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

FY16 Annual Review

Laurie Grindle
Project Manager

Davis Hackenberg
Deputy Project Manager, Integration

Agenda

8:30– 8:55	Welcome, Opening Remarks, Integrated Aviation Systems Program (IASP) Overview	Dr. Ed Waggoner
8:55 – 9:45	UAS-NAS Overview	Laurie Grindle
9:45 – 10:30	Technical Challenge Performance	Davis Hackenberg
10:30 – 10:45	Break	
10:45 – 11:40	Technical Challenge Performance (continued) Emerging Technical Challenge Performance	Davis Hackenberg
11:40 – 12:30	Project Level Performance & Fiscal Year (FY) 17 Look Ahead Review Summary	Laurie Grindle
12:30	Lunch	
1:00 – 3:00	Caucus	IRP and PRP separately
3:00 – 4:00	Initial Feedback	IRP and PRP
4:00	Adjourn	

Annual Review Overview

- Purpose - Conduct an assessment of the Project's quality and performance
- Approach - The Project will provide a programmatic review addressing the following:
  - Project's Goal and Technical Challenges (TC) and their alignment to NASA and Aeronautics Research Mission Directorate (ARMD) Strategy
  - Project background and alignment with community efforts
  - Key highlights and accomplishments for the Project's technical challenges
  - Project performance of the past year through examination of:
    - Cost/Resource, Schedule, and Technical Management
    - Progress in establishing partnerships/collaborations and their current status
  - Key activities, milestones, and "storm clouds" for FY17
  - Specific Topics:
    - Describe FY16 accomplishments toward implementing enhancements to Live, Virtual, Constructive – Distributed Environment (LVC-DE)

Outline

- UAS Integration in the NAS (UAS-NAS) Overview
  - FY16 Summary
  - UAS-NAS Project Background
- Technical Challenge Performance
- Emerging Technical Challenge Work
- Project Level Performance & FY17 Look Ahead
- Review Summary

FY16 Summary

- Successful completion of the Project’s Phase 1 Technical Challenges
- Successful completion of Project’s FY16 Research Portfolio
- Effective Project and Subproject Management
- Significant contributions to the UAS Community
- Concurrent Phase 2 Project planning (FY17 - FY20)

Significant Accomplishments
Kudos to the Team

NASA Strategic Plan Flow Down to UAS-NAS Project

STRATEGIC GOAL

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

OBJECTIVE

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

PERFORMANCE GOAL
UAS-NAS

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

Annual Performance Indicators (APIs)
UAS-NAS

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.

Success determined by fully completing 4 activities and gathering research findings

- Flight Test Series 3
- CNPC Gen-5 Flight Test
- Part Task Simulation 6
- Flight Test Series 4

ARMD Strategic Plan Flow Down to UAS-NAS Project

AERONAUTICS STRATEGIC THRUST

Thrust 1: Safe Efficient Growth in Global Operations

Thrust 6: Assured Autonomy for Aviation Transformation

AERONAUTICS OUTCOME

Outcome (2015 – 2025): ATM+1 Improved NextGen Operational Performance in Individual Domains, with Some Integration Between Domains

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

AERONAUTICS Research Theme

Airspace Operations Performance Enablers

Implementation and Integration of Autonomous Airspace and Vehicle Systems

Testing and Evaluation of Autonomous Systems

AERONAUTICS Overarching Technical Challenge

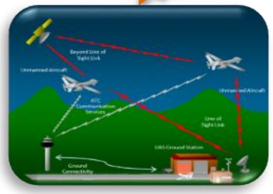
Develop Operational Standards for UAS in NAS

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

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

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

UAS-NAS *Technical Challenges*



TC-C2: Command and Control

TC-SAA: Sense and Avoid

TC-HSI: Human Systems Integration

TC-ITE: Integrated Test & Evaluation

Primary Mapping
Secondary Mapping

UAS-NAS Technical Challenge Autonomy Contributions

AERONAUTICS STRATEGIC THRUST

Thrust 6: Assured Autonomy for Aviation Transformation

AERONAUTICS OUTCOME

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

AERONAUTICS Research Theme

Implementation and Integration of Autonomous Airspace and Vehicle Systems

AERONAUTICS Overarching Technical Challenge

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

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

UAS-NAS *Technical Challenges*

TC-SAA

TC-HSI

TC-C2

TC-ITE

<u>TC-SAA & TC-HSI Alignment</u>:

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

<u>TC-C2 Alignment</u>:

- Development of requirements of automatic and/or autonomous unmanned aircraft control and non-payload communication system
- Examples: system wide removal of communication delays in time sensitive situations

<u>TC-ITE Alignment</u>:

- Implement, test, evaluate and demonstrate selected applications of increasingly autonomous systems

UAS-NAS Technical Challenge Autonomy Contributions

AERONAUTICS STRATEGIC THRUST

Thrust 6: Assured Autonomy for Aviation Transformation

AERONAUTICS OUTCOME

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

AERONAUTICS Research Theme

Testing and Evaluation of Autonomous Systems

AERONAUTICS Overarching Technical Challenge

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

UAS-NAS *Technical Challenges*

TC-ITE

<u>TC-ITE Portfolio</u>:

- Development of unmanned aircraft flight test methods and operational procedures relevant to small-scale applications of autonomy
    - Flight test of automatic and/or autonomous systems such as Airborne Collision Avoidance System (ACAS Xu)
    - Flight test of easily automated Sense and Avoid systems
- Leverage NASA airworthiness safety processes to provide operational assessments for automatic and autonomous systems

UAS Integration in the NAS Organizational Structure (FY14 – FY16)

Host Center

AFRC Director of Programs
Dennis Hines
Deputy Director: Joel Sitz

Program Office

IASP Program Director
Dr. Ed Waggoner
Deputy PD: Lee Noble

ExCom, RTCA Steering Committee, UAS Aviation Rulemaking Committee

External Interfaces

FAA, DoD, RTCA SC-228, Industry, etc.

Project Support

Lead Resource Analyst – Cindy Brandvig - AFRC
Lead Procurement Officer – R. Toberman - AFRC
Lead Scheduler – John Percy - AFRC
Risk and Outreach Lead – Jamie Turner - AFRC
Administrative Support – Lexie Brown - AFRC
Doc and Change Mgmt. – 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
Staff Systems Engineer – Dan Roth – AFRC

DPMf – AFRC	DPMf – ARC	DPMf – GRC	DPMf – LaRC
Heather Maliska	Karen Cate	Mike Jarrell	Vince Schultz

AFRC ARD
ARC ARD
GRC ARD
LaRC ARD

Subprojects/Technical Challenges (TC)

TC-SAA: SAA Performance Standards
Separation Assurance/Sense and Avoid Interoperability (SSI)
Co-PEs
Confesor Santiago - ARC
Keith Arthur - LaRC

TC-C2: C2 Performance Standards
Communications
PE
Jim Griner - GRC

TC-HSI: Human Systems Integration (HSI)
HSI
PE
Jay Shively - ARC

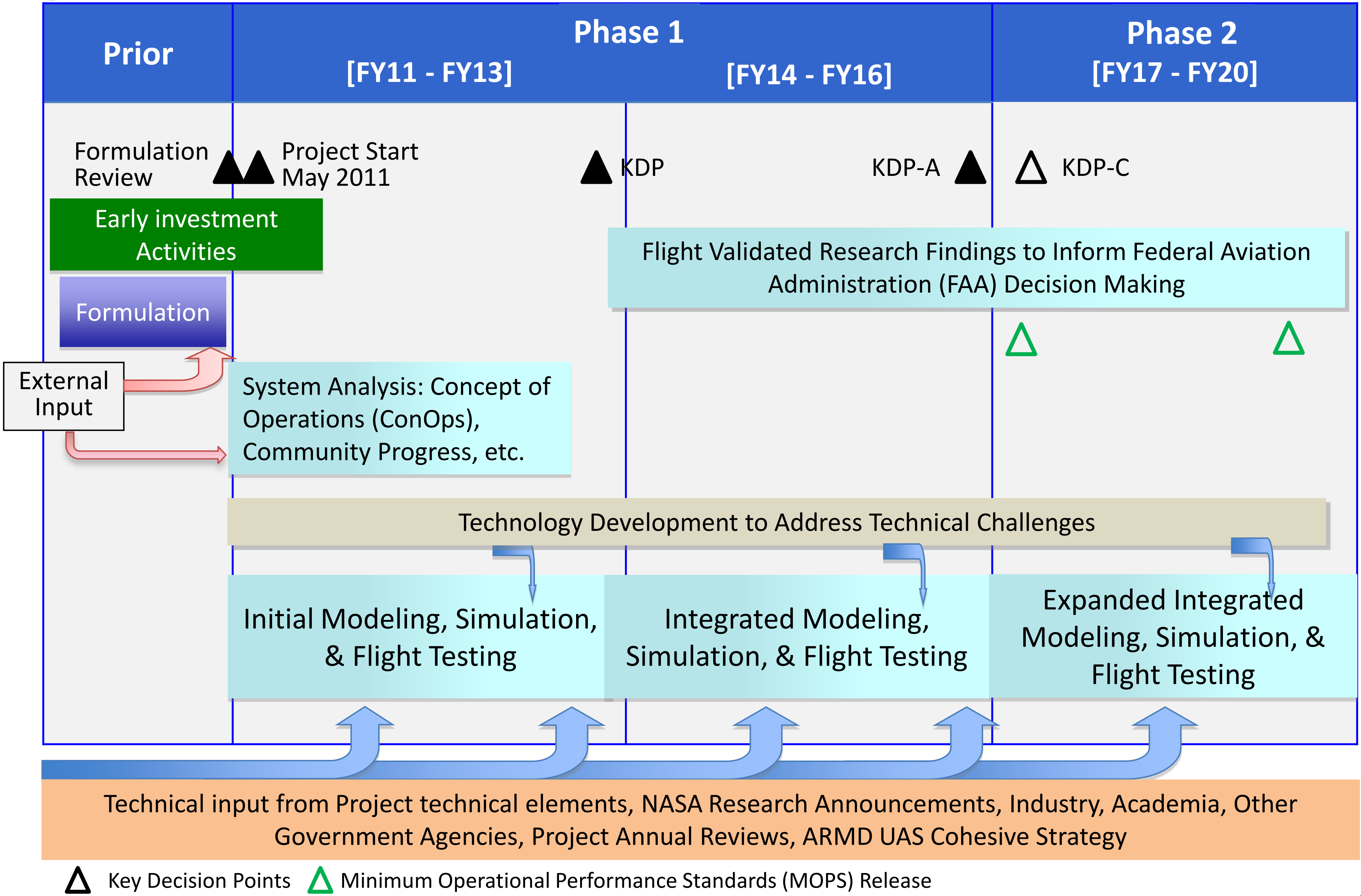
TC-ITE: Integrated Test and Evaluation (IT&E)
IT&E
Co-PEs
Sam Kim - AFRC
Jim Murphy - ARC

Certification
PE
Kelly Hayhurst
LaRC

PE: Project Engineer, DPMf: Deputy Project Manager for

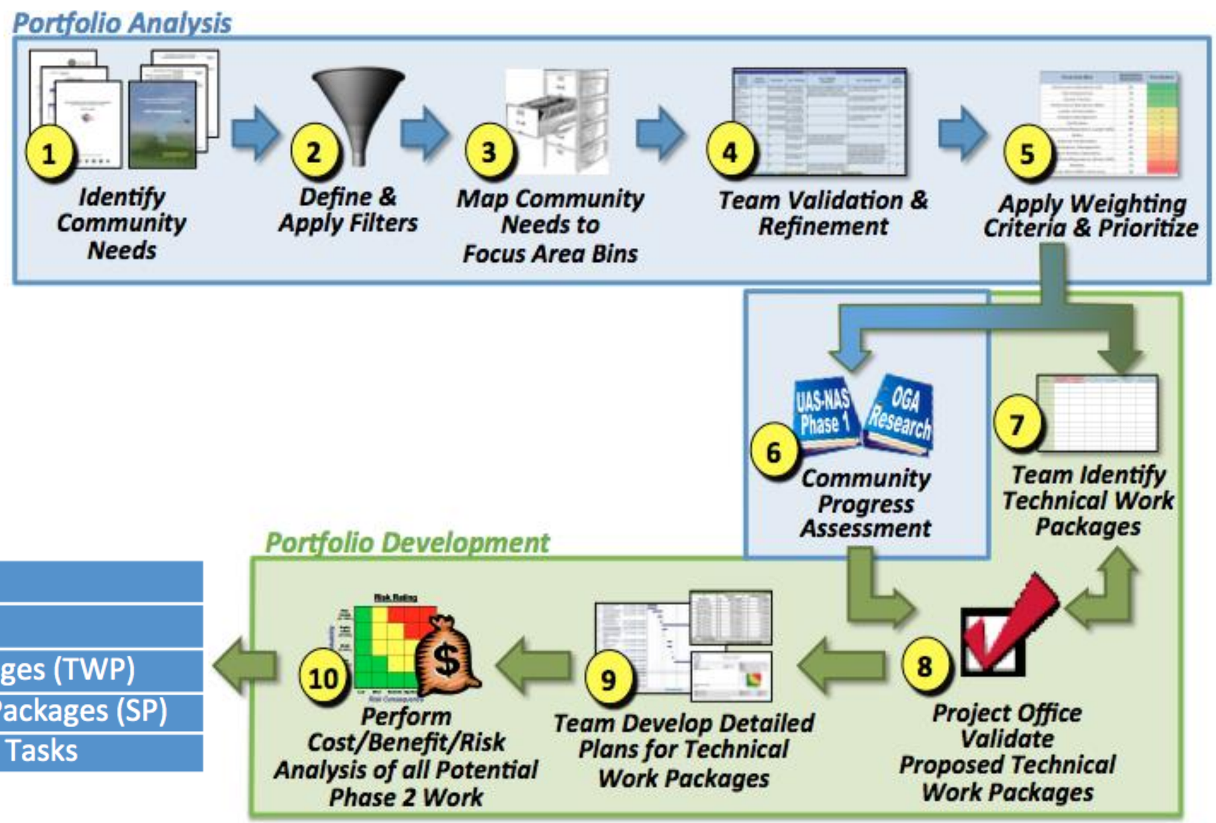
UAS-NAS Project Lifecycle

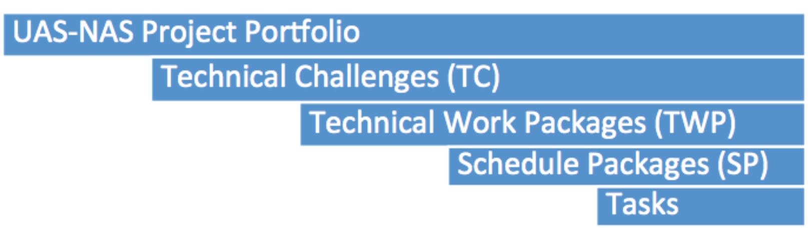
Timeframe for impact: 2015 - 2025



Community Needs Influence on Project Portfolio (FY14-FY16) and Technical Challenges

- 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 Project 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



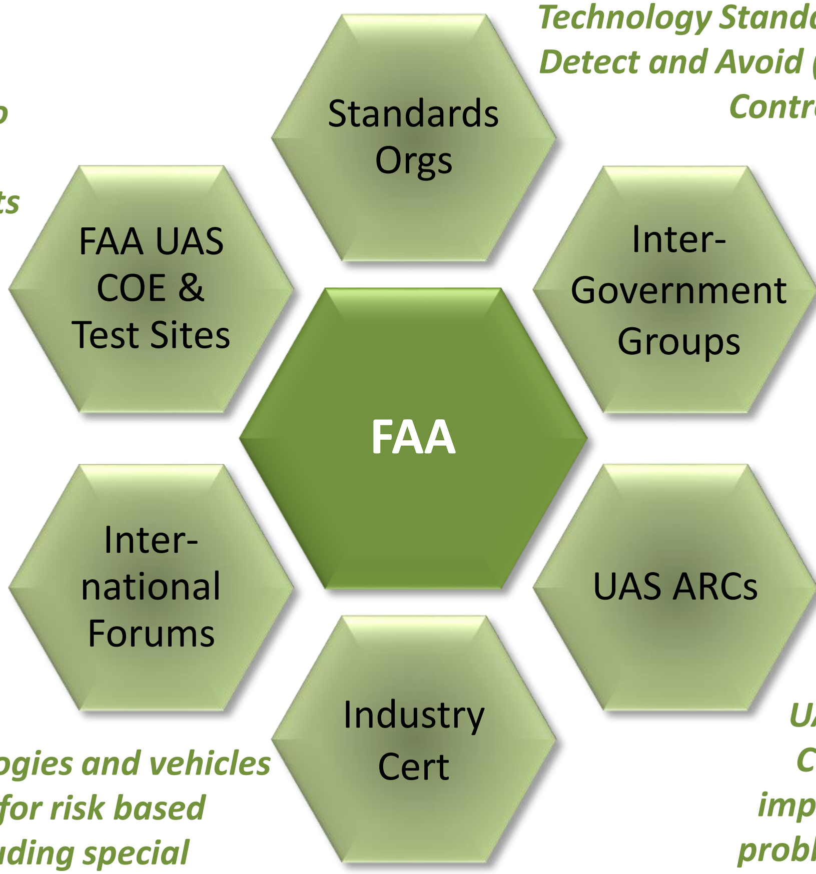


FAA Organizational Relationships

- The FAA is using several domestic forums, in conjunction with several international forums to lay out the pathway for their priorities and investments.

Standards Organizations chartered to develop Technology Standards, such as RTCA SC-228 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



Inter-government groups such as the UAS Executive Committee (ExCom), Senior Steering groups, OSD Sense and Avoid (SAA) Science and Research Panel (SARP), and Research Transition Teams (RTTs)

World Radio Conference (WRC) and International Civil Aviation Organization (ICAO) UAS Study Groups are addressing UAS access from an international perspective

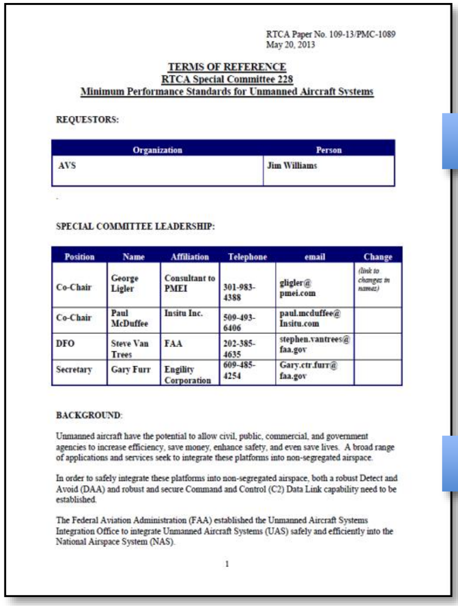
UAS Aviation Rulemaking Committee (ARC) groups implemented to solve specific problems as directed by the FAA

Industry developed technologies and vehicles brought directly to the FAA for risk based certification processes, including special projects such as Pathfinders

NASA has a leadership role within many domestic forums and participates in the international forums

RTCA SC-228 Phase 1 MOPS Terms of Reference

- RTCA SC-228 Terms of Reference (ToR) 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 to RTCA PMC
  - C2 and DAA White Papers (Dec 2013) - Assumptions, approach, and core requirements for UAS DAA and C2 Equipment
  - C2, DAA, and Radar MOPS for Verification and Validation (Jul 2015) – Preliminary MOPS Including recommendations for a Verification and Validation test program
  - C2 Final MOPS (Jul 2016)
  - DAA and Radar Final MOPS (Nov 2016)


RTCA Paper No. 109-13/PMC-1089
May 20, 2013

TERMS OF REFERENCE
RTCA Special Committee 228
Minimum Performance Standards for Unmanned Aircraft Systems

REQUESTORS:

Organization	Person
AVS	Jim Williams

SPECIAL COMMITTEE LEADERSHIP:

Position	Name	Affiliation	Telephone	email	Change
Co-Chair	George Ligler	Consultant to PMEI	301-983-4388	gligler@pmei.com	(link to changes in names)
Co-Chair	Paul McDuffee	Insitu Inc.	509-493-6406	paul.mcduffee@Insitu.com	
DFO	Steve Van Trees	FAA	202-385-4635	stephen.vantrees@faa.gov	
Secretary	Gary Furr	Engility Corporation	609-485-4254	Gary.ctr.furr@faa.gov	

BACKGROUND:

Unmanned aircraft have the potential to allow civil, public, commercial, and government agencies to increase efficiency, save money, enhance safety, and even save lives. A broad range of applications and services seek to integrate these platforms into non-segregated airspace.

In order to safely integrate these platforms into non-segregated airspace, both a robust Detect and Avoid (DAA) and robust and secure Command and Control (C2) Data Link capability need to be established.

The Federal Aviation Administration (FAA) established the Unmanned Aircraft Systems Integration Office to integrate Unmanned Aircraft Systems (UAS) safely and efficiently into the National Airspace System (NAS).

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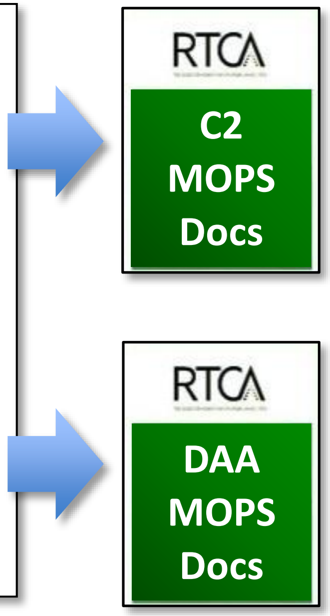
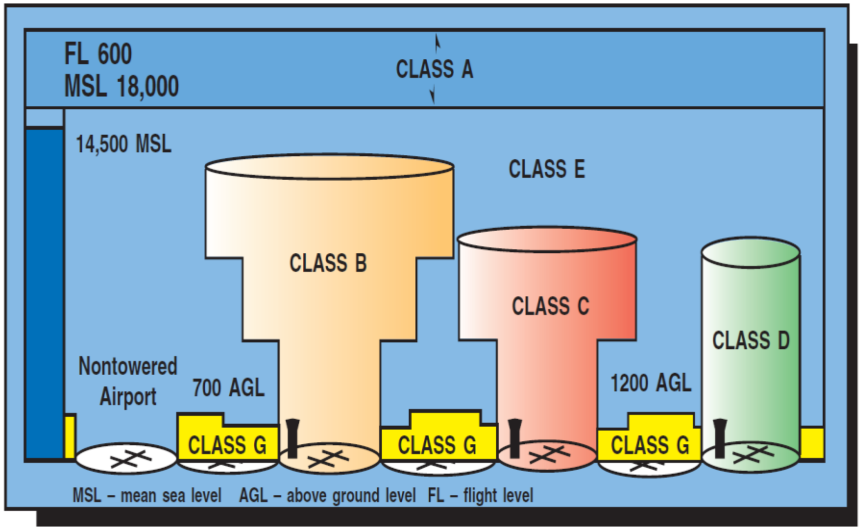
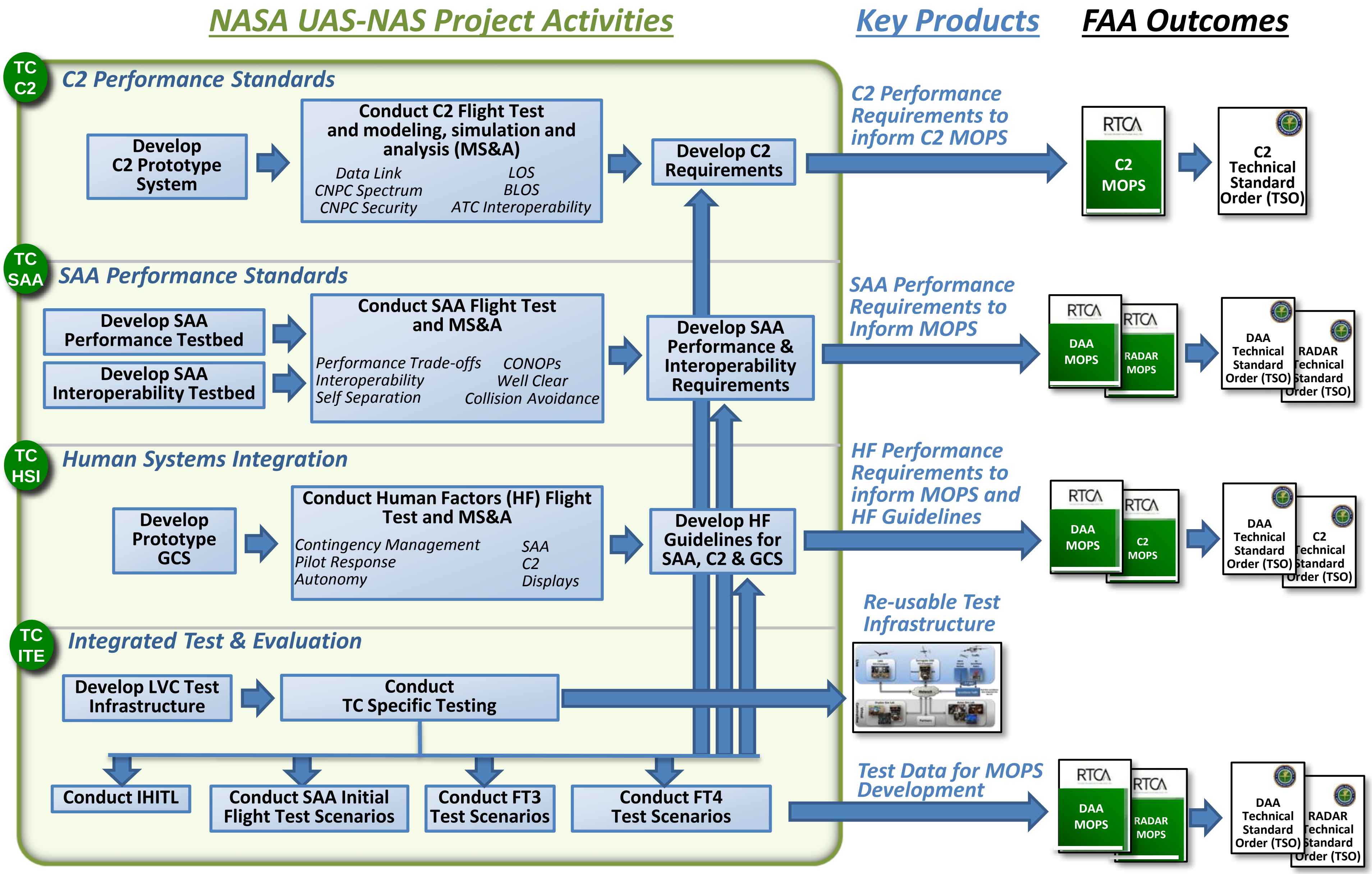
RTCA SC-228 ToR

