  – DAA/C2 early procurement activities

• Other ARMD uses of UAS Full Integration Analysis would cause additional impacts
Outline

- UAS-NAS Overview
- Technical Challenge Performance
- Non-Technical Challenge Work
- Project Processes Implementation – Davis Hackenberg
  - Project Rigor
  - Significant Changes against Baseline
  - Risk Management
  - FT3 Example
- Project Level Performance & FY16 Look Ahead
- Review Summary
• Due to the limited lifecycle of the Project, and importance of delivering commitments on time, the project has implemented rigorous management processes

• Rigor was re-evaluated and outcomes presented at the FY14 Annual Review
  – The project took steps to balance rigor with other time/overhead burdens
  – The Project team supported and understood the need for rigor

• The Project processes
  – Were instrumental in FY15 successes
  – Had room for improvement in FY15

• A review of the project processes with a focus on FT3 provides insight into process strengths and weaknesses
Project Document Tree

Project

Technology Development Project Plan
[UAS-PRO-1.1-004]

Risk/Resource Management Process
[Resides in the Project Plan]

Integrated Master Schedule
[UAS-IMS-1.1-002]

Public Outreach Plan
[UAS-OR-7.0-001]

Systems Engineering Management Plan
[UAS-PRO-1.1-007]

Records Retention Schedule
[UAS-PRO-1.1-003]

Change Management Plan
[UAS-PRO-1.1-002]

Schedule Management Plan
[UAS-PRO-1.1-008]

Data and Information Sensitivity Plan
[UAS-PRO-1.1-010]

Project Requirement Document
[UAS-PRO-1.1-005]

Technology Transfer Plan
[UAS-PRO-1.1-006]

SSI, Communication, HSI & Cert Subprojects

Subproject Implementation Plans
[UAS-SSI-4.1-001]
[UAS-HSI-4.2-001]
[UAS-COMM-4.3-001]
[UAS-CERT-4.4-001]

Center Policy/Procedures

IT&E Subproject

Subproject Implementation Plan
[UAS-ITE-5.1-001]

Configuration Management Plan

Software Development Plans

Risk Management Plan

Safety and Mission Assurance Plan

Mishap Preparedness & Contingency Plan

Verification & Validation Plan

Additional SE Documents

Center Policy/Procedures

Primary processes leveraged by examples

Secondary processes leveraged in this section
Significant Changes against the Baseline

• TC-SAA: Schedule Package Changes
  – Closed/eliminated SP S.3.20, “Well Clear Alerts/Resolutions with VFR and Pilot/Controller (ACES Simulation)” and added SP S.3.30, “Well Clear Alerting Logic, Methods, and Performance Requirements” to provide greater benefit to SC-228 by conducting work of greater importance to SC-228

• TC-ITE: FT3 Completion
  – FT3 completion change request was primarily based on completion of FT3 Config 1 (11 flights) on July 24, 2015 and the decision to cease data collection for Config 2 (8 system checkout flights and 3 data collection flights) on August 13, 2015. The L1 Milestone was closed on August 13, 2015
  – Deleted the FT3 related HSI research products and deliverables

• Non-TC: Certification L2 Milestone Deletion (off-ramp)
  – Goal Structured Notation (GSN) Safety case did not meet the original intent of the deliverable

• Non-TC: sUAS Addition of New Work (on-ramp)

• Project Office: Reserve Allocations
  – Multiple change requests to allocate Project Office reserves to Technical Challenge areas
### UAS-NAS Top Risks

#### Risk Matrix

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<tr>
<th>Likelihood</th>
<th>1</th>
<th>2</th>
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<th>4</th>
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#### CONSEQUENCE

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<td>High</td>
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<td>A - Accept, RA - Raise</td>
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<tr>
<td>Med</td>
<td>Increasing (Worsening)</td>
<td>M - Mitigate, E - Elevate, W - Watch, C - Close</td>
</tr>
<tr>
<td>Low</td>
<td>Unchanged</td>
<td>R - Research</td>
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</table>

(T) Indicates a Top Risk

**Risk Matrix**: 

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<td>3x5</td>
<td>3x3</td>
<td>W</td>
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</table>

**Risk Title**

- Validation of SAA Sensor Models
- Required Assets for Flight Test 4 (FT4) not available during test period
- Distributed Test Environment requirements for Integrated Flight Test 4 (FT4) not defined
- Output from Test Events has value to Project Stakeholders
- Project Focus Changes Due to External Influences
- RTCA SC-228 Requirements Development Delay

**Changes Since FY14 Annual Review**

- Added 7 risks, closed 19 risks, and accepted 1 Risk
- Interdependent Project Risk
  - Asset availability - multiple

**As of 9/30/15**
Process Successes and Areas for Improvement

FT3 Example
Outline

- UAS-NAS Overview
- Technical Challenge Performance
- Non-Technical Challenge Work
- Project Processes Implementation
- Project Level Performance & FY16 Look Ahead – Laurie Grindle
  - Resource Allocation and Utilization
  - Schedule
  - Requirements Summary
  - Partnerships and Collaboration
  - FY15 Accomplishments and FY16 Look Ahead
- Review Summary
Resource Allocation against Baseline Budget
Successful Workforce and Resource Utilization
Non-WYE Funding
FY15 Schedule Performance

• FY15 Milestone Count
  – Planned FY15 Milestones: 54
  – Milestones completed in FY15: 51

• Causes of Milestone Delays
  – Issues identified during testing or preparation for testing
  – Test scope increased due to SC-228 additional requirements; results in:
    • Extended data collection
    • Extended analysis
  – Export control/release process exceeds planned duration

• Impacts of Milestone Delays
  – No impact to Preliminary DAA or C2 MOPS
  – Acceptable impact to downstream test/simulation activities
1. “U6317 [SP S.1.20] Surveillance Requirements (Medium Fidelity) Brief results”
   Commitment Date: 9/3/15
   Estimated Date: 10/15/15

   Commitment Date: 9/30/15
   Estimated Date: 10/15/15

3. “U5597 [SP T.5.10] Capstone Test Requirements to Stakeholders”
   Commitment Date: 8/14/15
   Estimated Date: 10/2/15
Project Requirements Summary

• FY15 Status
  – FY15: 18 Requirements completed
  – Project Total:
    • 30 Requirements completed
    • 45 Requirements remain
  – Total Requirements decreased from 76 to 75 during FY15

• Four Requirements were deleted
  – TC-SAA ACES Simulation Deleted
  – Capstone Planning Document
  – Standalone FT4 Test Plan
  – Report on the HSI results from FT3

• Three Requirements were added
  – Comprehensive Research Report
  – TC-SAA ACES Simulation Added
  – Created a combined FT4 Test Plan and Capstone Planning Document

• Impacts of Requirements Changes
  – No significant impact as a result of these changes

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<tr>
<th>TWP</th>
<th>End of FY14</th>
<th>End of FY15</th>
<th>FY15 Completed</th>
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<tr>
<td>Total</td>
<td>76</td>
<td>75</td>
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<td>30</td>
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Current and Anticipated Partnership Issues
<table>
<thead>
<tr>
<th>Partner (Project Area)</th>
<th>Agreement In Place</th>
<th>Collaboration/Partnership Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFRL (TC-HSI)</td>
<td>Task Order</td>
<td>Coordinate activities on Vigilant Spirit Control Station. Status: On-going collaboration with AFRL supporting use of VSCS on HSI activities</td>
</tr>
<tr>
<td>Dragonfly Pictures (Non-TC-Certification)</td>
<td>SAA</td>
<td>Supporting the UAS certification case study by supplying the design of a UAS rotocraft. Status: Agreement in place for in-kind work, on-going</td>
</tr>
<tr>
<td>FAA UAS IO (Project Office)</td>
<td>MOA</td>
<td>Support by FAA leadership, management, and technical SMEs to validate work being done by the Project. Status: On-going coordination of Project deliverables</td>
</tr>
<tr>
<td>FAA R&amp;D Integration (Project Office)</td>
<td>MOA</td>
<td>Formal host of partnership agreements and collaborator for Integrated Test Activities. Status: On-going coordination of Project deliverables</td>
</tr>
<tr>
<td>FAA TCAS Program Office (ACAS Xu) (TC-SAA)</td>
<td>Software</td>
<td>Coordinating on collaboration for ACAS-Xu software and associated flight tests. Status: Successful SAA Initial Flight Tests</td>
</tr>
<tr>
<td>FAA UAS Test Sites (Project Office)</td>
<td>IDIQ Contract</td>
<td>Support of Task 1, UTM, and support of Task 2, LVC-DE efforts</td>
</tr>
<tr>
<td>General Atomics (TC-ITE)</td>
<td>SAA</td>
<td>Ikhana equipped with avionics and Proof of Concept SAA system directly supported by UAS-NAS Project. Status: Agreement in place with GA for SAA Initial Flight Test and FT3 and FT4 for in-kind support</td>
</tr>
</tbody>
</table>

Purple text indicates changes since FY14 AR
## Current Active Collaborations/Partnerships Status

<table>
<thead>
<tr>
<th>Partner (Project Area)</th>
<th>Agreement In Place</th>
<th>Collaboration/Partnership Role</th>
</tr>
</thead>
</table>
| Honeywell (TC-ITE)     | Contract           | Sensor data fusion support  
| NASA SASO (Project Office) | NA               | Coordination with AOSP on UTM and other activities  
Status: Collaborative effort working with FAA Test Sites |
| OSD SAA SARP (Project Office) | NA               | Assess SAA research gaps and generate recommendations to RTCA SC-228.  
Status: Project serves as board member for SARP. Project actively participates in SARP activities |
| Rockwell Collins (TC-C2) | Cooperative Agreement | CNPC radio development and flight test. Cost sharing with Rockwell Collins concentrated in FY11-13, totaling $3M contribution from Rockwell.  
Status: Rockwell Collins delivered Gen-4 and Gen-5 radios |
| RTCA SC-228 (TC-C2, TC-SAA) | NA               | Conduct modeling, simulation and analysis to support the development of MOPS  
Status: On-going support to DAA and C2 working groups |
| NASA SMART NAS (Project Office) | NA               | Coordination with SMART NAS Project on FY15 Augmentation tasks  
Status: Collaborative effort working on LVC/SMART NAS enhancements |
| UND (Non-TC-Certification) | SAA               | Exploring requirements for safe operation of UAS through a series of case studies, experiments and flight evals.  
Status: On-going collaboration and in-kind support |
| University of South Carolina (TC-C2) | Grant           | Develop channel models from RF channel sounding data and analysis of flight test data for channel fading and multipath effects. |

*Purple* text indicates changes since FY14 AR
FY15 Accomplishments

• Supported RTCA SC-228 and contributed to DAA and C2 Preliminary MOPS
• NASA IDIQ contract with all 6 FAA UAS Test Sites Established
• TC-SAA, TC-HSI, TC-ITE: SAA Initial Flight Test Successfully Executed
• TC-HSI, TC-SAA, TC-ITE: Part Task Simulation 5 Successfully Executed
• TC-C2: CNPC Gen-4 Flight Test Successfully Executed
• TC-SAA: CASSAT Successfully Executed
• TC-SAA: ACES Simulations Successfully Completed
• Non-TC [Cert]: Restricted Category Type Certification Report Successfully Completed
• Non-TC [sUAS]: Video Data Base Flight Test Successfully Executed
• NASA Honor Awards: ACAS-Xu and Self-Separation Group Achievement Award (TC-SAA, TC-HSI & TC-ITE), Langley Group Achievement Award (TC-SAA), Exceptional Leadership Award (TC-ITE), Exceptional Service Medal (PO, TC-HSI), Early Career Achievement Medal (PO)
• NASA X UAS-NAS Project Video won the Capital Region Emmy Award within the Informational/Instructional Category

FY16 Look Ahead

• TC-SAA, TC-C2, TC-HSI, TC-ITE: Flight Test Series 4
• TC-HSI, TC-SAA: Part Task Simulation 6
• TC-C2: CNPC Gen 5 Flight Test
FY16 Potential Storm Clouds

• FY16 Project Portfolio
  – Under examination to assess if original baseline plans have the right priorities
    • Working with SC-228 leadership for their prioritization of planned activities

• Major Test Activities
  – Flight Test Series 4 (FT4)
    • Path forward in work following decision to cease FT3 full mission data collection
    • Multiple options for full mission ownship
    • Potential Technical, Cost, Schedule impacts

• FY16 API
  – FT3 & FT4 execution and subsequent research findings contribute to the FY16 API

• SC-228
  – Stakeholder interest in Project test activities may impact FY16 Research Portfolio

• Resource Impact
  – FT4 path forward execution still in work; potential to exceed baseline budget
  – Potential IT&E workforce impact as a result of FAA UAS test site activities

• Potential Phase 2 MOPS Support Follow-on Project
  – Planning may impact FY16 Project baseline execution
FY15 Summary

✓ Successful execution of Project Phase 2 Portfolio
  – Executed multiple ground tests, simulations, and flight tests
  – FY15 Annual Performance Indicator (API)

✓ Balanced rigor with timely and effective project management
  – Incorporating process lessons learned

✓ Enhanced LVC distributed test environment with augmentation spending

✓ Integral member of RTCA SC-228

Delivered research findings and subject matter expertise integral to DAA and C2 Preliminary MOPS
UAS-NAS Overview
Backup Slides
Phase 2 Content Decision Process

• **Step 1: Identify Community Needs**
  – The Community Needs were collected from several strategic guidance documents that identified challenges preventing civil and commercial UAS from routinely operating within the NAS

• **Step 2: Define and Apply Filters**
  – Filters were selected to assess which community needs were relevant to NASA, ARMD, and the Project
  – Filters: NASA & ARMD Mission, ARMD Skills/Capabilities, Project Time Frame

• **Step 3: Map to Focus Area Bins**
  – Community needs that made it through the filters were binned into affinity groups

• **Step 4: Team Refine Sources and Bin Mapping**
  – Top Down (Project Office) and Bottoms Up (PEs & DPMfs) approaches come together to achieve consensus on sources and bins

• **Step 5: Applying Weight Criteria and Prioritization**
  – Prioritization used to identify lower priority community needs that the Project should not pursue for Phase 2
    • Weighting Criteria: Community Needs, Appropriate Organization, Ability to Complete, Complexity & Testing, Public Outreach/Acceptance
Phase 2 Content Decision Process (cont.)

- **Step 6: Community Progress Assessment**
  - Evaluates the progress made towards addressing the community needs by NASA and other government/industry organizations to identify the remaining gaps

- **Step 7: Team Identify Technical Work Packages**
  - Project Managers and Technical Leads provided assessments of which community needs the Project should be contributing towards in Phase 2

- **Step 8: Project Office Validate Proposed Technical Work Packages**
  - The Project Office reviewed the proposed TWPs supplied by the team and evaluated them according to many factors including: Consistency with existing Phase 1 plans, lessons learned, and Phase 2 Drivers

- **Step 9: Develop Detailed Plans for Validated Technical Work Packages**
  - Project Managers and Technical Leads developed detailed proposals for TWPs that address the UAS Community Needs

- **Step 10: Perform Cost, Benefit, and Risk Analysis for all Potential P2 Work**
  - The Project Office evaluated each Technical Work Package in the areas of cost, benefit, and risk to generate an initial portfolio
  - Initial portfolio was evaluated for additional considerations, including: Support of Phase 2 Drivers, UAS Subcommittee Feedback, and results of the Center Independent Cost Assessments
FAA Influence on Project Phase 2 Portfolio

• The FAA Concept of Operations (CONOPs) and Roadmap establish the vision and define the path forward for safely integrating civil UAS operations into the National Airspace System (NAS)

• The Civil UAS Implementation Plan builds upon the FAA CONOPs and Roadmap by defining:
  – The FAA Aviation Rule Making Committee (ARC) view of the activities needed to safely integrate UAS
  – An initial plan for means, resources and schedule necessary for the aviation community and stakeholders to safely and expeditiously integrate civil UAS into the NAS

• NASA UAS Integration in the NAS Project Role
  – Leverage strategic material developed through the FAA (and partners) to ensure NASA portfolio will transfer to UAS integration
  – Continue partnership with the FAA to develop technologies and standards, and necessary planning material, throughout the life of the project
UAS-NAS Technical Challenge Performance Backup Slides
Gen-2 Radio in Relevant Environment Flight Test

• Research Objectives:
  – Analyze the performance of the second generation CNPC System prototype in a relevant flight environment

• Results and Conclusions:
  – Demonstrated fluid transition “hand-off” of aircraft CNPC signal between two CNPC system ground stations
  – Demonstrated operation of remote CNPC system ground terminals through network
  – Measured data link transmission/reception times
  – Testing of the 2nd generation CNPC system demonstrated the ability to meet the initial SC-203 performance goals
  – Results from the test were analyzed and delivered to SC-228, providing validation data and technical basis for the draft C2 MOPS
  – Flight Test Report was completed and released

CNPC Radio for Development and V&V of C2 MOPS
Develop and Test Security Prototype

• **Research Objective:**
  – Define CNPC security recommendations for civil UAS operations based on analysis of laboratory test results

• **Results, Conclusions, and Recommendations:**
  – Implemented security mitigations identified in previous project studies
  – Performed full end-to-end testing of system in laboratory environment, utilizing Gen-2 radio hardware
  – Developed baseline for overhead and latency imposed by the recommended security measures
  – Results from the test were analyzed and delivered to SC-228, providing validation data for the security portions of the draft C2 MOPS
  – Test report was completed and released
Spectrum Compatibility Analysis

• **Research Objective:**
  – Develop data and rationale to obtain appropriate frequency spectrum allocations to enable the safe and efficient operation of UAS in the NAS

• **Interim Results, Conclusions, and Recommendations:**
  – Developed and delivered Annex 7 to ITU-R M.[UAS-FSS] report (Sharing studies on emissions from fixed satellite service earth station transmitters on-board unmanned aircraft into incumbent terrestrial services)
    • Conclusion is UA Fixed Satellite Service (FSS) transmitters do not cause Fixed Station (FS) protection criteria to be exceeded at altitudes ≥ 9 000 feet AGL and latitudes up to 70 degrees for 14.0-14.47 GHz
    • Conclusion is UA Fixed Satellite Service (FSS) transmitters do not cause Fixed Station (FS) protection criteria to be exceeded at altitudes ≥ 3 000 feet AGL and latitudes up to 70 degrees for 27.5-29.5 GHz
  – Results are being delivered at the 2015 World Radiocommunication Conference to support the allocation of Ku & Ka Band frequencies for UAS operations
• **Research Objective:**
  – Develop validated radio models, based on flight testing and development of performance profiles to be used during regional large scale simulations

• **Interim Results, Conclusions, and Recommendations:**
  – Update of radio models to Gen-5 FT radio implementation completed (early Sept) in Opnet
    • New CNPC Gen-5 waveforms and calibrations
    • New logic/messaging for CNPC connection establishment, authentication, waveform changes and handoffs
    • IPv6 with Mobility and Compression. Networked GS operation
    • CNPC data traffic profile changes by domain (airspace) and class (UA Class)
    • Inclusion of flight test propagation models data in Opnet
    • Inclusion of L-band ground antenna model characteristics
  – Currently working integration of Gen-5 model and its supporting ground station infrastructure into large-scale simulation
  – Model validation testing with Gen-5 radios is in progress in GRC lab

Start of Data Collection May 2015

Propagation data integration

L-band antenna models characteristics

CNPC Radio Simulation Development for Development and V&V of C2 MOPS

Schedule Package: C.4.10
Recommendations for Integration of CNPC and ATC Comm

**Research Objective:**
- Develop inputs to preliminary and final SC-228 C2 WG MOPS based on simulations conducted in OPNET and ACES Large-scale environments using specific MOPS and NAS Comm Architecture operations scenarios.

**Interim Results, Conclusions, and Recommendations:**
- Completed simulations and delivered results to SC-228 C2 WG, to define parameters for Gen-5 V&V radio.
- CNPC and ATC Comm integration simulations to be run in March 2016 with Gen-5 radio model.
  - Simulation analysis will look at the ability/performance of ATC communications in providing continued piloted aircraft ATC with ATC required for UA aircraft operations. UA Classes above sUAS for ATC.
  - Comparison of Relay vs. non-Relay architecture performance.
  - Varied air-traffic scenarios for mixed operations.
  - Evaluated for performance, safety, reliability.

