National Aeronautics and Space Administration

UAS Integration in the NAS Project
FY14 Annual Review

Laurie Grindle

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Debra Randall

Chief Systems Engineer, UAS Integration in the NAS Project

Davis Hackenberg

Deputy Project Manager, Integration

October 27, 2014

Agenda

11:00 – 11:30	Welcome, Opening Remarks	Ed Waggoner
11:30 – 12:00	UAS-NAS Overview	Laurie Grindle
12:00 – 1:30	Technical Challenge Performance	Debra Randall
1:30 – 1:45	Break	
1:45 – 2:30	Non-Technical Challenge Work Project Control Processes & Governing Documents	Davis Hackenberg
2:30 – 3:30	Project Level Performance, FY15 Look Ahead, & Summary	Laurie Grindle
3:30 – 4:30	IRP/PRP Caucus	
4:30 – 5:30	IRP/PRP Initial Feedback	

Annual Review Overview

- Purpose - Conduct an assessment of the Project's quality and performance
- Approach - The Project will provide a programmatic review addressing the following:
  - Project's Goal and Technical Challenges (TC) and their alignment to NASA and ARMD Strategy
  - Key highlights and accomplishments for the Project's technical challenges
  - Project performance of the past year through examination of:
    - Changes against the Project Baseline, the cause of the changes, and the resulting impacts
    - Management and control processes, e.g. Schedule, Risk, and Technical Management
    - Resource allocation and utilization
    - Progress in establishing partnerships/collaborations and their current status
  - Key activities, milestones, and "storm clouds" for FY15
  - Actions from Baseline Review
    - Describe the management of the Project's reserves and phasing
    - Describe how the Project balances the rigor and technical accomplishments
    - Describe the Project's plan for getting formal stakeholder buy-in on the LVC-DE as a relevant environment

Outline

- UAS Integration in the NAS (UAS-NAS) Overview
  - Purpose & Approach of Annual Review
  - UAS-NAS Background, Goal, and Technical Challenges
  - Phase 2 Portfolio Definition & Baseline Development
- TC Performance against the Baseline
- Non-Technical Challenge Work
- Project Control Processes & Governing Documents
- Project Level Performance & FY15 Look Ahead
- Review Summary

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-14-8: Conduct a human-in-the-loop (HITL) simulation where unmanned aircraft are mixed with manned aircraft and subjected to a range of test conditions

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

ARMD Strategic Plan Flow Down to UAS-NAS Project

AERONAUTICS STRATEGIC THRUST

Thrust 6: Assured Autonomy for Aviation Transformation

AERONAUTICS OUTCOME

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

UAS-NAS Project Goal

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

UAS-NAS Research Themes

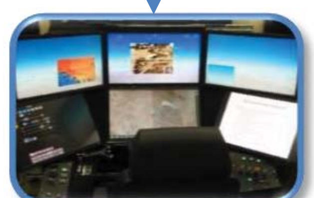
Research Theme 1: UAS Integration - Airspace integration procedures and performance standards to enable UAS integration in the air transportation system

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

UAS-NAS Technical Challenges

TC-SAA: Sense and Avoid Performance Standards

TC-C2: Command & Control Performance Standards



TC-HSI: Human Systems Integration

TC-ITE: Integrated Test & Evaluation

UAS Integration in the NAS Organizational Structure

Host Center

AFRC Director of Programs
Dennis Hines
Deputy Director: Joel Sitz

Program Office

ISRP Program Director
Dr. Ed Waggoner
Deputy PD: Cathy Bahm

ExCom, RTCA Steering Committee, UAS Aviation Rulemaking Committee

Project Support

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

External Interfaces

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

Senior Advisor: VACANT

DPMf – AFRC	DPMf – ARC	DPMf – GRC	DPMf – LaRC
Heather Maliska	Matt Knudson	Amy Jankovsky	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
Maria Consiglio - 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