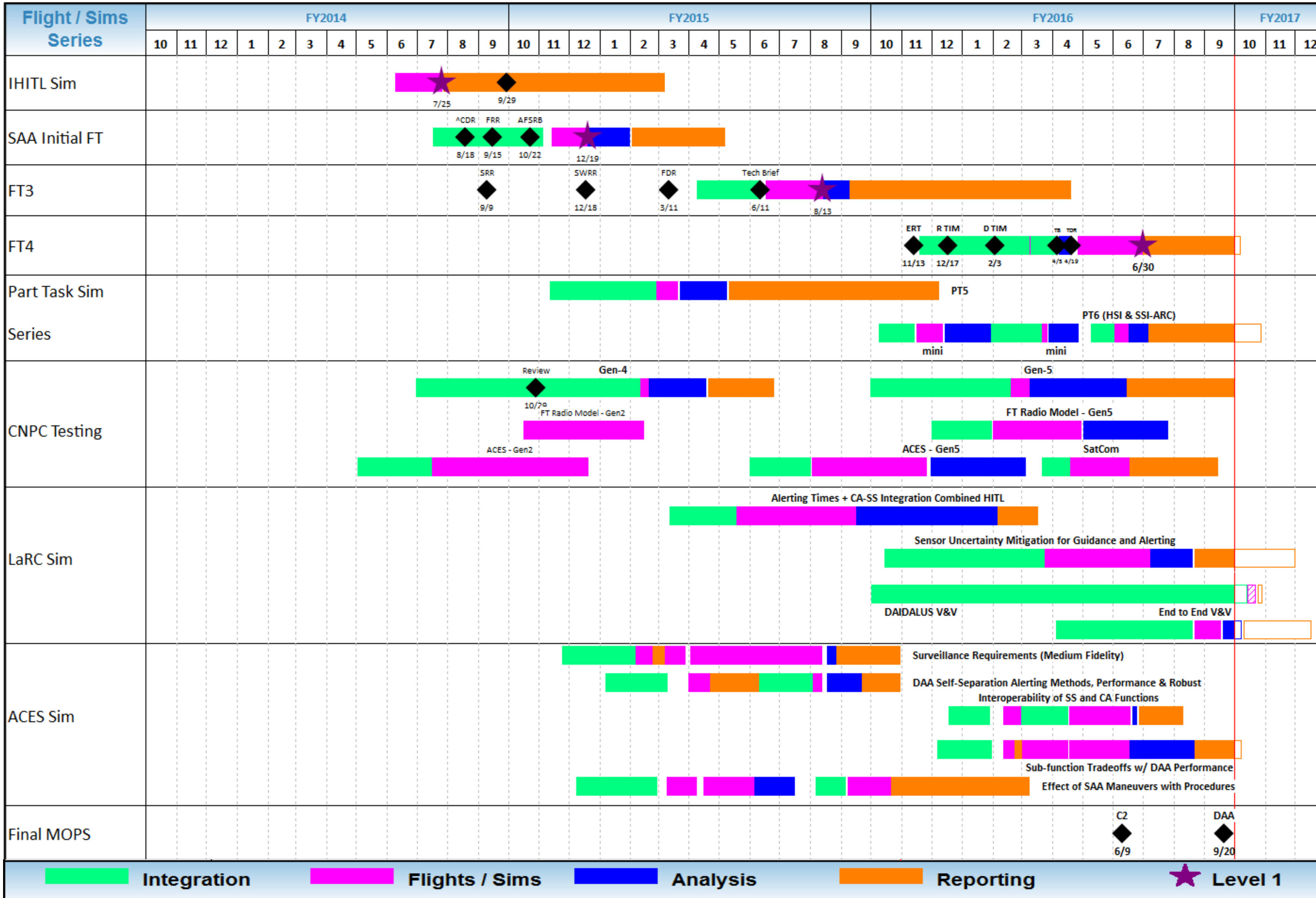




UAS Integration in the NAS Project
Phase 1 MOPS Value Proposition Flow Diagram

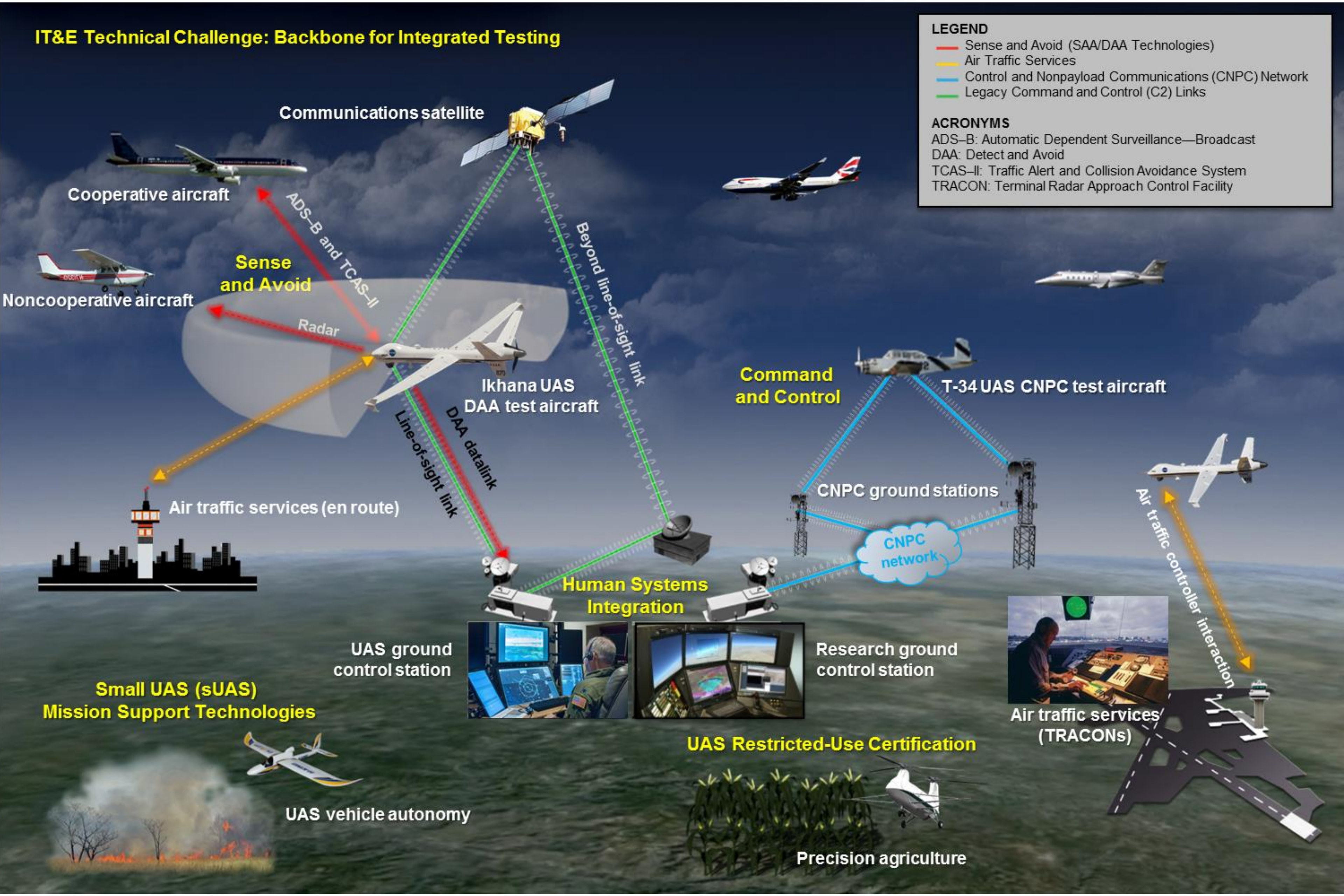


Flight and Simulation Overview



Red Status Line Date 9/30/16

UAS-NAS Project OV-1

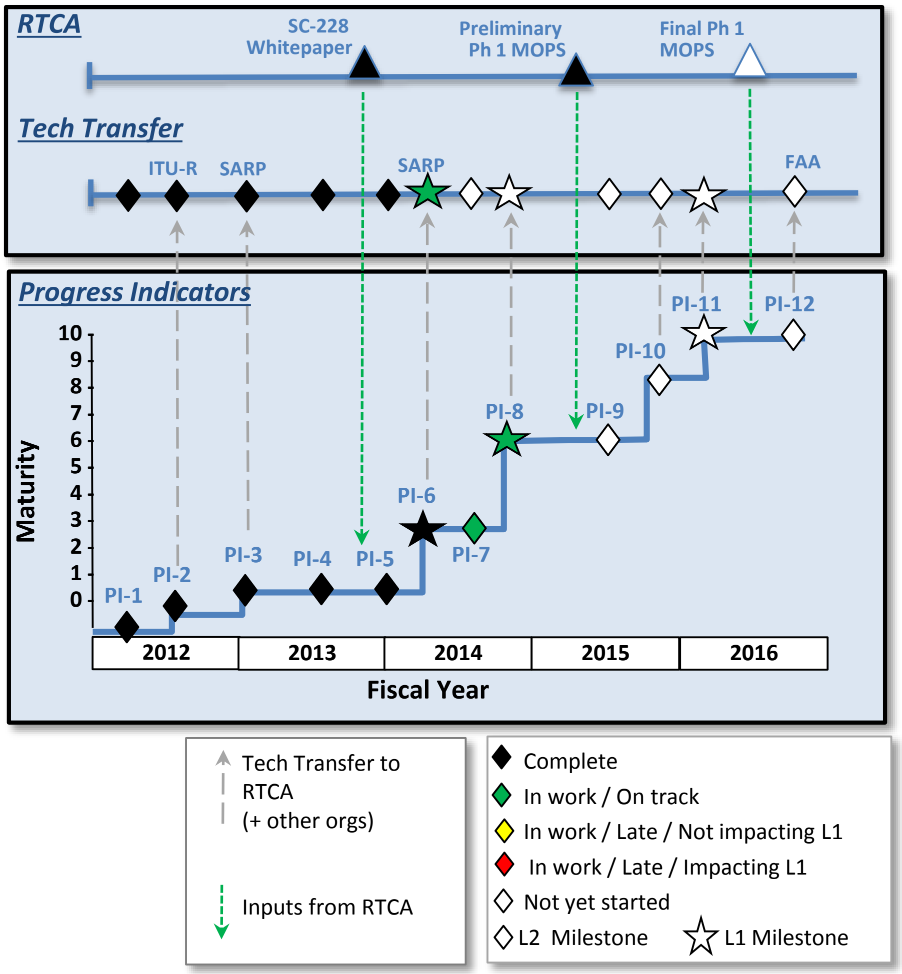


Outline

- UAS-NAS Overview
- Technical Challenge Performance – Davis Hackenberg
  - TC-C2
  - TC-SAA
  - TC-HSI
  - TC-ITE
- Emerging Technical Challenge Work
- Project Level Performance & FY17 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
- Progress Indicators, i.e. lower portion of the plot, represent execution/data collection of Project SP activities
- Tech Transfer (i.e. upper portion of the plot), plotted to coincide with execution, represents the data analysis and reporting of SP Activities
- Assessed individual contribution towards achieving the overall technical challenge
  - High = 2, i.e. Integrated Tests
  - Moderate = 1, i.e. multiple subproject technologies
  - Low = 0, i.e. foundational activities
- Results normalized and placed on a 10 point maturity scale represents meeting the content of the TC



- Progress is tracked against all the tasks in the schedule package using a red, yellow, green indicator

FY16 Progress Indicator Changes

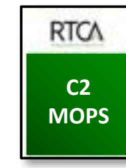
- Examination of research portfolio (Q1 FY16) to:
  - Ensure activities have the right priorities and are consistent with stakeholder needs
  - Address FY15 execution and research results
  - Sync up Research Portfolio, Resources, Schedule, and Risks
- TC-SAA
  - Modified content of simulations to align with DAA research and stakeholder needs
- TC-HSI
  - Replaced flight test verification and validation (V&V) of human factors aspects of alerting logic and display (Mission Oriented Configuration) with expanded HITL simulations
- TC-C2
  - Removed integrated flight test element of MOPS validation (Mission Oriented Configuration) relying on non-integrated radio flight tests only
- TC-ITE
  - Removed Mission Oriented Configuration in FT4 and Capstone
  - Modified FT4 scripted encounters to support DAA MOPS V&V team and lessons learned

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

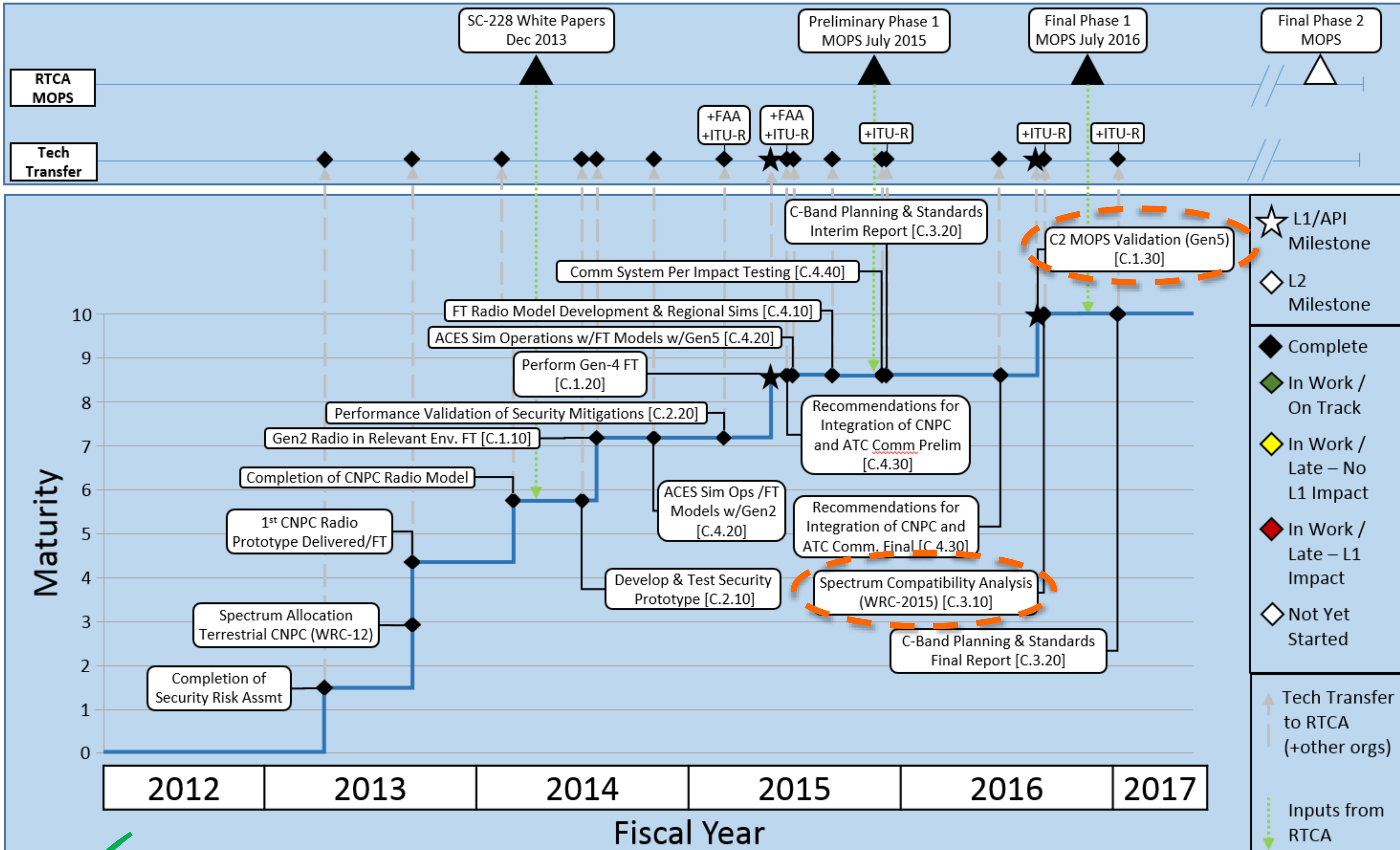
TC-C2: Command & Control Performance Standards

TC-HSI: Human Systems Integration

TC-SAA: Sense and Avoid Performance Standards

TC-C2: Progress Indicator

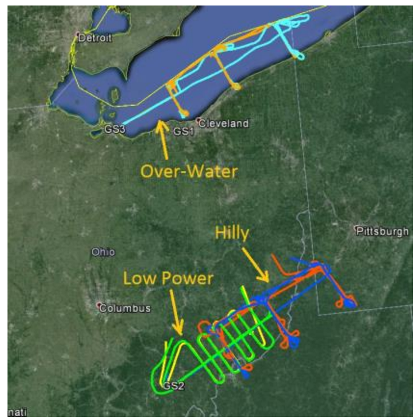
As of 9/30/16



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

Verify and Validate MOPS Requirements - Final C2 MOPS Input

- **Research Objective:**
  - Analyze the performance of fifth generation Control and Non-Payload Communication System (CNPC) prototypes in both laboratory and relevant flight environments, in order to validate MOPS requirements and verify performance of CNPC prototype equipment

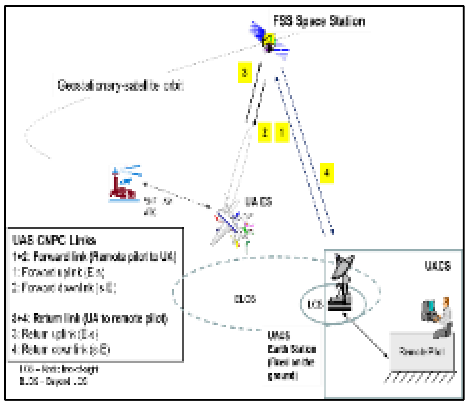


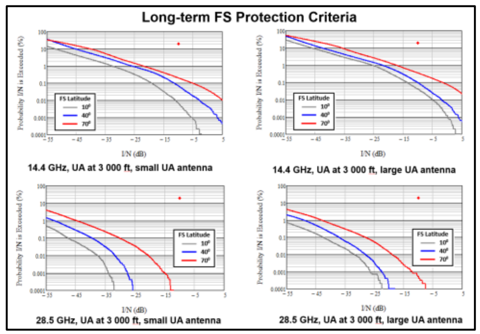
- **Results, Conclusions, and Recommendations:**
  - Used prototype Gen-5 CNPC radio in laboratory environment to develop verification procedures for C2 MOPS requirements. Selected verification procedures were performed, using the Gen-5 radio system, and results were documented in a C2 MOPS appendix. These tests of the Gen-5 radios established the baseline of the final C2 MOPS performance requirements.
  - Utilized Gen-5 radios at three CNPC ground stations and onboard GRC S-3B aircraft in order to collect data for performance in two relevant environments (hilly & over fresh water). Flight test performance data was documented in a C2 MOPS appendix, and was used to validate the final C2 MOPS performance requirements.
  - RTCA published DO-362 “Command and Control (C2) Data Link Minimum Operational Performance Standard (MOPS) (Terrestrial)” on September 22, 2016, containing significant NASA contributions.

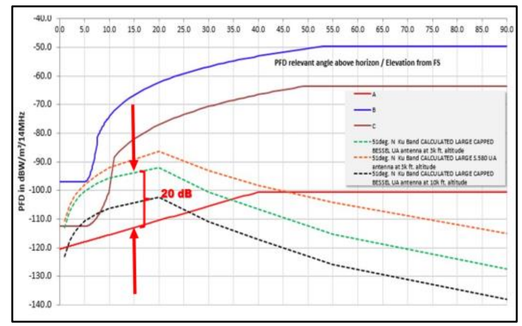
CNPC System Performance Requirements for C2 MOPS

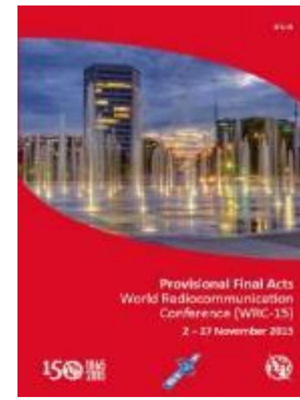
Spectrum Compatibility Analysis

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









- **Results, Conclusions, and Recommendations:**
  - Results from NASA conducted sharing studies were delivered at the 2015 World Radiocommunication Conference (WRC-15) to support the allocation of Ku & Ka Band frequencies for UAS operations
    - The outcome from WRC-15 was Resolution 155 that provides a way forward to continue the process of developing UAS BLOS CNPC and the supporting standards. However, much remaining work was built into this resolution that must be resolved before Ku & Ka Band frequencies can be used for UAS control communications.

CNPC Frequency Spectrum Allocation Requirements for C2 MOPS

TC-C2: C2 MOPS Contributions

NASA UAS-NAS Project Activities | *Key Products* | *FAA Outcomes*

TC C2 *C2 Performance Standards*

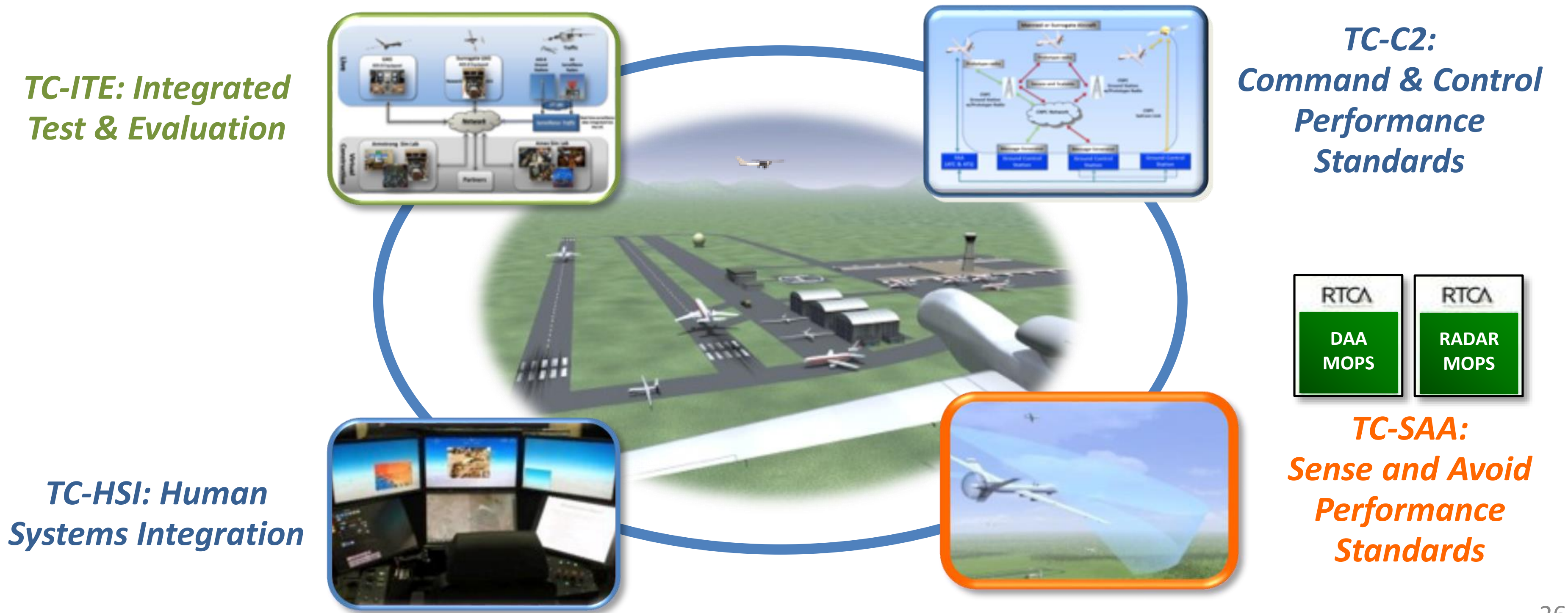
- Led RTCA C2 Working Group Security and Verification and Validation Subgroups
- Authored multiple C2 Final MOPS (DO-362) Sections and Appendices for Working Group Review Equipment Test Procedures Subsections
  - Equipment Performance Verification Procedures Section
  - Ten Appendices: Security Considerations, Data Rates, UAS CNPC Link Performance, Example CNPC Link Budgets, MOPS Baseline CNPC Link System, Bench Test Data for the MOPS Baseline CNPC Link System, Flight Test Data for the MOPS Baseline CNPC Link System, Compatibility of tactical air navigation (TACAN) Operations and CNPC Operations using L-Band Signals, Summary of NASA Air-Ground Channel Measurements and Models, CNPC Link Undesired-to-Desired Signal Ratios
- Developed five generations of radio systems for use in developing C2 MOPS
- Planned, executed, analyzed and reported on flight tests of a prototype radio system for C2 Final MOPS Verification and Validation
- Spectrum preparations for the World Radio Conference

TC-SAA: SAA Performance Standards

RT1 - UAS Integration

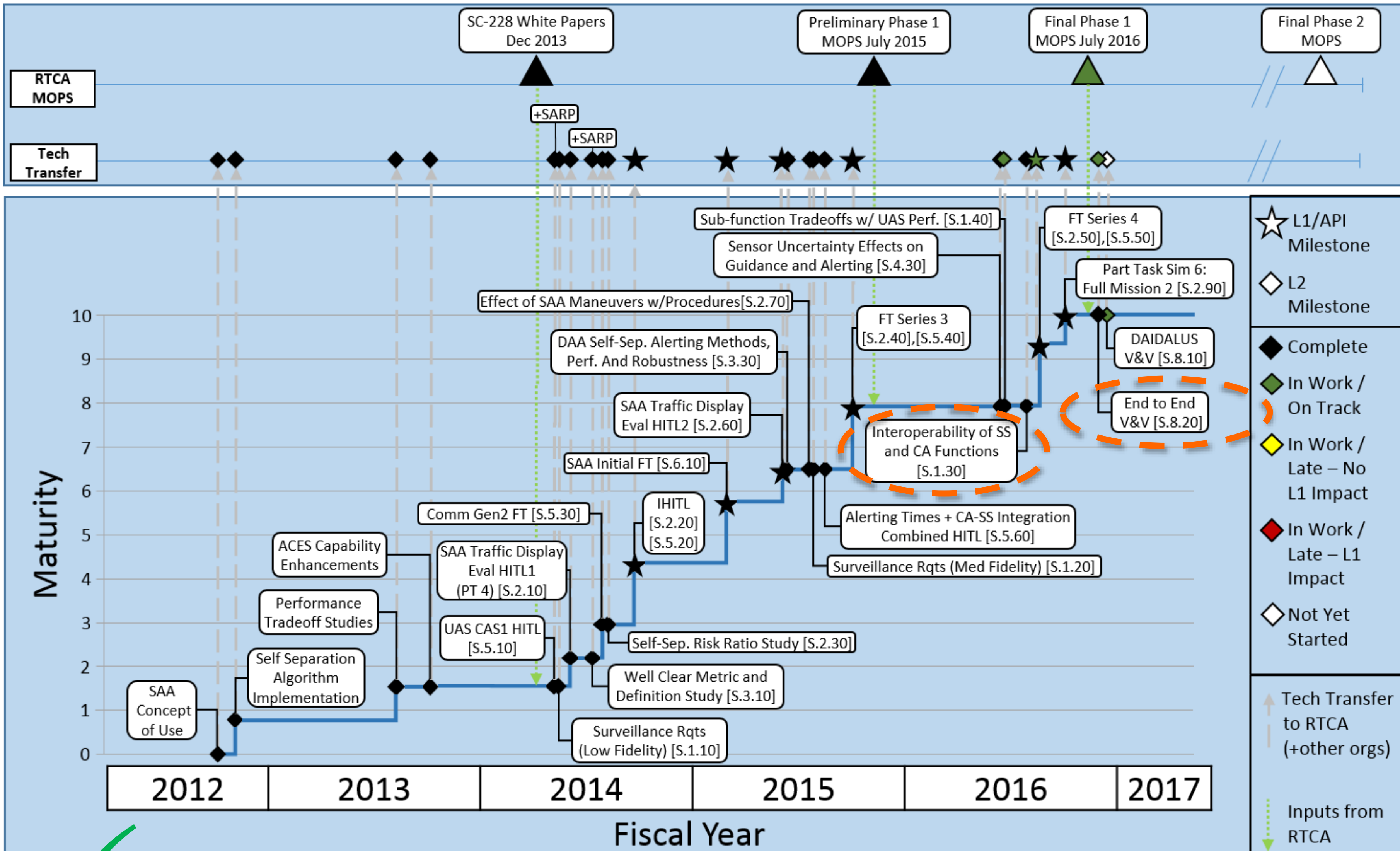
- Airspace integration procedures and performance standards to enable UAS integration in the air transportation system

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



TC-SAA: Progress Indicator

As of 9/30/16

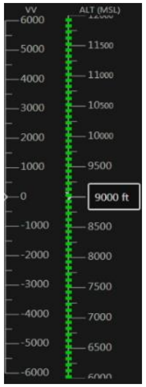


TC-SAA: Provide research findings to develop and validate UAS Minimum Operational Performance Standards (MOPS) for sense and avoid (SAA) performance and interoperability

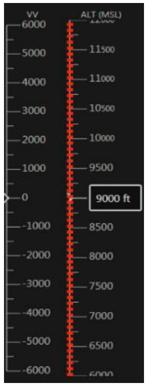
Interoperability of Self Separation and Collision Avoidance Functions (ACES Simulation)

- **Research Objective:**
  - Analyze the interoperability of self separation and collision avoidance algorithms and the level of integration required for self separation and collision avoidance algorithms

Altitude bands entirely green just before entering Collision Avoidance region

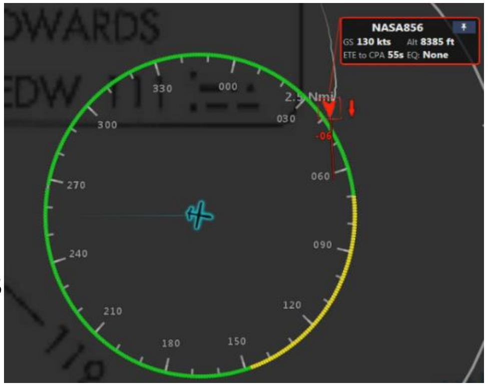


UAS and intruder enter Collision Avoidance region



Altitude bands saturated red because vertical guidance is suppressed

UAS is only allowed to perform heading maneuvers to remain well clear of intruders

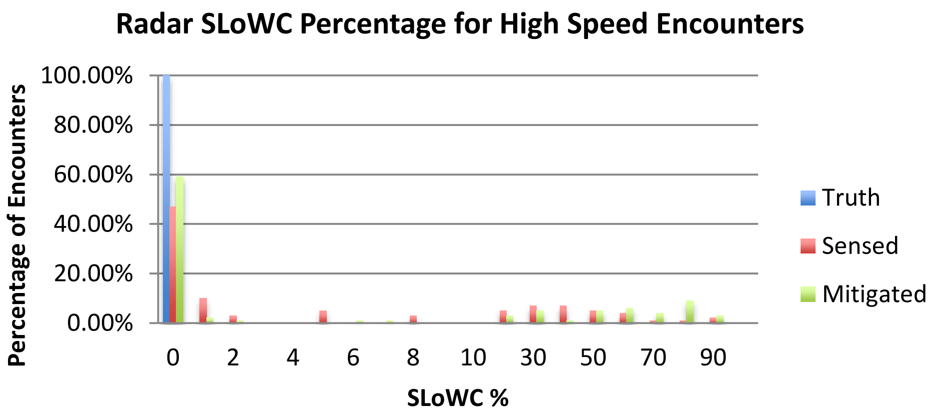


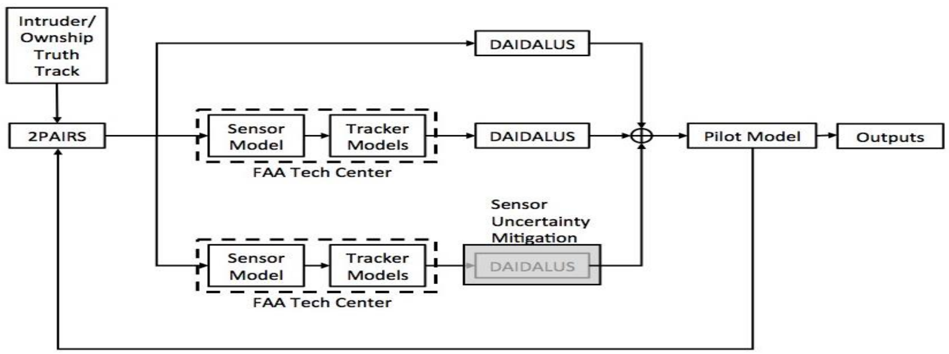
- **Results, Conclusions, and Recommendations:**
  - A definition was created for a Collision Avoidance region in which UAS vertical guidance is suppressed to prevent conflicts with manned aircraft TCAS Resolution Advisories (RA), which are all vertical maneuvers
  - The simulation results verified issues with the preliminary DAA/CA interoperability requirement leading to a more comprehensive strategy for blending DAA and CA functionalities
  - RTCA SC-228 accepted NASA's recommended definition of the Collision Avoidance region for use in the UAS DAA Minimum Operational Performance Standards to ensure interoperability with manned aircraft TCAS RAs

Self Separation – Collision Avoidance Systems Interoperability Requirements for DAA MOPS

End to End V&V (E2V2)

- **Research Objective(s):**
  - To Verify and Validate (V&V) a MOPS-representative Detect and Avoid (DAA) system in an End-to-End simulation environment representative of the MOPS

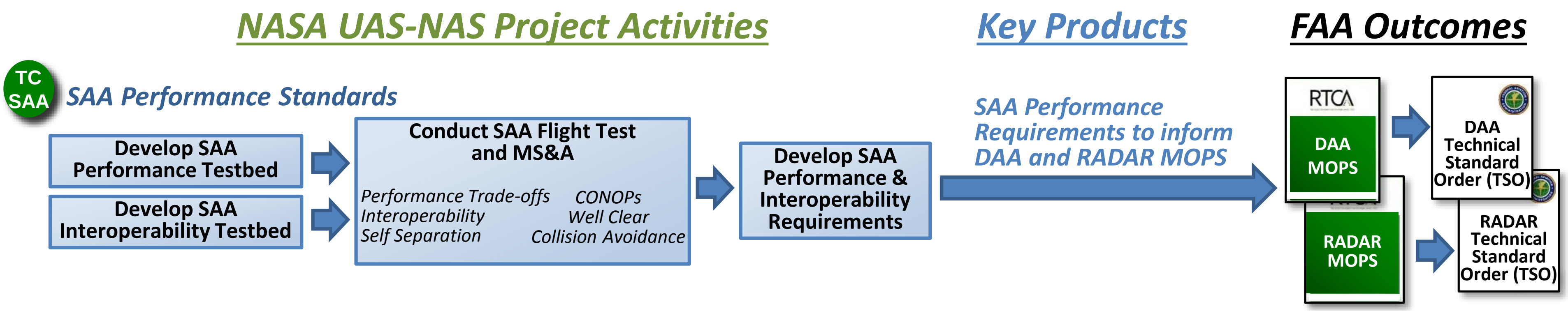




- **Results, Conclusions, and Recommendations:**
  - Final closed-loop, pilot (model)-in-the-loop, end-to-end simulation evaluation of MOPS
  - Integrated sensor/tracker from FAA Tech Center, pilot model from MIT/LL, DAA Alerting Logic and Maneuver Guidance for UAS (DAIDALUS) DAA code, 2PAIRS aircraft dynamic model
  - Encounter sets from MOPS test cases & MIT/LL NAS encounter model
  - Results support and confirm the requirements laid out in the Phase I MOPS