**NAS-Wide CNPC System Simulation for Development and V&V of C2 MOPS**

Schedule Package: C.4.30
• **Research Objective:**
  – Perform large-scale NAS simulations to assess impact of UAS on the NAS communications operations with different operating concepts and for different control and non-payload communication system architectures

• **Interim Results, Conclusions, and Recommendations:**
  – Simulations are using Gen-5 Radio model
  – Simulation analysis will look at the performance impact on NAS ATC communication, Datalink Communication and CNPC uplink and downlink for C2, Telemetry, Wx, DAA, and Navaid information handled over the CNPC link for varying air traffic loads
  – Varied air-traffic scenarios for mixed operations
  – Evaluate for performance, safety, reliability

NAS-Wide CNPC System Simulation for Development and V&V of C2 MOPS
<table>
<thead>
<tr>
<th>TC-C2 Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>[SP C.1.10] Gen2 Radio in Relevant Environment Flight Test</td>
<td>4/2014</td>
<td>• Analyze the performance of the second generation C-band CNPC System prototype in a relevant flight environment</td>
<td>• Results continue the development of the CNPC system terrestrial operation performance standards</td>
</tr>
</tbody>
</table>

- **Briefings, Papers, or Reports**
  - UAS-Comm-4.3-025-001, CNPC Prototype Radio Development Generation 2 Flight Test Program Overview, Briefing, August 2014
Verify Prototype Performance – Preliminary C2 MOPS Input

<table>
<thead>
<tr>
<th>TC-C2 Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP C.1.20] Verify Prototype Performance - Draft C2 MOPS Input | 1/2015 | • Analyze the performance of the fourth generation C-band Control and Non-Payload Communication System prototype in a relevant flight environment | • Results inform:  
  • Performance of CNPC System prototype in a Relevant, mixed traffic environment  
  • Development of a final, verified and validated, Command and Control Minimum Operational Performance Standards |

• Briefings, Papers, or Reports
Verify Prototype Performance - Final C2 MOPS Input

<table>
<thead>
<tr>
<th>TC-C2 Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP C.1.30] Verify Prototype Performance - Final C2 MOPS Input | 6/2015 (FT3) | • Analyze the performance of fourth generation Control and Non-Payload Communication System prototypes used for control and non-payload communication for a GCS implementing SAA algorithms and information display requirements controlling an unmanned aircraft surrogate operating in a mixed traffic environment | • Results inform:  
  • Performance of CNPC System prototype in a Relevant, mixed traffic environment  
  • Development of a final, verified and validated, Command and Control Minimum Operational Performance Standards |
| | 2/2016 (FT4) | | |

• Briefings, Papers, or Reports
  – Compliance ITU-R Prototype Comm System: Report on Results from FT3 Simulation planned for November 2015 (FT3)
Develop and Test Security Prototype

<table>
<thead>
<tr>
<th>TC-C2 Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>[SP C.2.10] Develop and Test Prototype</td>
<td>3/2014</td>
<td>• Define CNPC security recommendations for civil UAS operations based on analysis of laboratory test results</td>
<td>• Results inform understanding of CNPC system security architecture performance</td>
</tr>
</tbody>
</table>

• Briefings, Papers, or Reports
  – UAS-Comm-4.3-015-001, Security Test Plan for Lab Prototype, January 2014
  – UAS-Comm-4.3-026-001, CNPC Security Architecture Prototype, Briefing, August 2014
### Performance Validation of Security Mitigations - Relevant Flight Environment

<table>
<thead>
<tr>
<th>TC-C2 Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>[SP C.2.20] Performance Validation of Security Mitigations - Relevant Flight Environment</td>
<td>10/2014</td>
<td>• Determine CNPC security recommendations for civil UAS operations based on analysis of flight test results</td>
<td>• Results:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Inform CNPC system security design requirements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Inform control and non-payload security architecture performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Contribute to validation of security mechanisms designed to mitigate risks and vulnerabilities of CNPC system as incorporated in performance standards</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Inform understanding of CNPC system performance during hand-off between communication system ground stations and edge of coverage events</td>
</tr>
</tbody>
</table>

• Briefings, Papers, or Reports
## Spectrum Compatibility Analysis

<table>
<thead>
<tr>
<th>TC-C2 Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP C.3.10] Spectrum Compatibility Analysis | Not applicable | • Develop data and rationale to obtain appropriate frequency spectrum allocations to enable the safe and efficient operation of UAS in the NAS | • Analysis:  
  • Provides technical data on NASA UAS terrestrial CNPC developments to ICAO Aeronautical Communications Panel Working Group F to develop the technical parameters of the UAS LOS CNPC allocations and support international standards development  
  • Provides compatibility studies, in coordination with RTCA SC-228, to evaluate technical issues involved with the sharing of FSS spectrum for BLOS UAS CNPC  
  • Informs technical parameters for allocated UAS terrestrial spectrum, in International standards organizations |

- **Briefings, Papers, or Reports**
  - UAS-Comm-4.3-024-001, GRC Spectrum Update, Briefing (SC-228), August 2014
  - UAS CNPC Spectrum Final Report and Recommendations planned for September 2016
C-Band Planning & Standards

<table>
<thead>
<tr>
<th>TC-C2 Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP C.3.20] C-Band Planning & Standards | Not Applicable | • Develop data and rationale to define usage of terrestrial spectrum for UAS CNPC systems to enable the safe and efficient operation of UAS in the NAS | • Results inform:  
  • Technical parameters for allocated UAS terrestrial spectrum, in International standards organizations  
  • Development of C-Band band plans and standards, in coordination with RTCA SC-228 and delivered to ICAO Working Group F, to define usage of terrestrial spectrum for UAS CNPC systems |

• Briefings, Papers, or Reports
  – C-Band Planning and Standards briefing to SC-228 planned for February 2016
  – C-Band Planning & Standards Final report planned for September 2016
## Flight Test Radio Model Development and Regional Sims

<table>
<thead>
<tr>
<th>TC-C2 Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP C.4.10] Flight Test Radio Model Development and Regional Sims | 5/2015 | Develop validated radio models, based on flight testing and development of performance profiles to be used during regional large scale simulations | Results inform:  
  - Initial validation of proposed RTCA CNPC performance standards and to recommend necessary modifications prior to published C2 MOPS |

- **Briefings, Papers, or Reports**
**Recommendations for Integration of CNPC and ATC Comm**

<table>
<thead>
<tr>
<th>TC-C2 Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP C.4.30] Recommendations for Integration of CNPC and ATC Comm | Multiple | • Develop inputs to preliminary and final SC-228 C2 WG MOPS based on simulations conducted in OPNET and ACES Large-scale environments using specific MOPS and NAS Comm Architecture operations scenarios | • Results inform:  
  • Communication system performance and NAS-wide impact from large-scale NAS simulations incorporating UAS communication system and vehicle performance characteristics  
  • Validation of proposed RTCA CNPC performance standards prior to published MOPS  
  • Recommendations for the integration of CNPC and ATC Comm |

- **Briefings, Papers, or Reports**
  - Large Scale Sims to SC-228 for C2 Final MOPS draft report planned for June 2016
  - Recommendations for Integration of CNPC and ATC Comm report planned for September 2016
### Communication System Performance Impact Testing (Delays/Capacity)

<table>
<thead>
<tr>
<th>TC-C2 Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP C.4.40] Communication System Performance Impact Testing (Delays/Capacity) | 8/2015 | • Perform large-scale NAS simulations to assess impact of UAS on the NAS communications operations with different operating concepts and for different control and non-payload communication system architectures | • Results inform:  
  • ATC and CNPC Communications Performance Impact on NASA Delays/Capacity |

- **Briefings, Papers, or Reports**
  - ATC and CNPC Comm Performance Impact on NAS Delay/Capacity report planned for February 2016
## SatCom Simulations

<table>
<thead>
<tr>
<th>TC-C2 Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP C.4.50] SatCom Simulations | 2/2016 | • Analyze SatCom Control and Non-Payload Communication system using regional large scale simulations | • Results inform:  
  • Satcom assumptions utilized in SC-228 C2 terrestrial MOPS and provides initial inputs to draft SC-228 C2 Satcom MOPS |

- **Briefings, Papers, or Reports**
  - SatCom for UAS Sim Report planned for September 2016
## TC – C2

<table>
<thead>
<tr>
<th>Name</th>
<th>FY2014</th>
<th>FY2015</th>
<th>FY2016</th>
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<tbody>
<tr>
<td></td>
<td>Q1</td>
<td>Q2</td>
<td>Q3</td>
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<tr>
<td><strong>TC - C2 Performance Standards</strong></td>
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<tr>
<td>[TWP C.1] Datalink</td>
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<tr>
<td>[SP C.1.10] Gen2 Radio in Relevant Environment Flight Test</td>
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<tr>
<td>[SP C.1.20] Verify Prototype Performance - Draft C2 MOPS Input</td>
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<tr>
<td>[TWP C.2] Security</td>
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<td>[SP C.2.10] Develop and Test Prototype</td>
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<tr>
<td>[TWP C.3] Spectrum</td>
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<tr>
<td>[SP C.3.10] Spectrum Compatibility Analysis</td>
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<td>[SP C.3.20] C-Band Planning &amp; Standards</td>
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<tr>
<td>[TWP C.4] Simulation</td>
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<tr>
<td>[SP C.4.10] Flight Test Radio Model Development and Regional Sims</td>
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<tr>
<td>[SP C.4.20] ACES Sim Operations w/ Flight Test Models</td>
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<tr>
<td>[SP C.4.30] Recommendations for Integration of CNPC and ATC Comm</td>
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<tr>
<td>[SP C.4.40] Communication System Performance Impact Testing</td>
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<tr>
<td>[SP C.4.50] SatCom Phase I Simulations</td>
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</table>

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

*Green Status Line Date 9/30/15*
Surveillance Requirements (Medium Fidelity)  
(ACES Simulation)

• **Research Objective:**
  – Analyze the performance of updated sensor (ADS-B, TCAS, and radar) range and fields of regard requirements and sensitivities against Draft MOPS Alerting requirements
  – Assess airborne radar intruder detection frequency against realistic NAS traffic (IFR, cooperative VFR, and non-cooperative VFR) to inform radar tracker requirements

Preliminary:

• **Interim Results, Conclusions, and Recommendations**
  – 5-nm range appears to cover 99% of potential warning alerts DAA system would encounter with non-cooperative VFR providing verification that 5-nm declaration range for airborne radar is suitable (Preliminary Result)
  – When UAS had at least one non-cooperative VFR intruder in its field of regard, there were 3 or fewer non-cooperative aircraft 98% of the time (Preliminary Result)

---

Non-Cooperative Sensor Surveillance Requirements for DAA MOPS
IHITL Participation & Data Collection

• **Research Objective:**
  
  – Test Setup 1: Evaluate air traffic controller acceptability of UAS maneuvers in response to SAA advisories and pilot performance for remaining Well Clear
  
  – Test Setup 2: Evaluate the pilot’s ability to remain well clear as a function of detect-and-avoid display features and whether the display was stand-alone or integrated within the main traffic display

• **Results, Conclusions, and Recommendations:**
  
  – **Test Setup 1**
    
    • Controllers reported maneuvers requested between 60 and 90 seconds until closest point of approach were acceptable, and at 120 seconds were unacceptable.
    
    • Size of requested maneuvers was frequently judged to be too large, indicating a difference between the separation standard used by UAS pilots to remain Well Clear and manned aircraft.

  – **Test Setup 2**
    
    • Maneuver recommendations appear to be the ‘Advanced’ feature most effective in remaining Well Clear
    
    • Although non-cooperative aircraft can only be detected at a limited range, most losses of Well Clear can be prevented given alert time of at least 60 seconds to closest point of approach
    
    • Pilot response time results will help improve fidelity (ATC/UAS pilot interactions) of non-real-time-time simulations

ATC Interoperability Requirements for DAA MOPS
Self-Separation Risk Ratio Study

• **Research Objective:**
  – Estimate the achievable DAA self separation risk ratio under simplifying assumptions on pilot response and surveillance capabilities.
  – To identify necessary capabilities improvements for assessing draft MOPS requirements in future studies.

• **Research Objective:**

<table>
<thead>
<tr>
<th>Run #</th>
<th>SST time to LoWC (sec)</th>
<th>LoWC Prediction HMD/DMOD (incl. buffer) (ft.)</th>
<th>HMD Resolution Buffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40s</td>
<td>4000 ft.</td>
<td>10%</td>
</tr>
<tr>
<td>2</td>
<td>70s</td>
<td>4000 ft.</td>
<td>10%</td>
</tr>
<tr>
<td>3</td>
<td>40s</td>
<td>5000 ft.</td>
<td>10%</td>
</tr>
<tr>
<td>4</td>
<td>70s</td>
<td>5000 ft.</td>
<td>10%</td>
</tr>
<tr>
<td>5</td>
<td>40s</td>
<td>4000 ft.</td>
<td>20%</td>
</tr>
<tr>
<td>6</td>
<td>70s</td>
<td>4000 ft.</td>
<td>20%</td>
</tr>
<tr>
<td>7</td>
<td>40s</td>
<td>5000 ft.</td>
<td>20%</td>
</tr>
<tr>
<td>8</td>
<td>70s</td>
<td>5000 ft.</td>
<td>20%</td>
</tr>
</tbody>
</table>

• **Results, Conclusions, and Recommendations:**
  – Resolution horizontal miss distance buffer had negligible impact on Risk Ratio (may need larger buffers)
  – Increasing self-separation threshold demonstrated greatest Risk Ratio reduction: Highlights importance of pilot response modeling to DAA risk ratio estimation
  – Increasing predicted HMD/DMOD showed modest risk ratio reduction: poor risk ratios for no buffer case (4,000 feet prediction HMD/DMOD)... points to importance of prediction buffers

Self-Separation System Performance Requirements for DAA MOPS
**Research Objective:**
- Gather data on the performance of a SAA concept with flight representative trajectory uncertainties, control and non-payload communication system characteristics, vehicle dynamics, and SAA sensors in order to improve and calibrate simulation models

**Results, Conclusions, and Recommendations:**
- Test complete
- Data analysis is on-going
SAA Traffic Display Evaluation HITL2
(joint w/HSI Part Task Sim 5)

Research Objective:

- Build upon previous human-in-the-loop simulations results and lessons learned to identify minimum DAA display and guidance requirements for draft SC228 MOPS
- Evaluate pilot’s ability to remain well clear when considering sensor uncertainty, Preliminary MOPS alerting structure, and DAA guidance mode (informative vs. suggestive)

Results, Conclusions, and Recommendations:

- Info Only (19.8%) was roughly four times as likely as Stratway+ (6.5%) and Omni Bands (4.2%) to result in Loss of Well Clear, a significant difference ($p<.05$)
- No significant differences seen between the three guidance displays in terms of Loss of Well Clear
- Pilots responded, on average, 10 seconds faster to Self Separation Warning Alerts than they did to Corrective Self Separation Alerts
- Positive subjective feedback from pilots on Preliminary MOPS Alerting methodology
Research Objective:
- Gather data to support development of alerting logic, methods, and performance requirements using cooperative and non-cooperative VFR traffic and the SC-228 definition of Well Clear considering target level of safety and NAS-interoperability

Interim Results, Conclusions, and Recommendations:
- Correct SS Warning Alerts alerts have at least 15 seconds of lead time to LOWC in 83% of cases
- 72% of Warning alerts resulted in a loss of well clear suggest alerting criteria is within suitable performance bounds
- Even though the probability of false alert for Corrective alerts seem high, most of the encounter fall within the vertical or horizontal bounds of the well clear definition, which indicates a low severity level (most false alerts would be acceptable from a safety stand-point to overcome missed alerts)
**Research Objective:**
- Evaluate the impact of UAS SAA self separation maneuvers resulting for different SAA Well Clear volumes on controller perceptions of safety and efficiency

**Results, Conclusions, and Recommendations:**
- A horizontal miss distance of ~1.5 nm appears to be optimal for ATC acceptability (away from the airport vicinity)
- Horizontal miss distance of 1.5 nm is 150% larger than the TCAS resolution advisory horizontal miss distance for all airspace below Class A, and 136% larger in Class A
- 500’ IFR-VFR vertical separation (with no vertical closure rate) was universally acceptable during debrief sessions
- Air traffic controllers thought the SAA integration concept as presented was viable

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**Well Clear Separation & ATC Interoperability Requirements for DAA MOPS**

Schedule Package: S.5.10
• **Research Objective:**
  – Assess SAA-to-Traffic Alert and Collision Avoidance System interoperability and the impact of CNPC system delay on the execution of UAS pilot Self Separation tasks

• **Interim Results, Conclusions, and Recommendations:**
  – Simulation shows to maintain Well Clear and avoid almost all TCAS Resolution Advisories:
    • Above 10,000 feet with typical airliner speeds – need at least 1.5 nm Closet Point of Approach
    • Below 10,000 feet below 250 knots, need at least 1.2 nm Closet Point of Approach
SSI LaRC Support & Participation in FT3

• **Research Objectives:**
  – Evaluate the performance of self separation Stratway+ algorithm using a cooperative sensor in constrained geometric/operational conditions in the presence of real winds (Min Success)
  – Evaluate the performance of General Atomics Conflict Prediction and Display System vs. Stratway+ coordination of maneuver guidance and the performance of a self separation algorithm using both cooperative and non-cooperative sensors in the presence of real winds (Full Success)

• **Interim Results, Conclusions, and Recommendations:**
  – Testing successfully accomplished in July 2015
  – Analysis in progress
**Research Objective:**

- Develop and evaluate a concept of integrated Collision Avoidance and Safe Separation functions that enables UAS to execute automated maneuvers in terms of acceptability to ATC, as well as investigate the range of acceptable times to alert the UAS pilot to potential loss of well-clear condition.

**Interim Results, Conclusions, and Recommendations:**

- Testing successfully completed September 15, 2015
- Analysis in progress

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Automated Self-Separation Maneuver Requirements for DAA MOPS

Schedule Package: S.5.60
Surveillance Requirements (Medium Fidelity) (ACES Simulation)

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.1.10] Surveillance Requirements (Low Fidelity) (ACES Simulation) | 2/2014 | • Analyze tradeoffs in the performance of different surveillance ranges and fields of regard using perfect sensor and unmitigated (without Autoresolver) SAA encounters  
• Examine the impact on an aircrafts’ ability to remain “Well Clear” or avoid the Near Mid-Air Collision volume without a mitigation strategy (self separation algorithm) | • Results inform:  
• SAA surveillance system performance requirements for multiple self-separation and collision avoidance concepts/capabilities functional requirements  
• The performance characteristics of and interactions between SAA system functions  
• SAA algorithm development |

• Briefings, Papers, or Reports
  – Surveillance Requirements (Medium Fidelity) Brief results to SC-228 planned for October 2015
SAA Traffic Display Evaluation HITL1 (joint w/HSI Part Task Sim 4)

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.2.10] SAA Traffic Display Evaluation HITL1 (joint w/HSI Part Task Sim 4) | 2/2014 | • Evaluate integrated SAA system under perfect sensor conditions  
• Evaluate the pilot’s ability to remain clear as a function of self separation threshold  
• Evaluate the pilot’s acceptability of recommended Autoresolver maneuvers to avoid well-clear  
• Evaluate the utility of two different trial planner capabilities that aid an UAS in remaining well-clear of other traffic | • Results:  
• Inform SAA system display requirements to include trial planning capabilities  
• Contribute to defining performance characteristics for UAS human-automation systems  
• Provide estimates for the impact of UAS (pilot, traffic displays, SAA algorithm/concept/displays) operations on NAS safety over a range of UAS mission profiles  
• Provide estimates for number of Well Clear violations, pilot acceptability of autoresolver SAA maneuvers, pilot acceptability of alerting criteria, encounter characteristics if/when autoresolver fails to recommend a Well Clear maneuver, and Well Clear maneuver characteristics, pilot/air traffic controller negotiation times |

• Briefings, Papers, or Reports
  – UAS-SSI-4.1-033-001, PT4 Detect and Avoid Results Presentation, Briefing (SC-228), August 26 2014

Schedule Package: S.2.10
## IHITL Participation & Data Collection

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>[SP S.2.20] IHITL Participation &amp; Data Collection</td>
<td>6/2014</td>
<td>• Evaluate air traffic controller acceptability of UAS maneuvers in response to SAA advisories and pilot performance for remaining “Well Clear”</td>
<td>• Results inform and support understanding of:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Air traffic controller acceptability of UAS maneuvers in response to SAA advisories</td>
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<tr>
<td></td>
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<td></td>
<td>• UAS pilot’s performance at remaining Well Clear modeling non-cooperative sensor range, elevation, and azimuth performance as part of an SAA system</td>
</tr>
<tr>
<td></td>
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<td>• Existing air traffic control procedures and operations in the presence of a UAS</td>
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<td>• Interoperability between UAS pilot and air traffic controller</td>
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<tr>
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<td></td>
<td>• Sensor performance on UAS pilot’s ability to perform SAA functions and maintain Well Clear</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Impact of realistic estimate of CNPC system latency impact on UAS pilot and air traffic controller operations and performance</td>
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<tr>
<td></td>
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<td></td>
<td>• Well Clear as a airborne separation standard for UAS</td>
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<td></td>
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<td>• Air traffic controller ability to recognize/correct a Well Clear violation</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• UAS pilot workload</td>
</tr>
</tbody>
</table>