System-level Support and Confirmation of MOPS

TC-SAA: DAA and Air-to-Air RADAR MOPS Contributions



- Authored multiple SC-228 DAA Final MOPS Sections or Appendices for Working Group review
  - Guidance Processing Requirements Section
  - Equipment Test Procedures Subsections
  - UAS Maneuver Performance Requirements Appendix
  - DAA Alerting Logic and Maneuver Guidance for UAS (DAIDALUS) Reference Implementation Appendix
- Provided DAA and NAS subject matter expertise to SC-228 DAA Working Group
- Provided results from multiple simulations and flight tests
- Defined Collision Avoidance region for use to ensure DAA interoperability with manned aircraft TCAS
- Provided DAIDALUS for DAA MOPS reference implementation
- Developed Sensor Uncertainty Mitigation
- Provided recommendations for:
  - Detect and avoid guidance determination based on DAIDALUS and Java Architecture for Detect and Avoid Extensibility and Modeling (JADEM)
  - Alerting determination
  - Well Clear Recovery guidance, alerting, and display
- Supported SC-147 Traffic Alert & Collision Avoidance System (TCAS), which is working ACAS Xu

TC-HSI: Human Systems Integration

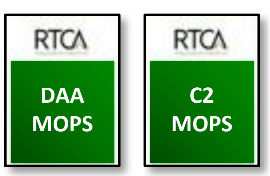
RT1 - UAS Integration

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

TC-HSI - 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-ITE: Integrated Test & Evaluation

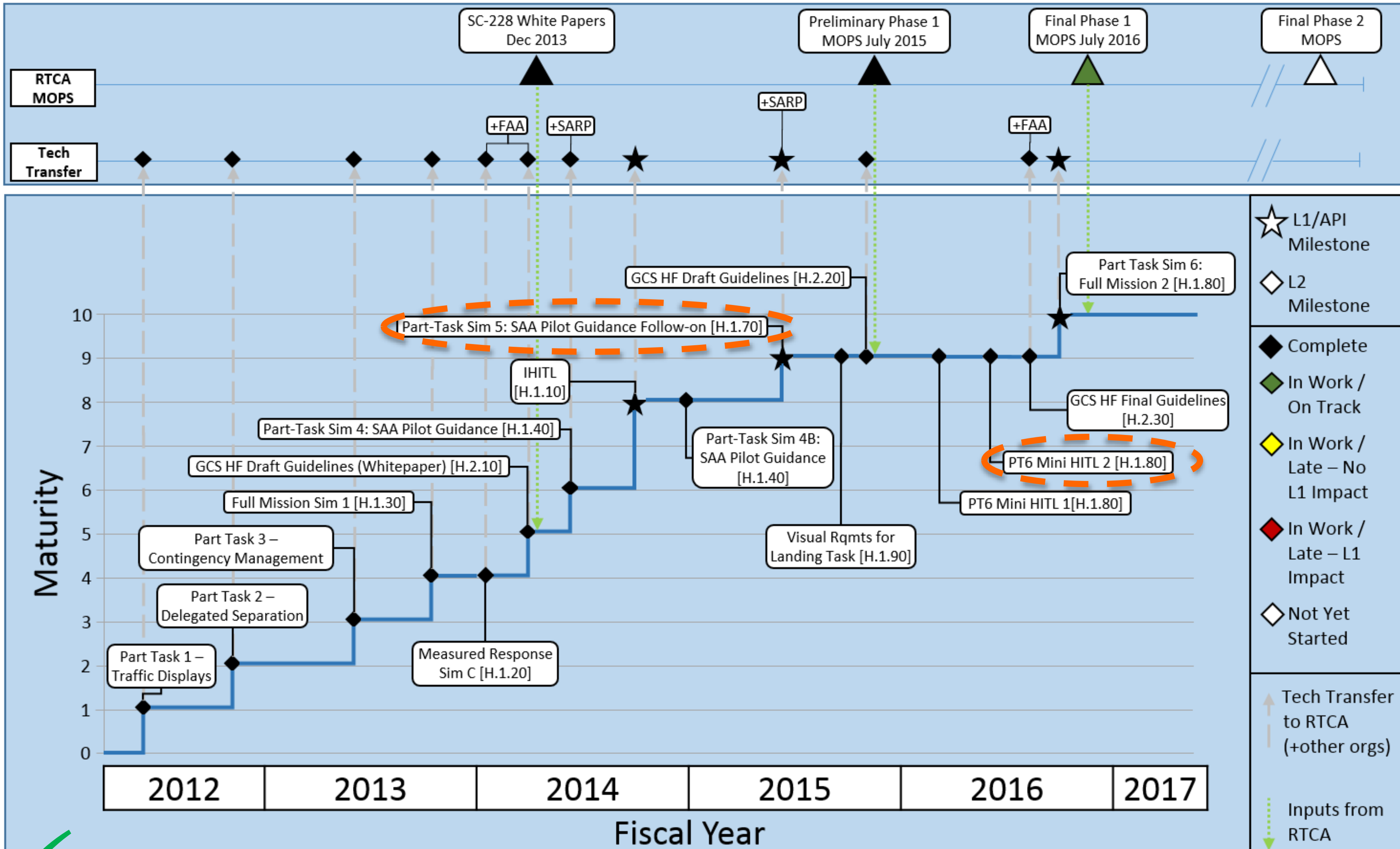
TC-C2: Command & Control Performance Standards



TC-HSI: Human Systems Integration

TC-SAA: Sense and Avoid Performance Standards

TC-HSI: Progress Indicator *As of 9/30/16*

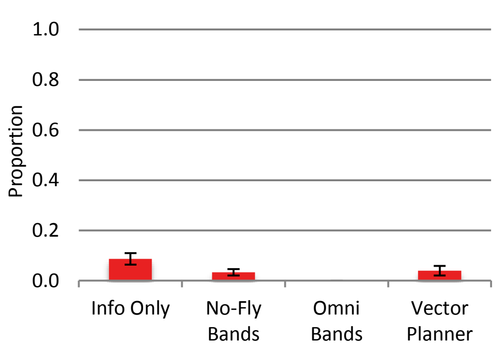


TC-HSI: Provide research findings to develop and validate human systems integration (HSI) ground control station (GCS) guidelines enabling implementation of the SAA and C2 performance standards

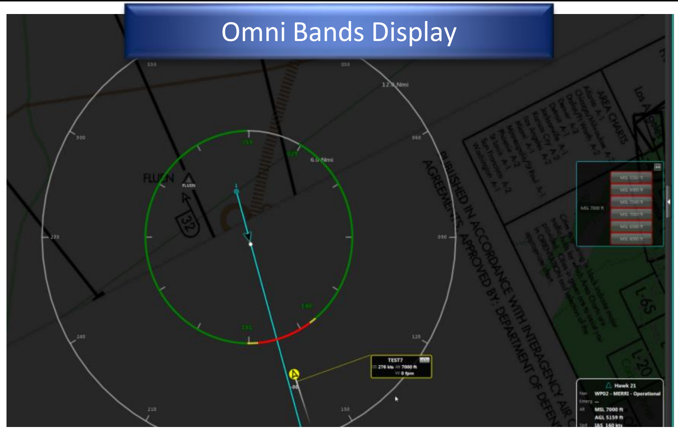
Part Task Simulation 5: SAA Pilot Guidance Follow-on

- **Research Objective:**
  - Build upon previous DAA human-in-the-loop simulations results and lessons learned to identify minimum DAA display and guidance requirements for draft SC-228 MOPS
    - Continue evaluation of the impact of informative versus suggestive maneuver guidance decision aiding tools on pilot performance of the traffic avoidance task

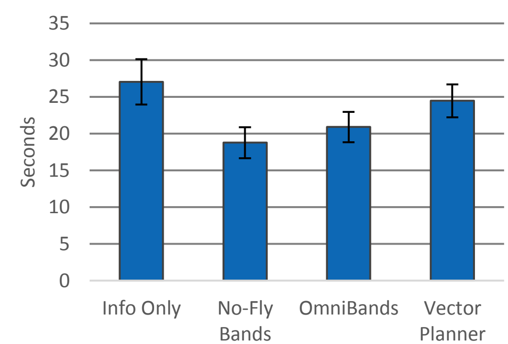
Proportion of LoWC



Omni Bands Display



Total Response Time

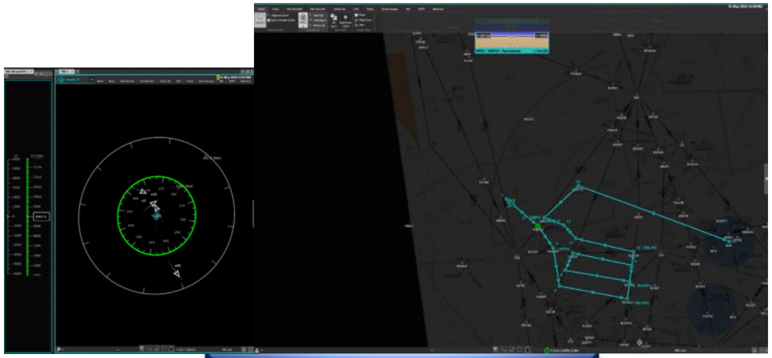


- **Results, Conclusions, and Recommendations:**
  - Suggestive guidance in the form of banding resulted in significantly ***faster*** response times and ***lower*** occurrences of losses of well clear (LoWC)
  - Suggestive maneuver guidance in the form of bands was accepted as a minimum requirement for the SC-228 Phase 1 MOPS

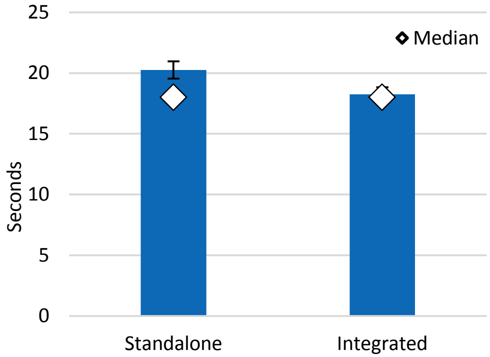
GCS Display Minimum Information Guidelines/Requirements for DAA and C2 MOPS

Part Task Simulation 6: Full Mission 2

- **Research Objectives:**
  - Conduct final V&V activity in support of the SC-228 DAA human machine interface requirements for displays, alerting, and guidance
    - Verify that pilot performance with notional implementation of minimum requirements is comparable to previous DAA simulations
    - Re-evaluate performance differences between a standalone versus an integrated DAA display configuration



Standalone DAA Display



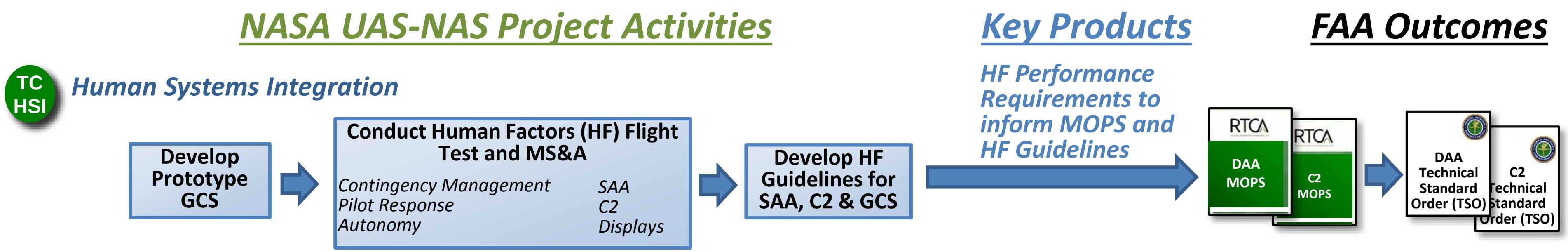
Total Response Time

Integrated DAA Display

- **Results, Conclusions, and Recommendations:**
  - Pilot performance in terms of response times and losses of well clear was consistent with, and in some cases better than, previous simulations when using the minimum display, alerting, and guidance requirements
  - No significant performance differences between standalone and integrated display configurations
  - Results show overall support for key display, alerting and maneuver guidance MOPS

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

TC-HSI: DAA and C2 MOPS Contributions



- Authored multiple SC-228 DAA Final MOPS Sections for Working Group Review
  - Traffic Display Subsystem Requirements Section
  - Equipment Test Procedures Subsections
- Provided Human Factors subject matter expertise to SC-228 DAA and C2 Working Group
- Provided results from human-in-the-loop multiple simulations
- Provided recommendations for:
  - Display of Suggestive guidance
  - Pilot interaction timeline associated with DAA guidance, alerting, and display
  - Detect and avoid audio and visual alerting
  - TCAS II Interoperability
  - Well Clear Recovery guidance, alerting, and display
- Supported SC-147 Traffic Alert & Collision Avoidance System (TCAS), which is working ACAS Xu

TC-ITE: Integrated Test and Evaluation

RT2 – Test Infrastructure

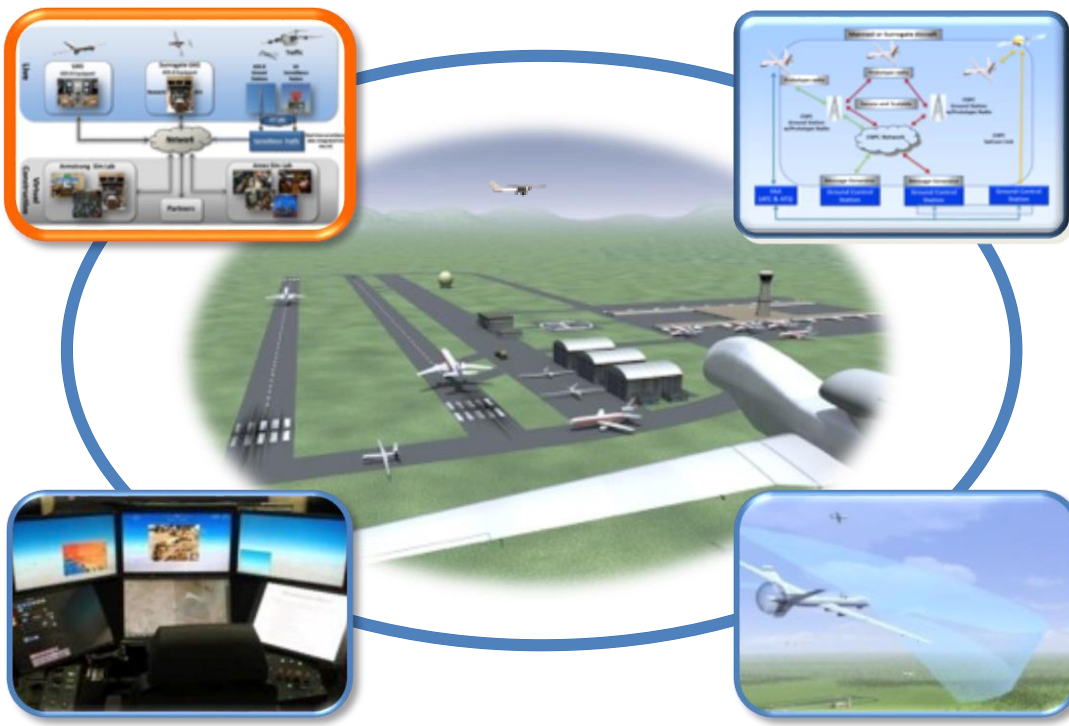
- Test infrastructure to enable development and validation of airspace integration procedures and performance standards

TC-ITE - 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

RTCA RADAR MOPS

TC-ITE: Integrated Test & Evaluation



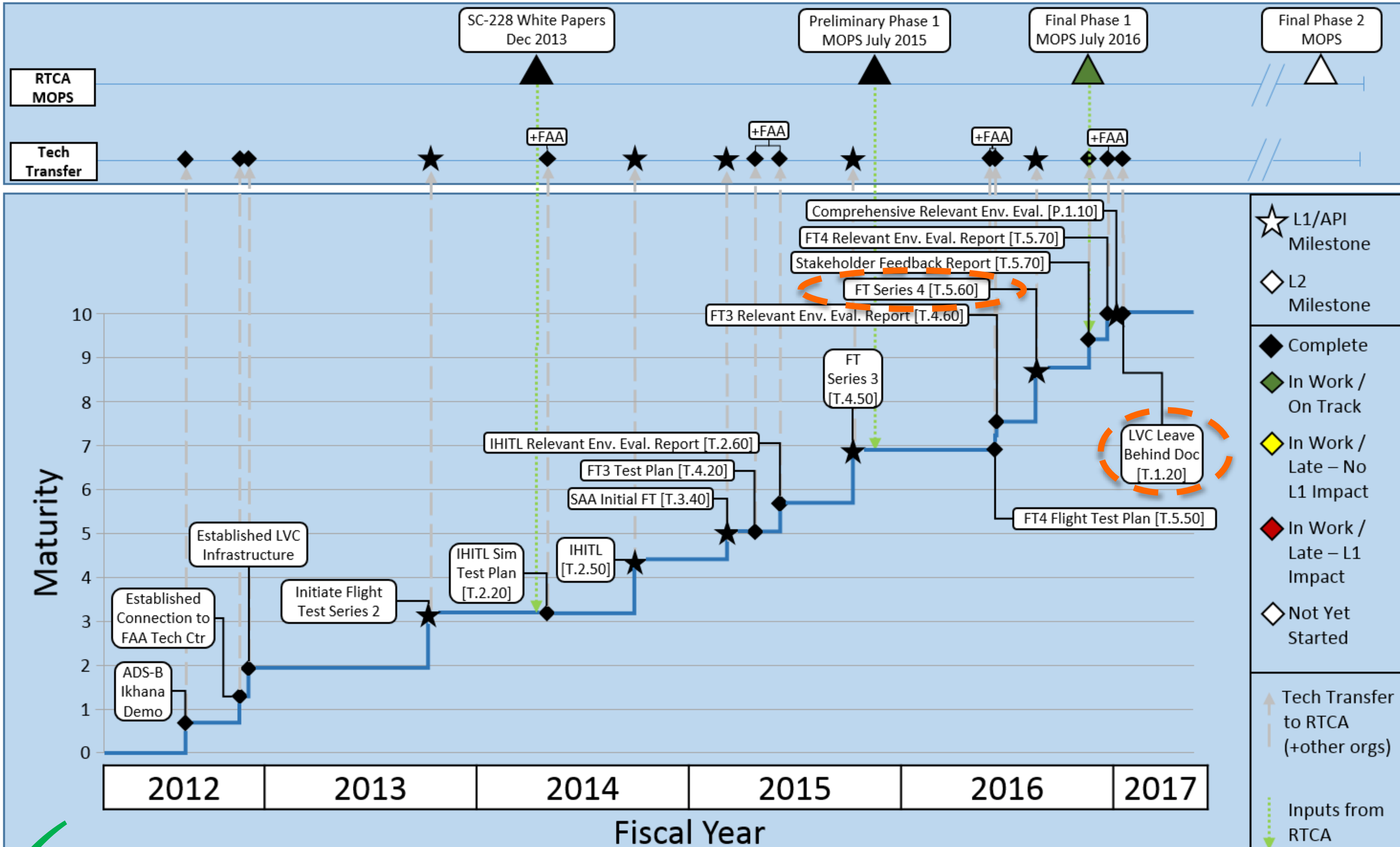
TC-C2: Command & Control Performance Standards

TC-HSI: Human Systems Integration

TC-SAA: Sense and Avoid Performance Standards

TC-ITE: Progress Indicator

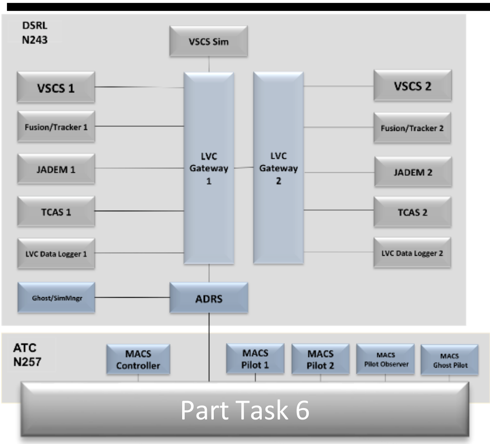
As of 9/30/16

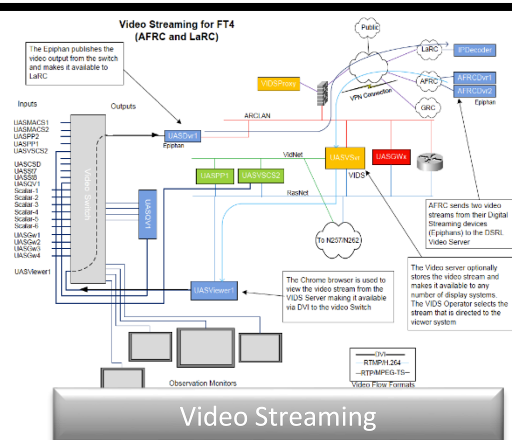


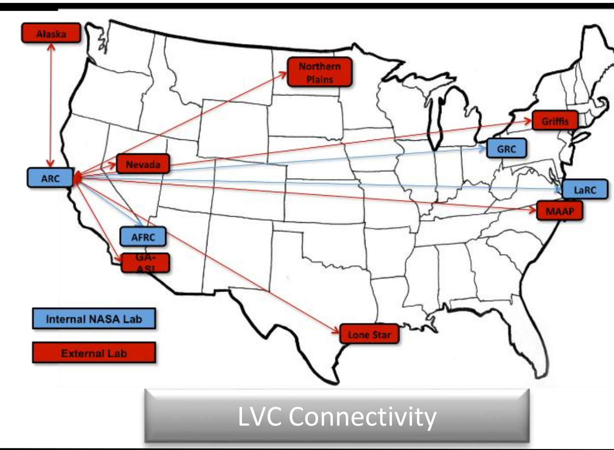
TC-ITE: Develop a relevant test environment for use in generating research findings to develop and validate HSI Guidelines, SAA & C2 MOPS with test scenarios supporting integration of UAS into the NAS

Simulation Support & Leave Behind Capability

- **Research Objective:**
  - Document the LVC test environment capability and characterize the performance of the LVC test environment
    - Additional detail: Develop and maintain a relevant test environment to support sub-project research simulations, identify and document the LVC interfaces, and maintain and update the infrastructure to support required technologies







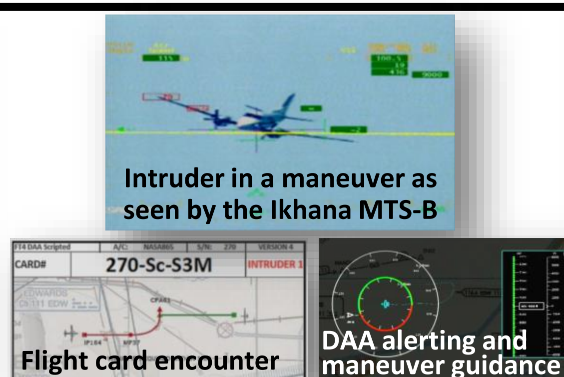
- **Results, Conclusions, and Recommendations:**
  - Expanded LVC test environment development
  - Enabled video streaming of live test displays to promote remote research monitoring
  - Extended LVC Connectivity to all six UAS Test Sites
  - Documented the state of the LVC infrastructure

Test Environment and Support for DAA MOPS and Future Testing

FT4 Execution

- **Research Objectives:**
  - Conduct Flight Test Series 4 integrating the latest SSI algorithms, HSI displays, and active test aircraft sensors using the Live, Virtual, Constructive test environment
  - Document the performance of the test infrastructure in meeting the flight test requirements

FT4 Flight Assets



Scripted Encounters

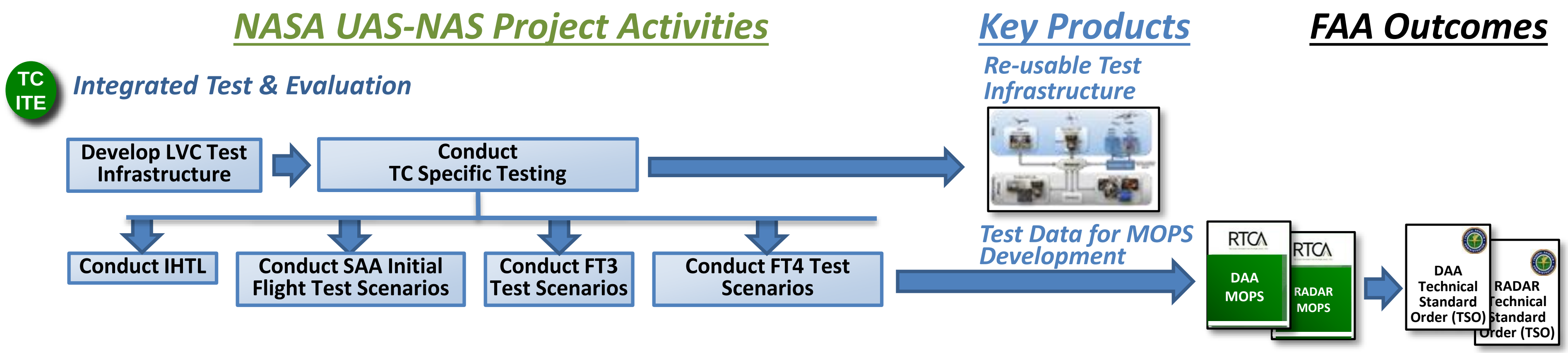
Flight Test Execution

- **Results, Conclusions, and Recommendations:**
  - FT4 successfully completed on 6/30/2016
    - Leveraged lessons learned and risk reduction from technology refinements to support P1 MOPS validation
    - 2 system checkout and 19 data collection flight tests
    - 11 weeks (April 12 - June 30)
    - 321 air-to-air encounters

- In concert with Project simulation activities, FT4 contributed significantly to the validation of DAA MOPS. It identified some key performance requirements that needed additional refinement
- Flight Test Report completed
- Lessons Learned documented

Test Environment for V&V of DAA and C2 MOPS

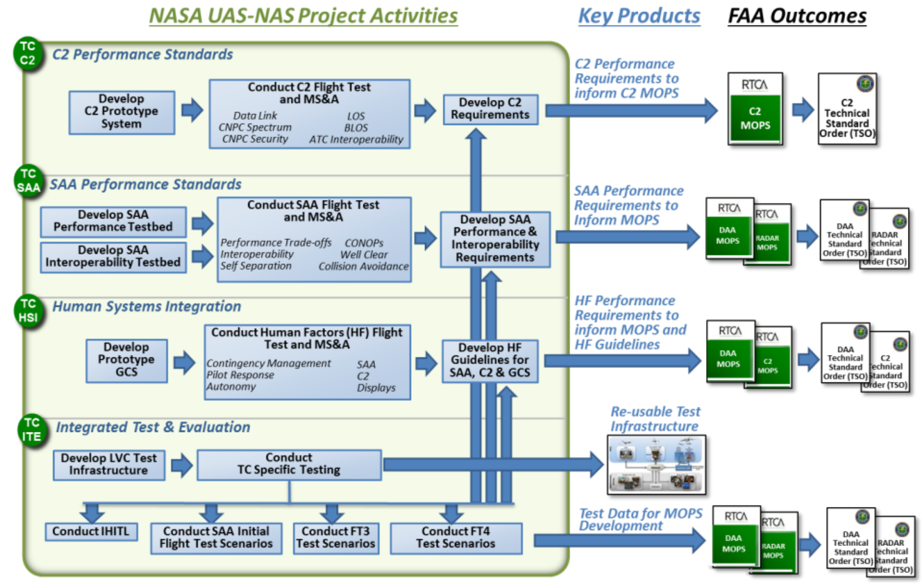
TC-ITE: DAA and Air-to-Air RADAR MOPS Contributions



- Provided flight test system subject matter expertise to SC-228 DAA Working Group's Verification and Validation Team
- Planned, executed, and disseminated data from Flight Test Series 4 to SC-228 DAA Working Group's Verification and Validation team
  - Completed 261 unique encounters (321 encounters total including repeats and resets)
  - Three different implementations of a DAA system

Technical Performance Summary

- DAA Final MOPS
  - Provided an unmanned aircraft DAA system for MOPS development and Verification and Validation
  - Developed, planned, executed, disseminated data, analyzed, and reported on multiple batch simulations, human-in-the-loop simulations, and flight tests



- C2 Final MOPS
  - Provided a C2 radio system for MOPS development and Verification and Validation
  - Developed, planned, executed, disseminated data, analyzed, and reported on multiple laboratory tests, simulations, and flight tests

- Authored multiple DAA and C2 Final MOPS Sections or Appendices for Working Group review
- Significant International Contributions
  - Human Autonomy Teaming support (NATO, ICAO)
  - Providing HF leadership and expertise (NATO)
  - Spectrum allocation support (ICAO, WRC)

Critical Contributions to DAA and C2 MOPS Development and Final MOPS Verification and Validation

Outline

- UAS-NAS Overview
- Technical Challenge Performance
- Emerging Technical Challenge Work – Davis Hackenberg
  - FY16 Emerging TC Performance
    - Certification
    - sUAS
    - LVC-DE Enhancements
- Project Level Performance & FY17 Look Ahead
- Review Summary

Emerging Technical Challenge Work

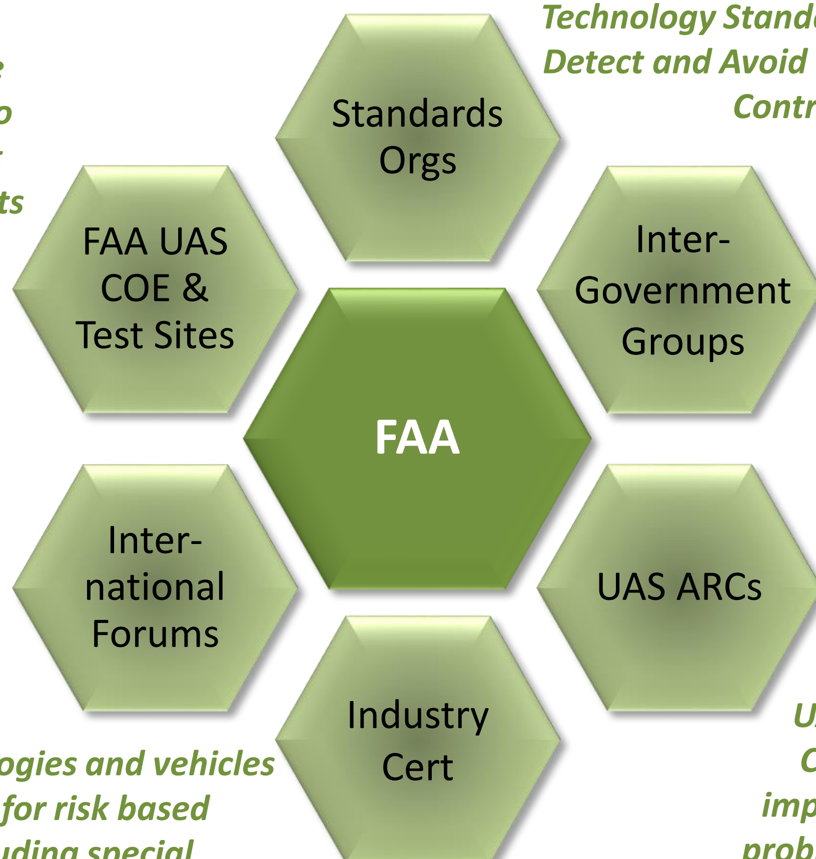
- Emerging Technical challenge work is technical work outside the core project focus areas
  - Includes far-reaching/higher risk activities with an emphasis on future (post-project) capabilities
  - Utilizes project management rigor, but to a lesser extent (i.e. No Progress Indicators)
  - Content is 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 Emerging TC work
- Emerging TC Work on UAS-NAS Project
  - Certification
  - sUAS Mission Support Technologies
  - Augmentation used for LVC-DE Enhancements

FAA Organizational Relationships

- The FAA is using several domestic forums, in conjunction with several international forums to lay out the pathway for their priorities and investments.

Standards Organizations chartered to develop Technology Standards, such as RTCA SC-228 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



Inter-government groups such as the UAS Executive Committee (ExCom), Senior Steering groups, OSD Sense and Avoid (SAA) Science and Research Panel (SARP), and Research Transition Teams (RTTs)

World Radio Conference (WRC) and International Civil Aviation Organization (ICAO) UAS Study Groups are addressing UAS access from an international perspective

Industry developed technologies and vehicles brought directly to the FAA for risk based certification processes, including special projects such as Pathfinders

UAS Aviation Rulemaking Committee (ARC) groups implemented to solve specific problems as directed by the FAA

NASA has a leadership role within many domestic forums and participates in the international forums

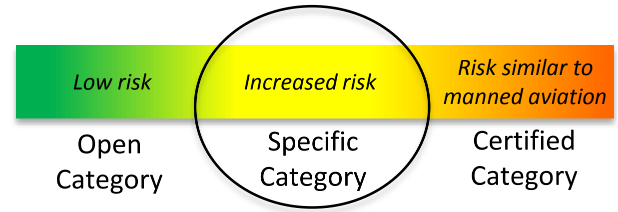
Certification Overview

Produced prototype design and performance requirements to support airworthiness certification of midrange, specific category UAS

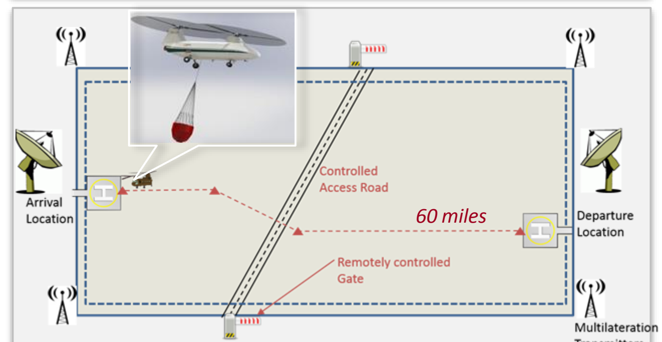
- Focused studies on *midrange* UAS
  - With attributes and capabilities beyond small UAS
  - Without all of the design or operational capabilities of commercially-operated manned aircraft
- Investigated the effect of concepts of operation (ConOps) on design requirements for airworthiness
  - Identified specific vehicle and operational factors that affect those requirements
- Developed 2 low-risk ConOps for a midrange unmanned rotorcraft
  - Precision aerial application (2015)
  - Cargo delivery (2016)

Beyond Visual Line of sight (BVLOS) ops contained over uninhabited areas

- Proposed design and performance criteria derived from hazard analysis and current regulations
  - Produced a set of 85 design requirements
    - ❖ 80 based on FAR Part 27 (Airworthiness Standards: Normal Category Rotorcraft, which contains 260 requirements)
    - ❖ 5 completely new for novel UAS systems and equipment



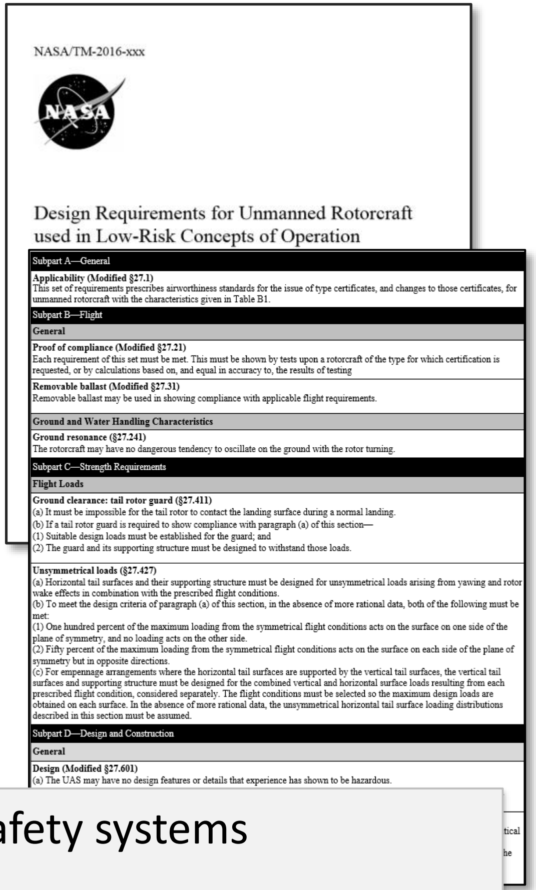
Precision Aerial Application



Cargo Delivery in Uninhabited Corridors

Certification Results

- The Certification research produced:
  - A unified set of design requirements suitable as a starting point for low-risk UAS type certification projects
  - An exemplar of an operation-centric approach to airworthiness certification for midrange UAS
  - Factors necessary for ConOps elicitation and useful for UAS classification
  - Overarching requirements for 8 design topics affected by novel aspects of UAS
    - Support further research into new vehicle technologies and their assurance needs for different UAS categories



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Design Requirements for Unmanned Rotorcraft used in Low-Risk Concepts of Operation

Subpart A—General
Applicability (Modified §27.1) This set of requirements prescribes airworthiness standards for the issue of type certificates, and changes to those certificates, for unmanned rotorcraft with the characteristics given in Table B1.
Subpart B—Flight
General
Proof of compliance (Modified §27.21) Each requirement of this set must be met. This must be shown by tests upon a rotorcraft of the type for which certification is requested, or by calculations based on, and equal in accuracy to, the results of testing
Removable ballast (Modified §27.31) Removable ballast may be used in showing compliance with applicable flight requirements.
Ground and Water Handling Characteristics
Ground resonance (§27.241) The rotorcraft may have no dangerous tendency to oscillate on the ground with the rotor turning.
Subpart C—Strength Requirements
Flight Loads
Ground clearance: tail rotor guard (§27.411) (a) It must be impossible for the tail rotor to contact the landing surface during a normal landing. (b) If a tail rotor guard is required to show compliance with paragraph (a) of this section— (1) Suitable design loads must be established for the guard; and (2) The guard and its supporting structure must be designed to withstand those loads.
Unsymmetrical loads (§27.427) (a) Horizontal tail surfaces and their supporting structure must be designed for unsymmetrical loads arising from yawing and rotor wake effects in combination with the prescribed flight conditions. (b) To meet the design criteria of paragraph (a) of this section, in the absence of more rational data, both of the following must be met: (1) One hundred percent of the maximum loading from the symmetrical flight conditions acts on the surface on one side of the plane of symmetry, and no loading acts on the other side. (2) Fifty percent of the maximum loading from the symmetrical flight conditions acts on the surface on each side of the plane of symmetry but in opposite directions. (c) For empennage arrangements where the horizontal tail surfaces are supported by the vertical tail surfaces, the vertical tail surfaces and supporting structure must be designed for the combined vertical and horizontal surface loads resulting from each prescribed flight condition, considered separately. The flight conditions must be selected so the maximum design loads are obtained on each surface. In the absence of more rational data, the unsymmetrical horizontal tail surface loading distributions described in this section must be assumed.
Subpart D—Design and Construction
General
Design (Modified §27.601) (a) The UAS may have no design features or details that experience has shown to be hazardous.

Traditional vehicle design topics

- Controllability, Maneuverability, and Stability
- Structural Integrity
- Powerplants and Supporting Systems

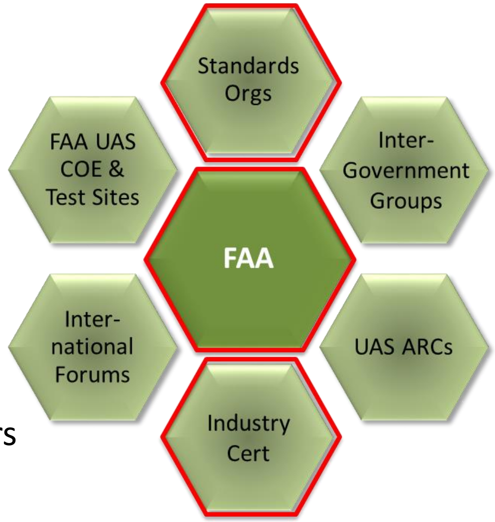
Novel vehicle safety systems

- Containment*
- Detect and Avoid Intruder Aircraft
- Detect and Avoid Ground-based Obstacles
- Safety-Critical Command and Control Link
- Systems and equipment to support the pilot and crew safety roles

* *The containment concept and requirements originating from this research underlie LAR-18781-1 Assured Geo-Containment System for Unmanned Aircraft. LAR-18781-1 was awarded a provisional patent in January and was recently recommended for further patent pursuit.*

Cert Relationship to Community Initiatives

- Industry Certification
  - BVLOS certification challenges are broad across industry
    - Companies such as AeroVironment are leveraging NASA guidance in FAA certification efforts
    - Reports requested by 2 current UAS certification projects
  - FAA Pathfinders have direct applicability from the operational perspective, and research is influencing the FAA certification directorates path forward
    - Research expands into a broader set of vehicle classes as the Pathfinders have limited diversity in size, weight and power considerations

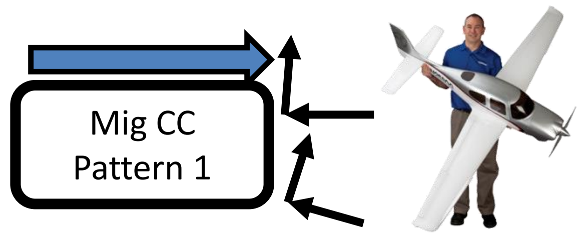


- Standards Organizations (i.e. RTCA SC-228)
  - Use case, ConOps, and vehicle size relevant to P2 MOPS
  - Hazard decomposition identifies several other high priority technology areas that would benefit from similar standards (i.e. U-1 Controllability, Maneuverability, & Stability, U-4 Containment)
- NASA Technical Challenge Emergence
  - Certification work is not planned to extend into P2 due to lack of direct alignment with P2 MOPS
  - The certification studies demonstrated a sound approach that can be applied to investigating a wide range of concepts of operation to identify critical technology and policy elements essential for UAS integration

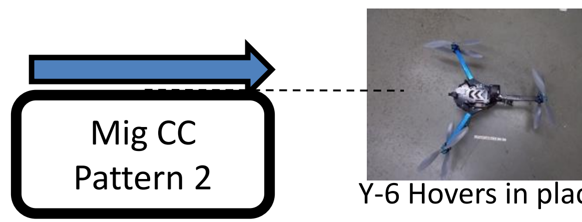
sUAS Mission Support Technologies

sUAS DAA continues to be a challenge and needs more research

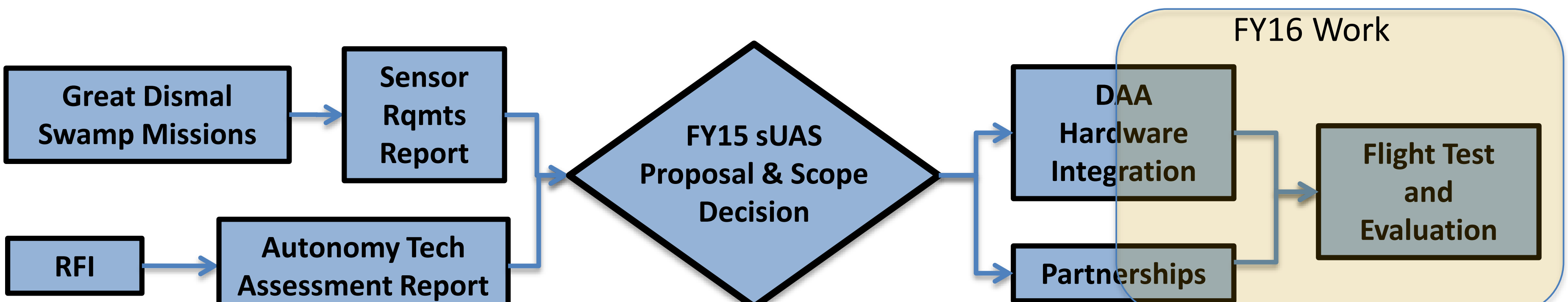
- **Top Level Research Goal**
  - Developing specific data relevant to partner Agencies while conducting high-value sUAS missions utilizing increasing levels of automation and sUAS technologies
- **Objectives**
  - Assess the state-of-the-art in sUAS Sense-and-Avoid capabilities
  - Develop and test one instantiation of an sUAS SAA system
  - Assess feasibility of BVLOS operation at GDS in Class G airspace
- **FY16 Accomplishments**
  - Video and telemetry data for various encounters of sUAS platforms leveraging Electro-Optic (EO) cameras evaluated
  - Determined to not be implementable within the scope of the emerging TC effort
  - Low SWAP ADS-B integration (without FAA TSO certification) proved challenging to get NASA Airworthiness Flight Safety Review Board (AFSRB) approval and shaped path forward for future possible research
  - DAA Low SWAP ADS-B evaluation inconclusive



Scaled SR-22 approaches, Turns away

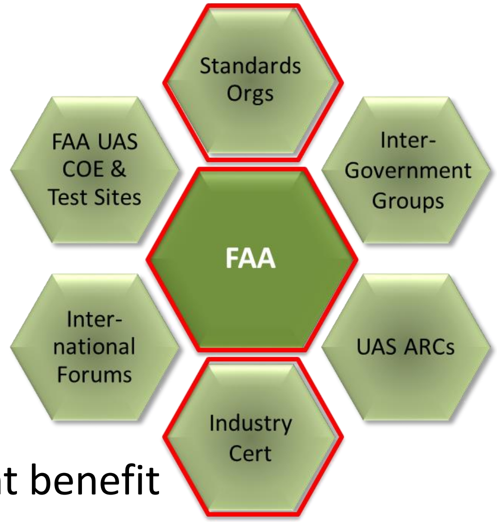


Y-6 Hovers in place



sUAS Relationship to Community Initiatives

- Industry Certification
  - Beyond Visual Line of Sight (BVLOS) operations will require Detect and Avoid Technologies, EO/IR is a technologies can be leveraged
  - Low cost and SWAP solutions are challenging to implement immediately
  - Industry is spending significant resources implementing both low power ADS-B and Electro-optic technologies to perform DAA and other Hazard Avoidance functions
  - Focused NASA/Industry partnerships could provide significant benefit towards standardizing technology implementations



- RTCA
  - Use case, CONOPS, and vehicle size may be relevant to Phase 1 MOPS
  - System capability and sensor characterization of a P2 MOPS relevant system were unsuccessful
- NASA Technical Challenge Emergence
  - sUAS DAA continues to be a challenge and needs more research, but is not within scope of P2 MOPS
  - DAA technology development provided lessons learned for future technology development and partnerships

UAS-NAS FY15/FY16 LVC-DE Enhancements

- Purpose
  - $6M in LVC-DE Enhancements that would benefit the development of Phase 2 MOPS

- Overview
  - The Project performed initial obligations by the end of FY15, and began implementation
  - Financial summary: 90.1% Costed
    - All LVC-DE enhancement tasks completed by the end of FY16
    - Test sites are still submitting final invoices after completing tasks in the month of September
- Highlights of LVC-DE enhancements include:
  - (3.1) All 6 Test Sites have satisfied NASA security requirements, implemented their initial connection, and provided NASA the necessary gap analysis to the LVC-DE Interface Control Document
  - (6.1) Distributed Display Infrastructure Set-up leveraged to to increase internal center capabilities and work more efficiently across the project/centers
  - (7.1) The SATCOM emulation capability provided an excellent jump start on P2 C2 MOPS and will significantly benefit SATCOM ConOps development in support of P2 SC-228 C2 MASPS

LVC-Distributed Display Infrastructure Set-up

ARC: Video streaming server and upgraded displays in Future Flight Central to support higher fidelity optics for Terminal Ops

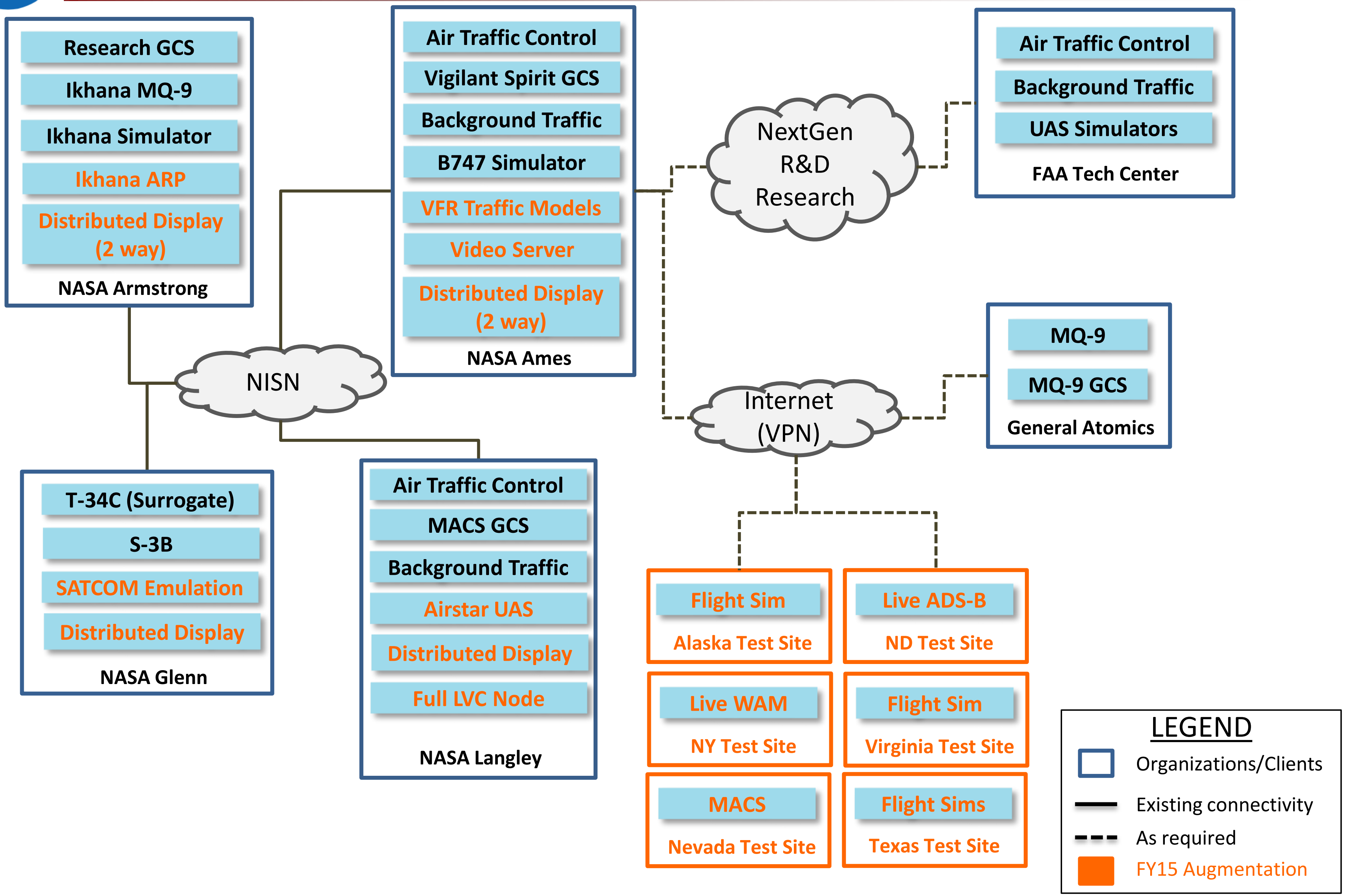
GRC: Control Center with capability to receive live flight test data and perform mission management functions

Video & Data

AFRC: Display replication for video streaming to support UAS flight test remote monitoring

LaRC: Demonstration display wall and video monitoring stations

UAS-NAS LVC-DE Build (end FY16)



Outline

- UAS-NAS Overview
- Technical Challenge Performance
- Emerging Technical Challenge Work
- Project Level Performance & FY17 Look Ahead – Laurie Grindle
  - Risk Management Performance
  - Resource Allocation and Utilization
  - Schedule Performance
  - Requirements Summary
  - Partnerships and Collaboration
  - FY16 Accomplishments and FY17 Look Ahead
- Review Summary

Success in Mitigating Risks

- Data Removed

Zero Active Risks at End of FY16

Project Office Risks Accepted/Closed in FY16

- Data Removed

Resource Allocation against Baseline Budget

- Data Removed

Resource Utilization FY16 Budget vs. Actuals Summary

- Data Removed

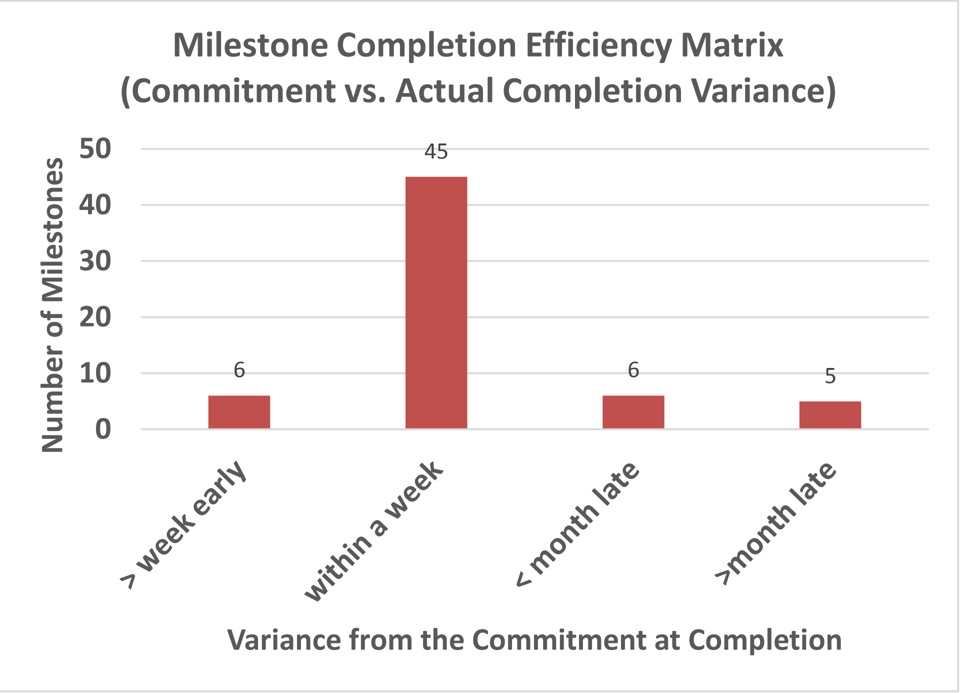
Successful Workforce And Resource Utilization

Non-WYE Procurement

- Data Removed

FY16 Schedule Performance

- Milestone Count
  - 62 Milestones completed in FY16
  - 8 Milestones remain open (P1 Closeout)
- Causes of Milestone Delays
  - Test scope increased due to SC-228 additional requirements; resulted in:
    - Extended data collection
    - Extended analysis
  - Export control/release processes are unpredictable resulting in milestone commitment date change requests
- Impacts of Milestone Delays
  - Acceptable impacts to Final DAA or C2 MOPS
  - Acceptable impacts to downstream test and simulation activities

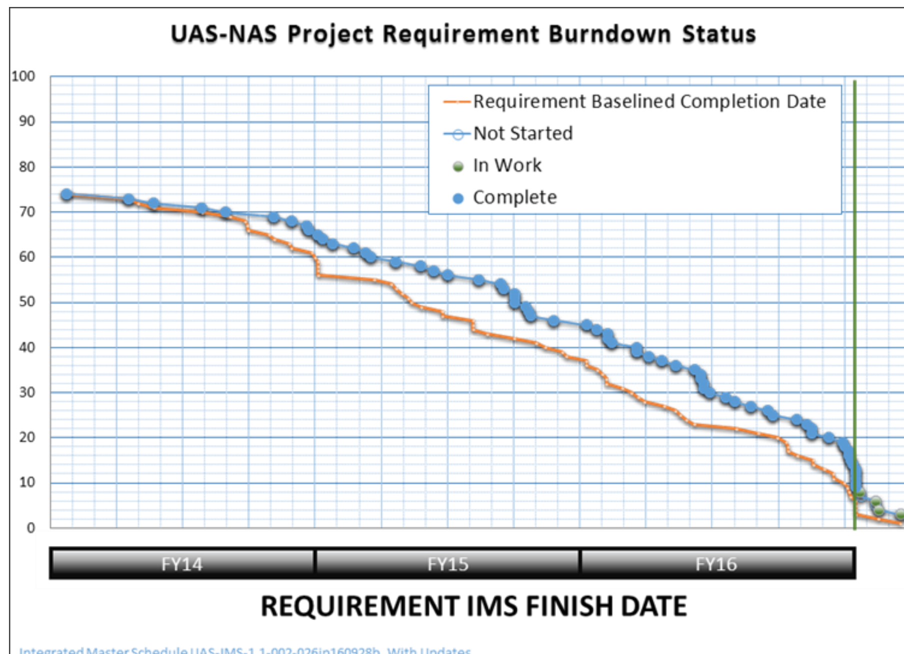


Successful Milestone Management

Requirements Summary

- FY16
  - Thirty-six Requirements completed
  - Six Requirements deleted
    - SSI comprehensive ACES Simulation
    - SSI CA/SS algorithm vs UA performance simulation
    - SSI sensor model stress testing and sensitivity HITL simulation
    - C2 FT4 infrastructure coordination
    - C2 FT4 UAS surrogate with CNPC
    - HSI FT4 report
  - Four Requirements added
    - SSI sensor uncertainty mitigation simulation
    - SSI DAIDALUS V&V
    - SSI end-to-end V&V simulation
    - HSI Part Task 6 HITL simulation
  - One Requirement added from counting error
- Project Total (FY14-FY16)
  - Requirements completed: 66
  - Requirements remaining open: 8

TWP	End of FY16 Planned	FY16 Completed	FY14-FY16 Total Completed
SAA	30	14	24
C2	15	9	15
HSI	11	4	10
ITE	13	7	13
PROJ	5	2	4
Total	74	36	66



Current and Anticipated Partnership Issues

- Phase 1 Partnerships are complete
- Critical Phase 2 partnerships still in work
  - C2 SATCOM partner; proposals under review
  - C2 Terrestrial partner; working sole source and the Justification of Other than Full and Open Competition (JOFOC)
  - DAA partner; TBD pending the TWP Content Decision process to be completed early November
    - IT&E partnerships for FT5 and FT6 are primarily dependent on TWP Content Decision
  - IT&E ACAS Xu partner; involves a complicated multi-partnership strategy
    - FY17 aspects of partnerships are all in work and considered low risk
    - Determination of future deliverables from partners like the FAA (TCAS Program Office) and other partners such as General Atomics are more challenging

Current Active Collaborations/Partnerships Status

Partner ***(Project Area)***	**Agreement In Place**	**Collaboration/ Partnership Role**
Air Force Research Lab *(TC-HSI)*	Task Order	Coordinate activities on Vigilant Spirit Control Station. Status: On-going collaboration with AFRL supporting use of VSCS on DAA activities
Cal State Long Beach *(TC-HSI)*	Grant	Provided significant support in the development of input to DAA Phase 1 MOPS.
Dragonfly Pictures *(Emerging TC-Certification)*	SAA	Supported the UAS certification case study by supplying the design of a UAS rotorcraft Status: No future work planned
FAA Office of UAS Integration *(Project Office)*	MOA	Support by FAA leadership, management, and technical subject matter experts (SME)s to validate work being done by the Project Status: On-going coordination of Project deliverables
FAA R&D Integration *(Project Office)*	MOA	Formal host of partnership agreements and collaborator for Integrated Test Activities Status: On-going coordination of Project deliverables
FAA TCAS Program Office (ACAS Xu) *(TC-SAA)*	Software	Coordinating on collaboration for ACAS-Xu software and associated flight tests Status: Worked together during FY16 for planning for ACAS-Xu FT2 in FY17
FAA UAS Test Sites *(Project Office)*	IDIQ Contract	Support of Task 2, LVC-DE efforts. Status: All 6 test sites successfully connected to the LVC
General Atomics *(TC-ITE)*	SAA	Ikhana equipped with avionics and Proof of Concept SAA system directly supported by UAS-NAS Project Status: Agreement in place with GA for FT4 for in-kind support and planning for ACAS-Xu FT2

Purple text indicates changes since FY15 AR

Current Active Collaborations/Partnerships Status

Partner *(Project Area)*	Agreement In Place	Collaboration/ Partnership Role
Honeywell *(TC-ITE)*	Contract	Sensor data fusion support Status: Supported FT4. Provided a Traffic alert and Collision Avoidance System (TCAS) II and ADS-B equipped intruder aircraft.
NASA AOSP (Project Office)	NA	Coordination with AOSP on UTM, SMART NAS, autonomy roadmapping, and other activities Status: Collaborative effort on UAS integration strategies and LVC development
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-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 group. Submitted Consolidated NASA Comments for C2 on 6/9/15 and DAA on 9/20/16
RTCA SC-147 *(TC-ITE, TC-DAA)*	NA	Close coordination between ACAS Xu and DAA standards required for success of P2 MOPS Status: Hosting workshops and performing flight test to ensure success of both working groups
University of South Carolina *(TC-C2)*	Grant	Perform technology and system architecture trade studies for terrestrial and satellite based UAS command and communications systems. Provide analysis of RF propagation effects in expected UAS operational environments.