- **Briefings, Papers, or Reports**
  - UAS-SSI-4.1-045-001, Airspace Concept Evaluation System (ACES) Simulation Study, Briefing (SC-228), November 2014

Schedule Package: S.2.20
## Self-Separation Risk Ratio Study

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.2.30] Self-Separation Risk Ratio Study | 4/2014 | • Gather data indicating the degree to which self separation systems mitigate the probability that an encounter to the self separation threshold will proceed to a Well Clear violation (self separation Airspace Safety Threshold) | • Results:  
  • Inform the understanding of the level of UAS safety a self-separation system could achieve in the NAS with multiple UAS mission profiles and NAS traffic estimates using perfect surveillance state information of cooperative VFR traffic  
  • Provide estimates of risk ratio as a function of self-separation threshold and Well Clear definition, number/rate of UAS-to-VFR conflicts to the self-separation threshold, number/rate of conflicts that progress to Well Clear violations, secondary encounters with other aircraft following execution of a self separation maneuver, deviation magnitude from flight plan, number of TCAS RAs generated  
  • Inform understanding of allowable tradeoffs between SAA system functions  
  • Inform UAS performance based rules for SAA equipage  
  • Contribute to air traffic control operating procedures for UAS SAA systems |

### Briefings, Papers, or Reports

- UAS-SSI-4.1-037-001, Final Overview of ACES Sim for Evaluating SARP Well Clear Definitions, Briefing (SARP), August 5 2014
- UAS-SSI-4.1-039-001, ACES Mitigated Results Supporting Selection of SARP Well-Clear Definition Maneuver Initiation Point MIP, Briefing (SC-228), August 7 2014
- UAS-SSI-4.1-040-001, ACES Unmitigated and some Mitigated Results Supporting Selection of SARP Well Clear Definition, Briefing (SC-228), August 5 2014
- UAS-SSI-4.1-042-001, Encounter Rate Simulation Study with UAS Missions, Briefing, September 2014
<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.2.40] FT3 Participation & Data Collection | 6/2015 | - Gather data on the performance of a SAA concept with flight representative trajectory uncertainties, control and non-payload communication system characteristics, vehicle dynamics, and SAA sensors in order to improve and calibrate simulation models | - Results used to calibrate models with flight test data (Communication system models, UAS performance models, sensor models, trajectory performance models)  
- Results inform DAA MOPS |

- Briefings, Papers, or Reports
  - FT3 Participation & Data Collection SSI ARC FT3 brief results to SC-228 planned for January 2016
  - FT3 Participation & Data Collection SSI ARC FT3 report/paper planned for January 2016
### SSI-ARC FT4 Participation & Data Collection

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baslined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.2.50] FT4 Participation & Data Collection | 2/2016 | • Determine the performance of a SAA concept  
• Gather data for additional validation of simulation models and results with flight representative trajectory uncertainties, control and non-payload communication system characteristics, vehicle dynamics, and SAA sensors | • Results inform:  
• DAA MOPS  
• Accuracy of ACES simulation results |

- **Briefings, Papers, or Reports**
  - FT4 Participation & Data Collection SSI ARC FT4 brief results to SC-228 planned for June 2016
  - FT4 Participation & Data Collection SSI ARC FT4 report/paper planned for June 2016
SAA Traffic Display Evaluation HITL2 (joint w/HSI Part Task Sim 5)

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.2.60] SAA Traffic Display Evaluation HITL2 (joint w/ HSI Part Task Sim 5) | 2/2015 | • Evaluate the pilot’s ability to remain clear of other traffic with different sensor range and field of regard limitations, and sensor uncertainties | • Results inform:  
  • Pilot’s acceptability of Autoresolver resolutions and trial planning capability  
  • And support the development of SAA system requirements and performance standards (MOPS) |

• Briefings, Papers, or Reports
  – SAA Traffic Display Evaluation HITL2 brief results to SC-228 planned for May 2015
  – SAA Traffic Display Evaluation HITL2 Results Simulation report planned for September 2015
**Effect of SAA Maneuvers with Procedures (ACES Simulation)**

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.2.70] Effect of SAA Maneuvers with Procedures (ACES Simulation) | 4/2015 | • Gather data indicating the degree to which Self Separation systems mitigate the probability that an encounter to the Self Separation threshold will proceed to a well clear violation (Self Separation Airspace Safety Threshold), using higher fidelity models of sensor uncertainties, communications latencies and pilot-controller interactions | • Results inform:  
  • risk ratio for self-separation systems with imperfect surveillance state information and realistic pilot-controller negotiation times against cooperative and non-cooperative VFR traffic  
  • And support the development of SAA system requirements and performance standards (MOPS) |

• Briefings, Papers, or Reports
  – ACES Simulation Report planned for December 2015
## Comprehensive Evaluation of Airspace Risk Threshold (ACES Simulation)

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.2.80] Comprehensive Evaluation of Airspace Risk Threshold (ACES Simulation) | 2/2016 | • Gather data indicating the degree to which Self Separation systems mitigate the probability that an encounter to the Self Separation threshold will proceed to a well clear violation, using higher fidelity models of sensor uncertainties, communications latencies and pilot-controller interactions that have been validated by flight test data | • Results inform:  
  • Fast-time simulation results, validated by flight tests, indicating which combinations of SAA system parameters would allow UAS operations to meet the airspace risk threshold  
  • AutoResolver (as a proxy for pilot-in-the-loop self-separation system) ability to mitigate well clear violations relative to the SST encounter rate  
  • The combinations of SAA system parameters (e.g. allowable latency, surveillance range) that allows UAS operations to meet the airspace risk threshold  
  • and support the development of SAA system requirements and performance standards (MOPS) |

- **Briefings, Papers, or Reports**
  - Comprehensive Evaluation of Airspace Risk Threshold SSI ARC Brief results to SC-228 planned for July 2016
  - ACES Simulation Report planned for August 2016
<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.3.10] Well Clear Metric and Definition Study | 4/2014 | • Gather data and develop recommendations for a quantified definition of “Well Clear” using cooperative Visual Flight Rule traffic that meets target level of safety requirements and NAS-interoperability considerations | • Results:  
  • Inform the development of a quantified Well Clear definition and SAA concept with multiple UAS mission profiles and NAS traffic estimates using perfect surveillance state information of cooperative VFR traffic  
  • Contribute to the definition of Well Clear time and/or distance dimensions  
  • Generate Well Clear maneuver resolution characteristics for UAS and cooperative VFR traffic for multiple definitions of Well Clear  
  • Provide estimates for risk ratio as a function of self-separation threshold and Well Clear definition, number/rate of Well Clear violation, number/rate of NMAC, number of generated TCAS RAs, number/rate of UAS-to-VFR traffic conflicts to the self-separation threshold |

• Briefings, Papers, or Reports  
  – UAS-SSI-4.1-026-001, Investigating Effects of Well Clear Definitions on UAS SAA Operations Slides, Briefing, Plan, May 2014  
## DAA Self-Separation Alerting Methods, Performance, and Robustness Study (ACES Simulation)

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.3.30] DAA Self-Separation Alerting Methods, Performance, and Robustness Study (ACES Simulation) | 3/2015 (Phase 1)            | • Gather data to support development of alerting logic, methods, and performance requirements using cooperative and non-cooperative VFR traffic and the SC-228 definition of Well Clear considering target level of safety and NAS-interoperability | • Results inform:  
  • Fast-time simulation results for a SAA concept incorporating well clear alerting logic with perfect surveillance state information against cooperative and non-cooperative VFR traffic  
  • Alerting logic methods and performance  
  • Selection of a particular SAA concept of operations using the fast time simulation results |
|                                                                                       | 7/2015 (Phase 2)            |                                                                                                                                                                                                                           |                                                                                                                                                                                                                           |

- **Briefings, Papers, or Reports**
  - UAS-SSI-4.1-061-001, Analysis of Baseline PT5 Alerting Scheme in Fast-Time Simulations without DAA Mitigation, Briefing, May 2015
  - Phase 2 - Document results in final report/briefing planned for December 2015
Collision Avoidance/Self Separation Algorithm Maneuvers vs. UA Performance Assessment

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baslined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.4.20] Collision Avoidance/Self Separation Algorithm Maneuvers vs. UA Performance Assessment | 2/2016 | • Generate performance data for the trade-off space between UAS and DAA algorithm performance | • Results inform:  
  • Maneuver time requirements for a spanning set of aircraft performance models over a broad range of encounters for selected algorithms  
  • DAA requirements  
  • DAA MOPS |

• Briefings, Papers, or Reports
  – Collision Avoidance/Self Separation Algorithm Maneuvers vs. UA Performance Assessment Preliminary Results for Stakeholders Available July 2016
  – Collision Avoidance/Self Separation Algorithm Maneuvers vs. UA Performance Assessment Results Paper planned for August 2016
# UAS CAS1 HITL

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.5.10] UAS CAS1 HITL | 1/2014 | • Evaluate the impact of UAS SAA self separation maneuvers resulting for different SAA Well Clear volumes on controller perceptions of safety and efficiency | • Results inform:  
  • Understanding of air traffic controller operational acceptability of UAS Stratway+ self-separation concept/capability  
  • Understanding of air traffic controller operational acceptability of quantifying the definition of Well Clear  
  • Understanding of air traffic controller workload in the presence of a UAS with Stratway+ self-separation concept/capability operating in the NAS  
  • Understanding of interoperability of UAS Stratway+ self-separation concept/capability and TCAS II |

- **Briefings, Papers, or Reports**
  - UAS-SSI-4.1-016-001, UAS Controller Acceptability Study 1 (UAS-CAS1) Test Plan, November 2013
  - UAS-SSI-4.1-019-001, UAS-CAS1 FER Slides, Briefing, November 2013
  - UAS-SSI-4.1-021-001, UAS CAS1, Briefing (AUVSI), May 2014
  - UAS-SSI-4.1-031-001, UAS-CAS1, Briefing (SC-228), May 2014
  - UAS-SSI-4.1-051-001, UAS in the NAS Air Traffic Controller Acceptability Study - 1 the Effects of Horizontal Miss Distances on Simulated UAS and Manned Aircraft Encounters, Briefing, May 2015
  - UAS-SSI-4.1-052-001, UAS in the NAS Air Traffic Controller Acceptability Study - 1 the Effects of Horizontal Miss Distances on Simulated UAS and Manned Aircraft Encounters, Paper, May 2015
**SSI-LaRC Support & Participation in IHITL**

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.5.20] Langley Support & Participation in IHITL | 6/2014 | • Assess SAA-to-Traffic Alert and Collision Avoidance System interoperability and the impact of CNPC system delay on the execution of UAS pilot self separation tasks | • Results inform and support understanding of:  
  • Air traffic controller acceptability of UAS maneuvers in response to SAA maneuvers  
  • Compatibility of the Stratway+ SAA concept (and Well Clear criteria implementation) with existing TCAS II equipped aircraft  
  • Impact of CNPC system latencies on UAS pilot and air traffic controller operations and performance  
  • Impact of wind direction and velocity on UAS pilot and air traffic controller operations and performance  
  • Interoperability of SAA concept with TCAS equipped aircraft Collision Avoidance Volumes |

**Briefings, Papers, or Reports**
- UAS-SSI-4.1-022-001, UAS Controller Acceptability Study 2 (UAS-CAS2) and IHITL Test Plan, May 2014
- UAS-SSI-4.1-023-001, UAS-CAS2 IHITL (PER-FER), Briefing, May 2014
- UAS-SSI-4.1-024-001, IHITL Experiment Plan-Controller Subjects (aka Configuration 1, test setup 1), Briefing, May 2014
- UAS-SSI-4.1-043-001, Completed, Ongoing and Upcoming Experiments iHITL-B747-TCAS and IHITL-CAS2 Overview and Results, Briefing (SC-228), November 2014
### SSI LaRC Support & Participation in FT3

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.5.40] SSI LaRC Support & Participation in FT3 | 6/2015                        | • Evaluate the performance of self separation Stratway+ algorithm using a cooperative sensor in constrained geometric/operational conditions in the presence of real winds (Min Success)  
• Evaluate the performance of General Atomics Conflict Prediction and Display System vs. Stratway+ coordination of maneuver guidance and the performance of a self separation algorithm using both cooperative and non-cooperative sensors in the presence of real winds (Full Success) | • Results inform:  
  • Performance of self separation-Stratway+ algorithm using a cooperative sensor in constrained geometric/operational conditions in the presence of real winds (min success).  
  • Performance of CPDS vs. Stratway+ coordination of maneuver guidance, and performance of a self separation algorithm (CPDS on Ikhana) using both cooperative and non-cooperative sensors, in the presence of real winds (full success)  
  • DAA requirements  
  • DAA MOPS |

- **Briefings, Papers, or Reports**
  - SSI LaRC Support & Participation in FT3 Brief Results to SC-228 planned for January 2016
  - SSI LaRC FT3 report/paper planned for February 2016
### SSI LaRC Support & Participation in FT4

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>[SP S.5.50] SSI LaRC Support &amp; Participation in FT4</td>
<td>2/2016</td>
<td>• Evaluate the performance of self separation Stratway+ algorithm in constrained geometric/operational conditions in the presence of real winds for both cooperative and non-cooperative targets utilizing a fast (~250 knots) surrogate UAS with a full DAA sensor suite and fusion/tracker capability (min success) • Evaluate the performance of a self separation algorithm in constrained geometric/operational conditions in the presence of real winds and a suite of sensors for both cooperative and non-cooperative targets utilizing a live UAS as part of the flight scenarios (full success)</td>
<td>• Results inform: • SAA system performance with fast (~250 knots) surrogate UAS equipped with CNPC, a full suite of sensors for cooperative and non-cooperative targets with guidance provided by Stratway+/RGCS (min success) • SAA system performance from Ikhana (or alternate, equivalent UAS capability) equipped with CNPC, a full suite of sensors for cooperative and non-cooperative targets with guidance provided by CPDS (or equivalent DAA algorithm capability such as Stratway+) (full success) • DAA requirements • DAA MOPS</td>
</tr>
</tbody>
</table>

**Briefings, Papers, or Reports**

- SSI LaRC Support & Participation in FT4 Brief Results to SC-228 planned for July 2016
- SSI LaRC FT4 report/paper planned for August 2016
Alerting Times + Collision Avoidance-Self Separation Integration Combined HITL

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.5.60] Alerting Times + Collision Avoidance-Self Separation Integration Combined HITL | 5/2015                         | • Develop and evaluate a concept of integrated Collision Avoidance and Safe Separation functions that enables UAS to execute automated maneuvers in terms of acceptability to ATC, as well as investigate the range of acceptable times to alert the UAS pilot to potential loss of well-clear condition | • Results inform:  
  • Declaration times: what are excessive, leading to nuisance alerts for controllers and UA pilots and what times are too short and provide insufficient time to query/negotiate maneuvers with ATC and execute them before triggering TCAS RAs.  
  • The feasibility of the integration of elf separation and collision avoidance functions as part of a complete SAA capability |

• Briefings, Papers, or Reports
  – UAS-SSI-4.1-059-001, UAS CAS3 CASSAT PER/FER, Briefing Plan, March 2015
  – Alerting Times + Collision Avoidance-Self Separation Integration Combined HITL Brief results to SC-228 planned for February 2016
  – HITL Results Paper planned for March 2016
### TC-SAA Test/Simulation | Baselined Execution Start Date | Test/Simulation Objective | Contribution to SC-228 MOPS
--- | --- | --- | ---
[SP S.6.10] SAA Initial Flight Test Participation w/IT&E | 11/2014 | • Perform collaborative flight tests and demonstrations to evaluate, validate and refine simulation-tested SAA concepts in an actual flight environment with prototype airborne sensors for non-cooperative intruders in addition to ADS-B and TCAS II, as well as prototype ground station information displays | • Results:
  • Performance data from flight test will continue to support the development of the Stratway+ SAA concept by verifying Stratway+ self-separation algorithm performance in a flight test environment
  • Provide risk reduction for the IT&E subproject live, virtual, constructive distributed test environment
  • Inform performance Self Separation requirements and standards
  • Inform the development of surveillance system architecture requirements

- **Briefings, Papers, or Reports**
## Sensor Model Stress Testing & Sensitivity Analysis HITL

<table>
<thead>
<tr>
<th>TC-SAA Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP S.7.10] Sensor Model Stress Testing & Sensitivity Analysis HITL                    | 2/2016                       | • Evaluation of the NASA developed Stratway+ SAA algorithm and pilot interface subject to various types and levels of uncertainty and sensor models errors in a human-in-the-loop simulation                                                                 | • Results inform:  
  • The performance of an integrated SAA capability (self separation and collision avoidance) in a HITL experiment with modeled sensor uncertainties and realistic traffic scenarios  
  • DAA requirements  
  • DAA MOPS  

### Briefings, Papers, or Reports

- Sensor Model Stress Testing & Sensitivity Analysis HITL Preliminary Results for Stakeholders Available July 2016
- HITL Results Paper planned for August 2016
## TC – SAA Performance Standards

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<tr>
<td>[TWP S.1] SAA Sub-function Tradeoffs and Requirements</td>
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<td>[SP S.1.10] Surveillance Requirements (Low Fidelity) (ACES Simulation)</td>
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<td>[SP S.1.20] Surveillance Requirements (Medium Fidelity) (ACES Simulation)</td>
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<td>[SP S.1.30] Interoperability of SS and CA Functions (ACES Simulation)</td>
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<td>[SP S.1.40] Sub-function Tradeoffs w/ UAS Performance (ACES Simulation)</td>
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<td>[TWP S.2] Interoperability and Impact of SAA-Equipped UAS on the NAS</td>
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<td>[SP S.2.01] ACES Software Development &amp; Support</td>
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<td>[SP S.2.10] SAA Traffic Display Evaluation HITL1 (joint w/ HSI Part Task Sim 4)</td>
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<td>[SP S.2.20] IHITL Participation &amp; Data Collection</td>
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<td>[SP S.2.30] Self-Separation Risk Ratio Study</td>
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<td>[SP S.2.40] FT3 Participation &amp; Data Collection</td>
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<td>[SP S.2.50] FT4 Participation &amp; Data Collection</td>
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<td>[SP S.2.60] SAA Traffic Display Evaluation HITL2 HITL (joint w/ HSI Part Task Sim 5)</td>
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<tr>
<td>[SP S.2.70] Effect of SAA Maneuvers with Procedures (ACES Simulation)</td>
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<td>[SP S.2.80] Comprehensive Evaluation of Airspace Risk Threshold (ACES Simulation)</td>
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<td>[TWP S.3] Well Clear Definition and SAA Concept of Operations</td>
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<td>[SP S.3.01] SC-228 Collaboration</td>
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<td>[SP S.3.10] Well Clear Metric and Definition Study</td>
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<td>[SP S.3.30] DAA Self-Separation Alerting Methods, Performance, and Robustness Study (ACES Simulation)</td>
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**Green Status Line Date 9/30/15**

**API**

**L1 Program (IASP)**

**L2 Project**
## TC – SAA (2 of 2)

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<td>[TWP S.4] SAA Performance &amp; MOPS Development</td>
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<td>[SP S.4.01] Subproject Management &amp; Overhead</td>
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<td>[SP S.4.02] SC-228 DAA WG Support</td>
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<td>[SP S.4.10] UAS - SAA Trade-off Assessments - Final</td>
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<td>[SP S.4.20] CA/SS Algorithm Maneuvers vs. UA Performance Assessment</td>
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<td>[SP S.4.03] Final Product Preparation (inputs to SC-228 MOPS, NASA Reports, and/or Conference Papers)</td>
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<tr>
<td>[TWP S.5] Airspace Integration &amp; SAA Interoperability</td>
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<td>[SP S.5.10] UAS CAS1 HITL</td>
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<td>[SP S.5.20] Langley Support &amp; Participation in IHITL</td>
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<td>[SP S.5.30] Comm Gen2 Flight Test Participation &amp; Data Collection</td>
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<td>[SP S.5.40] SSI LaRC Support &amp; Participation in FT3</td>
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<td>[SP S.5.50] SSI LaRC Support &amp; Participation in FT4</td>
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<td>[SP S.5.60] Alerting Times + CA-SS Integration Combined HITL</td>
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<td>[TWP S.6] CA-SS Coordination and Interoperability</td>
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<td>[SP S.6.10] Partner-FAA (SAA Initial Flight Tests) Flight Test Participation w/ IT&amp;E</td>
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<tr>
<td>[SP S.7.10] Sensor Model Stress Testing &amp; Sensitivity Analysis HITL</td>
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</tbody>
</table>

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

**Green Status Line Date 9/30/15**
HSI IHITL Participation & Data Collection

• Research Objective:
  – Evaluate an instantiation of the prototype GCS in relevant environment