Purple text indicates changes since FY15 AR

FY16 Accomplishments & FY17 Look Ahead

FY16 Accomplishments

- Authored multiple DAA and C2 Final MOPS Sections or Appendices for Working Group review
- Developed, planned, executed, disseminated data, analyzed, and reported on multiple research activities
  - TC-HSI, TC-SAA, TC-ITE: Part Task Simulation 6 Successfully Completed
  - TC-C2: CNPC Gen-5 Flight Test Successfully Completed
  - TC-SAA: ACES Simulations Successfully Completed
  - TC-ITE, TC-SAA: Flight Test 4 Successfully Completed
- Emerging TC [Cert]: Restricted Category Type Certification Report Successfully Completed
- All 6 FAA UAS Test Sites completed Task 2: connection to LVC-DE
- Conducted several Outreach activities using the FY16 DAA Demo (UNITD)
- NASA Honor Awards: Langley Group Achievement Award (TC-SAA), Early Career Achievement Medal – Langley (TC-SAA), Exceptional Achievement Medal - Ames (TC-HSI), Exceptional Achievement Medal – Ames (TC-SAA), Ames Honor Award (TC-ITE)
- Aviation Week Laureate Awards Finalist in Technology Category, ACAS Xu FT

FY17 Look Ahead

- TC-DAA/C2: SC-228 White Papers
- TC-ITE: ACAS Xu Flight Test 2
- Project: Key Decision Point – C (Baseline Review)
- Project: ARMD UAS Cohesive Strategy and FAA Research Transition Teams

FY17 Potential Storm Clouds

- Portfolio Baseline (KDP-C)
  - DAA WG doesn't meet current P1 MOPS development schedule
  - Technical work content
    - SC-228 White Paper
    - FAA Research Transition Team (RTT)
    - ARMD UAS Cohesive Strategy impacts to outyear portfolio
  - Critical Phase 2 partnerships still in work

- Resources
  - Increased WYE rates at Ames
  - Stakeholder level of support coordination
  - Chief Engineer position unfilled

FY16 Summary

✓ Successful completion of the Project's Phase 1 Technical Challenges
  – Completed all planned milestones and activities on schedule and within budget
  – Critical member of RTCA SC-228
    • Lead authors for multiple Sections and Appendices in Final DAA and C2 P1 MOPS
    • Primary source of Final DAA and C2 MOPS V&V flight test results

✓ Successful completion of Project's FY16 Research Portfolio
  – Executed analysis, multiple lab tests, batch and human-in-the-loop simulations, and flight tests
  – Accomplished Technology Transfer of all research findings
  – Developed and implemented C2 radio and DAA alerting logic and maneuver guidance
  – Completed FY16 Annual Performance Indicator (API)

✓ Effective Project and Subproject Management

✓ Significant contributions to the UAS Community
  – Domestic and International

✓ Concurrent Phase 2 Project planning (FY17 - FY20)

Significant Accomplishments
Kudos to the Team

UAS-NAS Overview

Backup Slides

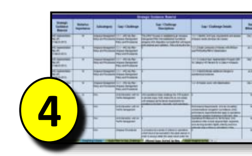
Phase 1 Content Decision Process

- **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

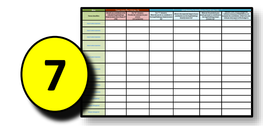


- **Step 5: Applying Weight Criteria and Prioritization**
  - Prioritization used to identify lower priority community needs that the Project should not pursue for Phase 1
    - Weighting Criteria: *Community Needs, Appropriate Organization, Ability to Complete, Complexity & Testing, Public Outreach/Acceptance*

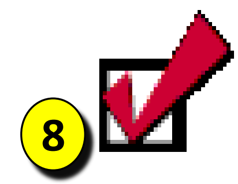
Phase 1 Content Decision Process (cont.)

- **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 1

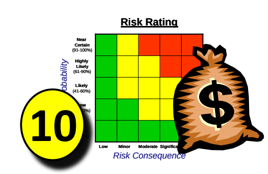


- **Step 8: Project Office Validate Proposed Technical Work Packages**
  - The Project Office reviewed the proposed TWPs supplied by the team and evaluated them according to many factors including: Consistency with existing Phase 1 plans, lessons learned, and Phase 1 Drivers



- **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 P1 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 1 Drivers, UAS Subcommittee Feedback, and results of the Center Independent Cost Assessments

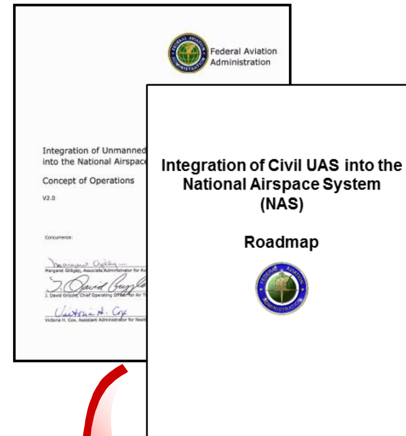


FAA Influence on Project Portfolio (FY14 – FY16)

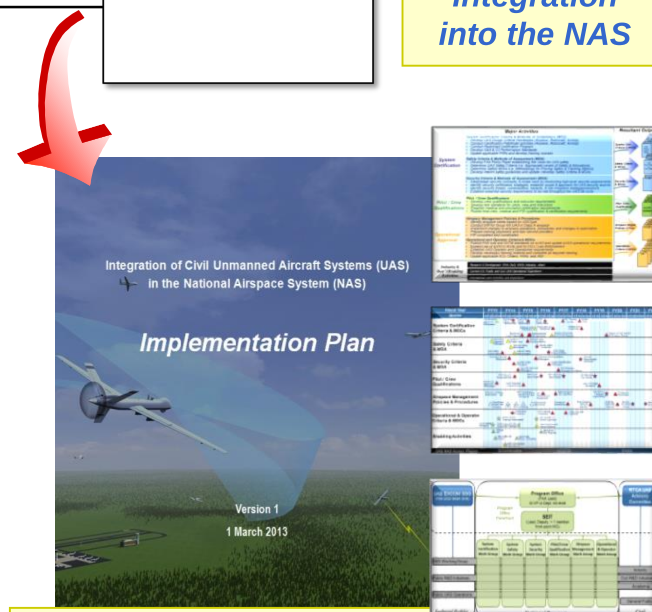
- The FAA *Concept of Operations (CONOPs)* and *Roadmap* establish the vision and define the path forward for safely integrating civil UAS operations into the National Airspace System (NAS)

- 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



The FAA CONOPs & Roadmap establish the vision and define the path forward for Civil UAS Integration into the NAS

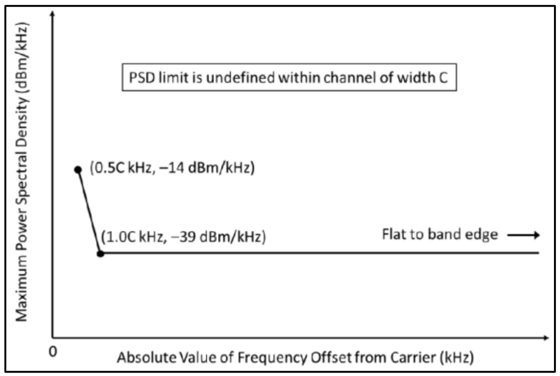


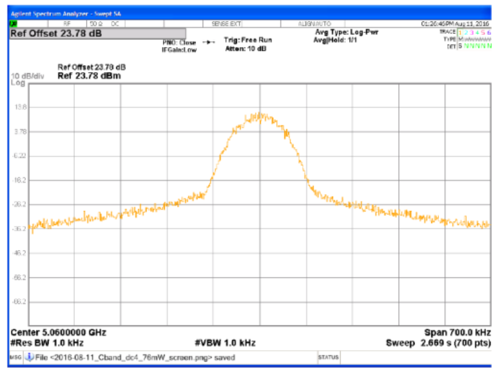
The Implementation Plan defines the means, resources, schedule, activities and structure for realizing the FAA CONOPs and Roadmap.

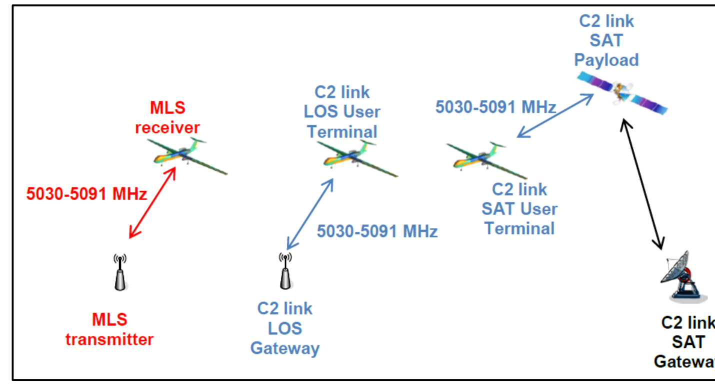
UAS-NAS Technical Challenge Performance Backup Slides

C-Band Planning & Standards

- **Research Objective:**
  - 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





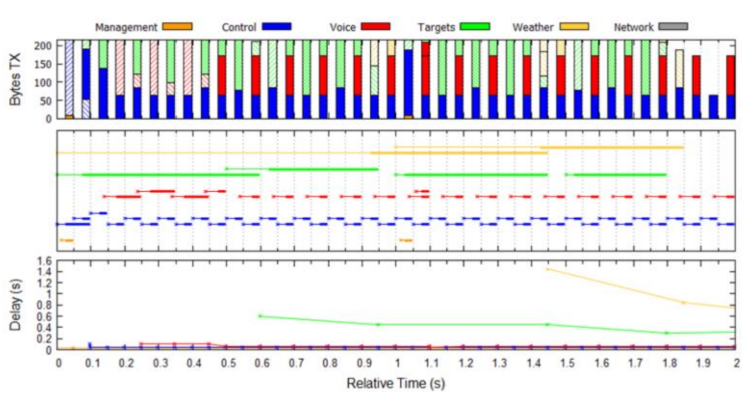


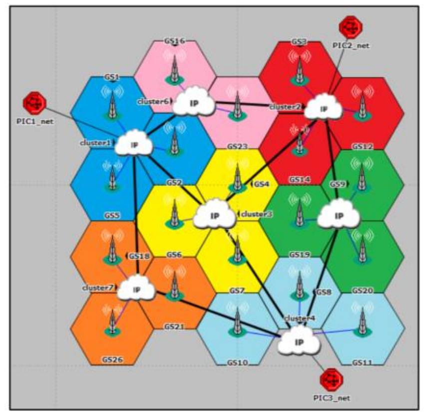
- **Results, Conclusions, and Recommendations:**
  - Participated in ITU-R Frequency working group (WG-F)
    - Presented results from CNPC C-Band flight testing
  - Results from NASA's Gen-5 CNPC radio development established the usage of C-Band (5030-5091MHz) frequencies for terrestrial systems. Based on this work, mechanisms are being developed for sharing of these frequencies for both terrestrial and SatCom systems (WRC-12 allocated C-Band frequencies for both terrestrial and SatCom systems).

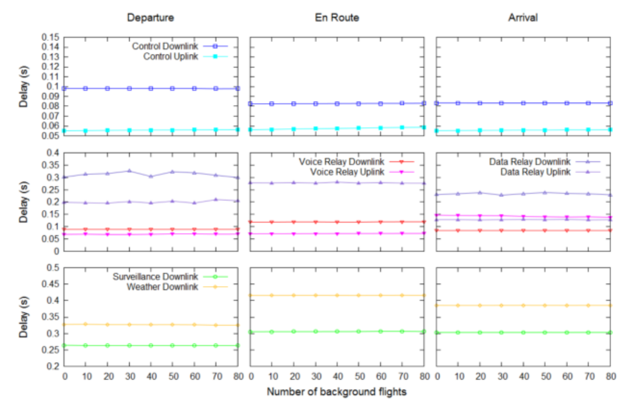
CNPC System Terrestrial Spectrum Usage Requirements for C2 MOPS

Flight Test Radio Model Development and Regional Sims

- **Research Objective:**
  - Develop validated radio models, based on flight testing and development of performance profiles to be used during regional large scale simulations





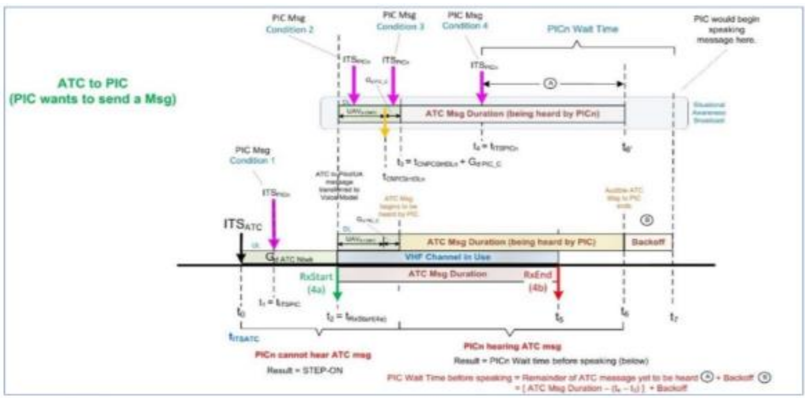


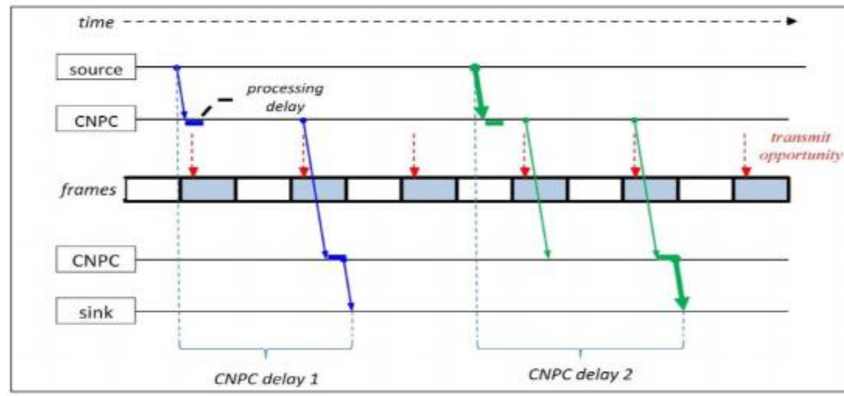
- **Results, Conclusions, and Recommendations:**
  - Completed integration of Gen-5 model and its supporting ground station infrastructure into regional simulation.
  - Completed model validation testing, based on Gen-5 radios flight and lab test data.
  - Completed regional simulations of Gen-5 radio system, which were used to verify the CNPC system could scale to meet future UAS demand. Results were documented in C2 MOPS appendices.

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

ACES Sim Operations w/Flight Test Models

- **Research Objective:**
  - Perform regional large scale simulations to assess CNPC system performance



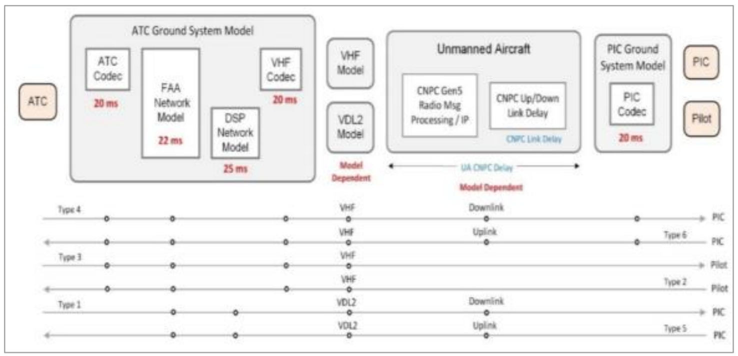


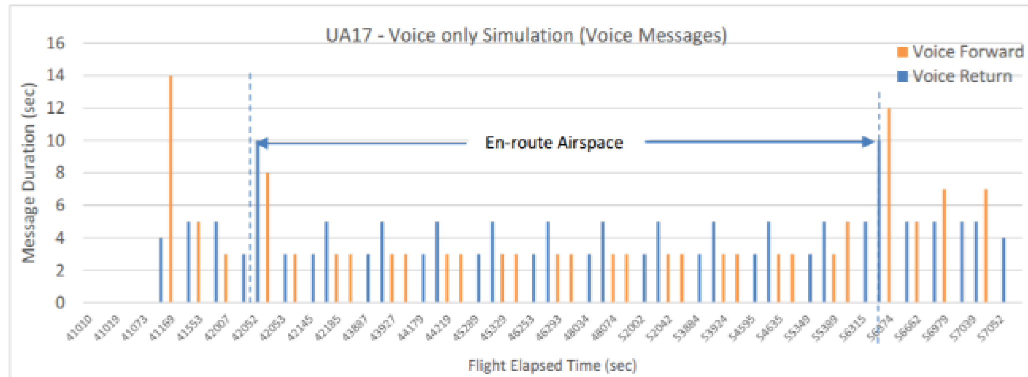
- **Results, Conclusions, and Recommendations:**
  - Completed Large-Scale Communication Architecture Simulations with Gen-5 CNPS radio model.
    - The simulated architectures use the NASA ACES application as the baseline architecture application to provide air traffic for the simulations and the platform for the ground communication system infrastructure. The Gen5 CNPC data-link radio system was integrated into the architecture, using models developed in OpNet Modeler, and provides a continuous uplink and downlink of UA command and control, navaid and surveillance data throughout the duration of a simulated UA flight, and for the relay of ATC Voice and CPDLC messaging data traffic services for Air Traffic Management.
    - Results of the simulations verified the functionality of the CNPC system within a relevant air traffic environment.

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

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



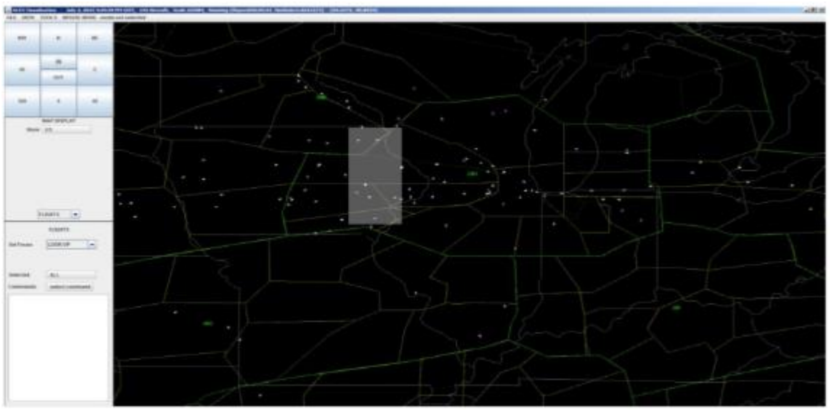


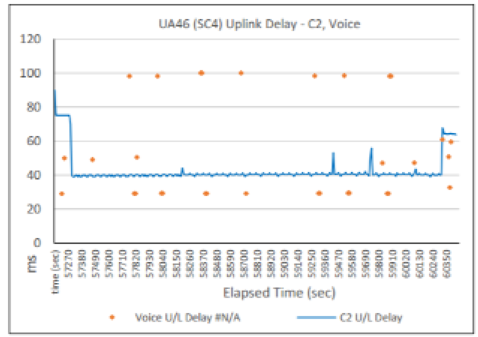
- **Results, Conclusions, and Recommendations:**
  - Completed simulations and delivered results to SC-228 C2 WG, to define parameters for Gen-5 V&V radio
  - Simulations resulted in four recommendations
    1. Use ATS digital messaging for routine ATC UA dialog to help minimize the use of voice communications for UA ATC.
    2. Continue research and technology development of system components to reduce latency associated with voice messaging.
    3. Refine CNPC radio voice traffic implementation for optimal radio performance
    4. Develop reliable, effective systems that use ground networks for ATC communication for UA in a Non-relay communication architecture implementation

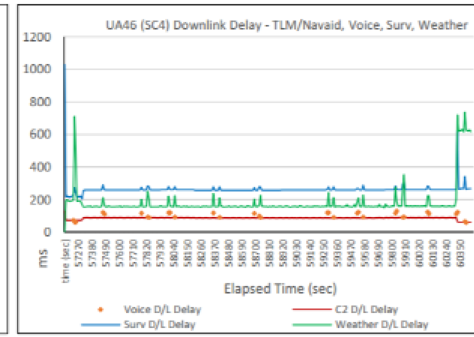
NAS-Wide CNPC System Simulation for Development and V&V of C2 MOPS

Communication System Performance Impact Testing (Delays/Capacity)

- **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





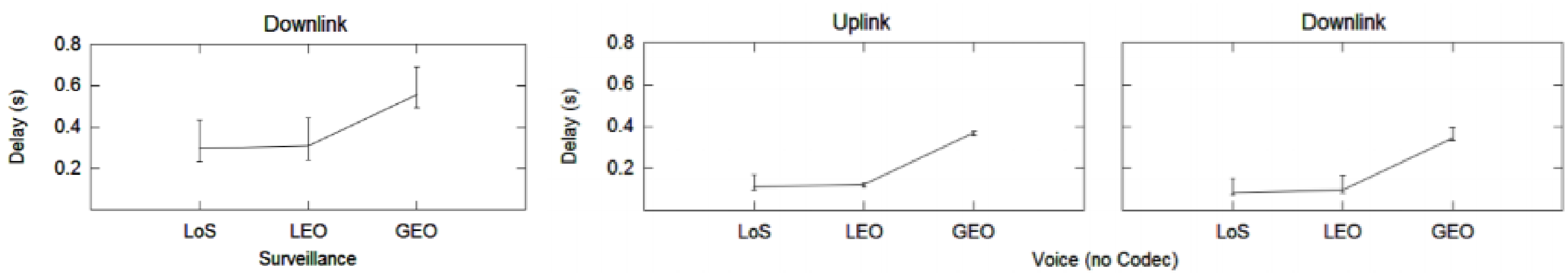


- **Results, Conclusions, and Recommendations:**
  – Completed simulations on ATC/CNPC Communications Performance Impact on NAS Delays and Capacity
    - Results from the simulations showed the greatest impact on capacity and delay from integrating UA in the NAS will come from the additional dialog service time required by ATC due to added aircraft in airspace, the complexity of managing aircraft with delays that occur in the dialog required to manage the system, and from lost link occurrences.

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

SatCom Simulations

- **Research Objective:**
  - Analyze SatCom Control and Non-Payload Communication system using regional large scale simulations



- **Results, Conclusions, and Recommendations:**
  - In order to have a starting point for planning of SatCom activities for the next phase of the UAS in the NAS project, a series of simulations were conducted. These simulations utilized the Opnet Modeler simulation tool and a modified version of the terrestrial CNPC model, in order to provide an approximation of a UAS SatCom system.
    - Two simulations were run for the SatCom scenario, one utilizing a delay for a low-earth orbit satellite, and one for a geosynchronous satellite.

SatCom CNPC System Performance Requirements for C2 MOPS

Gen2 Radio in Relevant Environment Flight Test

TC-C2 Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP C.1.10] Gen2 Radio in Relevant Environment Flight Test	4/2014	• Analyze the performance of the second generation C-band CNPC System prototype in a relevant flight environment	• Results continue the development of the CNPC system terrestrial operation performance standards

- 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 - Final C2 MOPS Input

TC-C2 Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP C.1.30] Verify Prototype Performance - Final C2 MOPS Input	6/2015 (FT3) 2/2016 (FT4)	• Analyze the performance of fifth generation Control and Non-Payload Communication System prototypes used for control and non-payload communication	• Results inform: • Performance of CNPC System prototype • Development of a final, verified and validated, Command and Control Minimum Operational Performance Standards

- Briefings, Papers, or Reports
  - UAS-Comm-4.3-029-001, V & V Update, Briefing, December 2014
  - UAS-Comm-4.3-043-001, Appendix N, Paper, June 2016
  - UAS-Comm-4.3-044-001, Appendix O, Paper, June 2016
  - UAS-Comm-4.3-051-001, CNPC Comm Prototype Radio Validation Flight Test, Report, September 2016
  - UAS-Comm-4.3-052-001, CNPC Comm Prototype Radio Verification Test, Report, September 2016

Spectrum Compatibility Analysis

TC-C2 Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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, August 2014
  - UAS-Comm-4.3-047, Spectrum Compatibility Analysis Final Report on WRC-2015, Report, August 2016
  - UAS-Comm-4.3-054-001, SatCom Simulation, Report, September 2016

C-Band Planning & Standards

TC-C2 Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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
  - UAS-Comm-4.3-016-001, Spectrum Element C-Band Planning and Standards Dev Plan, Paper, January 2014
  - UAS-Comm-4.3-034-001, C-Band Planning and Standards Development Interim Progress and Status Report, Paper, September 2015
  - UAS-Comm-4.3-053-001, C-Band Planning & Standards Final, Report, September 2016

Flight Test Radio Model Development and Regional Sims

TC-C2 Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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
  - UAS-Comm-4.3-037-001, Large Scale Communications Architecture Sims with Gen 2 Radio Model System Characterization and Performance Report, Report, January 2015
  - UAS-Comm-4.3-045-001, CNPC Gen 5 Regional Sim Report, Report, July 2016

ACES Sim Operations w/Flight Test Models

TC-C2 Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP C.4.20] ACES Sim Operations w/Flight Test Models	7/2014	• Perform regional large scale simulations to assess CNPC system performance. (Gen 1)	• Results inform understanding of: • Impact of introducing UAS CNPCs on existing NAS communication system performance • NAS communication system operations for proposed UAS relay and non-relay communication architecture • Scalability of CNPC system • Impact of CNPC system on existing NAS communication systems or other NAS traffic

- Briefings, Papers, or Reports
  - UAS-Comm-4.3-036-001, UAS-NAS -Large Scale Communication Architecture Simulations with NASA GRC Gen 5 Radio Model, Paper, October 2015

Recommendations for Integration of CNPC and ATC Comm

TC-C2 Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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
  - UAS-Comm-4.3-055-001, Analysis Results and Recommendations for Integration of CNPC and ATC communications Simulation, Report, September 2016

Communication System Performance Impact Testing (Delays/Capacity)

TC-C2 Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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

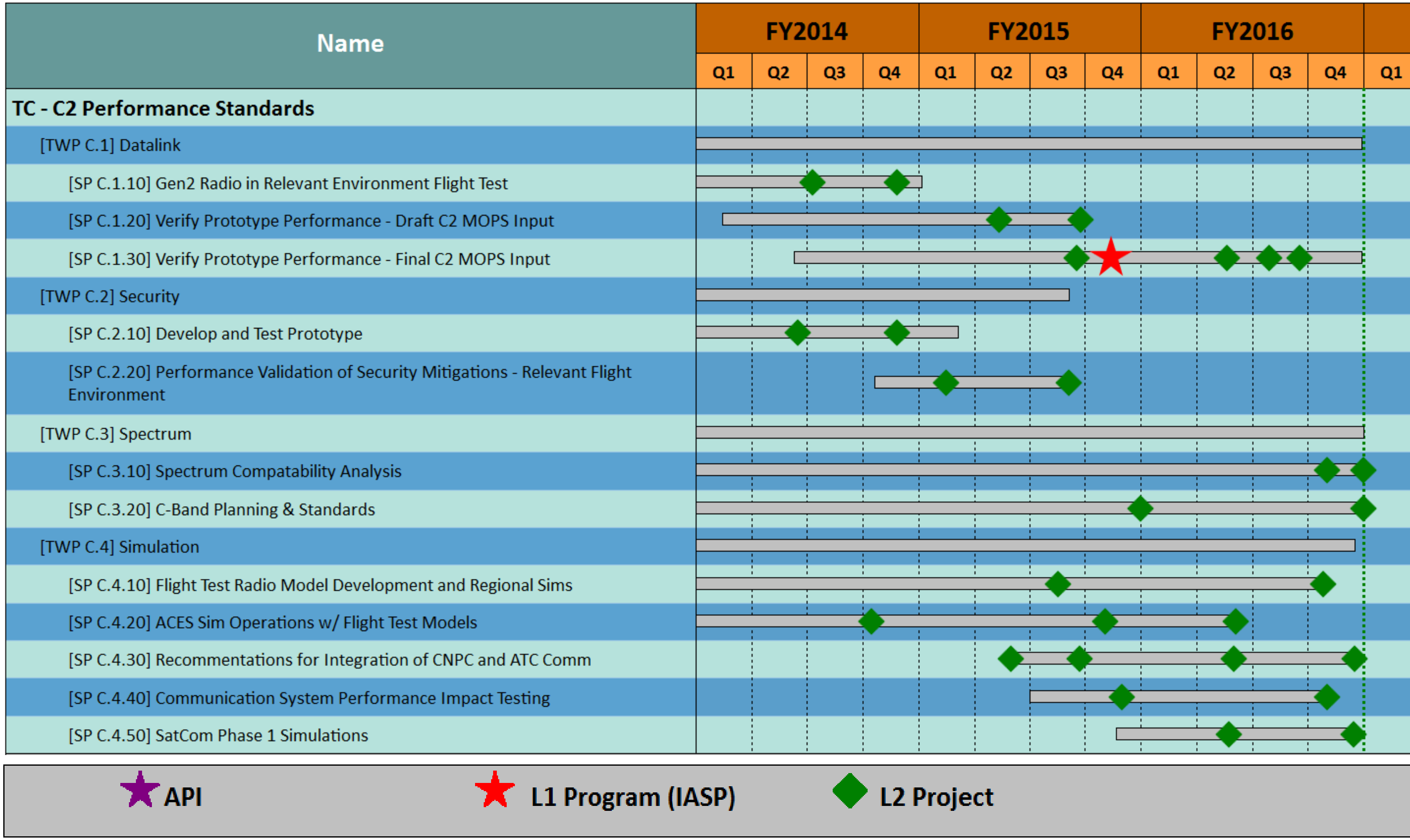
- Briefings, Papers, or Reports
  - UAS-Comm-4.3-042-001, UA Comm Impact on NAS Capacity and Delay, Paper, August 2016

SatCom Simulations

TC-C2 Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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
  - UAS-Comm-4.3-050-001, UAS in the NAS SatCom for UAS Simulation Report, September 2016, Not for public release

TC–C2

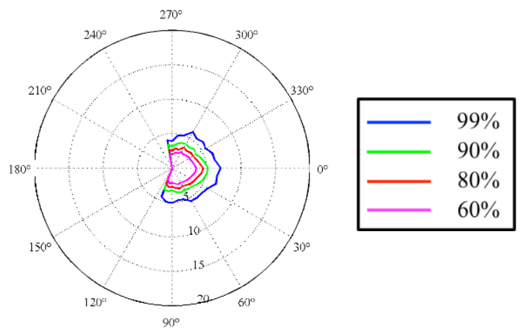


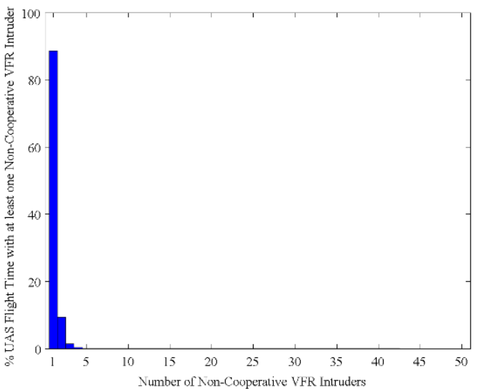
Green Status Line Date 9/30/16

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:





- **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-nmdeclaration 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

Sub-function Tradeoffs w/UAS Performance (ACES Simulation)

- **Research Objective:**
  - Analyze the tradeoffs in the performance of different SAA sub-functions (i.e. Evaluate, Determine, Command, Execute) using mitigated (Autoresolver) SAA encounters

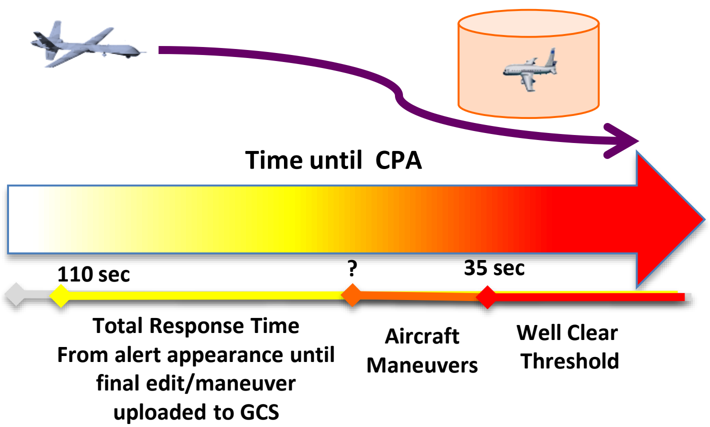
Activity expected to complete during Q1FY17

- **Results, Conclusions, and Recommendations:**

Self-Separation System Sub-Function Performance 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.