• Interim Results, Conclusions, and Recommendations:
  – Integration of guidance and auto pilot in the *auto-resolver* and *auto resolver + vector planner* conditions led to significantly faster pilot ‘edits’
  – No other significant differences in pilot response times

GCS Information Guidelines/Requirements for DAA and C2 MOPS

Schedule Package: H.1.10
• **Research Objective:**
  – Investigate the effects of number of UAS per sector and types of UAS on GCS information requirements

• **Results, Conclusions, and Recommendations:**
  – No significant effect on number of UAS on loss of separation
  – In terms of efficiency, the time it took aircraft to travel through the sector increased with more UAS and increased with mixed and fast UAS, when multiple UAS were present
  – Handoff accept time decreased with increasing number of UAS, due to the reduction in conventional aircraft entering the sector and varied as a function of the combination of number of UAS and the speed
  – The presence of additional UAS negatively impacted Air Traffic Controller performance

GCS Information Guidelines/Requirements for DAA and C2 MOPS
Part-task Simulation 5: SAA Pilot Guidance Follow-on

- **Research Objective:**
  - Evaluate various proposed informational and directive SAA displays to determine the basic information requirements and advantages of advanced pilot guidance

- **Interim Results, Conclusions, and Recommendations:**
  - Suggestive guidance in the form of banding resulted in *safer* and *more timely* maneuvers away from conflicts
    - Fewer overall number of LoWC for both banding displays
    - Faster overall response times for both banding displays
Visual Requirements for Landing Task

• **Research Objectives:**
  – Evaluate nose camera video display requirements for manual takeoff and landing
  – Determine the minimum C2 bandwidth that still enables the safe execution of the takeoff and landing tasks

• **Results, Conclusions, and Recommendations:**
  – Preliminary qualitative results obtained with three pilot participants indicated that the degraded video resolution and frame rates affected their ability to fly a safe approach in a number of ways
  – Overall the pilots stated that the degradation in the resolution was manageable, whereas they felt “dangerous” with the degradation in frame rate
  – Internal Project Paper: *Required Bandwidth for GCS Display(s) Supporting UAS Landing*

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GCS Display Minimum Information Guidelines/Requirements for DAA and C2 MOPS

Schedule Package: H.1.90
# HSI IHITL Participation & Data Collection

<table>
<thead>
<tr>
<th>TC-HSI Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP H.1.10] HSI IHITL Participation & Data Collection | 5/2014 | • Evaluate an instantiation of the prototype GCS in relevant environment. | • Results inform the understanding of:  
  • Acceptability to the air traffic controller of UA maneuvers in response to SAA advisories and air traffic controller clearances  
  • Acceptability to the air traffic controller of the procedures for negotiation with UAS pilots to conduct maneuvers to remain Well Clear  
  • The performance of the UAS pilot to control/maneuver the UA in response to SAA alerts, advisories, and situational awareness information displayed to the UAS pilot  
  • Acceptability to the UAS pilot of the procedures for negotiation with air traffic controllers to conduct maneuvers to remain Well Clear |

- **Briefings, Papers, or Reports**
  - UAS-HSI-4.2-025-001, IHITL: DAA Display Evaluation Preliminary Results, Briefing (SC-228), November 2014
  - IHITL results report/paper planned for October 2015
Measured Response Simulation C

<table>
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<tr>
<th>TC-HSI Test/Simulation</th>
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<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
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<tbody>
<tr>
<td>[SP H.1.20] Measured Response Simulation C</td>
<td>10/2013</td>
<td>• Investigate the effects of number of UAS per sector and types of UAS on GCS information requirements</td>
<td>• Results inform understanding of ground control station automation levels and the number of UAS per NAS sector and types of UAS in the sector</td>
</tr>
</tbody>
</table>

- Briefings, Papers, or Reports
  - UAS-HSI-4.2-013-001, Measured Response Simulation C-Preliminary Data Analyses, Briefing, Undated
  - UAS-HSI-4.2-019-001, UAS Response to Air traffic Control Clearances- Measured Responses, Paper, Undated
  - UAS-HSI-4.2-020-001, Measured Response For UAS-NAS, Paper, Undated
  - UAS-HSI-4.2-021-001, UAS Measured Response: The Effect of GCS Control Mode Interfaces on Pilot Ability to Comply with ATC Clearances, Paper, Undated
  - UAS-HSI-4.2-023-001, Measured Response The effect of GCS Control Mode Interfaces on Pilot Ability to Comply with ATC Clearances, Briefing (HFES), 2014
  - UAS-HSI-4.2-025-001, Air Traffic Controller Performance and Acceptability of Multiple UAS in a Simulated NAS Environment, Paper, Undated
  - UAS-HSI-4.2-026-001, Air Traffic Controller Performance and Acceptability of Multiple UAS in a Simulated NAS Environment, Paper, July 2014
Part-task Simulation 4: SAA Pilot Guidance

<table>
<thead>
<tr>
<th>TC-HSI Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>[SP H.1.40] Part-task Simulation 4: SAA Pilot Guidance</td>
<td>2/2014</td>
<td>• Evaluate efficacy of minimum information SAA displays, potential improvements for advanced information features and pilot guidance, and integrated vs. stand-alone GCS SAA displays</td>
<td>• Results inform ground control system display requirements associated with display class (integrated, stand alone), level of information (basic, advanced), and self-separation alerting threshold.</td>
</tr>
</tbody>
</table>

• Briefings, Papers, or Reports
  – UAS-HSI-4.2-022-001, PT4: DAA Display Evaluation-Prelim Results, Briefing (SC-228), August 2014
Part-task Simulation 5: SAA Pilot Guidance Follow-on

<table>
<thead>
<tr>
<th>TC-HSI Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
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</table>
| [SP H.1.70] Part-task Simulation 5: SAA Pilot Guidance Follow-on | 2/2015 | • Evaluate various proposed informational and directive SAA displays to determine the basic information requirements and advantages of advanced pilot guidance | • Results inform:  
  • DAA display requirements  
  • Classes of displays ability to meet proposed DAA GCS display requirements.  
  • Selection of SAA display for the prototype research GCS for use in subsequent simulations and flight tests |

• Briefings, Papers, or Reports
  – UAS-HSI-4.2-034-001, UAS-NAS Part Task 5 DAA Display Evaluation Primary Results, May 2015
  – UAS-HSI-4.2-032-001, PT5 DAA Display Evaluation Overview III, June 2015
  – NAS Compliant Ground Station Part-task Simulation 5 report planned for January 2016
Part Task Simulation 6

<table>
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<tr>
<th>TC-HSI Test/Simulation</th>
<th>Baseline Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
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</table>
| [SP H.1.80] Full-Mission Simulation 2 | 11/2015 | • Evaluate boundary between self separation and automatic collision avoidance mode
• Demonstrate operation of an instantiation of a GCS illustrating one manner of compliance with GCS guidelines | • Results inform:
  • Initial recommendations for allowable levels of automation
  • Demonstrate a robust system that provides:
    • Self-separation
    • Contingency management
    • Tolerable Pilot workload
    • High Pilot Situation Awareness
    • No adverse effects on ATM
  • Development of a prototype GCS that will instantiate one manner of compliance with proposed GCS guidelines and serve as GCS for the integrated events |

• Briefings, Papers, or Reports
  – Full-Mission 2 Briefing to SC-228 planned for March 2016
  – NAS Compliant Ground Station Full-mission Simulation 2 report planned April 2016

Schedule Package: H.1.80
## Visual Requirements for Landing Task (support for CSUN)

<table>
<thead>
<tr>
<th>TC-HSI Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
</tr>
</thead>
</table>
| [SP H.1.90] Visual Requirements for Landing Task (support for CSUN) | 10/2013                       | • Evaluate nose camera video display requirements for manual takeoff and landing, and determine the minimum C2 bandwidth that still enables the safe execution of the takeoff and landing tasks | • Results inform:  
  • Requirements for visual displays for landing (e.g., resolution, frame rate, color)  
  • CNPC system bandwidth requirements to support acceptable visual displays for landing |
## TC - HSI

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<td>[SP H.1.20] Measured Response Simulation C</td>
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<td>[SP H.1.30] Full-Mission Simulation 1: Levels of Automation</td>
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<td>[SP H.1.40] Part-task Simulation 4: SAA Pilot Guidance</td>
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<td>[SP H.1.80] Part Task 6 Simulation: Full Mission 2</td>
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<td>[SP H.1.90] Visual Requirements for Landing Task (support for CSUN)</td>
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<td>[TWP H.2] Guidelines</td>
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<td>[SP H.2.10] GCS HF Draft Guidelines (Whitepaper)</td>
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**API**  
**L1 Program (IASP)**  
**L2 Project**

Green Status Line Date 9/30/15
Sim and Demo Planning Support & Leave Behind Capability

• Research Objective:
  – Develop and maintain a relevant test environment to support sub-project research simulations, identify and document the LVC interfaces, and reduce risk for the integrated events by implementing the prototype infrastructure

• Results, Conclusions, and Recommendations:
  – LVC test environment development
    • Developed scenarios and integrated test components for Part Task 4, reducing IHITL implementation risk
    • Enabled real-time remote viewing of flight data via distributed test environment for SSI Subproject portion of Communication Gen 2 flight test
    • Supported center connections to GRC and LaRC
  – Designed and developed a data archive scheme for integrated events
    • Proposing expansion of archive for all Project events

Test Environment and Support for Draft DAA and C2 MOPS
FT3 Execution

• **Research Objectives:**
  – Conduct Flight Test Series 3 integrating the latest SSI algorithms, Control and Non-Payload Communication System prototype, and HSI displays using the Live, Virtual, Constructive test environment
  – Document the performance of the test infrastructure in meeting the flight test requirements

• **Results, Conclusions, and Recommendations:**
  – Flight test divided into scripted encounters and full mission configurations
  – Scripted encounters finished successfully with 11 flights/208 test points: conducted June 2015 to July 2015
    • Ikhana as ownship, single and multiple simultaneous intruders
    • Due Regard Radar, ADS-B, and TCAS/Mode S sensors
    • Data was successfully collected for each test point and archived at NASA ARC for researcher access
  – Full mission finished after 3 flights: conducted August 2015
    • Distributed live aircraft at AFRC and virtual traffic from ARC
    • Surrogate aircraft command latency and performance issues
  – Required data provided to researchers on schedule

Test Environment for V&V of DAA and C2 MOPS
## Sim and Demo Planning Support

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<th>TC-ITE Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
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<td>[SP T.1.10] Sim and Demo Planning Support</td>
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<td>• Not applicable</td>
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<tr>
<td>[SP T.1.20] Submit LVC Leave behind document</td>
<td>10/2013</td>
<td>• Not Applicable</td>
<td>• Not Applicable</td>
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- **Briefings, Papers, or Reports**
  - SP T.1.10, None Planned
  - SP T.1.20, LVC Leave Behind Capabilities Report, Planned for September 2016

Schedule Package: T.1.10 & T.1.20
<table>
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</tr>
</thead>
<tbody>
<tr>
<td>[SP T.2.60] Integrated Human-in-the-Loop Relevant Environment Analysis</td>
<td>2/2015</td>
<td>• Evaluate the performance of the simulation infrastructure to emulate the intended Integrated Human-in-the-Loop operational system and provide a realistic environment for air traffic controller simulation subjects.</td>
<td>• A realistic environment contributes useful data to SC-228 MOPS development</td>
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</table>

- Briefings, Papers, or Reports
  - UAS-ITE-5.0-008-001, IHITL Test Environment Report
### SAA Initial Flight Tests Execution

<table>
<thead>
<tr>
<th>TC-ITE Test/Simulation</th>
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<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
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</thead>
<tbody>
<tr>
<td>[SP T.3.40] SAA Initial Flight Test Execution</td>
<td>11/2014</td>
<td>• Conduct SAA Initial Flight Test using the Live, Virtual, Constructive test environment and document the performance of the test infrastructure in meeting the flight test requirements</td>
<td>• Results inform acceptability of the live, virtual, constructive distributed test environment as a realistic test environment for use in verifying and validating MOPS</td>
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- Briefings, Papers, or Reports

Schedule Package: T.3.40
# FT3 Execution

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<tr>
<td>[SP T.4.50] FT3 Execution</td>
<td>6/2015</td>
<td>Conduct Flight Test Series 3 integrating the latest SSI algorithms, Control and Non-Payload Communication System prototype, and HSI displays using the Live, Virtual, Constructive test environment and document the performance of the test infrastructure in meeting the flight test requirements</td>
<td>Results inform acceptability of the live, virtual, constructive distributed test environment as a realistic test environment for use in verifying and validating MOPS</td>
</tr>
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</table>

- Briefings, Papers, or Reports
  - Integrated Flight Test 3 Flight Test Report, Planned October 2015
## FT4 Execution

<table>
<thead>
<tr>
<th>TC-ITE Test/Simulation</th>
<th>Baselined Execution Start Date</th>
<th>Test/Simulation Objective</th>
<th>Contribution to SC-228 MOPS</th>
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<tr>
<td>SP T.5.60 FT4 Execution</td>
<td>2/2016</td>
<td>• Conduct Flight Test Series 4 integrating the latest SSI algorithms, Control and Non-Payload Communication System prototype, HSI displays, and active test aircraft sensors using the Live, Virtual, Constructive test environment and document the performance of the test infrastructure in meeting the flight test requirements</td>
<td>• Results inform acceptability of the live, virtual, constructive distributed test environment as a realistic test environment for use in verifying and validating MOPS</td>
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- **Briefings, Papers, or Reports**
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<td>[TWP T.1] LVC Distributed Test Environment</td>
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<td>[SP T.1.01] Modify MACS to emulate ERAM Display</td>
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<td>[SP T.1.20] Leave Behind Capability</td>
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<td>[TWP T.2] Integrate Technology &amp; Execute IHITL</td>
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<td>[SP T.2.60] IHITL Relevant Environment Analysis</td>
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<td>[SP T.3.40] SAA Initial Flight Tests Execution</td>
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**Green Status Line Date 9/30/15**
<table>
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<th>FY2016</th>
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<tr>
<td></td>
<td>Q1</td>
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<td>Q3</td>
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<td>[TWP T.4] Integrate Technology &amp; Execute FT3</td>
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<tr>
<td>[SP T.4.10] FT3 Scenario &amp; Mission Development</td>
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<td>[SP T.4.20] Test Planning</td>
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<td>[SP T.4.30] FT3 Readiness and Reviews</td>
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<tr>
<td>[TWP T.5] Integrate Technology and Execute FT4</td>
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<td>[SP T.5.10] Capstone Planning</td>
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<td>[SP T.5.20] FT4 Test Planning</td>
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<tr>
<td>[SP T.5.70] FT4 Relevant Environment Analysis</td>
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</table>

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

*Green Status Line Date 9/30/15*
## FT4 Full Mission Ownership Evaluation Summary

<table>
<thead>
<tr>
<th>Desired Aircraft</th>
<th>Ownship DAA Phase 1 MOPS Sensor Suite (2 of 3 sensors required)</th>
<th>Autopilot Interface (Heading and Altitude Control from C2 link with GCS)</th>
<th>RGCS C2 Interface (latency from cmd execution to a/c response ≤2 sec)</th>
<th>Contract</th>
<th>Overall Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFRC Ikhana (870)</td>
<td>Equipped (BAE DPX-7)</td>
<td>Equipped (GA-ASI/EDM DRR)</td>
<td>Full UAS (C2 link with Ikhana GCS)</td>
<td>Can not implement in time</td>
<td>Developing RGCS connectivity can not be completed in time due to IT Security constraints</td>
</tr>
<tr>
<td>NGC Firebird Demonstrator</td>
<td>Equipped (L3 TCAS/ADS-B)</td>
<td>Must be Integrated (AFRL/CEI A/A Radar integration planned)</td>
<td>Surrogate UA (C2 link with NGC GCS but onboard pilot must acknowledge cmds)</td>
<td>Must be Integrated (NGC GCS G2 is already STANAG 4586 compliant)</td>
<td>Need</td>
</tr>
<tr>
<td>Calspan Learjet</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>Developing a C2 link and RGCS connectivity can not be completed in time</td>
</tr>
<tr>
<td>AdvAero Avanti</td>
<td>Equipped (but need interface to ADS-B data)</td>
<td>Equipped (but need interface to TCAS data)</td>
<td>Surrogate UA (Calspan Variable Stability System but no C2 link)</td>
<td>Must be Integrated</td>
<td>Need</td>
</tr>
<tr>
<td>GRC T-34C (608)</td>
<td>Equipped (GDL-88)</td>
<td>Must be Integrated</td>
<td>Surrogate UA (5-TEC 55X equipped but has only heading control and cmd execution to a/c response latencies in excess of 2 sec)</td>
<td>CNPC</td>
<td>Assessment to be provided by joint AFRC/GRC independent review team</td>
</tr>
<tr>
<td>GRC S-3B (601)</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>CNPC</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

**Aircraft ADS-B (1090 IN/OUT)**

- **Mode S Transponder (TCAS I)**
- **A/A Radar (8 nm detection range, 20° x 30° FOR)**
- **TCAS II (v7.1)**
- **Tracker/Sensor Fusion**

---

**Contract**

- **Existing (GA-ASI Ikhana Support)**
- **Developing (RGCS connectivity can not be completed in time due to IT Security constraints)**
- **Need**
- **Assessment to be provided by joint AFRC/GRC independent review team**
- **Assessment to be provided by GRC**

---

**FT4 Full Mission Ownship Evaluation Summary**

10/08/2015
### Ownship DAA Phase 1 MOPS Sensor Suite

(2 of 3 sensors required)

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>ADS-B (1090 IN/OUT)</th>
<th>Mode S Transponder (TCAS I)</th>
<th>A/A Radar (8 nm detection range, 20° x 30° FOR)</th>
<th>TCAS II (v7.1)</th>
<th>Tracker/Sensor Fusion</th>
<th>Autopilot Interface (Heading and Altitude Control from C2 link with GCS)</th>
<th>RGCS C2 Interface (latency from cmd execution to a/c response ≤2 sec)</th>
<th>Contract</th>
<th>Overall Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>LaRC SR-22 (501)</td>
<td>Must be Integrated</td>
<td>Not an Option</td>
<td>Not an Option</td>
<td>Not an Option</td>
<td>Must be Integrated</td>
<td>Surrogate UA (S-TEC 55X equipped but UHF C2 link with GCS is limited in range)</td>
<td>Must be Integrated (UHF C2 Link limited in range)</td>
<td>N/A</td>
<td>Unable to integrate 2 surveillance sensors</td>
</tr>
<tr>
<td>LaRC HU-25C (525)</td>
<td>Equipped (but need interface to ADS-B data)</td>
<td>Must be Integrated</td>
<td>Must be Integrated (but need interface to TCAS data)</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>Must be Integrated (UHF C2 Link limited in range)</td>
<td>N/A</td>
<td>Developing a C2 link and RGCS connectivity can not be completed in time</td>
</tr>
<tr>
<td>AFRC GIII (502)</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>Must be Integrated (but need interface to TCAS data)</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>AFRC Platform Precision Autopilot but no C2 link to GCS</td>
<td>Must be Integrated</td>
<td>N/A</td>
<td>Aircraft not available to support integration and test schedule</td>
</tr>
<tr>
<td>JSC GIII (992)</td>
<td>Must be Integrated (GDL-88 planned)</td>
<td>Must be Integrated</td>
<td>Must be Integrated (but need interface to TCAS data)</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>Must be Integrated (UHF C2 Link limited in range)</td>
<td>N/A</td>
<td>Developing a C2 link and RGCS connectivity can not be completed in time</td>
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<tr>
<td>AFRC GIII (808)</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>Must be Integrated (but need interface to TCAS data)</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>Must be Integrated</td>
<td>Must be Integrated (UHF C2 Link limited in range)</td>
<td>N/A</td>
<td>Developing a C2 link and RGCS connectivity can not be completed in time</td>
</tr>
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</table>
UAS-NAS Non-Technical Challenge Work
Backup Slides
Authority to Proceed  |  Partnership Established  |  Eliminate Safety Case Work  |  Stop work after development of type certification basis  |  Stop work after first deliverable report on the type certification basis  |  Stop work after any one of the analysis questions. That is, there will be logical breakpoints throughout the analysis phase to stop work.


ON-R-1  |  ON-R-2  |  OFF-R-0  |  OFF-R-1  |  OFF-R-2
sUAS Plan and Status

• Great Dismal Swamp (GDS) Missions:
  – Execution of GDS Flights to determine in-situ ability to locate small, nascent fires was conducted Nov. 19th, 2014.