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

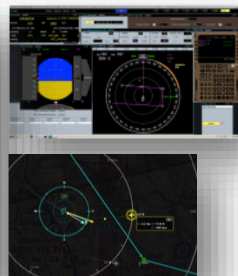
- **Results, Conclusions, and Recommendations:**
  - Resolution horizontal miss distance buffer had negligible impact on Risk Ratio (may need larger buffers)
  - Increasing self-separation threshold demonstrated greatest Risk Ratio reduction : Highlights importance of pilot response modeling to DAA risk 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

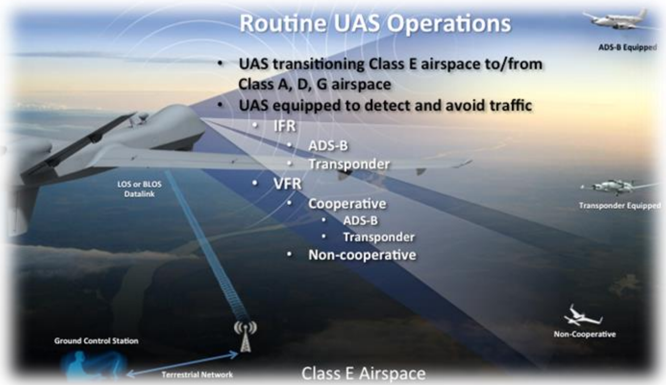
SSI-ARC FT3 Participation & Data Collection

- **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

Research GCS



Displays of Proximal Traffic
SAA/DAA Algorithms



AFRC Ikhana

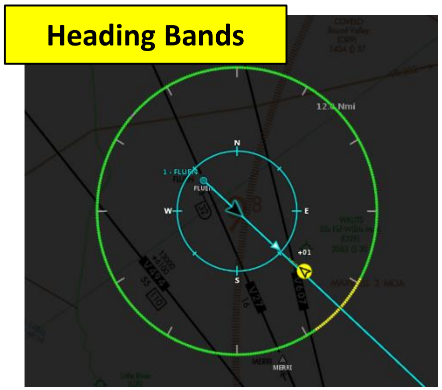
Live Intruder
- ***ADS-B***
- ***TCAS II Instm***
- ***High speed***

- **Results, Conclusions, and Recommendations:**
  - The analysis of Flight Test Series 3 data was primarily focused on assessing the effects of surveillance sensors on trajectory prediction accuracy and DAA alerting performance
  - Vertical separation errors for radar-derived trajectories were found to be an order of magnitude greater than ADS-B trajectories at look-ahead times between 110 and 120 seconds
  - Mean predicted vertical separation error was nearly 3000 feet with the radar compared to less than 500 feet with ADS-B for the same scenarios
  - The application of a Kalman filter to the radar altitude and vertical speed measurements could reduce the predicted vertical separation errors to levels comparable to that of ADS-B without an unacceptable amount of lag

Self-Separation System Performance Requirements for DAA MOPS

SSI-ARC FT4 Participation & Data Collection

- **Research Objectives:**
  - Determine the performance of a SAA concept and 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



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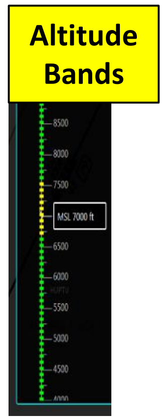
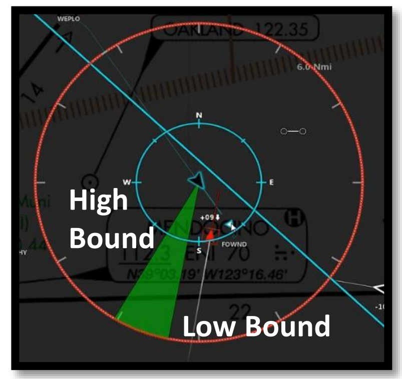
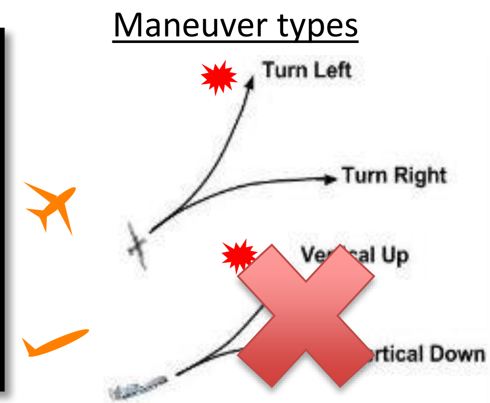






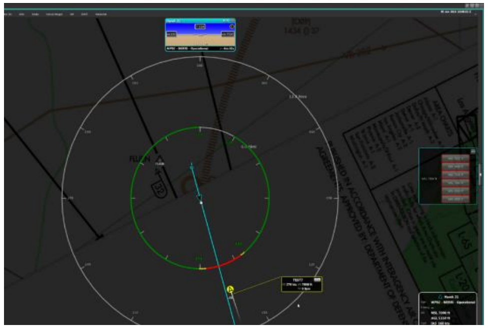
- **Results, Conclusions, and Recommendations:**
  - A wide array of encounters were successfully executed to evaluate the performance of prototype DAA alerting and guidance logic in a realistic environment
  - Alert timing was largely acceptable, providing ample time for pilot to evaluate guidance and maneuver aircraft in most encounters
  - Well Clear Recovery guidance was of limited utility for intruders lacking ADS-B
  - Stability of guidance for Mode C intruders appears adequate, but further investigation is warranted due to the limited sample size, particularly for high-speed, Mode C intruders

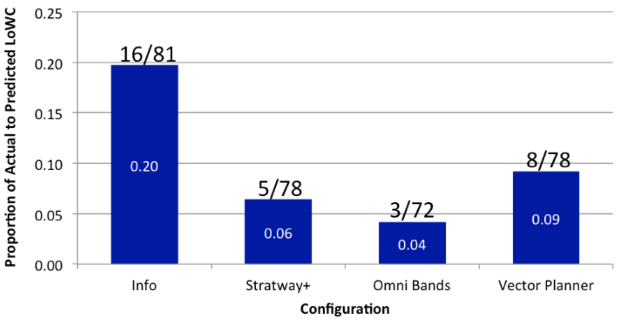
Self-Separation System Performance Requirements for DAA MOPS

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)

Symbol	Name	Pilot Action	Buffered Well Clear Criteria	Time to Loss of Well Clear	Aural Alert Verbiage
	Self Separation Warning Alert	• ***Immediate action required*** • Notify ATC as soon as practicable after taking action	DMOD = 0.75 nmi HMD = 0.75 nmi ZTHR = 450 ft modTau = 35 sec	25 sec (TCPA approximate: 60 sec)	"Traffic, Maneuver Now"
	Corrective Self Separation Alert	• On current course, ***corrective action required*** • Coordinate with ATC to determine an appropriate maneuver	DMOD = 0.75 nmi HMD = 0.75 nmi ZTHR = 450 ft modTau = 35 sec	75 sec (TCPA approximate: 110 sec)	"Traffic, Separate"
	Preventive Self Separation Alert	• On current course, corrective action ***should not be required*** • Monitor for intruder course changes • Talk with ATC if desired	DMOD = 0.75 nmi HMD = 1.0 nmi ZTHR = 700 ft modTau = 35 sec	75 sec (TCPA approximate: 110 sec)	"Traffic, Monitor"
	Self Separation Proximate Alert	• Monitor target for potential increase in threat level	DMOD = 0.75 nmi HMD = 1.5 nmi ZTHR = 1200 ft modTau = 35s	85 sec (TCPA approximate: 120 sec)	N/A
	None (Target)	• No action expected	Within surveillance field of regard	X	N/A



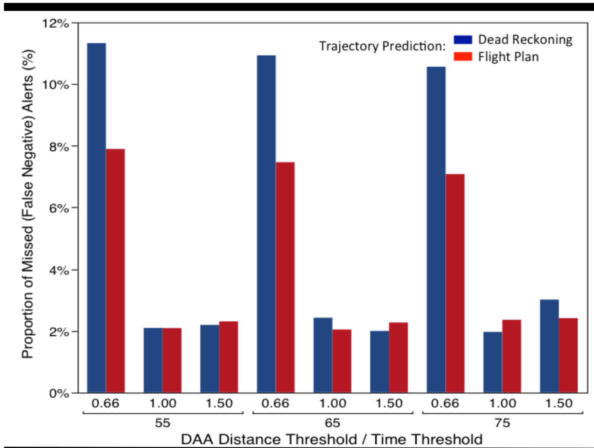


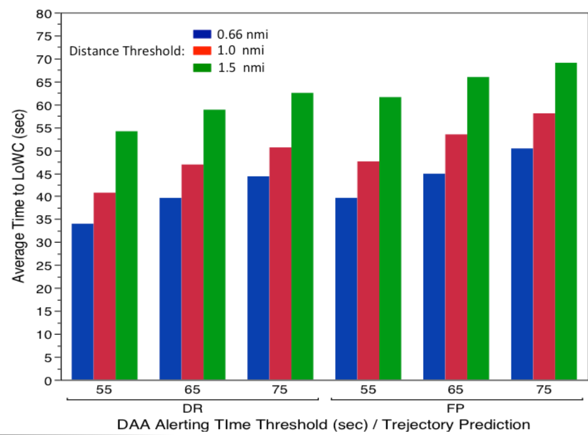
- ## Results, Conclusions, and Recommendations:
  - Info Only (19.8%) was roughly *four times* as likely as Stratway+ (6.5%) and Omni Bands (4.2%) to result in Loss of Well Clear, a significant difference (p<.05)
  - No significant differences seen between the three guidance displays in terms of Loss 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

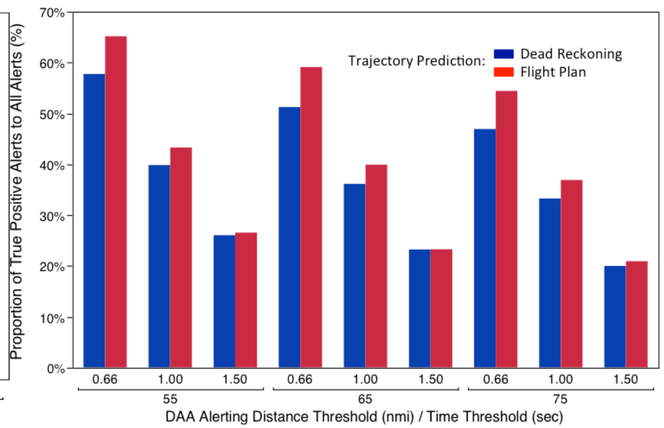
Self-Separation Sensor Performance Requirements for DAA MOPS

Effect of SAA Maneuvers with Procedures (ACES Simulation)

- **Research Objective:**
  - 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





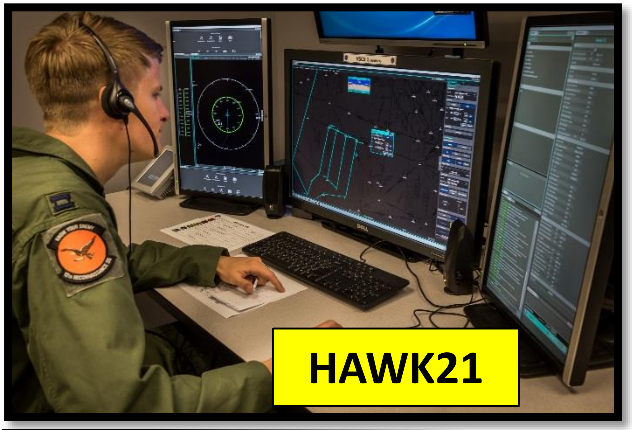


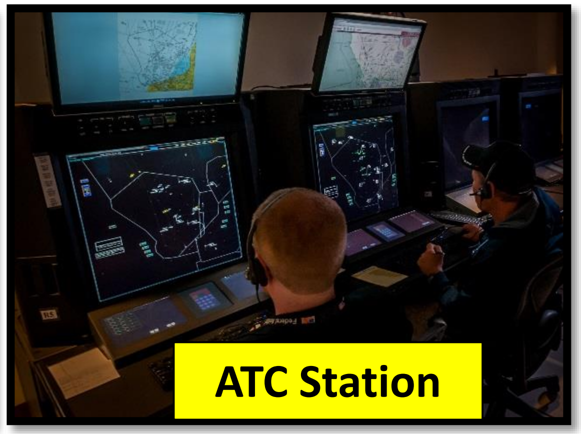
- **Results, Conclusions, and Recommendations:**
  - The DAA alerting distance threshold parameter has a key role in reducing missed alerts and increasing alert lead time
  - The missed alert rate dropped significantly from ~11 % to ~2 % when the alerting distance threshold increased from 0.66 nmi to 1.0 nmi.
  - When the alerting distance threshold was increased from 0.66 nmi to 1.5 nmi, the average time to actual LoWC was increased by 20 seconds
  - While increased distance thresholds have beneficial effects on alert lead time and missed alert rate, they also generate higher false alert rates

Self-Separation System Performance Requirements for DAA MOPS

Part Task Simulation 6: Full Mission 2

- **Research Objectives:**
  - Evaluate the pilot's ability to remain clear with DAA prototype system that captures draft DAA MOPS requirements
  - Study DAA self-separation and TCAS interoperability challenges
  - Additional details:
    - Evaluate boundary between self separation and automatic collision avoidance mode
    - Demonstrate operation of an instantiation of a Ground Control Station illustrating one manner of compliance with GCS guidelines





- **Results, Conclusions, and Recommendations:**
  - Overall pilot performance was consistent with previous simulations when using minimum display, alerting & guidance requirements
    - LoWC most common with less than 25 sec to loss of well clear at time of first alert
    - 75 TCAS RAs issued throughout first half of data collection
      - 71 RAs did not lose well clear, RA Compliance Rate = 70% (50/71) when well clear was not lost. No pilot flew in opposite sense of RA guidance (disregarded)
      - 4 RAs lost well clear, 3 were Warning at First Alert (insufficient time to respond),1 Corrective at First Alert
    - RA Compliance Rate = 100%, compliance within 6 sec
  - Data supports display, alerting & guidance requirements as currently drafted

Results Contributed to the V&V of DAA Alerting and Guidance Requirements in the MOPS

DAA Self-Separation Alerting Methods, Performance, and Robustness Study (ACES Simulation)

- **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

Symbol	Name	Pilot Action	Buffered Well Clear Criteria	Time to Loss of Well Clear	Aural Alert Verbiage
	Self Separation Warning Alert	• ***Immediate action required*** • Notify ATC as soon as practicable after taking action	DMOD = 0.75 nmi HMD = 0.75 nmi ZTHR = 450 ft modTau = 35 sec	25 sec (TCPA approximate: 60 sec)	"Traffic, Maneuver Now"
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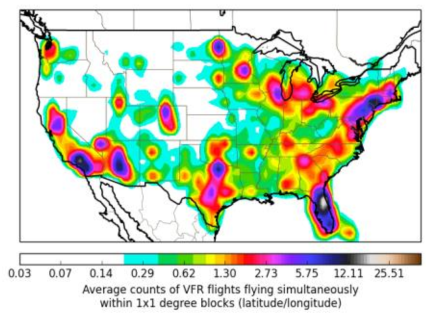
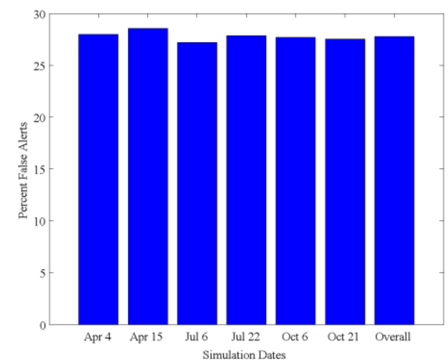




- **Results, Conclusions, and Recommendations:**
  - Correct SS Warning Alerts alerts have at least 15 seconds of lead time to LOWC in 83% of cases
  - 72% of Warning alerts resulted in a loss of well clear suggest alerting criteria is within suitable performance bounds
  - Even though the probability 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)

Self-Separation Alerting Requirements for DAA MOPS

Sensor Uncertainty Mitigation for Guidance and Alerting

- **Research Objective:**
  - Develop mitigations for the noise and uncertainty inherent in surveillance data so that the output of the Detect and Avoid algorithm is smooth and well-behaved

Activity expected to complete during Q1FY17

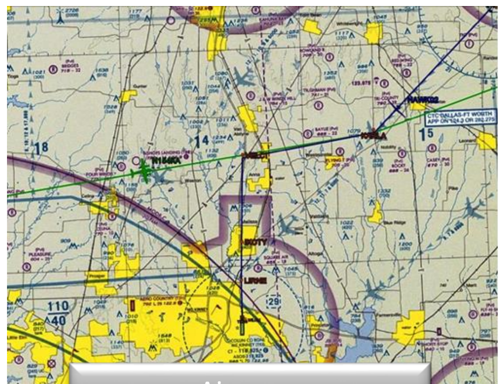
- **Expected Results, Conclusions, and Recommendations:**

Unmanned Aircraft – DAA Sensor Uncertainty Mitigation for DAA MOPS

SSI-LaRC Support & Participation in IHITL

- **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

Boeing 747



Airspace

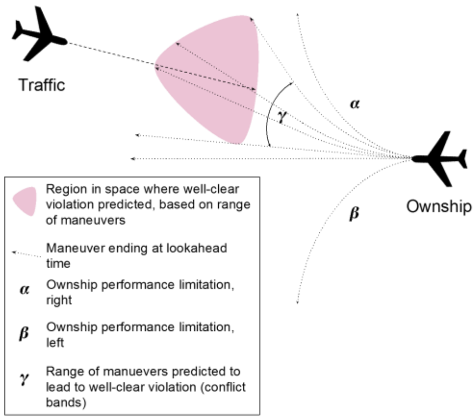
MACS GCS Stratway+

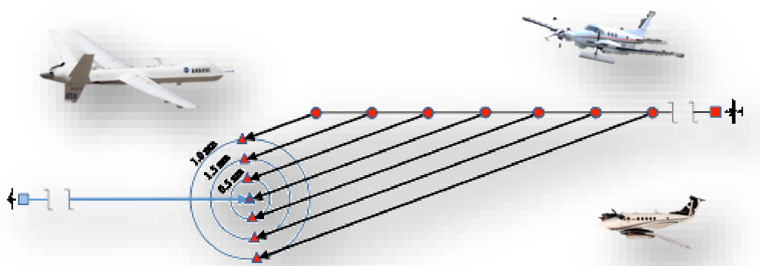
- **Results, Conclusions, and Recommendations:**
  - Simulation shows to maintain Well Clear and avoid almost all TCAS Resolution Advisories:
    - Above 10,000 feet w/ typical airliner speeds – need at least 1.5 nm Closet Point of Approach
    - Below 10,000 feet below 250 knots, need at least 1.2 nm Closet Point of Approach

DAA – TCAS & ATC Interoperability Requirements for DAA MOPS

SSI LaRC Support & Participation in FT4

- **Research Objectives:**
  - 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)



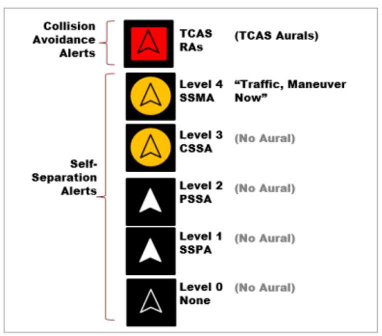


- **Results, Conclusions, and Recommendations:**
  - Extensive encounter geometries, speed combinations, and intruder combinations tested
  - DAA algorithm performance verified in numerous conditions
  - DAA algorithm successfully provides avoidance maneuver guidance
  - Algorithm performance parameters tuned and verified

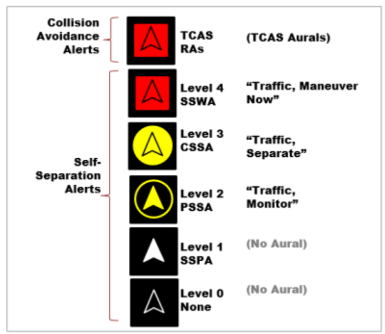
Self-Separation System Performance Requirements for DAA MOPS

Alerting Times + Collision Avoidance-Self Separation Integration Combined HITL

- **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

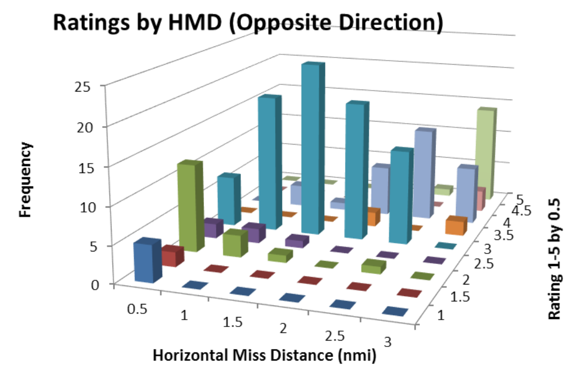


CASSAT DAA Alert Structure + TCAS CA



Draft MOPS DAA Alert Structure + TCAS CA

DAA Alerting



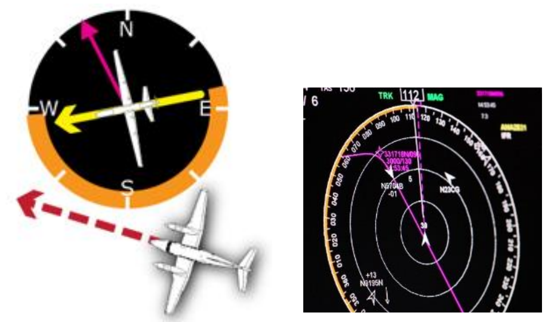
Horizontal Miss Distance Results

- **Results, Conclusions, and Recommendations:**
  - 1.0 – 2.0 nmi horizontal miss distance is range of acceptability for Air Traffic Controllers
  - Modified structure of alerting for intruder aircraft is more acceptable to UAS operators and provides interoperability with TCAS
  - Acceptable range of alert times for intruder aircraft established for operators and controllers

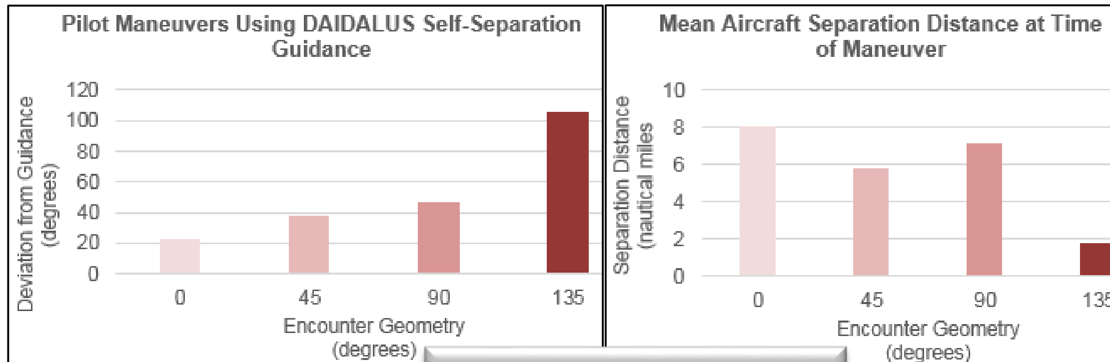
Automated Self-Separation Maneuver Requirements for DAA MOPS

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



Display Guidance



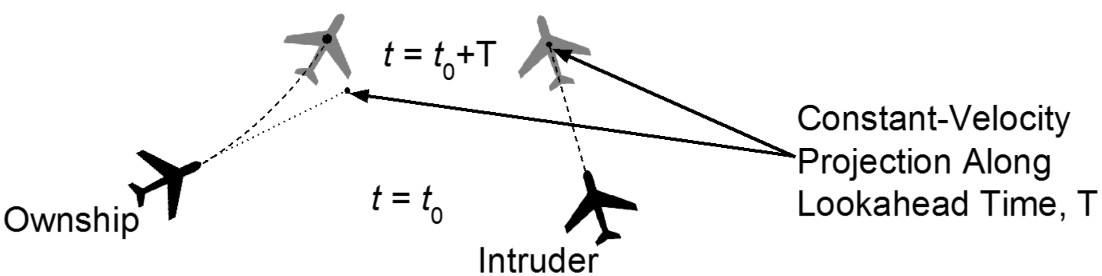
Results

- **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

DAA System Maturation for Development and V&V of DAA MOPS

DAIDALUS V&V

- **Research Objective:**
  - Formally verify and validate (V&V) the DAIDALUS software as the reference algorithm included in the SC-228 UAS Minimum Operational Performance Standards (MOPS) for sense and avoid (SAA) performance and interoperability.



DAIDALUS

- **Results, Conclusions, and Recommendations:**
  - Well-clear concept and DAIDALUS core algorithms have been formally specified and verified for functional correctness in the *Prototype Verification System* (PVS)
  - Prototype implementations in both Java and C++ have been validated against formal models (PVS) using stressing case scenarios
  - The stakeholder can have high confidence in the proper functioning of the reference algorithm published in the Phase I Minimum Operational Performance Standards (MOPS for UAS Detect and Avoid system.
  - Reference implementation available to public; used by industry, other government agencies

MOPS Reference Implementation Verified With Confidence

Surveillance Requirements (Medium Fidelity) (ACES Simulation)

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS

[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
  - UAS-SSI-4.1-067-001, Analysis of UAS DAA Surveillance in Fast-Time Simulations without DAA Mitigation, Briefing, October 2015

Interoperability of Self Separation and Collision Avoidance Functions (ACES Simulation)

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP S.1.30] Interoperability of Self Separation and Collision Avoidance Functions (ACES Simulation)	4/2016	• Analyze the interoperability of self separation and collision avoidance algorithms and the level of integration required for self separation and collision avoidance algorithms	• Results inform: • Guidelines for ensuring self separation and collision avoidance algorithms are compatible • Development of SAA system performance guidelines and MOPS

- Briefings, Papers, or Reports
  - UAS-SSI-4.1-081-001, ACES M&S - Unmitigated Factorial Encounter Study on DAA-TCAS Interoperability, Briefing, July 2016
  - UAS-SSI-4.1-084-001, SC--228 Defining the Collision Avoidance Region for DAA Systems, Paper, August 2016

Sub-function Tradeoffs w/UAS Performance (ACES Simulation)

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP S.1.40] Sub-function Tradeoffs w/UAS Performance (ACES Simulation)	3/2016	• Analyze the tradeoffs in the performance of different SAA sub-functions (i.e. Evaluate, Determine, Command, Execute) using mitigated (Autoresolver) SAA encounters	• Results inform: • Performance requirements for SAA systems • DAA MOPS • Tradeoffs among different DAA sub-functions

- Briefings, Papers, or Reports
  - Sub-function Tradeoffs w/UAS Performance Brief to SC-228 planned for December 2016
  - ACES Simulation report planned for December 2016

Self-Separation Risk Ratio Study

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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, August 2014
  - UAS-SSI-4.1-039-001, ACES Mitigated Results Supporting Selection of SARP Well-Clear Definition Maneuver Initiation Point MIP, Briefing, August 2014
  - UAS-SSI-4.1-040-001, ACES Unmitigated and some Mitigated Results Supporting Selection of SARP Well Clear Definition, Briefing, August 2014
  - UAS-SSI-4.1-042-001, Encounter Rate Simulation Study with UAS Missions, Briefing, September 2014
  - UAS-SSI-4.1-060-001, Airspace Safety Threshold Study- NAS-wide Encounter Rate Evaluation using Historical Radar Data and ACES, Briefing, May 2015
  - UAS-SSI-4.1-071-001, Evaluating Alerting and Guidance Performance of a UAS Detect and Avoid System, Report, February 2016, Associated with S.2.70

SSI-ARC FT3 Participation & Data Collection

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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
  - UAS-SSI-4.1-074-001, FT3 Final Report FT3 Data Analysis of JADEM, Paper, May 2016
  - FT3 Participation & Data Collection SSI ARC FT3 brief results to SC-228 planned for October 2016

SSI-ARC FT4 Participation & Data Collection

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS

[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
  - UAS-SSI-4.1-080-001, FT4 JADEM Preliminary Results, Briefing, July 2016
  - FT4 Participation & Data Collection SSI ARC FT4 report/paper planned for October 2016

SAA Traffic Display Evaluation HITL2 (joint w/HSI Part Task Sim 5)

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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
  - UAS-SSI-4.1-072-001, Piloted Well Clear Performance Evaluation Detect and Avoid Systems with Suggestive Guidance, Report, March 2016

Effect of SAA Maneuvers with Procedures (ACES Simulation)

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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
  - UAS-SSI-4.1-049-001, UAS DAA SS Risk Ratio Study AKA Effect of SAA Maneuvers with Procedures Experiment Design Review, Brief, September 2014
  - UAS-SSI-4.1-071-001, Evaluating Alerting and Guidance Performance of a UAS Detect and Avoid System, Report, February 2016, Associated with S.2.30

Part Task Simulation 6: Full-Mission 2

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS

[SP S.2.90] Part Task Simulation 6: Full-Mission 2	10/2015	• Evaluate the pilot's ability to remain clear with DAA prototype system that captures draft DAA MOPS requirements.
		• Study DAA self-separation and TCAS interoperability challenges.
			• Results inform:
			  • Pilot's ability to remain clear with DAA prototype system (that captures draft DAA MOPS requirements)
			  • DAA self-separation and TCAS interoperability

- Briefings, Papers, or Reports
  - UAS-SSI-4.1-083-001, PT6 V&V Simulation Prelim Results, Briefing, July 2016

DAA Self-Separation Alerting Methods, Performance, and Robustness Study (ACES Simulation)

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP S.3.30] DAA Self-Separation Alerting Methods, Performance, and Robustness Study (ACES Simulation)	3/2015 (Phase 1) 7/2015 (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

- Briefings, Papers, or Reports
  - UAS-SSI-4.1-050-001, UAS DAA Alerting Studies and ACES Fast Time Simulation, Brief, February 2015
  - UAS-SSI-4.1-061-001, Analysis of Baseline PT5 Alerting Scheme in Fast-Time Simulations without DAA Mitigation, Briefing, May 2015
  - UAS-SSI-4.1-066-001, Analysis of UAS DAA Alerting in Fast-Time Simulations without DAA Mitigation, Briefing, October 2015

Sensor Uncertainty Mitigation for Guidance and Alerting

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP S.4.30] Sensor Uncertainty Mitigation for Guidance and Alerting	3/2016	• Develop mitigations for the noise and uncertainty inherent in surveillance data so that the output of the Detect and Avoid algorithm is smooth and well-behaved	• Results inform: • Sensor Uncertainty Mitigation for Guidance and Alerting • DAA requirements • DAA MOPS

- Briefings, Papers, or Reports
  - UAS-SSI-4.1-076-001, Sensor Uncertainty Mitigation Study, Briefing, May 2016
  - Sensor Uncertainty Mitigation for Guidance and Alerting Report planned for November 2016