• sUAS Sense and Avoid Barrier Elimination:
  – Developed research plan to assess sUAS SAA current state-of-the-art capabilities
  – Created partnerships with various organizations to assess a variety of methodologies using real-world data to be supplied by NASA
  – Conducted first set of 12 multi-UAS video encounter experiment flights at Ft. A. P. Hill Sept. 21-25, 2015

• Next Steps: “Publishing” the data base and conducting the algorithmic assessments with partners.
# Non-Technical Challenges

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<th>Name</th>
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<th>FY2016</th>
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<tr>
<td><strong>Non-Technical Challenge</strong></td>
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<td>[TWP N.1] Certification</td>
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<td>[SP N.1.10] Case Study</td>
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<td>[TWP N.2] sUAS Support to Initial Rulemaking</td>
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<td>[SP N.2.10] sUAS Testing</td>
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<td>[SP N.2.20] Overcoming sUAS Sense and Avoid Barrier</td>
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<td><strong>Augmentation</strong></td>
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<td>[TWP N.3] Standard LVC-DE Connection and Interface</td>
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<td>[SP N.3.10] Prototype connection equipment &amp; Test Site Connections</td>
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<td>[SP N.3.20] LVC Connection to scaled Vehicles</td>
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<td>[SP N.3.30] Investigation of UAS LVC middleware</td>
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<td>[TWP N.4] UAS Aircraft and Trajectory Modeling</td>
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<td>[TWP N.7] Data Storage and Accessibility</td>
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<tr>
<td>[SP N.7.20] Adaptable SAA Architecture and LVC Connection</td>
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*API*  
*L1 Program (IASP)*  
*L2 Project*

**Green Status Line Date 9/30/15**
# Augmentation Technical Status Summary

<table>
<thead>
<tr>
<th>Task</th>
<th>Status</th>
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<tbody>
<tr>
<td><strong>3.1 Prototype connection equipment &amp; test site connections</strong></td>
<td>Complete FY15: All Test Sites under contract to connect to the LVC. Remaining FY16: All Test Sites will perform actual connection work in FY16.</td>
</tr>
<tr>
<td><strong>3.2 LVC connection to scaled vehicles</strong></td>
<td>Complete FY15: Preparation for install complete, all hardware purchased, and some hardware installed. Remaining FY16: Install remaining hardware, connect Airstar “mid-sized” UAS, demonstrate HLA bridge.</td>
</tr>
<tr>
<td><strong>3.3 Investigation of ideal middleware</strong></td>
<td>Complete FY15: Report delivered documenting recommendations for short and long term connectivity. Recommendations will be used for Test Site Connections and other long term partners. Remaining FY16: none.</td>
</tr>
<tr>
<td><strong>4.1 VFR Traffic Model Development and Integration</strong></td>
<td>Complete FY15: Processing VFR track data from 21 sample days, and apply a noise reduction algorithm. Remaining FY16: Create ACES formatted scenario files, and use ACES to fully smooth the data, then deliver new, smoothed VFR track data by Nov 20.</td>
</tr>
<tr>
<td><strong>6.1 Distributed Display Infrastructure Set-up</strong></td>
<td>Complete FY15: All hardware procured for each center. Remaining FY16: Final installations and checkout.</td>
</tr>
<tr>
<td><strong>7.1 Satcom emulation capability on LVC</strong></td>
<td>Complete FY15: Developed requirements, purchased hardware, performed initial lab testing. Remaining FY16: Finalize software update on S-3B and perform LVC connectivity testing for flight test data collection.</td>
</tr>
<tr>
<td><strong>7.2 Adaptable SAA Architecture and LVC Connection</strong></td>
<td>Complete FY15: GA under contract to deliver ARP capability. Remaining FY16: Implement upgrades to allow NASA algorithms to run in place of current SAA-related algorithms to command vertical speed and heading changes.</td>
</tr>
</tbody>
</table>
Standard LVC Connection and Interface

- **Technical Objectives:**
  - Investigate LVC middleware options for future simulations and flight testing
  - Establish connection between each UAS Test Site and the LVC
  - Develop interface and test connection between scaled models and LVC

- **Significant Results, Conclusions, and Recommendations:**
  - LVC middleware report outlines strategies for long term LVC connectivity
  - All 6 UAS Test sites under contract; planning prototype connection test FY16 Q3
  - Initial connection of LaRC AirStar system to LVC complete; check-out test expected in December

Investigation of ideal middleware; Prototype connection equipment & test site connections; LVC connection to scaled vehicles

Augmentation Packages: 3.1; 3.2; 3.3
LVC Connection to Scaled Vehicles

**Technical Objectives:**
- Develop Infrastructure to enable addition of vehicles into the LVC to conduct live testing of DAA algorithms for Phase 2 MOPS (BAT, AirStar, Flight Operations and Command Center)
- Create a UAS Research Data Collection and Repository (Actual Database Server SW and HW)
- Deploy and test Display software for Common Operating Picture for use in UAS Lab in Phase 2 MOPS Development.
- Establish LaRC as a full node on LVC: Include IT infrastructure, storage, connectivity, communication links.

**Significant Results, Conclusions, and Recommendations:**
- Performed architecture analysis
- Purchased and installed enabling hardware: LVC Gateway servers, AirStar hardware, Video wall installation pending
- DDS-LVC Gateway toolbox complete, pending gateway test; LVC Gateway installed
- DDS-HLA Bridge in development

Investigation of ideal architecture; Prototype connection equipment & center-to-center connections; LVC connection to scaled vehicles
Distributed Display Infrastructure

**Technical Objectives:**
- Develop the ability to share displays to be across locations connected to the LVC (i.e. aeronautics centers), without changing the test software or impacting test subjects
- Update displays at Ames IT&E demonstration and tower facility

**Significant Results, Conclusions, and Recommendations:**
- Video streaming equipment procured and tested between AFRC and ARC
- Video server and display equipment procured; connection between ARC and each Center in place; testing planned for FY16 Q1
- Display projector bids under evaluation for FY16 installation
SatCom Emulation Capability on LVC

• **Research Objective:**
  – Develop SatCom emulation capability and interface to LVC, in order to assist in the development of SatCom specifications and UAS operations ConOps under higher communication latency conditions.

• **Significant Results, Conclusions, and Recommendations:**
  – Developed SatCom emulation requirements
  – Developed SatCom emulation
  – Performed initial lab testing of SatCom emulation
  – Currently updating software on S-3B aircraft.
  – Coordinating with ARC on LVC system connectivity for flight test data collection.
Define & Apply Weighting Criteria

**Opportunity:** Ability to accelerate schedule, reduce costs, and leverage technologies

- Clarity and efficiency of implementation path
- Collaboration with others
- Leverage existing technologies and efforts

**Risk:** Effects from not achieving the desired outcome

- Size, complexity, and difficulty of implementation
- Negative impact on civil/commercial market
- Potential delays to full integration
- Degrading efficiency of the NAS (without degrading safety)

**Benefit:** Impact toward achieving the overall vision of “full integration”
Prioritize Remaining Gaps
Benefit adjusted Opportunity / Risk Tornado Diagram
Prioritize Remaining Gaps
Lead / Collaborate / Leverage Recommendations
MOE Considerations

• **Attendance:** 30-40 people max

• **Purpose:** Attain consensus from the UAS community on...
  – Bin definitions
  – Vision/concepts of what it means to be complete
  – Gaps to achieve full integration

• **Representation:**
  – Various organizations (e.g. FAA, RTCA, DOD, AUVSI, Academia, Industry, etc)
  – Experts in each technical area (e.g. DAA, C3, Automation, Ops, etc)

• **Recommendation:** Separate audience into smaller break out groups
  – Read-ahead material and telecon 2 weeks prior will set the stage and instigate initial inputs/questions/comments for review
  – All attendees involved in every bin is inefficient, disengaging and will be very difficult to reach consensus
  – Most people will have knowledge overlapping multiple bins. Some bins will require more participation, or be more controversial
  – One MTSI person will facilitate each breakout session
Project Processes Implementation
Backup Slides
<table>
<thead>
<tr>
<th>CR(s)#</th>
<th>Area</th>
<th>Change</th>
<th>Impact</th>
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</thead>
<tbody>
<tr>
<td>040</td>
<td>PO</td>
<td>Redefined L2 Milestones related to Comprehensive Research Report to reflect 1 final report. Final report was elevated to L1 Milestone – “Comprehensive FT4 Research Report”</td>
<td>Schedule, Technical</td>
</tr>
<tr>
<td>042, 043, 067</td>
<td>TC-SAA</td>
<td>Closed/eliminated SP S.3.20, “Well Clear Alerts/Resolutions with VFR and Pilot/Controller (ACES Simulation)” and added SP S.3.30, “Well Clear Alerting Logic, Methods, and Performance Requirements” to provide greater benefit to SC-228 by conducting work of greater importance to SC-228</td>
<td>Schedule, Technical</td>
</tr>
<tr>
<td>049</td>
<td>PO</td>
<td>Reallocated funds to LaRC for CASSATT efforts</td>
<td>Cost</td>
</tr>
<tr>
<td>053, 079</td>
<td>TC-HSI</td>
<td>Deletion of L2 Milestone – “HSI PT4B Briefing to RTCA” (CR053) and deletion of associated tasks (079) as briefing was to be completed by GA, and not HSI.</td>
<td>Schedule, Technical</td>
</tr>
<tr>
<td>058, 062</td>
<td>TC-ITE</td>
<td>Original FT4 Test Plan was broken into an ORD and the FT4/Capstone Test Plan. FT4/Capstone test plan was captured in CR062. Creation of L2 Milestone - SP T.5.50, “FT4/Capstone Flight Test Plan”</td>
<td>Schedule, Technical</td>
</tr>
<tr>
<td>064</td>
<td>Non-TC-sUAS</td>
<td>Additional work approved for sUAS – N.2.20 sUAS SAA Testing</td>
<td>Cost, Schedule, Technical</td>
</tr>
<tr>
<td>065</td>
<td>PO</td>
<td>L1 Milestone date changes to MOPS comments to coincide with SC-228 schedule</td>
<td>Schedule</td>
</tr>
<tr>
<td>070</td>
<td>Non-TC-Certification</td>
<td>Deletion of L2 Milestone. GSN Safety case did not meet the original intent of the deliverable</td>
<td>Cost, Schedule, Technical</td>
</tr>
<tr>
<td>080</td>
<td>TC-HSI</td>
<td>Reallocated funds to HSI for MUSIM efforts</td>
<td>Cost</td>
</tr>
<tr>
<td>083</td>
<td>TC-C2</td>
<td>Deletion of FT3 related milestone as subproject was not intending to use FT3 data to brief SC-228</td>
<td>Technical</td>
</tr>
<tr>
<td>086</td>
<td>ITE</td>
<td>Documentation of FT3 Completion.</td>
<td>Technical</td>
</tr>
<tr>
<td>088</td>
<td>TC-HSI</td>
<td>Deletion of FT3 related milestone. Data was found to be insufficient to brief to SC-228</td>
<td>Technical</td>
</tr>
<tr>
<td>091</td>
<td>PO</td>
<td>Reallocation of funds to cover the following: FAA Test Site efforts, TCAS II antenna, and to fund HSI grant with CSULB.</td>
<td>Cost</td>
</tr>
</tbody>
</table>
# FT3 Related Change Requests

## Change Requests Related to Schedule

<table>
<thead>
<tr>
<th>CR #</th>
<th>Project/ TC</th>
<th>Title /Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>014</td>
<td>SSI</td>
<td>TC-SAA L2 Milestone Changes; change in date for</td>
</tr>
<tr>
<td>020</td>
<td>HSI</td>
<td>TC-HSI L2 Milestone Changes in TWP H.1; change in date for HSI FT3 Briefing to RTCA</td>
</tr>
<tr>
<td>026</td>
<td>PO</td>
<td>ADD API Level 1 Milestone for FY16 – FT3</td>
</tr>
<tr>
<td>046</td>
<td>ITE</td>
<td>Change to FT3 Configuration Freeze date</td>
</tr>
<tr>
<td>047</td>
<td>ITE</td>
<td>Change to FT3 FDR Date</td>
</tr>
<tr>
<td>061</td>
<td>PO, SAA, C2, HSI, ITE</td>
<td>Change to FT3 Completion Date – L1 Milestone</td>
</tr>
</tbody>
</table>

## Change Requests Related to Technical

<table>
<thead>
<tr>
<th>CR #</th>
<th>Project/ TC</th>
<th>Title /Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>014</td>
<td>SSI</td>
<td>TC-SAA L2 Milestone Changes; change in date for</td>
</tr>
<tr>
<td>086</td>
<td>PO</td>
<td>FT3 Completion</td>
</tr>
<tr>
<td>083</td>
<td>C2</td>
<td>TC Comm Level 2 Milestone deletion</td>
</tr>
<tr>
<td>088</td>
<td>HSI</td>
<td>TC HSI, SP H.1.50 Level 2 Milestone deletion</td>
</tr>
</tbody>
</table>
## FT3 Related Risks

<table>
<thead>
<tr>
<th>Risk ID</th>
<th>Project/ TC</th>
<th>Risk Title</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.1.1.10</td>
<td>PO</td>
<td>Output from Test Events has value to Project Stakeholders</td>
<td>Mitigate</td>
</tr>
<tr>
<td>U.4.3.8</td>
<td>C2</td>
<td>Radios flight tested in FT3 and FT4 Series may not fully validate MOPS</td>
<td>Closed 7/31/2014</td>
</tr>
<tr>
<td>U.4.3.9</td>
<td>C2</td>
<td>FT3 CNPC Preparations Stressing C2 Preliminary MOPS Development</td>
<td>Closed 9/24/2015</td>
</tr>
<tr>
<td>U.4.3.10</td>
<td>C2</td>
<td>FT3 Radio Frequency Coverage</td>
<td>Closed 9/24/2015</td>
</tr>
<tr>
<td>U.4.3.11</td>
<td>C2</td>
<td>FT3 CNPC Equipment Installation at California</td>
<td>Closed 9/24/2015</td>
</tr>
<tr>
<td>U.4.1.4</td>
<td>SAA</td>
<td>A test bed for airborne sense and avoid flight tests equipped with the command and non-payload communications radio may not be available</td>
<td>Closed 10/16/2014</td>
</tr>
<tr>
<td>U.4.1.9</td>
<td>SAA</td>
<td>Delay of TC1/SSI Technology Developments Impact to Integrated Test Events (IHITL, FT3 and FT4)</td>
<td>Mitigate</td>
</tr>
<tr>
<td>U.4.2.9</td>
<td>HSI</td>
<td>Delay of TC3/HSI Technology Development Impact to Integrated Test Events (IHITL, FT3 and FT4)</td>
<td>Mitigate</td>
</tr>
<tr>
<td>U.4.2.11</td>
<td>HSI</td>
<td>Availability of Vigilant Spirit Control Station for Flight Test Series</td>
<td>Mitigate</td>
</tr>
<tr>
<td>U.5.1.7</td>
<td>IT&amp;E</td>
<td>Distributed Test Environment requirements for Integrated Flight Test 3 (FT3) not defined</td>
<td>Closed 3/26/2015</td>
</tr>
<tr>
<td>U.5.1.10</td>
<td>IT&amp;E</td>
<td>Required Assets for Flight Test 3 (FT3) not available during test period</td>
<td>Closed 8/20/2015</td>
</tr>
<tr>
<td>U.5.1.15</td>
<td>IT&amp;E</td>
<td>Inability to achieve TCAS II Self-separation IHITL Objectives due to lack of an IT Security Authority to Operate (ATO)</td>
<td>Closed 4/17/2014</td>
</tr>
<tr>
<td>U.5.1.16</td>
<td>IT&amp;E</td>
<td>Completion of TC6/IT&amp;E Technical Objectives that Rely upon Formal Partnerships</td>
<td>Closed 5/23/2015</td>
</tr>
<tr>
<td>U.5.1.17</td>
<td>IT&amp;E</td>
<td>The T-34 (UA Surrogate) for FT3 and FT4 may not be available</td>
<td>Watch</td>
</tr>
<tr>
<td>U.5.1.23</td>
<td>IT&amp;E</td>
<td>No formal agreement in place to access Honeywell data fusion algorithm</td>
<td>Mitigate</td>
</tr>
<tr>
<td>U.5.1.24</td>
<td>IT&amp;E</td>
<td>Timing of Part Task 5 impact on Flight Test 3 design</td>
<td>Closed 4/23/2015</td>
</tr>
<tr>
<td>U.5.1.25</td>
<td>IT&amp;E</td>
<td>Shortage of Resources – AFRC IT Security Experts</td>
<td>Closed 7/23/2015</td>
</tr>
<tr>
<td>U.5.1.26</td>
<td>IT&amp;E</td>
<td>ADS-B Receiver may not be received in time to support FT-3</td>
<td>Closed 8/20/2015</td>
</tr>
<tr>
<td>U.5.1.27</td>
<td>IT&amp;E</td>
<td>FT-3 Ikhana and Intruder Pilot Availability</td>
<td>Closed 8/20/2015</td>
</tr>
</tbody>
</table>
The T-34 (UA Surrogate) for FT3 and FT4 may not be available

Subproject Execution

Risk ID: U.5.1.17
Risk Owner: Jim Griner
TC-ITE
Trend

Criticality

Current L x C
1 x 3
(Technical =3, Schedule = 3, Cost = 1)

Target L x C
1 x 3

Open Date
11/25/13

with
1x5

Planned Closure Date
TBD: Based on trade study completion

Risk Statement

Given the FT3 and FT4 activities require the T-34 be utilized as a UA surrogate aircraft (containing the CNPC radio), should the T-34 not be available for FT3 and/or FT4 the L1 milestones associated with FT3/FT4 will not be met.

Original Impact

Technical = 5. Should the T-34 not be available for flight test the L1 milestones associated with FT3 and FT4 will not be met.
Schedule = 5. A greater than 2 month schedule slip may be incurred if the T-34 aircraft is not available for flight test
Cost = 1. TBD

Status

9/24/2015: Risk not accepted for closure at MRB. Risk will remain in watch status.
9/15/2015: Risk proposed for closure.
8/18/2015: Risk will remain in watch. Need to review after FT3 meetings (August 24-25 and September 9-10).
12/4/14: Risk will remain in watch.
9/18/14: Reviewed risk during IT&E RWG meeting. Risk to trending flat (unchanged) at this time.

Risk Approach: Watch

Mitigation Trigger (if current action is Watch): At GRC airplane being considered to support other operations in same timeframe as FT3/FT4

| Mitigation Step/Task Description: | Cost to Implement (if exceeds current budget) | Start Date | End Date | New LxC
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduct Glenn T-34 replacement/back-up trade study for Flight Test 3. (Mitigation 01) COMPLETE</td>
<td></td>
<td>12/16/13</td>
<td>4/15/14</td>
<td>1x3 C: (T3, S3, C1)</td>
</tr>
<tr>
<td>Conduct Glenn T-34 replacement/back-up trade study for Flight Test 4. (Mitigation 02)</td>
<td></td>
<td>TBD</td>
<td>TBD</td>
<td>1x3 C: (T3, S3, C1)</td>
</tr>
</tbody>
</table>

Rationale for Closure:
Validation of SAA Sensor Models

Top Risk

Risk Statement
Given the lack of access to a sensor suite that includes both cooperative and non-cooperative sensors (e.g. TCAS, ADS-B, EO/IR, airborne radar) there is a possibility that the validation of the sensor models used in ACES and PT6 won’t be completed. Actual implementations of SAA capabilities will need to address real-world sensor uncertainties, and will be studied in simulation. Validation of the sensor models will require access to flight test platforms with sensor suites that include both cooperative and non-cooperative sensors (e.g. TCAS, ADS-B, EO/IR, airborne radar) to enable the validation of ACES results that will support surveillance requirements covered in the DAA MOPS. The completion of these research tasks may be impacted by lack of access to a sensor suite, since NASA does not own a flight asset with a SAA sensor suite.

Status
9/15/2015: Risk is trending flat. Integration of sensor model into ACES from Honeywell is going well. Matlab has been auto coded. Once complete, team will be testing against Matlab results to ensure there are no bugs. Team has the data from FT3 configuration 1 that passed through the Honeywell tracker. Data is sufficient to validate model. End date of mitigation 02 extended form 8/31/2015 to 10/31/2015 due to no-cost extension added to Honeywell contract.

8/17/2015: Risk is trending up. LxC score increases from 2x3 to 3x3. Integration and testing of models may not be complete by 8/31 (issue with generic fusion algorithm and not finished integration task). Honeywell is pursuing 2-month no-cost extension. This adds risks to PT6 and the “comprehensive” ACES simulation. Mitigation 03 added.

Risk Approach: Mitigate

<table>
<thead>
<tr>
<th>Mitigation Step/Task Description:</th>
<th>Cost to Implement (if exceeds current budget)</th>
<th>Start Date</th>
<th>End Date</th>
<th>New LxC C: (Tech, Schedule, Cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract out the validation of sensor models and tracking/fusion algorithms using data from representative flight tests (Mitigation 01) (Santiago) <strong>COMPLETE</strong></td>
<td>FY15=$190k FY14 = $362k</td>
<td>7/15/14</td>
<td>9/30/14</td>
<td>3x3 C: (T3,S1, C2)</td>
</tr>
<tr>
<td>Execute representative flight tests and carry out validation of sensor models and tracking/fusion algorithms using flight test data (Mitigation 02) (Santiago)</td>
<td><strong>NA</strong></td>
<td>1/1/15</td>
<td>8/31/15</td>
<td>2x2 C: (T2, S1, C1)</td>
</tr>
<tr>
<td>Add task to Honeywell contract stating that they will supply their Data Fusion Software and support integration for PT6 and “comprehensive” ACES simulation. (Mitigation 03) (Santiago)</td>
<td></td>
<td>8/17/15</td>
<td>1/19/16</td>
<td>2x2 C: (T2, S1, C1)</td>
</tr>
</tbody>
</table>
**Top Risk**

Required Assets for Flight Test 4 (FT4) not available during test period

---

### Risk Statement

Distributed Test Environment assets required to execute Flight Test 4 are not available during the data collection period, FT4 reporting and closeout. This will impact L1 milestone UAS/NAS FY16 Annual Performance Indicator (API) and FT4 test planning activities and schedule. Technical delays in integrating components of the Distributed Test Environment results in schedule slips past test event milestones.

### Original Impact

**Technical** = 2; This will put the L1 milestone UAS/NAS FY16 Annual Performance Indicator (API) at risk.

**Schedule** = 3; Technical delays in integrating components of the Distributed Test Environment results in schedule slips past test event milestones.

**Cost** = 1; Bringing in additional WYEs or FTEs will not prevent slippage in schedule because appropriate skill mix is needed.

---

### Status

9/15/2015: Mitigation 01 includes all assets including identifying intruders. End dates for mitigations 01 and 1A extended from 9/30/2015 to 11/13/2015. End dates for mitigations 02 and 03 extended from 10/16/2015 to 11/13/2015 to coincide with the FT4 ERT. Review of risk is ongoing through FT4 path forward and decision point 2 (Nov 13) outcome.

8/20/15: Need to review/clean-up risk after post FT3/FT4 path forward meetings (August 24-25 and September 9-10).

8/18/15: Jim Murphy provided updated text for Mitigation 1A.

### Risk Approach: Mitigate

---

<table>
<thead>
<tr>
<th>Mitigation Step/Task Description</th>
<th>Cost to Implement</th>
<th>Start Date</th>
<th>End Date</th>
<th>New LxC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determine required FT4 assets (including facility and equipment requirements). [Kim/Murphy/All PEs] <strong>(Mitigation 01)</strong></td>
<td>TBD</td>
<td>1/15/15</td>
<td>9/30/15, 11/13/15</td>
<td>2 x 3 (T2,S3, C1)</td>
</tr>
<tr>
<td>Create plan and schedule for procuring long lead facilities or equipment identified during requirements gathering and system design and track integration into the test environment. If necessary, track asset procurement and integration under a separate risk. <strong>(Mitigation 1A)</strong></td>
<td>TBD</td>
<td>7/20/2015</td>
<td>9/30/15, 11/13/15</td>
<td>2 x 3 (T2,S3, C1)</td>
</tr>
<tr>
<td>Develop rapid prototype interfaces into the LVC for new components. [Kim/Murphy/All PEs] <strong>(Mitigation 02)</strong></td>
<td>NA</td>
<td>4/11/13</td>
<td>11/13/15</td>
<td>2 x 3 (T2,S3, C1)</td>
</tr>
<tr>
<td>Schedule assets that meet specified requirements for the time periods that cover the testing and conduct of FT4. [Kim/Murphy/All PEs] <strong>(Mitigation 03)</strong></td>
<td>NA</td>
<td>1/15/15</td>
<td>11/13/15</td>
<td>1 x 3 (T2,S3, C1)</td>
</tr>
<tr>
<td>Identify and procure key equipment that can be readily replaced if failure occurs during testing and where procurement of a replacement is economically feasible. [Kim/Murphy/All PEs] <strong>(Mitigation 04)</strong></td>
<td>TBD</td>
<td>10/1/14</td>
<td>1/4/16</td>
<td>1 x 3 (T1,S3, C1)</td>
</tr>
</tbody>
</table>
Distributed Test Environment requirements for Integrated Flight Test 4 (FT4) not defined

**Top Risk**

**Risk Statement**
Given timely definition of system requirements is necessary in order to ensure proper development of the environment, delayed execution of FT4 reporting and closeout will impact the execution of the L1 milestone Capstone Event and FY16 Project reporting and closeout by Sep 30th, 2016.

**Original Impact**
- **Technical** = 3; If LVC system requirements are not defined per schedule then FT4 L2 dates will not be met.
- **Schedule** = 3; The Level 1 milestone, UAS/NAS FY14 Annual Performance Indicator (API) will be at risk.
- **Cost** = 1; De-Scope

**Status**
9/15/2015: Mitigation 03 is complete. End dates of mitigations 04 and 05 extend from 8/31/2015 to 10/31/2015. Review of risk is ongoing through FT4 path forward and decision point 2 (Nov 13) outcome.
8/20/15: Need to review/clean-up risk after post FT3/FT4 path forward meetings (August 24-25 and September 9-10).
8/6/15: Risk continues to trend flat. End date for Mitigation 03 extended from 7/31/15 to 8/31/15. Documented the radar requirement and noted that IT&E is not going to meet it.

**Risk Approach: Mitigate**

<table>
<thead>
<tr>
<th>Mitigation Step/Task Description:</th>
<th>Cost to Implement (if exceeds current budget)</th>
<th>Start Date</th>
<th>End Date</th>
<th>New LxC C: (Tech, Schedule, Cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduct IHITL SRR to define draft and include all known FT3 and FT4 requirements for inclusion in IHITL SRR. (Mitigation 01) COMPLETED</td>
<td>N/A</td>
<td>8/15/13</td>
<td>11/7/13</td>
<td>2 x 3 C: (T3,S3, C1)</td>
</tr>
<tr>
<td>Define draft and include all known FT4 requirements for inclusion in FT3 SRR. (Mitigation 02) COMPLETED</td>
<td>N/A</td>
<td>8/15/13</td>
<td>9/10/2014</td>
<td>2 x 3 C: (T2,S3, C1)</td>
</tr>
<tr>
<td>Work with the researchers to define and baseline specific FT4 objectives and test requirements and disseminate them to the key stakeholders for review. (Mitigation 03) COMPLETED</td>
<td>N/A</td>
<td>3/25/15</td>
<td>7/31/15</td>
<td>2 x 3 C: (T2,S3, C1)</td>
</tr>
<tr>
<td>Lessons learned from Flight Test 3 Activity will be applied to FT4. (Mitigation 04)</td>
<td>N/A</td>
<td>9/1/14</td>
<td>8/31/15</td>
<td>2 x 3 C: (T1,S3, C1)</td>
</tr>
<tr>
<td>Complete the FT4 specific requirements document with inputs from FT3 lessons learned and stakeholder responses to the baseline. (Mitigation 05)</td>
<td>N/A</td>
<td>3/25/15</td>
<td>8/31/15</td>
<td>1 x 3 C: (T1,S3, C1)</td>
</tr>
<tr>
<td>Develop the ITE architecture description document by baselining the FT3/FT4 architecture for the Distributed Test Environment (Mitigation 06)</td>
<td>N/A</td>
<td>6/6/13</td>
<td>10/13/15</td>
<td>1 x 3 C: (T1,S3, C1)</td>
</tr>
</tbody>
</table>
Output from Test Events has value to Project Stakeholders

**Top Risk**

**Risk Statement**
Given the diversity of testing to be conducted and schedule and cost constraints, it is possible that the type/kinds of data collected during tests may not be sufficient or timely for MOPS development. The Project is conducting subproject individual and joint testing, and the integrated test events. Output from these events need to provide value to the Project Stakeholders. Superseded risk U.5.1.5.

**Status**
9/15/15: LxC and additional mitigations will be assessed based upon FT4 path forward and decision point 2 (Nov 13) outcome.
8/6/15: Risk is trending up. Loss of radar on S3-B caused a significant change to what was planned. May add additional mitigations as result of next steps.
6/4/15: Risk is trending flat. Debra Randall briefed SC-228 and explained how to communicate requirements that they wanted for FT4 and how NASA would take those requirements in and determine if we would meet them or not. On May 29th Debra briefed Code R on plan to coordinate with stakeholders.

**Risk Approach: Mitigate**

<table>
<thead>
<tr>
<th>Mitigation Step/Task Description:</th>
<th>Cost to Implement</th>
<th>Start Date</th>
<th>End Date</th>
<th>New LxC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide the Project L1/L2 Milestones, Milestone Dates, and Project Requirements Document to our Stakeholders [FAA (ANG-80, AFS-80), SC-228 DAA and C2 Working Groups, and SARP] (Mitigation 04)</td>
<td>NA</td>
<td>3/1/14</td>
<td>9/30/15</td>
<td>2x3 C: (Tech, Schedule, Cost)</td>
</tr>
<tr>
<td>NASA project personnel coordinate with SC-228 working group peers to identify opportunities for flight test 4 to support development of MOPS requirements. Then brief test design, plans, and objectives to SC-228 WG (Mitigation 06)</td>
<td>$0</td>
<td>3/1/14</td>
<td>1/15/16</td>
<td>2x3 C: (T3, S2, C2)</td>
</tr>
<tr>
<td>NASA project personnel coordinate with SC-228 working group peers to identify opportunities for subproject test events to support development of MOPS requirements. Then brief test design, plans, and objectives to SC-228 WG. (Mitigation 07)</td>
<td>$0</td>
<td>3/1/14</td>
<td>7/1/16</td>
<td>2x3 C: (T3, S2, C2)</td>
</tr>
<tr>
<td>NASA Project personnel to brief test objectives, design, and plans to FAA personnel and obtain stakeholder feedback for FT3 &amp; FT4. (Mitigation 08)</td>
<td>$0</td>
<td>10/1/14</td>
<td>3/30/15</td>
<td>2x3 C: (T3, S2, C2)</td>
</tr>
</tbody>
</table>

**Original Impact**
*Technical = 4; Technology maturation may be moderately impacted by a failure of the Project to deliver data products relevant to the needs of our Project Stakeholders.*
*Scheduled = 3; Added flight or simulation events will slip schedule.*
*Cost = 2; If the Project needs to add a flight or simulation event to collect data due to non-delivery of relevant data to a stakeholder, then the marching army costs for the event could be an issue.*
# UAS-NAS Project Focus Changes Due to External Influences

## Risk Statement
Discussions between NASA, FAA and others in the UAS community were used to identify project Technical Challenges, which were used to scope project content during Formulation. These activities continue to refine the UAS integration in the NAS efforts at the national level through roadmap development. While IASP and the UAS-NAS Project participate in these activities, resultant changes to the UAS roadmap could lead to changes in UAS-NAS Project content. This risk captures the potential for loss of relevance of UAS-NAS work content and the potential that stakeholder/customer needs might change.

## Impact
Planned activities in the UAS-NAS Project may not be relevant, resulting in significant project replanning.

## Status
- **4/9/15:** Updated risk to reflect FY15 ARMD restructure nomenclature with new Program name IASP
- **03/13/14:** Worked with UAS-NAS Project Risk team and Stuart to create new mitigation steps on 2/19/14. The FAA Roadmap and JPDO Comprehensive Plan were released on November 7th, 2013. This in turn closed our second mitigation.
- **01/08/14:** RTCA SC-228 White papers have been through the FRAC process as of 12/6/2013 and the white papers should be released through the PMC in the March timeframe. NASA work has been evaluated against white papers and the portfolio does not appear to require changes in focus. Additionally, NASA has worked closely with the SARP at Well Clear and Deep Dive workshops to ensure relevance of other SAA and HSI TWP’s.
- **11/14/13:** This risk will likely be lowered with the release of the white paper. The stability and maturity of SC-228 should also lower this risk.
- **8/22/13:** Likelihood decreased to 2 based on: Independent assessment from the NAC; participation in SC-228; and development of Phase 2 portfolio that is aligned with ARC implementation plan, FAA ConOps and JPDO comprehensive plan.
- **4/25/13:** RTCA released a new ToR which eliminated SC-203 and new Minimum Operational Performance specs, and FAA got rid of their SSI-related objective. Changes re being accounted for via KDP planning for Phase 2. Present mitigations remain effective.
- **6/12/12:** Established monthly meetings with FAA UAS Integration office
- **4/12/12:** Risk baselined
- **3/9/12:** Risk brought to RMB. Action given to reword and bring back to RMB.
- **1/31/12:** Risk brought to RMB as a Candidate Risk but deferred for further discussions if this should be a Project or Program risk.

## Risk Action: Mitigate
**Mitigation Trigger (if current action is Watch):** When external efforts that could result in possible changes to UAS-NAS scope are on-going.

## Rationale for Closure:
## UAS-NAS Project Focus Changes Due to External Influences

### Risk Statement
Discussions between NASA, FAA and others in the UAS community were used to identify project Technical Challenges, which were used to scope project content during Formulation. These activities continue to refine the UAS integration in the NAS efforts at the national level through roadmap development. While IASP and the UAS-NAS Project participate in these activities, resultant changes to the UAS roadmap could lead to changes in UAS-NAS Project content. This risk captures the potential for loss of relevance of UAS-NAS work content and the potential that stakeholder/customer needs might change.

### Impact
Planned activities in the UAS-NAS Project may not be relevant, resulting in significant project replanning.

<table>
<thead>
<tr>
<th>Mitigation Step/Task Description:</th>
<th>Cost to Implement</th>
<th>Start Date</th>
<th>End Date</th>
<th>New L x C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remain involved with major policy making, shareholder, and stakeholder organizations (FAA-UAS-PO, RTCA SC-228, DoD, MIT-LL, AFRL, etc.). Gain FAA agreement on NASA body of research/technology developments.</td>
<td>$0</td>
<td>End of Project</td>
<td>2 x 3</td>
<td></td>
</tr>
<tr>
<td>Remain cognizant of FAA and JPDO roadmapping efforts to provide insight to FAA and JPDO thinking on research and technology development needs. The delivery date for these roadmaps is unknown so the mitigation will end upon publication.</td>
<td>$0</td>
<td>Closed 11/7/13</td>
<td>2 x 3</td>
<td></td>
</tr>
<tr>
<td>Remain cognizant of FAA integration efforts to provide insight to FAA thinking on research and technology development needs.</td>
<td>$0</td>
<td>End of Project</td>
<td>2 x 3</td>
<td></td>
</tr>
<tr>
<td>Participation in the RTCA SC-228 working groups, SARP, UAS Senior Steering Group of ExCom, and UAS Aviation Rulemaking Committee.</td>
<td>$0</td>
<td>Release of Final MOPS 7/15/16</td>
<td>2 x 3</td>
<td></td>
</tr>
</tbody>
</table>
### Risk Statement

Given the DAA and C2 WG are continuing to refine the requirements and V&V plans, and given the project technical objectives and schedule have been baselined there is a possibility the requirements they define will impact the project baseline technical objectives and schedule. As an example the CNPC radio, originally designed to SC-203 seedling requirements, continues to be refined based on developing C2 MOPS.

### Status:
- **5/21/15:** MRB approved moving risk to watch status. *Risk was TOP RISK – due to original LxC score 3x5 (red). No longer a top risk due to watch status.*
- **5/19/15:** During PPBE 17 the Project provided ARMD/IASP with a proposed follow-on project which would decrease the likelihood. The Project has done everything it can do until this risk is triggered. Mitigations are actively being worked. If risk is triggered then approved contingency plan will be implemented. Proposed to move into watch status. Trigger will be RTCA SC-228 schedule delay.
- **4/13/15:** Project Office Risk Workshop held. Received action at IASP/UAS RMB on April 9th to review scores. Examined LxC scores and the likelihood of 3 is consistent with information from WG meetings in the absence of something more definitive from leadership. The consequence score reflects impact of not completing the technical challenge.

### Risk Approach: Watch

**Mitigation Trigger (if current action is Watch):** The trigger is RTCA SC-228 schedule delay.

### Contingency Plan
- **Project Controlled Contingency Plan on next slides.**
- **IASP Controlled Contingency Plan captured in mitigation below**

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**Risk Approaches**

<table>
<thead>
<tr>
<th>Mitigation Step/Task Description</th>
<th>Cost to Implement</th>
<th>Start Date</th>
<th>End Date</th>
<th>New LxC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrate NASA personnel into SC-228 C2 working groups to understand and influence C2 WG requirements and their impacts on the Flight Test planning, and share C2 research, objectives, plans, and results with C2 WG. <em>(Mitigation 01)</em> [Griner]</td>
<td>$0</td>
<td>9/5/14</td>
<td>12/31/15</td>
<td>3x3 C (T3, S3, C1)</td>
</tr>
<tr>
<td>Integrate NASA personnel into DAA working groups to understand and influence DAA MOPS requirements and their impacts on the Flight Test planning <em>(Mitigation 02)</em> [Arthur/Santiago]</td>
<td>$0</td>
<td>9/5/14</td>
<td>12/31/15</td>
<td>3x3 C (T3, S3, C1)</td>
</tr>
</tbody>
</table>

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**Contingency Plan**

- **IASP Controlled Contingency Plan captured in mitigation below**

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Work towards extending the life of the Project or including appropriate Project personnel in another ARMD activity to support the SC-228 Phase 2 MOPS.
Risk ID 1.1.12.  Risk Statement  Given the SC-228 detect and avoid (DAA) and command and control (C2) Data Link Working Groups (WG) are continuing to develop their Minimum Operational Performance Standards (MOPS) and MOPS verification and validation (V&V) plans, and given the project technical objectives and schedule were baselined to reasonably support the published SC-228 schedule, there is a possibility that potential changes to the MOPS or V&V plans development schedules or requirements will impact the project baselined technical objectives and schedule.

As an example the UAS-NAS project is developing a prototype control and non-payload communication (CNPC) radio for use in MOPS development and MOPS V&V. A CNPC radio is one of several key technologies required for MOPS development and MOPS V&V. As CNPC radios take several years to design and build the NASA CNPC prototype radio design was initiated with RTCA SC-203 seedling requirements. While the design of the radio continues to mature, there is risk that changes in C2 Working Group MOPS may not be implementable in the CNPC radio design if they are too extensive or require more schedule than is available within the UAS-NAS Project.

Background: RTCA SC-228 is the primary stakeholder to the majority of the Project’s research portfolio. The SC-228 Terms of Reference (TOR) defined requirements with respect to developing MOPS for DAA, and C2. The requirements included producing Preliminary MOPS and a MOPS V&V Plan by July 2015 (Phase One), and Final MOPS based on the MOPS V&V by July 2016 (Phase Two). The two phases of SC-228 are unrelated to the two phases of the UAS-NAS Project. Both DAA and C2 have independent working groups defining MOPS for the respective technology areas. The working groups each have elements of Human Systems Integration embedded. NASA’s research activities contribute to developing Preliminary MOPS, supporting MOPS V&V, and developing Final MOPS for each respective Working Group. The technology transfer process for NASA research findings described below will be relevant to MOPS development Phase 1 only, UAS-NAS Project Phase 2.

The UAS-NAS Project baselined milestone dates are generally aligned with the SC-228 MOPS delivery dates. The risk is whether the UAS-NAS Project’s baseline technology transfer of research findings plan can support MOPS development and MOPS V&V plans if the results from those efforts are delayed later than the Project can adapt or when delivered the results are significantly different from the UAS-NAS initial assumptions.

NASA is participating in SC-228 at all levels.

- From a project management level the UAS-NAS Project is coordinating a strategy for documenting deliverables to SC-228. Laurie Grindle, Davis Hackenberg, and Debra Randall attend the Plenary sessions to maintain awareness at a high level.
- NASA is a key contributor at the working group level to within several sub working groups. Project participation in the SC-228 working groups by the subproject PE’s (Confesor Santiago, Maria Consiglio, Jay Shively, Jim Griner) provides a method of influencing MOPS requirements and feeding back SC-228 discussions into UAS-NAS Project plans.
**Risk ID 1.1.12. Contingency Plan:** Assuming the RTCA SC-228 Preliminary and Final MOPS delivery schedules slip or the MOPS or MOPS V&V Plans are substantially different from initial Project assumptions the UAS-NAS Project may not be able to adapt based upon Project currently baselined Level 1 and Level 2 Milestones.

Assumptions:

1) Next FY President’s Budget includes the extension of funding to the first quarter of FY17.
2) No additional funding available for changes to the Project baseline within baselined project completion date of Sep 30, 2016 (EOFY16).
3) No additional funding available to extend the Project beyond the first Quarter of FY17.