SSI-LaRC Support & Participation in IHITL

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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, November 2014
  - UAS-SSI-4.1-053-001, UAS Air Traffic Controller Acceptability Study 2 - Effects of Communications Delays and Winds in Simulation, Paper, May 2015
  - UAS-SSI-4.1-068-001, UAS Air Traffic Controller Acceptability Study 2 - Evaluating Detect and Avoid Technology and Communication Delays in Simulation, Report, December 2015

SSI LaRC Support & Participation in FT4

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS

[SP S.5.50] SSI LaRC Support & Participation in FT4	2/2016	• 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)
			• 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

- Briefings, Papers, or Reports
  - UAS-SSI-4.1-085-001, FT4 DAIDALUS Test Prelim Results, Briefing, September 2016
  - SSI LaRC Support & Participation in FT4 Brief Results to SC-228 planned for October 2016
  - SSI LaRC FT4 report/paper planned for October 2016

Alerting Times + Collision Avoidance-Self Separation Integration Combined HITL

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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, March 2015
  - UAS-SSI-4.1-073-001, UAS Human in the Loop Controller and Pilot Acceptability Study- Collision Avoidance, Self Separation and Alerting Times, Report, April 2016
  - UAS-SSI-4.1-082-001, CASSAT Study- Effects of Horizontal Miss Distances and Alert Times on Manned - UA Encounters, Briefing, July 2016

GA-FAA (SAA Initial Flight Tests) Flight Test Participation w/IT&E

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
  - None

DAIDALUS V&V

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP S.8.10] DAIDALUS (Detect and Avoid Alerting Logic for Unmanned Systems) V&V	9/2016	• Verify and validate DAIDALUS (Detect and Avoid Alerting Logic for Unmanned Systems)	• Results inform: • Verification and Validation of DAIDALUS (Detect and Avoid Alerting Logic for Unmanned Systems) as described in an appendix to the DAA MOPS

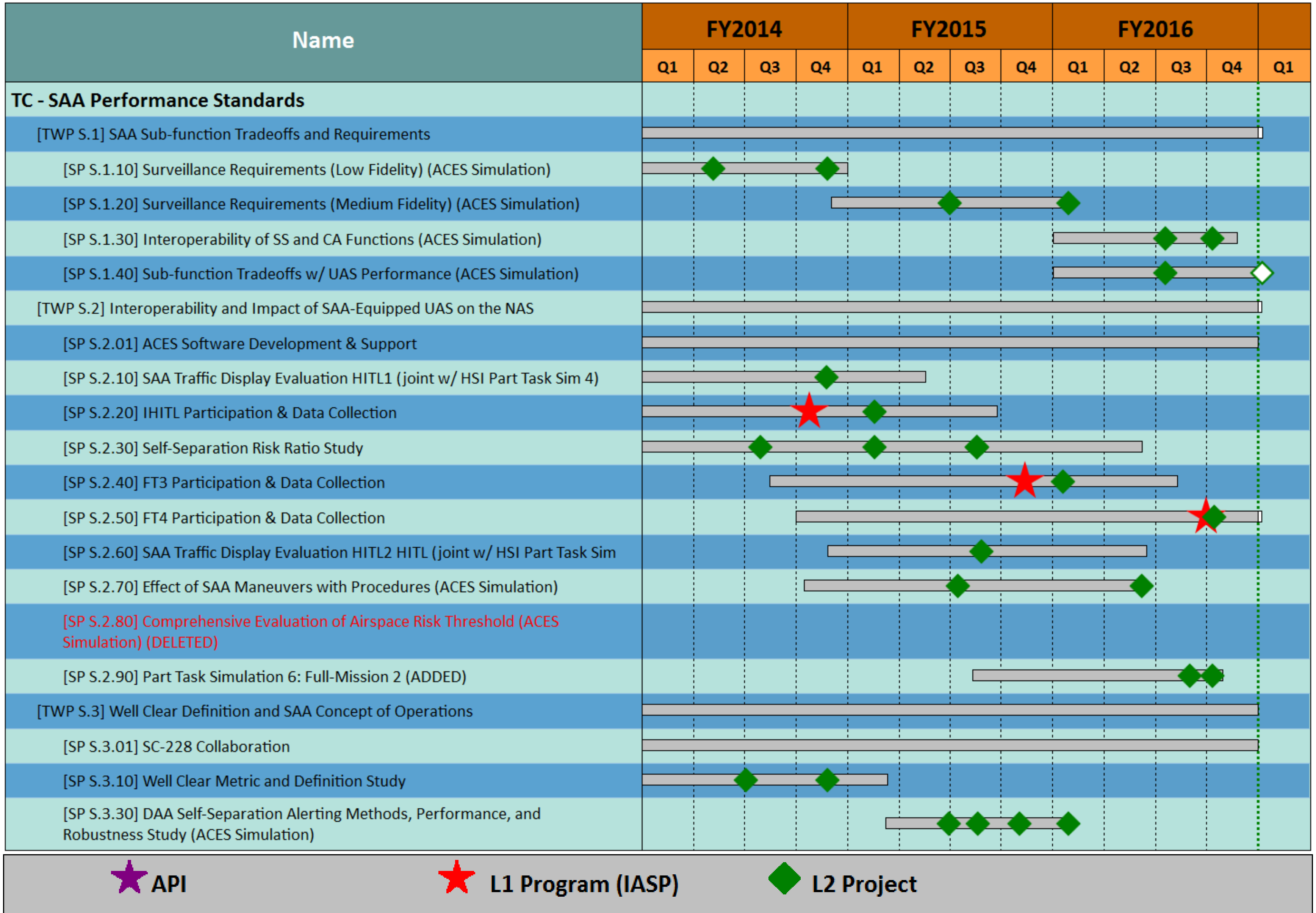
- Briefings, Papers, or Reports
  - DAIDALUS (Detect and Avoid Alerting Logic for Unmanned Systems) V&V briefing planned for October 2016

End to End V&V (E2V2)

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP S.8.20] End to End V&V	8/2016	• Verify and validate the end-to-end Detect and Avoid system as outlined in the MOPS.	• Results inform: • End-to-End Verification and Validation of a Detect and Avoid system as described in the DAA MOPS

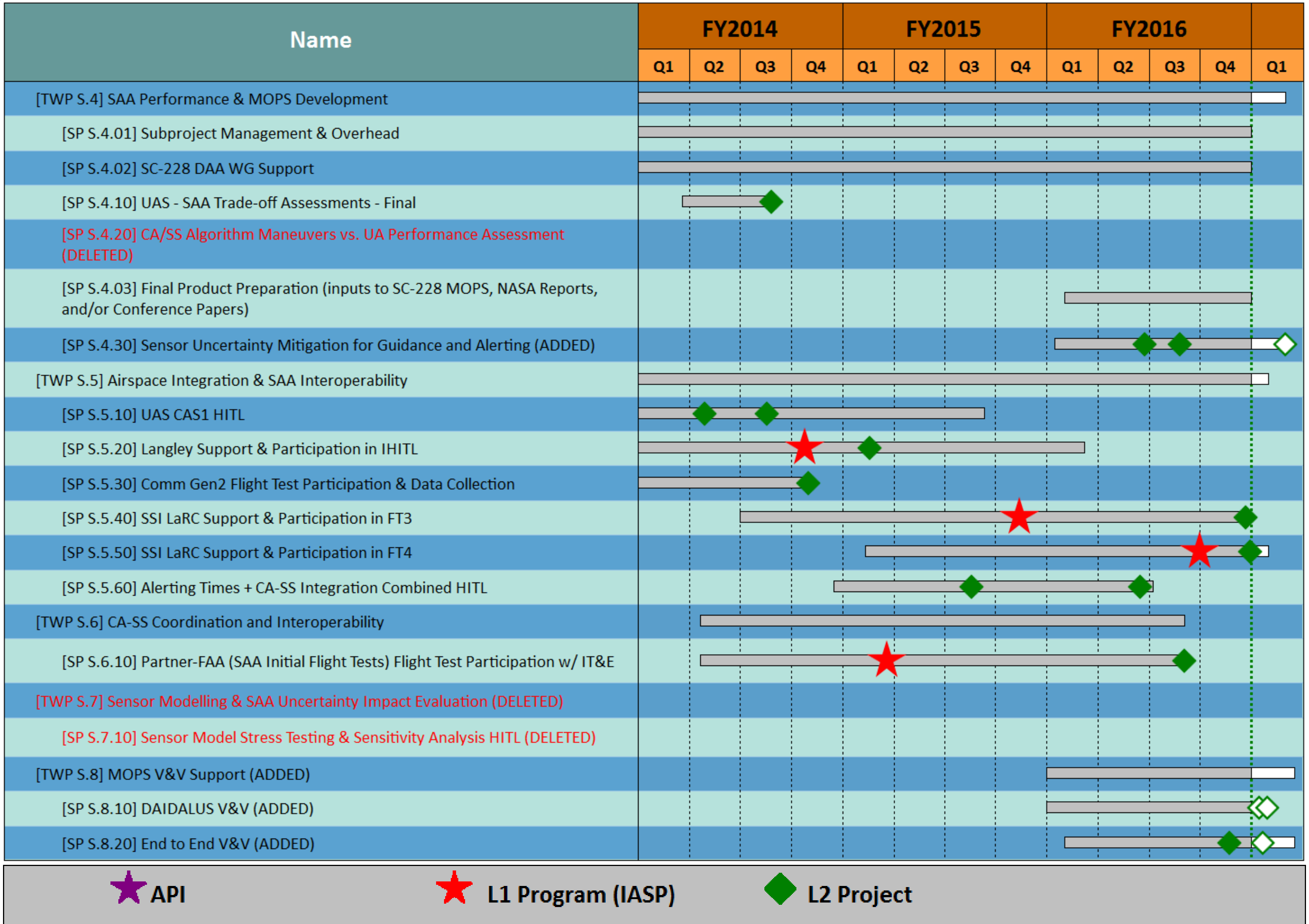
- Briefings, Papers, or Reports
  - End-to-End V&V briefing planned for October 2016
  - End-to-End V&V report planned for December 2016

TC–SAA (1 of 2)



Green Status Line Date 9/30/16

TC–SAA (2 of 2)



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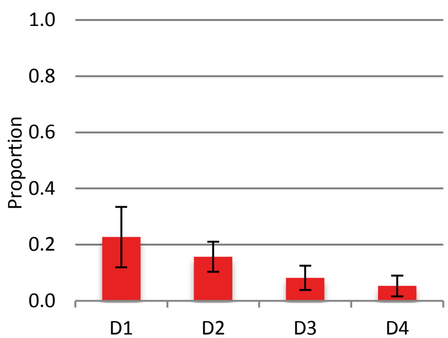
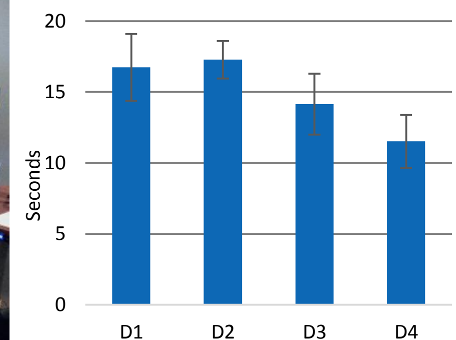
HSI IHITL Participation & Data Collection

- **Research Objective:**
  - Evaluate the individual contribution of various advanced detect and avoid tools from previous simulation (PT4) on pilots' performance of the traffic avoidance function
    - Comparison of *informative*, *suggestive* and *directive* decision aiding tools on pilots' response times and ability to maintain well clear



Proportion of LoWC


RGCS and Researcher Stations



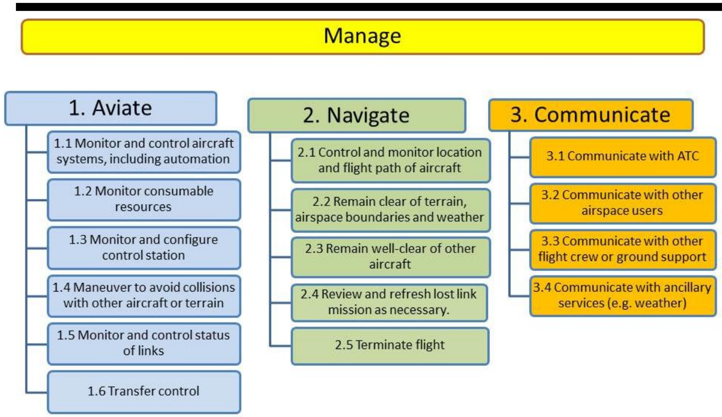
Total Response Time

- **Results, Conclusions, and Recommendations:**
  - Integration of *directive* maneuver guidance and GCS control and navigation interface in the D3 and D4 configurations led to a trend in lower total response times and proportions of losses of well clear (LoWC)
  - Results contributed to SC-228 DAA Working Group making a decision for suggestive displays as minimum.
  - Recommendation to study the effect of information only versus suggestive guidance displays that were decoupled from the control and navigation interface on pilot performance in follow on study.

GCS Information Guidelines/Requirements for DAA and C2 MOPS

GCS HF Final Guidelines

- **Research Objective:**
  - Develop GCS Guidelines



Guidelines were organized using a model of remote pilot responsibilities.

Example guidelines

- The aural warning for lost control link should be a unique sound, not also used to signify other conditions.
- The RPS should enable the pilot to set the duration of a link outage that must occur before a lost link response is triggered.
- Two distinct and dissimilar actions of the RPAS crew should be required to initiate the flight termination command.
- Payload controls should be separate from controls with safety-of-flight functions.

Results, Conclusions, and Recommendations:

- Final guidelines document received 1676 approval, and was delivered to project
  - 160 guidelines on UAS-specific issues.
  - Five types of guidelines: Performance-based, Displays, Controls, Interface properties, General.
  - Guidelines adopt ICAO terminology and are not tied to specific designs or technologies.
- Final guidelines were revised to account for differences in terminology in ICAO and delivered to the RPAS Panel on Airworthiness/Remote Pilot Station for possible modification/inclusion in the RPAS manual.

Results Contribute to C2 MOPS/ ICAO RPAS Panel

HSI IHITL Participation & Data Collection

TC-HSI Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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, November 2014
  - UAS-HSI-4.2-036-001, An examination of UAS Pilots Interaction with ATC while responding to DAA Conflicts, Paper, June 2015
  - UAS-HSI-4.2-038-001, The Impact of Integrated Maneuver Guidance Information on UAS Pilots Performing the Detect and Avoid Task, Paper, October 2015, Associated with SP H.1.40
  - UAS-HSI-4.2-039-001, Effects of Display Location and Information Level on UAS Pilot Assessments of a Detect and Avoid System, Paper, October 2015

Part-task Simulation 5: SAA Pilot Guidance Follow-on

TC-HSI Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[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-4.2-032-001, PT5 DAA Display Evaluation Overview III, Briefing, June 2015
  - UAS-HSI-4.2-034-001, UAS-NAS Part Task 5 DAA Display Evaluation Primary Results, Briefing, May 2015
  - UAS-HSI-4.2-040-001, The Impact of Suggestive Maneuver Guidance on UAS Pilots Performing the Detect and Avoid Function, Paper, May 2015
  - NAS Compliant Ground Station Part-task Simulation 5 report planned for January 2016
  - Monk, K. & Roberts, Z. (2016). UAS Pilot Evaluations of Suggestive Guidance on Detect-and-Avoid Displays. *Proceedings of the Human Factors and Ergonomics Society 60th Annual Meeting,* Washington, D.C.

Part Task Simulation 6: Full Mission 2

TC-HSI Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS

[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

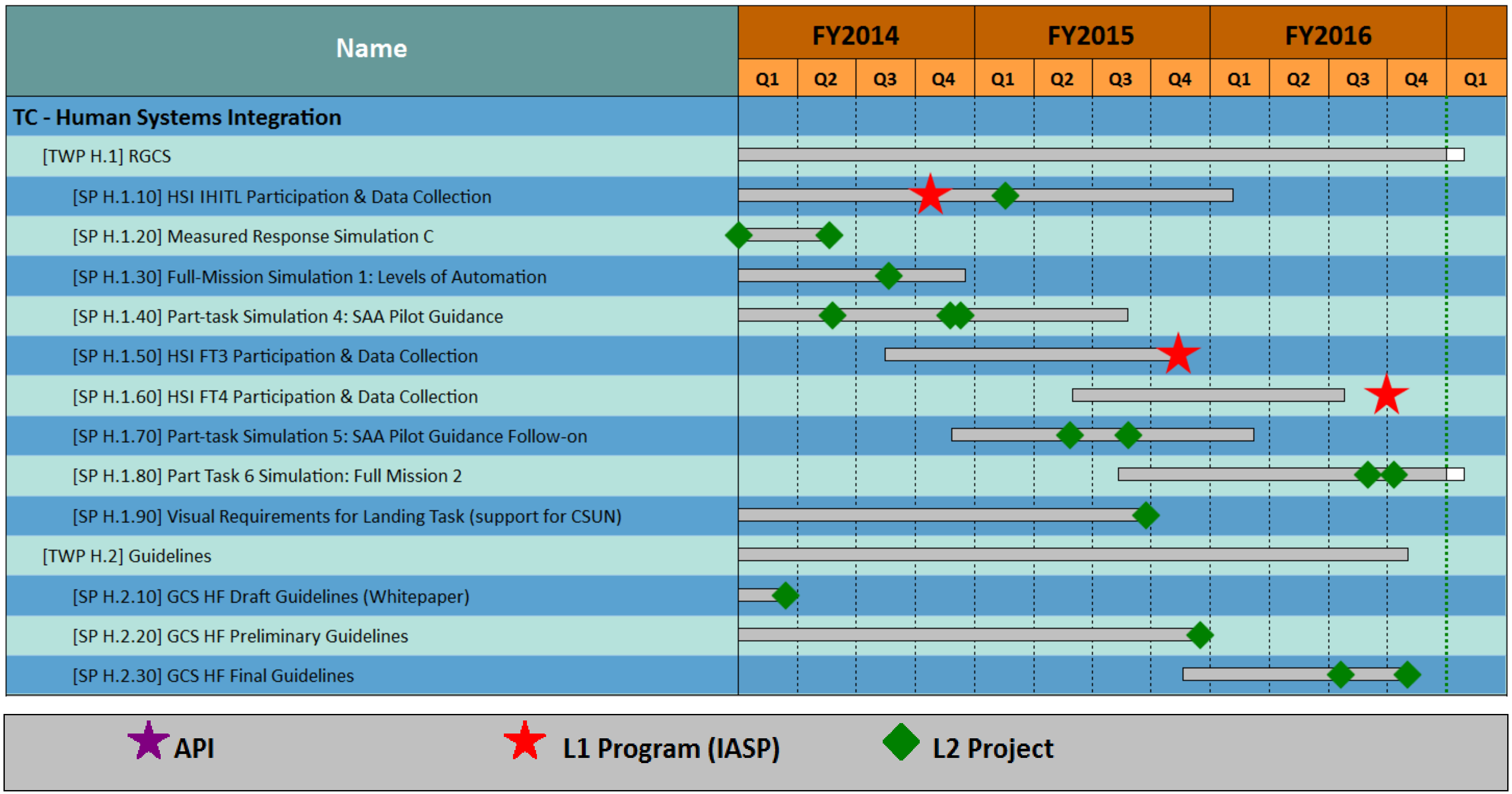
- Briefings, Papers, or Reports
  - UAS-HSI-4.2-044-001, PT6 V&V Simulation Primary Results, Briefing, July 2016
  - Compliant Ground Station Part-Task Simulation 6: Full-Mission 2 Results report planned September 2016

GCS HF Final Guidelines

TC-HSI Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[H.2.30] The HSI Subproject shall document Final GCS Human Factors Guidelines	6/30/2016	• Develop GCS Guidelines	• Results inform: • Guidelines for Ground Control Stations

- Briefings, Papers, or Reports
  - UAS-HSI-4.2-037-001, Human Factors Guidelines for UAS GCS (DRAFT), Paper, September 2015
  - UAS-HSI-4.2-046-001, GCS HF Guidelines for RPAS RDP, Paper, July 2016

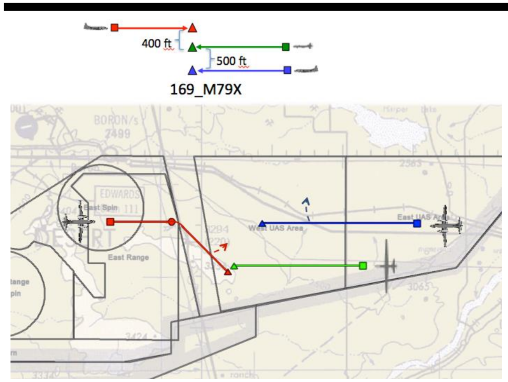
TC-HSI



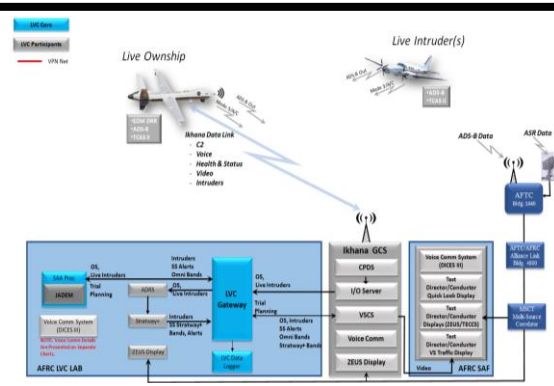
Green Status Line Date 9/30/16

FT3 Execution

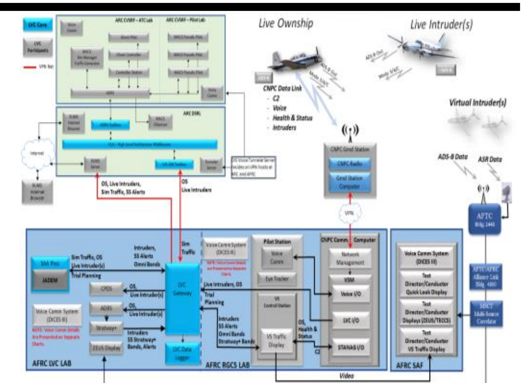
- **Research Objectives:**
  - Conduct Flight Test Series 3 integrating the latest SSI algorithms, Control and Non-Payload Communication System prototype, and HSI displays using the Live, Virtual, Constructive test environment
  - Document the performance of the test infrastructure in meeting the flight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



FT3 Scripted Encounter Example



Scripted Encounter Configuration



Full Mission Configuration

- **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

TC-ITE Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP T.1.10] Sim and Demo Planning Support	10/2013	• Not applicable	• Not applicable
[SP T.1.20] Submit LVC Leave behind document	10/2013	• Not Applicable	• Not Applicable

- Briefings, Papers, or Reports
  - UAS-ITE-5.1-022-001, LVC Leave Behind Capabilities, Report, September 2016

FT3 Execution & Relevant Environment Analysis

TC-ITE Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP T.4.50] FT3 Execution [SP T.4.60] FT3 Relevant Environment Analysis	6/2015	• 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	• Results inform acceptability of the live, virtual, constructive distributed test environment as a realistic test environment for use in verifying and validating MOPS

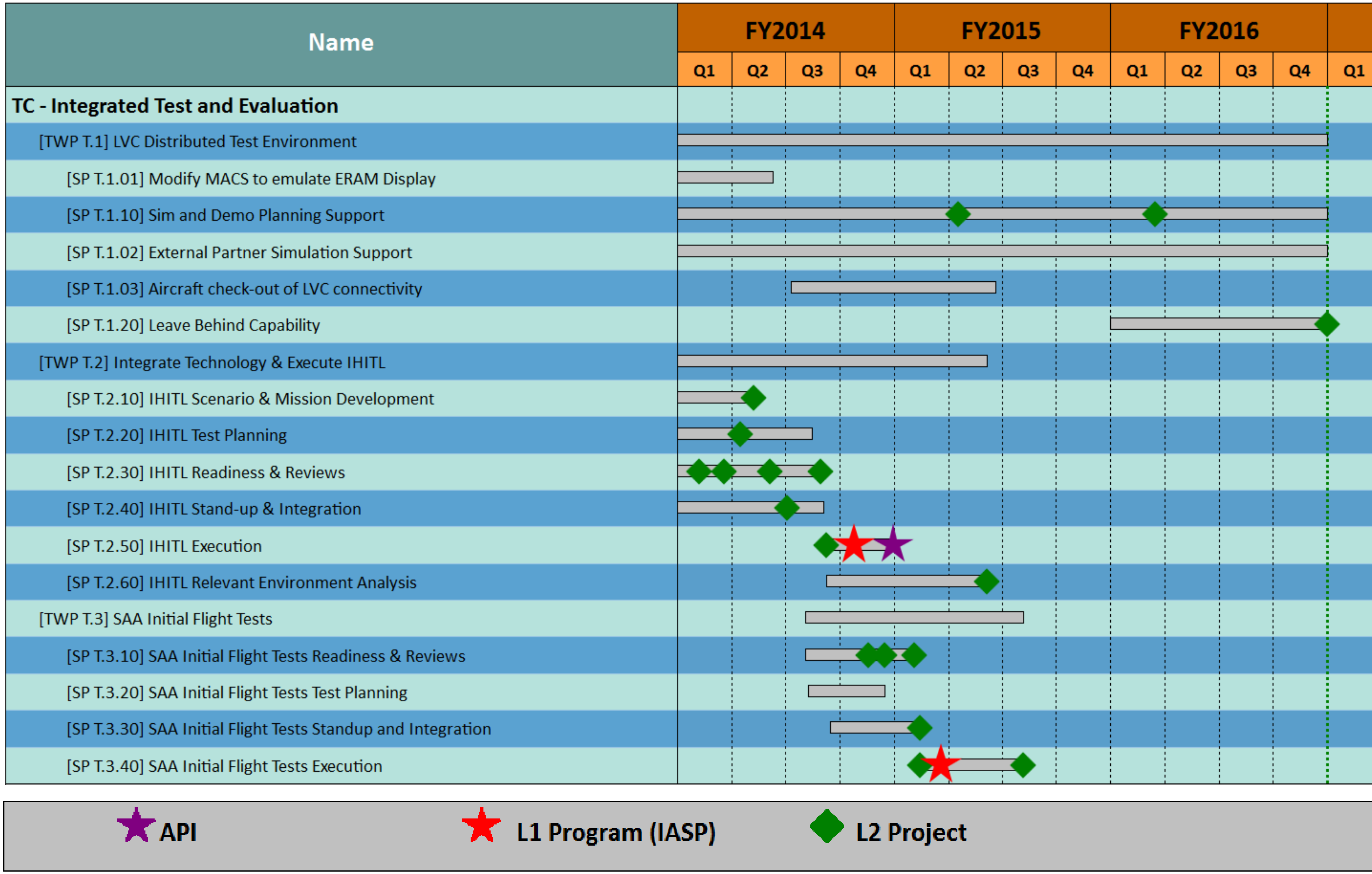
- Briefings, Papers, or Reports
  - UAS-ITE-5.1-010-001, FT3 Test Plan - Rev E, Plan, July 2015
  - UAS-ITE-5.1-011-001, FT3 Sortie Summary, Briefing, September 2015
  - UAS-ITE-5.1-014-001, Flight Test Series 3 Flight Test Report, Report, October 2015
  - UAS-ITE-5.1-018-001, FT3 Relevant Environment, Report, April 2016

FT4 Execution & Relevant Environment Analysis

TC-ITE Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP T.5.60] FT4 Execution [SP T.5.70] FT4 Relevant Environment Report	2/2016	• 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	• Results inform acceptability of the live, virtual, constructive distributed test environment as a realistic test environment for use in verifying and validating MOPS

- Briefings, Papers, or Reports
  - UAS-ITE-5.1-017-001, FT4 Test Plan, March 2016
  - UAS-ITE-5.1-019-001, FT4 Overview VIP Day, Briefing, May 2016
  - UAS-ITE-5.1-020-001, Stakeholder Feedback, Report, September 2016
  - UAS-ITE-5.1-021-001, FT4 Relevant Environment Evaluation, Report, September 2016
  - UAS-ITE-5.1-023-001, FT4, Report, September 2016

TC–ITE (1 of 2)



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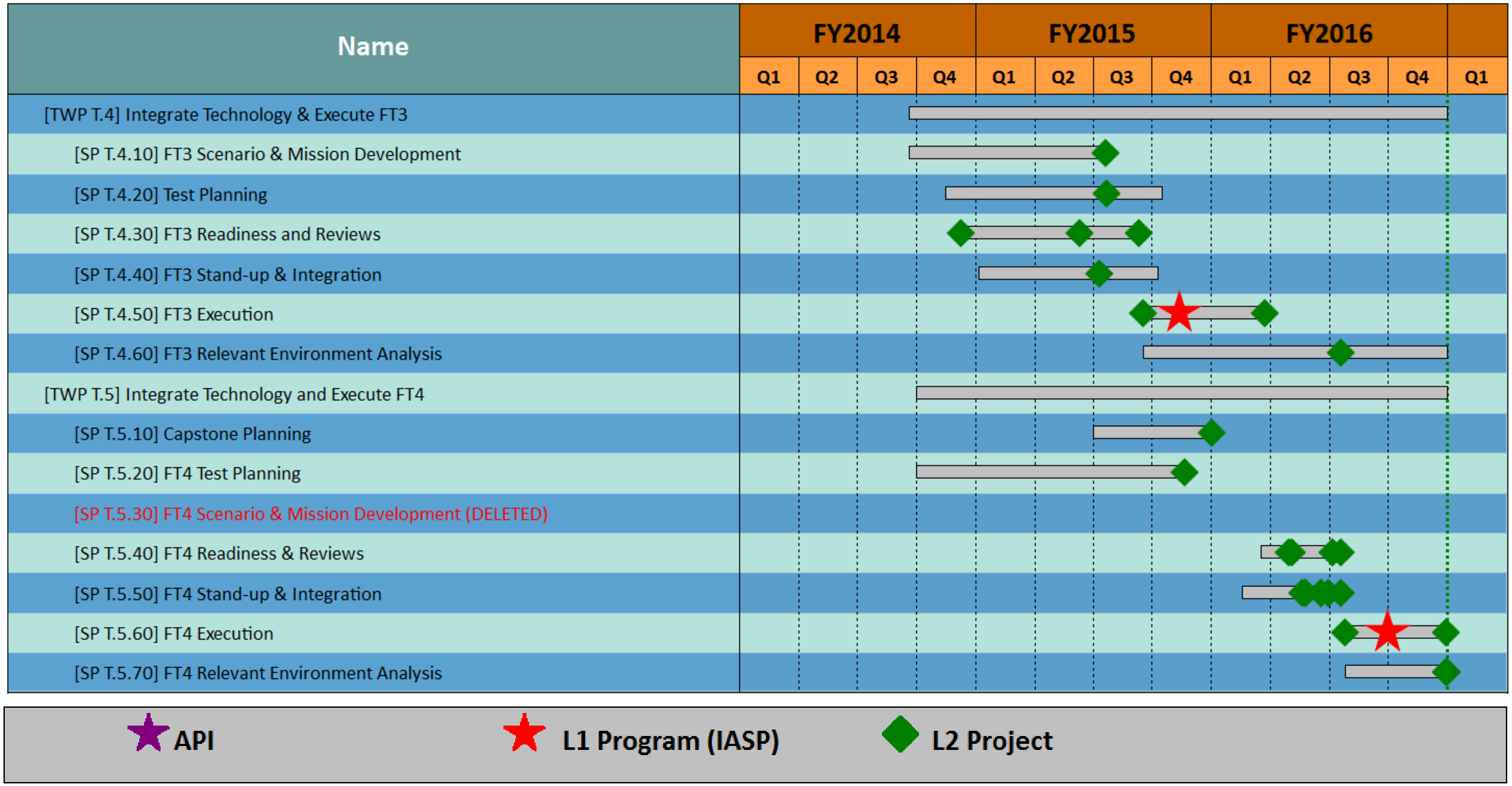
TC–ITE (2 of 2)