The following general scenarios are possible and provided for potential contingency plan discussions:

<table>
<thead>
<tr>
<th>If</th>
<th>Then</th>
<th>Potential Impact to Project Cost, Schedule, Technical Baseline</th>
<th>Potential Impact to SC-228</th>
</tr>
</thead>
</table>
| All SC-228 changes to MOPS or MOPS V&V Plan can be accommodated within Project Cost Baseline (that includes the one quarter funding extension) | Project accommodates changes by moving Milestones or modifying Technical Baseline | • Cost: 1, funded with already approved one quarter extension  
• Schedule: 5, potential up to 3-month slip to Project Level 1 or 2 Milestones  
• Technical Baseline: 4, potential moderate impact to objective, technical challenge, or technology maturation | • None  
• Consequence = 1 |
| Some of SC-228 changes to MOPS or MOPS V&V Plan can be accommodated within Project Cost Baseline (that includes the one quarter funding extension) | Project accommodates those changes it can by moving Milestones or modifying Technical Baseline, but not incurring costs approved the approved cost baseline (that includes the one quarter funding extension) | • Cost: 1, funded with already approved one quarter extension  
• Schedule: 5, potential up to 3-month slip to Project Level 1 or 2 Milestones  
• Technical Baseline: 4, potential moderate impact to objective, technical challenge, or technology maturation | • Some Project results delivered per changed Project baselined schedule and Technical Baseline do not meet SC-228 MOPS or MOPS V&V Plan needs  
• Consequence = 2 - 4 |
| SC-228 changes to MOPS or MOPS V&V Plan cannot be accommodated within Project Cost Baseline (that includes the one quarter funding extension) | Project does not change Baseline Milestone Schedule or Technical Baseline | • None as the Project does not make any changes to approved Schedule Baseline or Technical Baseline | • Project results delivered per Project baselined schedule and Technical Baseline do not meet SC-228 MOPS or MOPS V&V Plan needs  
• Related to risk U.1.1.10 Output from Test Events has value to Project Stakeholders  
• Consequence = 5 |
As of 9/30/15

- Changes Since 2014 Annual Review
  - Added 3 Risks (4.3.9, 4.3.10, 4.3.11)
  - Closed 6 Risks (4.3.2, 4.3.4, 4.3.6, 4.3.9, 4.3.10, 4.3.11)
  - Moved risk 5.1.17 from TC-IT&E to TC-C2

### Risk Matrix

<table>
<thead>
<tr>
<th>Consequence</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
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<tbody>
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<td>Likelihood</td>
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<td>1</td>
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</tr>
</tbody>
</table>

### Risk Summary

- Risk ID: 4.3.5
  - Trend: Decreasing (Improving)
  - LxC: 3x3
  - Target LxC: 2x1
  - Approach: M
  - Risk Title: Additional Spectrum Analysis Requirements

- Risk ID: 5.1.17
  - Trend: NA
  - LxC: 1x3
  - Target LxC: 2x2
  - Approach: W
  - Risk Title: The T-34 (UA Surrogate) for FT3 and FT4 may not be available

(T) Indicates a Top Risk

<table>
<thead>
<tr>
<th>Criticality</th>
<th>L x C Trend</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Decreasing (Improving)</td>
<td>Accept</td>
</tr>
<tr>
<td></td>
<td>Increasing (Worsening)</td>
<td>RA - Raise</td>
</tr>
<tr>
<td></td>
<td>Unchanged</td>
<td>Mitigate</td>
</tr>
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</table>

- Research

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### TC-SAA: Risk Matrix and Summary

#### Risk Matrix

<table>
<thead>
<tr>
<th>Risk ID</th>
<th>Trend</th>
<th>LxC</th>
<th>Target LxC</th>
<th>Approach</th>
<th>Risk Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1.11</td>
<td>➔</td>
<td>3x3</td>
<td>2x2</td>
<td>M</td>
<td>Validation of SAA Sensor Models</td>
</tr>
<tr>
<td>4.1.9</td>
<td>➔</td>
<td>2x3</td>
<td>1x3</td>
<td>M</td>
<td>Delay of SAA/SSI Technology Developments Impact to Integrated Test Events (IHITL, FT3 and FT4)</td>
</tr>
<tr>
<td>4.1.10</td>
<td>NA</td>
<td>2x2</td>
<td>2x2</td>
<td>W</td>
<td>Completion of SAA/SSI Technical Objectives that Rely upon Formal Partnerships</td>
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</tbody>
</table>

#### As of 9/30/15

- Changes Since 2014 Annual Review
  - Closed 2 Risks (4.1.7, 4.1.8(T))
**TC-HSI: Risk Matrix and Summary**

### Risk Matrix

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<thead>
<tr>
<th>L</th>
<th>ID</th>
<th>Trend</th>
<th>LxC</th>
<th>Target LxC</th>
<th>Approach</th>
<th>Risk Title</th>
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<td>4.2.9</td>
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<td>1x1</td>
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<td>Delay of HSI Technology Development Impact to Integrated Test Events (IHITL, FT3 and FT4)</td>
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<tr>
<td>4</td>
<td>4.2.8</td>
<td>☓</td>
<td>2x2</td>
<td>2x2</td>
<td>M</td>
<td>Endorsement of HSI GCS Guidelines from a Recognized Standards-based Group</td>
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<tr>
<td>3</td>
<td>4.2.11</td>
<td>✩</td>
<td>1x3</td>
<td>1x3</td>
<td>M</td>
<td>Availability of Vigilant Spirit Control Station for Flight Test Series</td>
</tr>
<tr>
<td>2</td>
<td>4.2.10</td>
<td>NA</td>
<td>2x2</td>
<td>2x2</td>
<td>W</td>
<td>Completion of HSI Technical Objectives that Rely upon Formal Partnerships</td>
</tr>
<tr>
<td>1</td>
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</table>

<table>
<thead>
<tr>
<th>Risk ID</th>
<th>Trend</th>
<th>LxC</th>
<th>Target LxC</th>
<th>Approach</th>
<th>Risk Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2.9</td>
<td>✦</td>
<td>3x3</td>
<td>1x1</td>
<td>M</td>
<td>Delay of HSI Technology Development Impact to Integrated Test Events (IHITL, FT3 and FT4)</td>
</tr>
<tr>
<td>4.2.8</td>
<td>☓</td>
<td>2x2</td>
<td>2x2</td>
<td>M</td>
<td>Endorsement of HSI GCS Guidelines from a Recognized Standards-based Group</td>
</tr>
<tr>
<td>4.2.11</td>
<td>✩</td>
<td>1x3</td>
<td>1x3</td>
<td>M</td>
<td>Availability of Vigilant Spirit Control Station for Flight Test Series</td>
</tr>
<tr>
<td>4.2.10</td>
<td>NA</td>
<td>2x2</td>
<td>2x2</td>
<td>W</td>
<td>Completion of HSI Technical Objectives that Rely upon Formal Partnerships</td>
</tr>
</tbody>
</table>

### Changes Since 2014 Annual Review
- Closed 1 Risk (4.2.12)
- Moved 1 Risk to Watch (4.2.10)

**As of 9/30/15**

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<table>
<thead>
<tr>
<th>Criticality</th>
<th>LxC Trend</th>
<th>Approach</th>
</tr>
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<tbody>
<tr>
<td>High</td>
<td>Decreasing (Improving)</td>
<td>Accept, RA – Raise</td>
</tr>
<tr>
<td>Med</td>
<td>Increasing (Worsening)</td>
<td>Mitigate, E – Elevate</td>
</tr>
<tr>
<td>Low</td>
<td>Unchanged</td>
<td>Watch, C – Close</td>
</tr>
</tbody>
</table>

(T) Indicates a Top Risk
TC-ITE: Risk Matrix and Summary

### Risk Matrix

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<tr>
<th>Likelihood</th>
<th>Risk ID</th>
<th>Trend</th>
<th>LxC</th>
<th>Target LxC</th>
<th>Approach</th>
<th>Risk Title</th>
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</thead>
<tbody>
<tr>
<td>5</td>
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<td>3</td>
<td>5.1.11</td>
<td>5.1.23</td>
<td>3x4</td>
<td>1x1</td>
<td>M</td>
<td>No formal agreement in place to access Honeywell data fusion algorithm</td>
</tr>
<tr>
<td>2</td>
<td>5.1.8</td>
<td></td>
<td>3x3</td>
<td>1x3</td>
<td>M</td>
<td>Required Assets for Flight Test 4 (FT4) not available during test period</td>
</tr>
<tr>
<td>1</td>
<td></td>
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<td>2x3</td>
<td>1x3</td>
<td>M</td>
<td>Distributed Test Environment requirements for Integrated Flight Test 4 (FT4) not defined</td>
</tr>
</tbody>
</table>

**As of 9/30/15**

### Changes Since 2014 Annual Review

- Added 3 Risks (5.1.25, 5.1.26, 5.1.27)
- Closed 9 Risks (5.1.7(T), 5.1.10, 5.1.16, 5.1.21, 5.1.22, 5.1.24, 5.1.25, 5.1.26, 5.1.27)
## Certification Risk Matrix and Summary

### Risk Matrix

<table>
<thead>
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<th>LIKELIHOOD</th>
<th>CONSEQUENCE</th>
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### Risk Title

<table>
<thead>
<tr>
<th>Risk ID</th>
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<th>LxC</th>
<th>Target LxC</th>
<th>Approach</th>
<th>Risk Title</th>
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<tbody>
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<td>4.4.5</td>
<td>NA</td>
<td>2x3</td>
<td>1x2</td>
<td>W</td>
<td>Availability of Designated Engineering Representatives Resources</td>
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</table>

### Changes Since 2014 Annual Review
- Moved 1 Risk to Watch (4.4.5)

As of 9/30/15
Project Management Risk Matrix and Summary

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<tr>
<th>Risk Matrix</th>
<th>Risk Title</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Project Focus Changes Due to External Influences</td>
</tr>
<tr>
<td></td>
<td>Output from Test Events has value to Project Stakeholders</td>
</tr>
<tr>
<td></td>
<td>Lack of Definition for Capstone</td>
</tr>
<tr>
<td></td>
<td>Capstone Partnership Development and Formalization</td>
</tr>
<tr>
<td></td>
<td>RTCA SC-228 Requirements Development Delay</td>
</tr>
</tbody>
</table>

**Changes Since 2014 Annual Review**
- Added 1 Risk (1.1.14)
- Accepted 1 Risk (1.1.7)
- Closed 1 Risk (1.1.4(T))
- Moved 1 Risk to Watch (1.1.12)
<table>
<thead>
<tr>
<th>Risk ID</th>
<th>Project/TC</th>
<th>Risk Title</th>
<th>Date Closed</th>
<th>Closing Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.4.3.2</td>
<td>C2</td>
<td>Communication Security Requirements Exceed CNPC Link Constraints</td>
<td>4/23/15</td>
<td>All mitigations are complete reducing the LxC to target score of 1x3. Comm team has worked with Rockwell Collins and RTCA to approve data rates for communication link. All security functions needed are being handled by that data rate.</td>
</tr>
<tr>
<td>U.4.3.4</td>
<td>C2</td>
<td>Availability of OPNET Modeler Expertise</td>
<td>12/18/14</td>
<td>Mitigations are complete resulting in a LxC score of 1x2. Contractor has been hired on and trained. There is no longer an issue in this area.</td>
</tr>
<tr>
<td>U.4.3.6</td>
<td>C2</td>
<td>Higher Communications Aircraft Fuel Cost</td>
<td>9/24/15</td>
<td>As FT3 has concluded and GRC aircraft are not being used in FT4, there is no further basis for this risk.</td>
</tr>
<tr>
<td>U.4.3.9</td>
<td>C2</td>
<td>FT3 CNPC Preparations Stressing C2 Preliminary MOPS Development</td>
<td>9/24/15</td>
<td>As both the preliminary C2 MOPS and FT3 have been completed, there is no longer a basis for this risk.</td>
</tr>
<tr>
<td>U.4.3.10</td>
<td>C2</td>
<td>FT3 Radio Frequency Coverage</td>
<td>9/24/15</td>
<td>Mitigation 2 was completed, indicating the frequency coverage for FT3 was adequate. FT3 has been completed, and there is no longer a basis for this risk.</td>
</tr>
<tr>
<td>U.4.3.11</td>
<td>C2</td>
<td>FT3 CNPC Equipment Installation at California</td>
<td>9/24/15</td>
<td>Installation of FT3 CNPC equipment was installed at a single alternate site at AFRC. As FT3 has been completed, there is no longer a basis for this risk.</td>
</tr>
<tr>
<td>U.4.1.7</td>
<td>SAA</td>
<td>Lack of Collision Avoidance Model Availability and Integration Support</td>
<td>4/21/15</td>
<td>All mitigations are complete reducing the LxC to target score of 1x3. SAA integrated TCAS II model and is using it for testing.</td>
</tr>
<tr>
<td>U.4.1.8</td>
<td>SAA</td>
<td>Sense and Avoid Sensor Suite Availability</td>
<td>12/18/14</td>
<td>All mitigations are complete resulting in a target LxC score of 2x2. Partnership with GA is established and plans are in place to equip Ikhana.</td>
</tr>
<tr>
<td>Risk ID</td>
<td>Project/TC</td>
<td>Risk Title</td>
<td>Date Closed</td>
<td>Closing Rationale</td>
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<td>-----------------------------------------------------------------------------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>U.4.2.12</td>
<td>HSI</td>
<td>New Requirements associated with HSI Part Task 5</td>
<td>12/18/14</td>
<td>Additional WYE has been hired. Mitigation 01 is complete, reducing the LxC from 4x3 to 2x2</td>
</tr>
<tr>
<td>U.5.1.7</td>
<td>ITE</td>
<td>Distributed Test Environment requirements for Integrated Flight Test 3 (FT3) not defined</td>
<td>3/26/15</td>
<td>The Flight Test 3 requirements have been gathered and vetted through the System Requirements Review, presented to our stakeholders for comment, and finalized at the Final Design Review. All Mitigations have been successfully completed.</td>
</tr>
<tr>
<td>U.5.1.10</td>
<td>ITE</td>
<td>Required Assets for Flight Test 3 (FT3) not available during test period</td>
<td>8/20/15</td>
<td>FT3 deemed complete on 8/13/2015.</td>
</tr>
<tr>
<td>U.5.1.16</td>
<td>ITE</td>
<td>Completion of TC6/IT&amp;E Technical Objectives that Rely upon Formal Partnerships</td>
<td>4/23/15</td>
<td>GA Space Act Agreement with NASA has been signed. Any required modifications are being tracked by the Project Office. Mitigations tracked by IT&amp;E have been successfully completed.</td>
</tr>
<tr>
<td>U.5.1.21</td>
<td>ITE</td>
<td>Aggressive ACAS-Xu Flight Test Schedule Jeopardizes Full Success Criteria</td>
<td>1/27/15</td>
<td>All mitigations were implemented successfully to complete the ACAS-Xu CA flight testing on time. Although the AFSR schedule was impacted by 1 week, close coordination with the FRR Board Members resulted in an uneventful AFSR Review and subsequent flight test approval.</td>
</tr>
<tr>
<td>U.5.1.22</td>
<td>ITE</td>
<td>Compressed AFSR Schedule Results in Schedule Delay</td>
<td>12/18/14</td>
<td>All mitigations were implemented successfully to complete the ACAS-Xu CA flight testing on time. Although the AFSR schedule was impacted by 1 week, close coordination with the FRR Board Members resulted in an uneventful AFSR Review and subsequent flight test approval.</td>
</tr>
<tr>
<td>Risk ID</td>
<td>Project/TC</td>
<td>Risk Title</td>
<td>Date Closed</td>
<td>Closing Rationale</td>
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<tr>
<td>U.5.1.24</td>
<td>ITE</td>
<td>Timing of Part Task 5 impact on Flight Test 3 design</td>
<td>4/23/15</td>
<td>The Flight Test 3 design has been reviewed and finalized at FDR. All mitigations were completed and the system is on track for data collection.</td>
</tr>
<tr>
<td>U.5.1.25</td>
<td>ITE</td>
<td>Shortage of Resources – AFRC IT Security Experts</td>
<td>7/23/15</td>
<td>Full ATO signed on June 29. ATO was granted to the Ikhana project. Risk has been fully mitigated reducing the LxC to target score of 1x4 (green).</td>
</tr>
<tr>
<td>U.5.1.26</td>
<td>ITE</td>
<td>ADS-B Receiver may not be received in time to support FT-3</td>
<td>8/20/15</td>
<td>A second receiver is scheduled to be delivered 8/17. The first receiver will be repaired prior to FT4 and will be used as a backup. Given FT4 is six months away, IT&amp;E does not consider this a risk.</td>
</tr>
<tr>
<td>U.5.1.27</td>
<td>ITE</td>
<td>FT-3 Ikhana and Intruder Pilot Availability</td>
<td>8/20/15</td>
<td>FT3 deemed complete on 8/13/2015</td>
</tr>
<tr>
<td>U.1.1.4</td>
<td>PO</td>
<td>The predicted or projected UAS mission profiles and traffic estimates used by the subprojects for their technology development efforts may not be realistic or accurate.</td>
<td>3/26/15</td>
<td>All mitigations are complete resulting in a target LxC score of 1 x 3.</td>
</tr>
<tr>
<td>U.1.1.7</td>
<td>PO</td>
<td>Negative Public Perception of UAS in NAS</td>
<td>12/18/14</td>
<td>All mitigations are captured in the UAS-NAS Public Outreach plan reducing the LxC to 2x3. Outreach tasks have been added to the IMS. Project has allocated a set amount of resources and feel that is the limit to what we want to contribute to influence the public's opinion.</td>
</tr>
</tbody>
</table>
Risk Process

• Risk Management
  – Utilizes a Continuous Risk Management (CRM) process to identify, analyze, plan, track, and control risks
    • Risk Workshops and Risk Review meetings conducted monthly
    • Integrated Test & Evaluation Subproject holds a weekly risk working group meeting to address their risks
  – Risks are communicated in IASP UAS-NAS Risk Review Board, AFRC & Partner Center CMCs

• Path Forward to address Process Failure
  – To gain higher perspective, Project Manager and Management Support Specialist will implement monthly risk brainstorming meeting to review concerns and discuss any potential new concerns/candidate risks
UAS-NAS Risk Summary Card

### Likelihood

<table>
<thead>
<tr>
<th>5</th>
<th>Very High</th>
<th>Qualitative: Nearly certain to occur. Controls have little or no effect.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>High</td>
<td>Qualitative: Highly likely to occur. Controls have significant uncertainties.</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Qualitative: May occur. Controls exist with some uncertainties.</td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
<td>Qualitative: Not likely to occur. Controls have minor limitations /uncertainties.</td>
</tr>
<tr>
<td>1</td>
<td>Very Low</td>
<td>Qualitative: Very unlikely to occur. Strong Controls in Place</td>
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### Consequence

<table>
<thead>
<tr>
<th>CONSEQUENCE</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>Cost</td>
<td>≤ 1% Total Project Yearly Budget (≤ $300K)</td>
<td>1% - 5% Total Project Yearly Budget ($300K - $1.5M)</td>
<td>5% - 10% Total Project Yearly Budget ($1.5M - $3M)</td>
<td>10% - 15% Total Project Yearly Budget ($3M – $4.5M)</td>
<td>&gt;15% Total Project Yearly Budget (&gt; $4.5M)</td>
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<tr>
<td>Schedule *</td>
<td>Level 2 Milestone(s): &lt; 1 month impact</td>
<td>Level 2 Milestone(s): ≥ 1 month impact</td>
<td>Level 1 Milestone(s): ≤ 1 month impact</td>
<td>Level 1 Milestone(s): &gt; 1 month impact</td>
<td>Level 1 Milestone(s): &gt; 2 month impact</td>
</tr>
</tbody>
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Note: L1 = ISRP  L2 = Project
Project Level Performance
Backup Slides
Reserve Strategy
Resource Allocation FY16 Budget
# FY15 Project Deliverables

<table>
<thead>
<tr>
<th>Phase 2 Technical Challenge Deliverables - SAA</th>
<th>Date</th>
<th>Type of Deliverable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completed, Ongoing, and Upcoming Experiments IHITL/B747-TCAS and IHITL/CAS2 Overview and Results</td>
<td>Nov-14</td>
<td>Briefing</td>
</tr>
<tr>
<td>Pilot Detect-and-Avoid Evaluation</td>
<td>Nov-14</td>
<td>Briefing</td>
</tr>
<tr>
<td>Investigating the Impacts of a Separation Standard for UAS Enroute and Transition Airspace</td>
<td>Nov-14</td>
<td>Paper</td>
</tr>
<tr>
<td>UAS CAS3 CASSAT PER/FER</td>
<td>Mar-15</td>
<td>Briefing</td>
</tr>
<tr>
<td>Fast Time Simulation Studies</td>
<td>May-15</td>
<td>Briefing</td>
</tr>
<tr>
<td>Detect and Avoid Research</td>
<td>May-15</td>
<td>Briefing</td>
</tr>
<tr>
<td>Characterizing the Effects of a Vertical Time Threshold for a Class of Well-Clear Definitions</td>
<td>May-15</td>
<td>Paper</td>
</tr>
<tr>
<td>Appendix A NAS wide evaluation using historical radar data and airspace</td>
<td>May-15</td>
<td>Paper</td>
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<tr>
<td>UAS in the NAS Air Traffic Controller Acceptability Study - 1 the Effects of Horizontal Miss Distances on Simulated UAS and Manned Aircraft Encounters</td>
<td>May-15</td>
<td>Briefing &amp; Paper</td>
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<tr>
<td>UAS Air Traffic Controller Acceptability Study 2 - Effects of Communications Delays and Winds in Simulation</td>
<td>May-15</td>
<td>Paper</td>
</tr>
<tr>
<td>Airspace Safety Threshold Study- NAS-wide Encounter Rate Evaluation using Historical Radar Data and ACES</td>
<td>May-15</td>
<td>Briefing</td>
</tr>
<tr>
<td>Analysis of Baseline PT5 Alerting Scheme in Fast-Time Simulations without DAA Mitigation</td>
<td>May-15</td>
<td>Briefing</td>
</tr>
<tr>
<td>Characteristics of a Well Clear Definition and Alerting Criteria for Encounters between UAS and Manned Aircraft in Class E Airspace</td>
<td>Jun-15</td>
<td>Paper</td>
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<tr>
<td>DAIDALUS: Detect and Avoid Alerting Logic for Unmanned Systems</td>
<td>Sep-15</td>
<td>Paper</td>
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<tr>
<td>HITL Experimental Research for DAA</td>
<td>Sep-15</td>
<td>Briefing</td>
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<tr>
<td>Detect and Avoid Alerting Logic for Unmanned Systems</td>
<td>Sep-15</td>
<td>Briefing</td>
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## FY15 Project Deliverables

<table>
<thead>
<tr>
<th>Phase 2 Technical Challenge Deliverables – C2</th>
<th>Date</th>
<th>Type of Deliverable</th>
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<tbody>
<tr>
<td>Gen-4 and Gen-5 Radio Plans</td>
<td>Dec-14</td>
<td>Briefing</td>
</tr>
<tr>
<td>V &amp; V Update</td>
<td>Dec-14</td>
<td>Briefing</td>
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<tr>
<td>CNPC Prototype Gen 2 Security Architecture Lab Test Report</td>
<td>Dec-14</td>
<td>Report</td>
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<tr>
<td>CNPC System Development and Testing</td>
<td>Apr-15</td>
<td>Briefing</td>
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<table>
<thead>
<tr>
<th>Phase 2 Technical Challenge Deliverables – HSI</th>
<th>Date</th>
<th>Type of Deliverable</th>
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<tbody>
<tr>
<td>Measured Response The effect of GCS Control Mode Interfaces on Pilot Ability to Comply with ATC Clearances</td>
<td>Oct-14</td>
<td>Briefing</td>
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<tr>
<td>A report on the Human Systems Integration Phase 1 Activities</td>
<td>Oct-14</td>
<td>Briefing</td>
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<tr>
<td>IHITL: Detect and Avoid Display Evaluation Prelim Results</td>
<td>Nov-14</td>
<td>Briefing</td>
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<tr>
<td>HSI Display Evaluation Overview</td>
<td>Mar-15</td>
<td>Briefing</td>
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<tr>
<td>NASA's UAS Integration into the NAS: A Report on the Human Systems Integration Phase 1 Simulation Activities</td>
<td>May-15</td>
<td>Briefing</td>
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<tr>
<td>Human Performance Issues in Remotely Piloted Aircraft Systems</td>
<td>Mar-15</td>
<td>Briefing</td>
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<tr>
<td>Automation in Unmanned Aerial Vehicles</td>
<td>Mar-15</td>
<td>Briefing</td>
</tr>
<tr>
<td>Part Task 5 Detect and Avoid Display Evaluation Overview III</td>
<td>May-15</td>
<td>Briefing</td>
</tr>
<tr>
<td>An Evaluation of DAA Displays for Unmanned Aircraft Systems The Effect of Information Level and Display Location on Pilot Performance</td>
<td>May-15</td>
<td>Paper</td>
</tr>
<tr>
<td>UAS-NAS Part Task 5 Detect and Avoid Display Evaluation Primary Results</td>
<td>May-15</td>
<td>Briefing</td>
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# FY15 Project Deliverables

## Project Phase 2 Technical Challenge Deliverables – HSI Continued

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<tr>
<th>Project</th>
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<tr>
<td>UAS-NAS DAA Display Evaluation in Support of SC-228 MOPS Development</td>
<td>Jun-15</td>
<td>Briefing</td>
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<tr>
<td>An examination of UAS Pilots Interaction with ATC while responding to DAA Conflicts</td>
<td>Jun-15</td>
<td>Paper</td>
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## Project Phase 2 Technical Challenge Deliverables – ITE

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<tr>
<th>Project</th>
<th>Date</th>
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<tr>
<td>RUMS- Real-time Visualization and Evaluation of Live Virtual, Constructive Simulation Data</td>
<td>Jan-15</td>
<td>Paper</td>
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<tr>
<td>Message Latency Characterization of a Distributed Live, Virtual, Constructive Simulation Environment</td>
<td>Jan-15</td>
<td>Paper</td>
</tr>
<tr>
<td>IHITL Test Environment Report</td>
<td>Mar-15</td>
<td>Report</td>
</tr>
<tr>
<td>Project Overview and A distributed environment for testing UAS concepts</td>
<td>May-15</td>
<td>Briefing</td>
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<tr>
<td>FT3 Test Plan - Rev E</td>
<td>Jul-15</td>
<td>Report</td>
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<tr>
<td>FT4 Test Requirements</td>
<td>Aug-15</td>
<td>Report</td>
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## Project Phase 2 Technical Challenge Deliverables – Non-TC Certification

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<th>Project</th>
<th>Date</th>
<th>Type of Deliverable</th>
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<tr>
<td>Mock Type Certification Basis for an Unmanned Rotorcraft for Aerial Application Operations</td>
<td>Mar-15</td>
<td>Paper</td>
</tr>
<tr>
<td>A Case Study for Assured Containment</td>
<td>May-15</td>
<td>Paper</td>
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<tr>
<td>Mock Certification Basis for an Unmanned Rotorcraft for Precision Agricultural Spraying</td>
<td>Sep-15</td>
<td>Paper</td>
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## Project Phase 2 Technical Challenge Deliverables – Non-TC sUAS

<table>
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<th>Project</th>
<th>Date</th>
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<tr>
<td>sUAS Flight Experiments for Great Dismal Swamp Fire Detection</td>
<td>Dec-14</td>
<td>Paper</td>
</tr>
</tbody>
</table>
Technology Transfer Coordination (UAS-NAS to Stakeholder)

### Monthly/Quarterly Coordination

- **Stakeholder Working Groups**
  - SC-228
  - Sub WG Planning
  - Key Issues Resolution
  - Technical Exchange
  - Briefings

- **Stakeholder Face to Face Meetings**
  - Cross WG Planning
  - Key Issues Resolution
  - Results Validation
  - Briefings

### Annual Coordination

- **Stakeholder & Project Annual Meetings**
  - Strategic Planning
  - Project Annual Meetings
  - Professional Annual Meetings
  - Final Reports/Presentations

### Daily/Weekly Coordination

- **UAS TWP Integrated Events**
- **RTCA SC-228**
  - Baseline PRD Content
  - Initial Tech Transfer Briefings
  - Final Reports

- **FAA**
  - Test Plans
  - Final Reports

- **OSD SAA SARP**
  - Research Findings

- **ITU-R**
  - Spectrum Analysis

### Transfer Method

- Publicly releasable material: NASA ARMD Website
- Controlled data, e.g. ITAR: Secure email/server/website

---

**RTCA SC-228**

- White Papers
- Preliminary & Final MOPS

**FAA**

- Integration Road Maps
- Rules and Regulations

**OSD SAA SARP**

- Recommendations

**ITU-R**

- Authorization
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<tr>
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<th>FY2015</th>
<th>FY2016</th>
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Green Status Line Date 9/30/15
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<tr>
<th>Area</th>
<th>FAA Test Site</th>
<th>Partner POCs</th>
<th>Agreement In Place</th>
<th>In Execution</th>
<th>Collaboration/Partnership Role</th>
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<tr>
<td>TC-ITE</td>
<td>University of Alaska Fairbanks</td>
<td>Ro Bailey</td>
<td>✓</td>
<td>✓</td>
<td>Support of Task 1, UTM and support of Task 2. LVC-DE efforts</td>
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<td>TC-ITE</td>
<td>State of Nevada</td>
<td>Thomas Wilczek</td>
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<td>✓</td>
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<td>New York – Griffiss UAS Test Site</td>
<td>Chad Lawrence</td>
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<td>Robert Becklund</td>
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<td>✓</td>
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<td>TC-ITE</td>
<td>Texas A&amp;M University</td>
<td>Dr. Luis Cifuentes</td>
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<td>✓</td>
<td>Support of Task 1, UTM and support of Task 2. LVC-DE efforts</td>
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<td>TC-ITE</td>
<td>Virginia Tech</td>
<td>John Rudd</td>
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# Acronym List

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tr>
<td>AA</td>
<td>Associate Administrator</td>
</tr>
<tr>
<td>ACAS</td>
<td>Airborne Collision Avoidance System</td>
</tr>
<tr>
<td>ACES</td>
<td>Airspace Concept Evaluation System</td>
</tr>
<tr>
<td>ADS-B</td>
<td>Automatic Dependent Surveillance Broadcast</td>
</tr>
<tr>
<td>AFRC</td>
<td>Armstrong Flight Research Center</td>
</tr>
<tr>
<td>AFRL</td>
<td>Air Force Research Lab</td>
</tr>
<tr>
<td>AFSRB</td>
<td>Airworthiness and Flight Safety Review Board</td>
</tr>
<tr>
<td>AIAA</td>
<td>American Institute of Aeronautics and Astronautics</td>
</tr>
<tr>
<td>AOSP</td>
<td>Airspace Operations and Safety Program</td>
</tr>
<tr>
<td>APG/I</td>
<td>Annual Performance Goal/Indicator</td>
</tr>
<tr>
<td>ARC</td>
<td>Ames Research Center/Aviation Rule Making Committee</td>
</tr>
<tr>
<td>ARD</td>
<td>Aeronautics Research Director</td>
</tr>
<tr>
<td>ARMD</td>
<td>Aeronautics Research Mission Directorate</td>
</tr>
<tr>
<td>ASRS</td>
<td>Aviation Safety Reporting System</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Controller</td>
</tr>
<tr>
<td>ATO</td>
<td>Air Traffic Organization-FAA Organization</td>
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<tr>
<td>ATOL</td>
<td>Air Traffic Operations Lab</td>
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<tr>
<td>AUVSI</td>
<td>Association for Unmanned Vehicle Systems International</td>
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<tr>
<td>BLOS</td>
<td>Beyond Line of Sight</td>
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<td>BVLOS</td>
<td>Beyond Visual Line of Sight</td>
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<td>C2</td>
<td>Command and Control</td>
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<td>Collision Avoidance</td>
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<td>CAS</td>
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<td>Definition</td>
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<td>CDP</td>
<td>Content Decision Process</td>
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<td>CDR</td>
<td>Critical Design Review</td>
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<td>CIO</td>
<td>Chief Information Officer</td>
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<tr>
<td>CM</td>
<td>Change Management or Contingency Management</td>
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<tr>
<td>CMC</td>
<td>Center Management Council</td>
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<tr>
<td>CNPC</td>
<td>Control and Non-Payload Communications</td>
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<td>COA</td>
<td>Certificate of Waiver or Authorization</td>
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<td>COE</td>
<td>Center of Excellence</td>
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<tr>
<td>ConOps</td>
<td>Concept of Operations</td>
</tr>
<tr>
<td>CPA</td>
<td>Closest Point of Approach</td>
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<td>CPDS</td>
<td>Conflict Prediction and Display System</td>
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<td>CR</td>
<td>Change Request</td>
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<td>CRM</td>
<td>Continuous Risk Management</td>
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<td>CSD</td>
<td>Cockpit Situation Display</td>
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<tr>
<td>CSUN</td>
<td>Cal State University Northridge</td>
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<td>CTD</td>
<td>Concepts and Technology Development Project</td>
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<td>DAA</td>
<td>Detect and Avoid</td>
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<td>DAIDALUS</td>
<td>Detect and Avoid Alerting Logic for Unmanned Systems</td>
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<td>Department of Defense</td>
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<td>Department PM for</td>
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<tr>
<td>EAFB</td>
<td>Edwards Air Force Base</td>
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<td>EIP</td>
<td>Early Implementation Plan</td>
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<td>EL</td>
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<td>Definition</td>
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<td>EO</td>
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<td>ExCom</td>
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<td>FAA</td>
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<td>FAR</td>
<td>Federal Aviation Regulations</td>
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<td>FL</td>
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<td>FRR</td>
<td>Flight Readiness Review</td>
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<td>GA-ASI</td>
<td>General Atomics Aeronautical Systems Inc.</td>
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<td>Human Factors</td>
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<td>Human-In-The-Loop</td>
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<td>HLA</td>
<td>High Level Architecture</td>
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<td>HMD</td>
<td>Horizontal Miss Distance</td>
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<td>HSI</td>
<td>Human Systems Integration Subproject</td>
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<td>IAA</td>
<td>Inter-Agency Agreement</td>
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### Acronym List

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<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>IAI</td>
<td>Intelligent Automation Inc.</td>
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<tr>
<td>IASP</td>
<td>Integrated Aviation Systems Program</td>
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<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<td>Inter Center Autonomy Study Team</td>
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<td>IFR</td>
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<td>IMS</td>
<td>Integrated Master Schedule</td>
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<td>International Traffic in Arms Regulations</td>
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<td>ITU-R</td>
<td>International Telecommunication Union-Radiocommunication Sector</td>
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<td>KDP</td>
<td>Key Decision Point</td>
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<td>L1</td>
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<td>L2</td>
<td>Level 2</td>
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<tr>
<td>LaRC</td>
<td>Langley Research Center</td>
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<td>LOS</td>
<td>Line of Sight</td>
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<td>LSTAR</td>
<td>Lightweight Surveillance and Target Acquisition Radar</td>
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<tr>
<td>LSUASC</td>
<td>Lone Star UAS Center of Excellence</td>
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<td>LVC</td>
<td>Live Virtual Constructive</td>
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<tr>
<td>LVC-DE</td>
<td>Live Virtual Constructive Distributed Environment</td>
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<td>Acronym</td>
<td>Definition</td>
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<td>MACS</td>
<td>Multi-Aircraft Control System</td>
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<td>MIPR</td>
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<tr>
<td>MIT/LL</td>
<td>Massachusetts Institute of Technology Lincoln Labs</td>
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<td>MOA</td>
<td>Memorandum of Agreement/Methods of Assessment</td>
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<td>MOCC</td>
<td>Mobile Operations Control Center</td>
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<td>MOE</td>
<td>Meeting of Experts</td>
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<td>MOPS</td>
<td>Minimum Operational Performance Standard</td>
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<td>Measured Response</td>
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<td>MS&amp;A</td>
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<td>Multiple UAS Simulation</td>
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<td>National Airspace System</td>
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<tr>
<td>NATO</td>
<td>North Atlantic Treaty Organization</td>
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<td>NRA</td>
<td>NASA Research Announcement</td>
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<td>NUANCE</td>
<td>Nevada Unmanned, Autonomous, and NextGen Collaborative Environment</td>
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<td>OPNET</td>
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<td>Office of the Secretary of Defense</td>
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<td>Phase 1</td>
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<tr>
<td>P2</td>
<td>Phase 2</td>
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<tr>
<td>PDR</td>
<td>Preliminary Design Review</td>
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<tr>
<td>PE/Co-PE</td>
<td>Project Engineer/Co-Project Engineer</td>
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<tr>
<td>PI</td>
<td>Progress Indicator</td>
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<tr>
<td>PM</td>
<td>Program Manager or Project Manager</td>
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<td>PMT</td>
<td>Project Management Tool</td>
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<td>Acronym</td>
<td>Description</td>
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<td>PO</td>
<td>Project Office</td>
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<tr>
<td>PPBE</td>
<td>Planning Programming Budgeting and Execution</td>
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<td>Research and Development</td>
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<td>RA</td>
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<td>RFP</td>
<td>Request for Proposal</td>
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<td>Research GCS</td>
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<td>Situational Awareness/Separation Assurance</td>
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<tr>
<td>SAA</td>
<td>Sense and Avoid/Space Act Agreement</td>
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<td>SASO</td>
<td>Safe, Autonomous Systems Operations</td>
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<tr>
<td>SBIR</td>
<td>Small Business Innovative Research</td>
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<td>SC</td>
<td>Special Committee</td>
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<tr>
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<tr>
<td>SMART NAS</td>
<td>Shadow Mode Assessment using Realistic Technologies for the National Airspace System</td>
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<td>Subject Matter Expert</td>
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<td>SMP</td>
<td>Schedule Management Plan</td>
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<td>Schedule Package</td>
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<td>Senior Steering Group</td>
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<td>SSI</td>
<td>Separation Assurance/Sense and Avoid Interoperability Subproject</td>
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## Acronym List

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<tr>
<th>Acronym</th>
<th>Definition</th>
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<tr>
<td>SST</td>
<td>Self-Separation Threshold</td>
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<td>SSV</td>
<td>Self-Separation Volume</td>
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<td>SUA</td>
<td>Special Use Airspace</td>
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<tr>
<td>sUAS</td>
<td>small Unmanned Aircraft System</td>
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<tr>
<td>SWAP</td>
<td>Size Weight And Power</td>
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<td>TASATS</td>
<td>Traffic Advisory and Safety Alerting Threshold Simulation</td>
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<tr>
<td>TC</td>
<td>Technical Challenges</td>
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<td>TCAS</td>
<td>Traffic Alert and Collision Avoidance System</td>
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<td>ToR</td>
<td>Terms of Reference</td>
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<td>TPWG</td>
<td>Test Plan Working Group</td>
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<td>TRACON</td>
<td>Terminal Radar Approach Control Facilities</td>
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<tr>
<td>TWP</td>
<td>Technical Work Package</td>
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<tr>
<td>UA</td>
<td>Unmanned Aircraft</td>
</tr>
<tr>
<td>UAS</td>
<td>Unmanned Aircraft Systems</td>
</tr>
<tr>
<td>UAV</td>
<td>Unmanned Aircraft Vehicle</td>
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<tr>
<td>UTM</td>
<td>UAS Traffic Management</td>
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<tr>
<td>V&amp;V</td>
<td>Verification and Validation</td>
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<td>VFR</td>
<td>Visual Flight Rules</td>
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<tr>
<td>VSCS</td>
<td>Vigilant Spirit Control Station</td>
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<td>WBS</td>
<td>Work Breakdown Structure</td>
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<td>Working Group</td>
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<td>WJHTC</td>
<td>William J Hughes Technical Center</td>
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<td>WRC</td>
<td>World Radio Conference</td>
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<tr>
<td>WYE</td>
<td>Work Year Equivalent</td>
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</table>
UAS Integration in the NAS Project

Goal: Provide research findings to reduce technical barriers associated with integrating Unmanned Aircraft Systems (UAS) into the National Airspace System (NAS) utilizing integrated system level tests in a relevant environment.

**Sense and Avoid (SAA) Performance Standards**
- Developed algorithms to assist UAS pilots to remain well clear of traffic.
  - Use simulation and flight test to assess algorithm performance.

**Command and Control (C2) Performance Standards**
- Developed Control Non-Payload Communications (CNPC) system for C2 and voice communications.
  - Use simulation, ground and flight test to assess CNPC performance.

**Human Systems Integration (HSI)**
- Developed prototype ground control station (GCS) and displays to examine human factors components of SAA & C2.
  - Use simulation and flight test to develop GCS guidelines.

**Integrated Test & Evaluation (IT&E)**
- Developed Live Virtual Constructive (LVC) test environment
  - Execute relevant environment testing to gather SAA, C2, and HSI research data.

**RTCA SC-228** developing Minimum Operational Performance Standards (MOPS).
- Expected release in summer 2016. Project research supports MOPS development
  - DAA: MOPS for transitioning of a UAS to and from Class A or special use airspace, traversing Class D and E, and perhaps Class G airspace.