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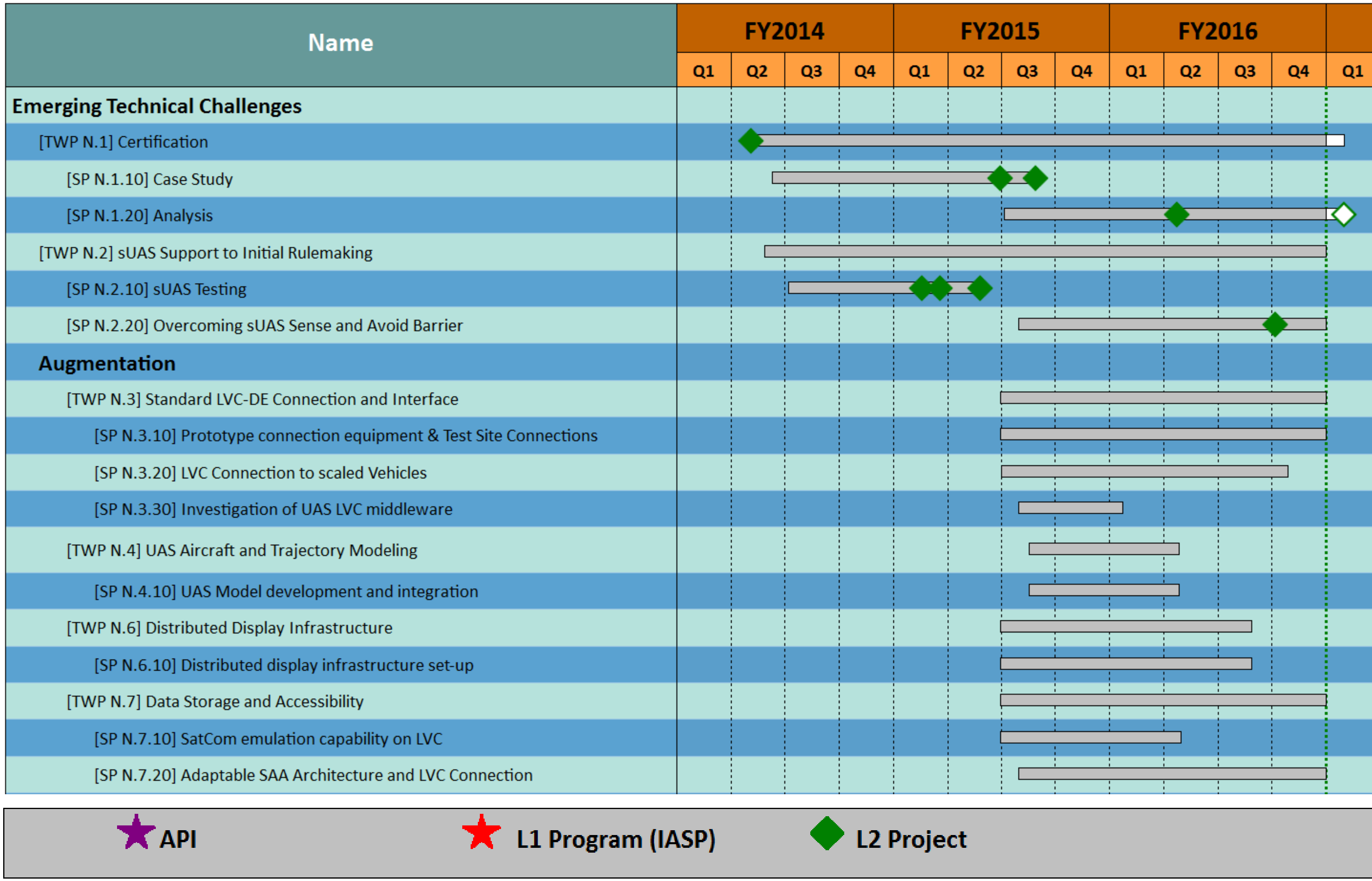
UAS-NAS Emerging Technical Challenge Work Backup Slides

Current Active Collaborations/Partnerships Status – FAA Test Sites

Area	FAA Test Site	Agreement In Place	Fully Completed*	Collaboration/ Partnership Role
TC-ITE	University of Alaska Fairbanks	✓ Contract	✓	Successfully completed Task 1, UTM and Task 2, LVC-DE efforts
TC-ITE	State of Nevada	✓ Contract	✓	Successfully completed Task 1, UTM and Task 2, LVC-DE efforts
TC-ITE	New York – Griffiss UAS Test Site	✓ Contract	✓	Successfully completed Task 1, UTM and Task 2, LVC-DE efforts
TC-ITE	North Dakota – Northern Plains Test Site	✓ Contract	✓	Successfully completed Task 1, UTM and Task 2, LVC-DE efforts
TC-ITE	Texas A&M University	✓ Contract	✓	Successfully completed Task 1, UTM and Task 2, LVC-DE efforts
TC-ITE	Virginia Tech	✓ Contract	✓	Successfully completed Task 1, UTM and Task 2, LVC-DE efforts

* Costing is not fully completed. All deliverables are complete.

Emerging Technical Challenges



Green Status Line Date 9/30/16

Project Level Performance
Backup Slides

FY16 Significant Changes Against Baseline

CR(s)#	Area	Change	Impact (Cost, Schedule, Technical)
089	TC-SAA	SSI-LaRC had planned to ramp down, but due to next phase planning additional funding was needed to continue work at current level of effort. Reallocated $199k to LaRC	Cost
098	TC-SAA	Reallocated $100k to SSI-ARC to be used towards .5 WYE and for upgrading the lab to support the mini-hitl and PT6.	Cost
104	TC-C2	Post FT3 Re-Planning; Added two new milestones under SP C.1.30 – "Start Perform Lab Testing of Selected Verification Procedures" and Deliver C2 MOPS Verification Procedures Results to SC-228	Schedule, Technical
106	TC-IT&E	Post FT3 Re-Planning; Milestone additions and deletions including deletion of Capstone	Schedule, Technical
107,108, 109	TC-SAA	Post FT3 Re-planning of work; SP S.4.20 was deleted. SP S.8.10 (DAIDALUS) and SP S.8.20 (E2V2) were added. SP S.7.10 was deleted and efforts were re-directed to SP S.4.30	Schedule, Technical
113	TC-IT&E	$100k was reallocated to Ames IT&E for PT6 and documentation support	Cost
115	PO	To align with SC-228 schedule, dates were changed for C2 and DAA consolidated comments which are L1 Milestones	Schedule
133	TC-HSI	Reallocated $50k to HSI to fund Cal State Long Beach Grant	Cost
146	TC-SAA	SSI-LaRC requested to change commitment dates which extended into October of FY17	Schedule
147	TC-SAA	SSI-ARC moved briefing into October of FY17 and removed the mitigated results from the schedule package and requirement reflecting only unmitigated.	Schedule, Technical
148	PO	Draft and Final Comprehensive Research Report were moved into October and December of FY17	Schedule

TC-C2 Risks Accepted/Closed in FY16

- Data Removed

TC-SAA Risks Accepted/Closed in FY16

- Data removed

TC-HSI Risks Accepted/Closed in FY16

- Data Removed

TC-ITE Risks Accepted/Closed in FY16 (1 of 2)

- Data Removed

TC-ITE Risks Accepted/Closed in FY16 (2 of 2)

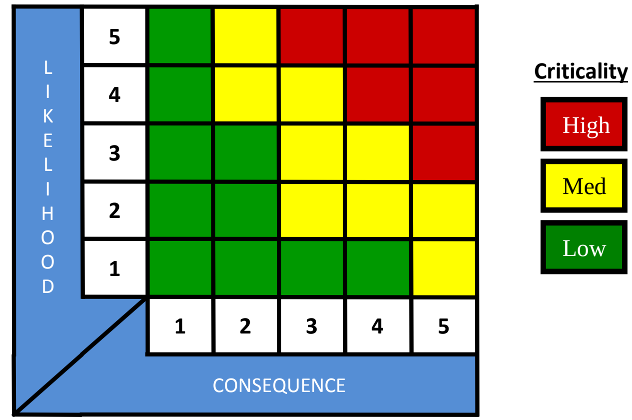
- Data Removed

Cert Risks Accepted/Closed in FY16

- Data Removed

UAS-NAS Risk Summary Card

LIKELIHOOD		
5	**Very High**	**Qualitative: Nearly certain to occur.** Controls have little or no effect.
4	**High**	**Qualitative: Highly likely to occur.** Controls have significant uncertainties.
3	**Moderate**	**Qualitative: May occur.** Controls exist with some uncertainties.
2	**Low**	**Qualitative: Not likely to occur.** Controls have minor limitations /uncertainties.
1	**Very Low**	**Qualitative: Very unlikely to occur.** Strong Controls in Place



CONSEQUENCE	1	2	3	4	5
Technical	Negligible Impact to Objective, Technical Challenge, Technology Maturation	Minor Impact to Objective, Technical Challenge, Technology Maturation	Some Impact to Objective, Technical Challenge, Technology Maturation	Moderate Impact to Objective, Technical Challenge, Technology Maturation	Major Impact/Cannot Complete to Objective, Technical Challenge, Technology Maturation
Cost	≤ 1% Total Project Yearly Budget (≤ $300K)	1% - 5% Total Project Yearly Budget ($300K - $1.5M)	5% - 10% Total Project Yearly Budget ($1.5M - $3M)	10% - 15% Total Project Yearly Budget ($3M – $4.5M)	>15% Total Project Yearly Budget (> $4.5M)
Schedule *	Level 2 Milestone(s): < 1 month impact	Level 2 Milestone(s): ≥ 1 month impact	Level 1 Milestone(s): ≤1 month impact Level 2 Milestone(s): ≤ 2 month impact	Level 1 Milestone(s): > 1 month impact Level 2 Milestone(s): > 2 month impact	Level 1 Milestone(s): > 2 month impact Level 2 Milestone(s): ≥ 3 month impact

Note: L1 = IASP L2 = Project

Resource Allocation FY16 Budget

- Data Removed

FY16 Project Deliverables

Phase 1 TC – C2 Deliverables	Date	Type of Deliverable
CNPC Coverage and Performance	Oct-15	Paper
UAS-NAS -Large Scale Communication Architecture Simulations with NASA GRC Gen 5 Radio Model	Oct-15	Paper
Large Scale Communications Architecture Sims with Gen 2 Radio Model System Characterization and Performance Report	Jan-15	Report
Overview AUVSI	May-16	Briefing
Appendix N	Jun-16	Appendix
Appendix O	Jun-16	Appendix
CNPC Gen 5 Regional Sim Report	Jul-16	Report
UA Comm Impact on NAS Capacity and Delay	Aug-16	Report
Spectrum Compatibility Analysis Final Report on WRC-2015	Aug-16	Report
Benefits and Constraints of Adding UAVs to the Research Tool Box HyDRUS	Aug-16	Briefing
Addressing Technical Barriers to UAS Control Communications through NASA Collaborative Partnerships	Aug-16	Briefing
UAS in the NAS SatCom for UAS Simulation Report	Sep-16	Report
CNPC Comm Prototype Radio Validation Flight Test Report	Sep-16	Report
CNPC Comm Prototype Radio Verification Test Report	Sep-16	Report
C-Band Planning and Standards Final Report	Sep-16	Report
SatCom Simulation Report	Sep-16	Report
Analysis Results and Recommendations for Integration of CNPC and ATC communications Sim Report	Sep-16	Report

FY16 Project Deliverables

Phase 1 TC - SAA Deliverables	Date	Type of Deliverable
Using Simulation to Evaluate Air Traffic Controller Acceptability of Unmanned Aircraft with DAA Technology	Oct-15	Paper
Analysis of UAS DAA Alerting in Fast-Time Simulations without DAA Mitigation	Oct-15	Briefing
Analysis of UAS DAA Surveillance in Fast-Time Simulations without DAA Mitigation	Oct-15	Briefing
UAS Air Traffic Controller Acceptability Study 2 - Evaluating Detect and Avoid Technology and Communication Delays in Simulation	Dec-15	Report
Effects of Basing UAS DAA Requirements on Intruder Speeds Lower Than the Statute Speed Limit	Jan-16	Briefing
Effects of Basing UAS DAA Requirements on Intruder Speeds Lower Than the Statute Speed Limit	Jan-16	Paper
Evaluating Alerting and Guidance Performance of a UAS Detect and Avoid System	Feb-16	Report
Piloted Well Clear Performance Evaluation Detect and Avoid Systems with Suggestive Guidance	Mar-16	Paper
UAS Human in the Loop Controller and Pilot Acceptability Study- Collision Avoidance, Self Separation and Alerting Times	Apr-16	Report
FT3 Final Report FT3 Data Analysis of JADEM	May-16	Report
Sensor Uncertainty Mitigation Study	May-16	Briefing
LaRC AUVSI Presentation	May-16	Briefing
ARC AUVSI Presentation	May-16	Briefing
FT4 JADEM Preliminary Results	Jul-16	Briefing
ACES M&S - Unmitigated Factorial Encounter Study on DAA-TCAS Interoperability	Jul-16	Briefing
CASSAT Study- Effects of Horizontal Miss Distances and Alert Times on Manned - UA Encounters	Jul-16	Briefing
PT6 V&V Simulation Prelim Results	Jul-16	Briefing
SC-228 Defining the Collision Avoidance Region for DAA Systems	Aug-16	Report
FT4 DAIDALUS Test Preliminary Results	Sep-16	Briefing

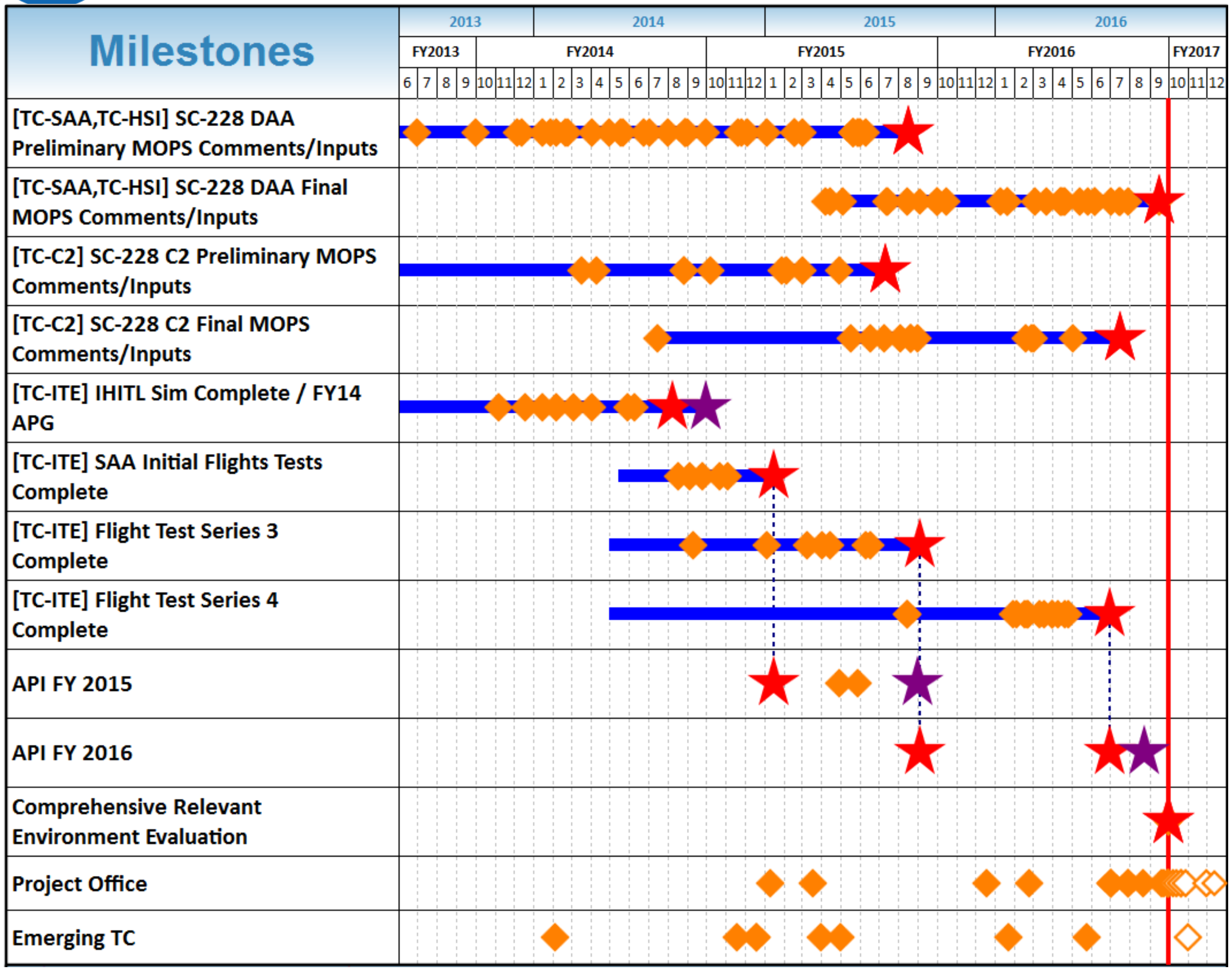
FY16 Project Deliverables

Phase 1 TC – HSI Deliverables	Date	Type of Deliverable
The Impact of Integrated Maneuver Guidance Information on UAS Pilots Performing the Detect and Avoid Task	Oct-15	Paper
Effects of Display Location and Information Level on UAS Pilot Assessments of a Detect and Avoid System	Oct-15	Paper
The Impact of Suggestive Maneuver Guidance on UAS Pilots Performing the Detect and Avoid Function	Oct-15	Paper
HSI AUVSI Presentation	Dec-15	Briefing
Detect and Avoid Display Eval in Support of SC-228 MOPS Development - ARMD Monthly Tech Seminar	May-16	Briefing
PT6 V&V Sim Primary Results - SC-228 Presentation	Jul-16	Briefing
Workload Measurement in Human Autonomy Teaming - How and Why - Blue Sky workshop	Jul-16	Briefing
GCS HF Guidelines for RPAS RDP	Jun-16	Paper
Collection of Human Factors Incident Reports via UAS Pilot Focus Groups	Jul-16	Paper
NESC Academy: Human Factors of Remotely Piloted Aircraft Systems: Lessons Learned from Incident Reports	Sep-16	Webcast
UAS Pilot Evaluation of Suggestive Guidance on Detect and Avoid Displays	Sep-16	Paper
Phase 1 TC - ITE Deliverables	**Date**	**Type of Deliverable**
Flight Test Series 3 Flight Test Report	Oct-15	Report
Flight Test Overview for UAS Integration in the NAS Project	Dec-15	Paper
FT4 Tech Brief	Apr-16	Briefing
FT4 Test Plan	Mar-16	Plan
FT3 Relevant Environment	Apr-16	Report

FY16 Project Deliverables

Phase 1 TC - ITE Deliverables	Date	Type of Deliverable
Stakeholder Feedback Report	Sep-16	Report
FT4 Test Environment Report	Sep-16	Report
LVC Leave Behind Document	Sep-16	Report
Flight Test Series 4 Flight Test Report	Sep-16	Report
Phase 1 Emerging TC – Certification Deliverables	**Date**	**Type of Deliverable**
Mock Certification Basis for an Unmanned Rotorcraft for Precision Agricultural Spraying	Nov-15	Report
Expanding the Envelope of UAS Certification - What it Takes to Type Certify a UAS for Precision Agricultural Spraying	May-16	Paper
Expanding the Envelope of UAS Certification - What it Takes to Type Certify a UAS for Precision Agricultural Spraying	May-16	Briefing
Final Report on Extensions to the Type Certification Basis	Sep-16	Report
Phase 1 Emerging TC – sUAS Deliverables	**Date**	**Type of Deliverable**
Use of a sUAS for Autonomous Fire Spotting at the Great Dismal Swamp	Dec-15	Paper

Milestone Summary



1 2 3 4 5 6 7

8

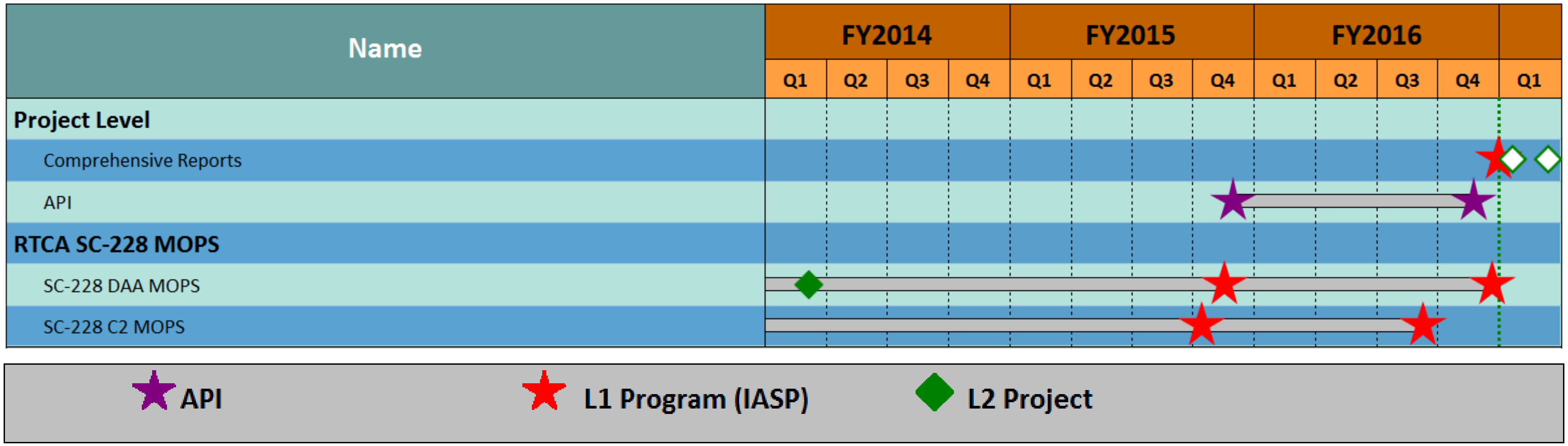
Red Status Line Date 9/30/16

Remaining Open

1. Sub-function Tradeoffs w/ UAS Perf.: TT completion est. on 10/7/16.
2. Start of Simulation for DAIDALUS V&V completion est. on 10/14/16.
3. End to End V&V Preliminary Results to Stakeholders (SC-228) completion est. on 10/21/16.
4. Draft Comprehensive Research Report completion est. on 10/21/16.
5. DAIDALUS Results to Stakeholders (SC-228) completion est. on 10/28/16.
6. Sensor Uncertainty Mitigation for Guidance and Alerting Report completion est. on 11/30/16.
7. Comprehensive Research Report completion est. on 12/13/16.

8. Final Report on Extensions to the TCB completion est. on 10/31/16.

Project Office



Green Status Line Date 9/30/16

UAS-NAS Phase 2
Project Organization Structure

PROJECT OFFICE LEVEL

Project Leadership

Project Manager (PM)	Laurie Grindle, AFRC
Deputy PM	Robert Sakahara, AFRC
Deputy PM, Integration	Davis Hackenberg, AFRC
Chief Engineer	TBD, TBD

Project Support: Project Planning & Control

Lead Resource Analyst	April Jungers, AFRC
Resource Analysts	Winter Preciado, AFRC
	Carmen Park, ARC
	Julie Blackett, GRC
	Pat O'Neal, LaRC
Scheduler	Shirley Sternberg, AFRC
Risk Manager	Jamie Turner, AFRC
Change/Doc. Mgmt	Stacey Jenkins, AFRC
Admin	Lexie Brown, AFRC

Project Support: Technical

Staff Engineer	Dan Roth, AFRC
Systems Eng Lead	TBD, TBD

TECHNICAL CHALLENGE/ SUBPROJECT LEVEL

Command and Control (C2)
TC-C2
Subproject Manager
Mike Jarrell, GRC
Subproject Technical Lead
Jim Griner, GRC

Detect and Avoid (DAA)
TC-DAA
Subproject Manager
Jay Shively, ARC
Subproject Technical Leads
Confesor Santiago, ARC; TBD, ARC;; Tod Lewis, LaRC

Integrated Test & Evaluation
TC-ITE
Subproject Manager
Heather Maliska, AFRC
Subproject Technical Leads
Jim Murphy, ARC; Sam Kim, AFRC

ELEMNET/ TWP LEVEL

Technical Work Packages (TWP): Terrestrial Extensions, Ku-/Ka-band SatCom, C-band SatCom

Technical Work Packages (TWP): Alternative Surveillance, Well Clear, ACAS Xu, External Collaboration, Integrated Events

Technical Work Packages (TWP):, Integration of Technologies into LVC-DE, Simulation Planning and Integration, Integrated Flight Test, LVC-DE Infrastructure Sustainment

Acronyms

ACAS	Airborne Collision Avoidance System
ACAS-Xu	Version of ACAS for Unmanned Aircraft
ACES	Airspace Concept Evaluation System
ADS-B	Automatic Dependent Surveillance - Broadcast
AFRC	Armstrong Flight Research Center
AFRL	Air Force Research Lab
AFSRB	Airworthiness and Flight Safety Review Board
AOSP	Airspace Operations and Safety Program
API	Annual Performance Indicator
AR	Annual Review
ARC	Ames Research Center or Aviation Rule Making Committee
ARD	Aeronautics Research Director
ARMD	Aeronautics Research Mission Directorate
ATC	Air Traffic Controller
ATCS	Air Traffic Control Specialist
ATO	Air Traffic Organization-FAA Organization/Authority to Operate
AUVSI	Association for Unmanned Vehicle Systems International
BLOS	Beyond Line of Sight
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CA	Collision Avoidance

Acronyms

CAS	Collision Avoidance System
CASSAT	Collision Avoidance Self Separation Alerting Times
CDP	Content Decision Point
CE	Chief Engineer
Cert	Certification
CMB	Change Management Board
CNPC	Control and Non-Payload Communications
COA	Certificate of Authorization or Waiver
COE	Center of Excellence
Comm	Communications
CONOPS	Concept of Operations
CPDS	Conflict Prediction and Display System
CR	Change Request or Continuing Resolution
CS	Civil Servant
CSE	Chief System Engineer
CSULB	Cal Sate University of Long Beach
DAA	Detect and Avoid
DAIDALUS	Detect and Avoid Alerting Logic for Unmanned Systems
DER	Designated Engineering Representative
dGPS	Differential Global Positioning System
DoD	Department of Defense

Acronyms

DPMf	Deputy Project Manager for
E2V2	End to End Verification and Validation
EO	Electro Optic
ERT	Engineering Review Team
ExCom	Executive Committee
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FRAC	Final Review and Comment
FT	Flight Test
FTE	Full Time Equivalent
FY	Fiscal Year
GA	General Atomics
GA-ASI	General Atomics Aeronautical Systems Inc.
GBSAA	Ground Based Sense and Avoid
GCS	Ground Control Station
GDS	Great Dismal Swamp
Gen	Generation
GPS	Global Positioning System
GRC	Glenn Research Center
HMD	Horizontal Missed Distance

Acronyms

HF	Human Factors
HITL01	Human-in-the-loop Sim 1
HSI	Human Systems Integration
HQ	Headquarters
IASP	Integrated Aviation Systems Program
ICAO	International Civil Aviation Organization
IDIQ	Indefinite-Delivery, Indefinite-Quantity
IFR	Instrument Flight Rules
IH	In House
IHITL	Integrated Human-In-The-Loop
IMS	Integrated Master Schedule
IR	Infra Red
IRP	Independent Review Panel
IT&E or ITE	Integrated Test and Evaluation
ITU-R	International Telecommunication Union-Radiocommunication
JADEM	Java Architecture for Detect and Avoid Extensibility and Modeling
JOFOC	Justification of Other than Full and Open Competition
KDP	Key Decision Point
L1	Level 1
L2	Level 2
LaRC	Langley Research Center

Acronyms

LOS	Line of Sight
LoWC	Losses of Well Clear
LS	Large Scale
LVC	Live Virtual Constructive
LVC-DE	Live Virtual Constructive Distributed Environment
MACS	Multi Aircraft Control Station
MIT-LL	Massachusetts Institute of Technology Lincoln Labs
MITRE	MITRE Corporation
MOA	Memorandum of Agreement
MOPS	Minimum Operational Performance Standards
MRB	Management Review Board
MS&A	Modeling, Simulation, and Analysis
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NextGen	Next Generation
NRA	NASA Research Announcement
OCFO	Office of Chief Financial Officer
OPNET	OPNET Technologies
OSD	Office of the Secretary of Defense Slide 15
OV-1	Operational View
P1	Phase 1

Acronyms

P2	Phase 2
PE	Project Engineer
PER	Preliminary Experiment Review
PI	Progress Indicator
PM	Project Manager
PMC	Program Management Committee
PO	Project Office
PP	Project Plan
PPBE	Planning, Programming, Budgeting, and Execution
PRD	Project Requirements Document
PROJ	Project
PRP	Performance Review Panel
PT	Part Task
PVS	Prototype Verification System
RA	Resolution Advisory
RADAR	Radio Detection and Ranging
R&D	Research and Development
RF	Radio Frequency
RFI	Request for Information
RFP	Request for Proposal
RPAS	Remotely Piloted Aircraft Systems

Acronyms

RT	Research Theme
SAA	Sense and Avoid or Space Act Agreement
SAAP	Sense and Avoid Processor
SARP	Science and Research Panel
SATCOM	Satellite Communications
SCO	System Checkout Flights
SC	Special Committee
SEMP	System Engineering Management Plan
Sim	Simulation
SME	Subject Matter Expert
SMP	Schedule Management Plan
SP	Schedule Package
SS	Self Separation
SSI	Separation Assurance/Sense and Avoid Interoperability
sUAS	Small Unmanned Aircraft Systems
SWAP	Size Weight and Power
TBD	To Be Determined
TC	Technical Challenge
TCAS	Traffic Collision Avoidance System
TCB	Type Certification Basis
ToR	Terms of Reference

Acronyms

TRACON	Terminal Radar Approach Control Facilities
TSO	Technical Standard Order
TT	Technology Transfer
TTP	Technology Transfer Plan
TWP	Technical Work Package
UA	Unmanned Aircraft
UAS	Unmanned Aircraft Systems
UAS-NAS	Unmanned Aircraft Systems Integration in the National Air Space System
UAV	Unmanned Aircraft Vehicle
UNITD	UAS-NAS Interoperability for TCAS and DAA
UTM	UAS Traffic Management
V&V	Verification and Validation
VFR	Visual Flight Rules
VPN	Virtual Private Network
VSCS	Vigilant Spirit Control Station
WG	Working Group
WRC	World Radio Conference
WYE	Work Year Equivalent