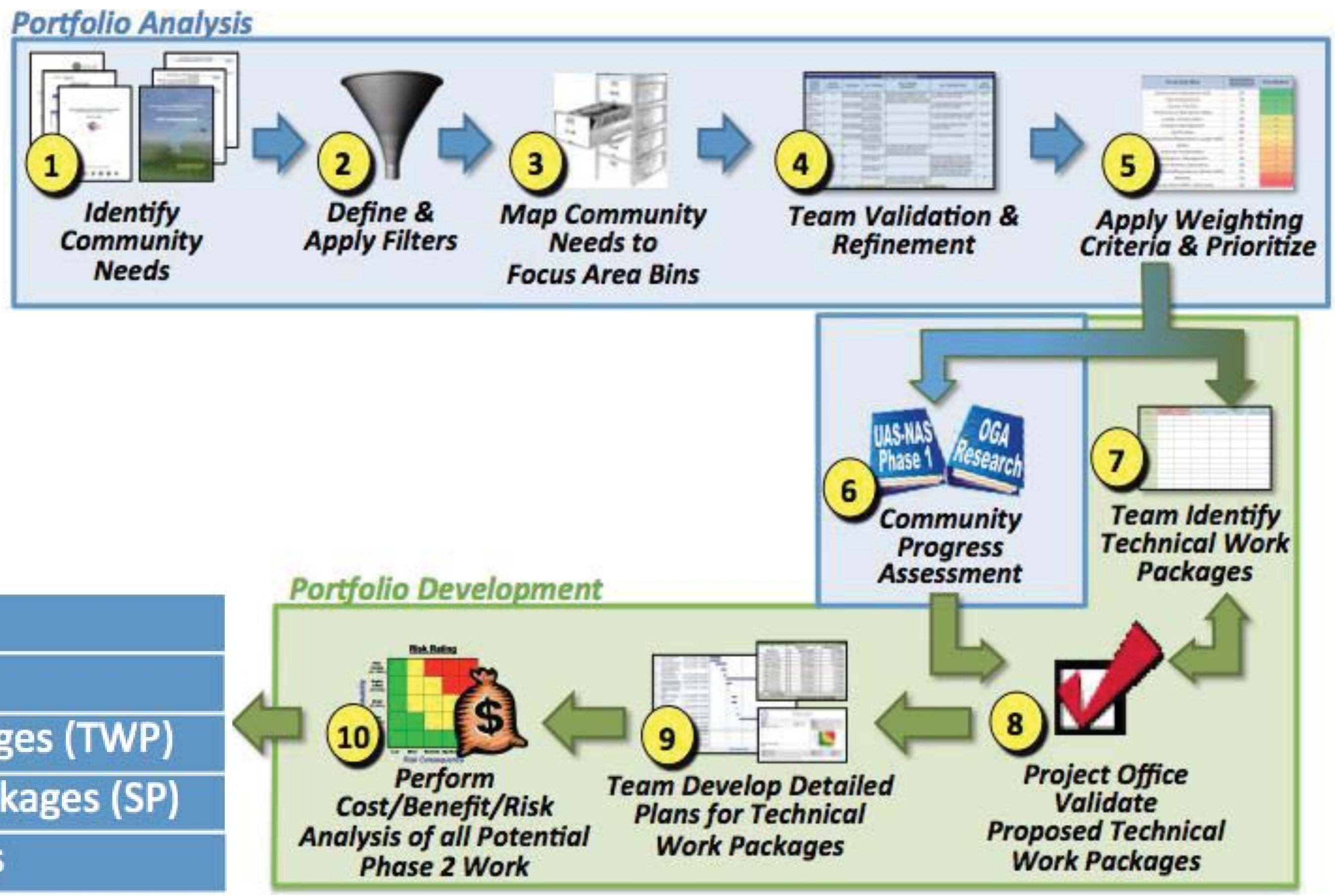
PE: Project Engineer, DPMf: Deputy Project Manager for

UAS-NAS Programmatic Review Summary

- Completed KDP review that focused on:
  - How the Project is addressing the UAS Community needs for NAS Access
  - The Phase 2 technical content and associated resource estimates, schedule, and risks
- Completed Baseline review that focused on:
  - Phase 2 execution plans including project controls for the execution
  - Readiness to baseline the Phase 2 Portfolio and associated needs, objectives, deliverables, requirements, resource estimates, schedules, and risks
  - Technical Challenge cost and schedule are adequate estimates that reflect the scope, objectives and requirements
  - Phase 2 portfolio has sufficient reserves, addressing both known and unknown risks
  - Center evaluations of ability to execute Phase 2 Portfolio

Community Needs Influence on Phase 2 Portfolio and Technical Challenges

- Phase 2 Content Decision Process (CDP) included an evaluation of the technical needs of the UAS Community
- Resultant prioritized list, and Community Progress Assessment, of Focus Area Bins served as the foundation for Phase 2 Portfolio and Technical Challenges
- Technical challenges, Technical Work Packages, and detailed executable Schedule Packages were evaluated using a cost/benefit/risk process to determine the final portfolio



- Phase 2 Portfolio
  - Technical Challenges (TC)
    - Technical Work Packages (TWP)
      - Schedule Packages (SP)
        - Tasks

UAS Integration in the NAS Project

Value Proposition Flow Diagram

NASA UAS-NAS Project Activities	Key Products	Resultant Outcomes

TC SAA — *SAA Performance Standards*

- Develop SAA Performance Testbed
- Develop SAA Interoperability Testbed

→ **Conduct SAA Flight Test and MS&A**

Performance Trade-offs, Interoperability, Self Separation, CONOPs, Well Clear, Collision Avoidance

→ **Develop SAA Performance & Interoperability Requirements**

→ *SAA Performance Requirements to inform DAA MOPS* → RTCA DAA MOPS → SAA Technical Standard Order (TSO)

TC C2 — *C2 Performance Standards*

Develop C2 Prototype System

→ **Conduct C2 Flight Test and MS&A**

Data Link, CNPC Spectrum, CNPC Security, LOS, BLOS, ATC Interoperability

→ **Develop C2 Requirements**

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

TC HSI — *Human Systems Integration*

Develop Prototype GCS

→ **Conduct Human Factors (HF) Flight Test and MS&A**

Contingency Management, Pilot Response, Autonomy, SAA, C2, Displays

→ **Develop HF Guidelines for SAA, C2 & GCS**

→ *HF Performance Requirements to inform DAA & C2 MOPs, HF Guidelines* → RTCA DAA MOPS, RTCA C2 MOPS → SAA Technical Standard Order (TSO), C2 Technical Standard Order (TSO)

TC ITE — *Integrated Test & Evaluation*

Develop LVC Test Infrastructure

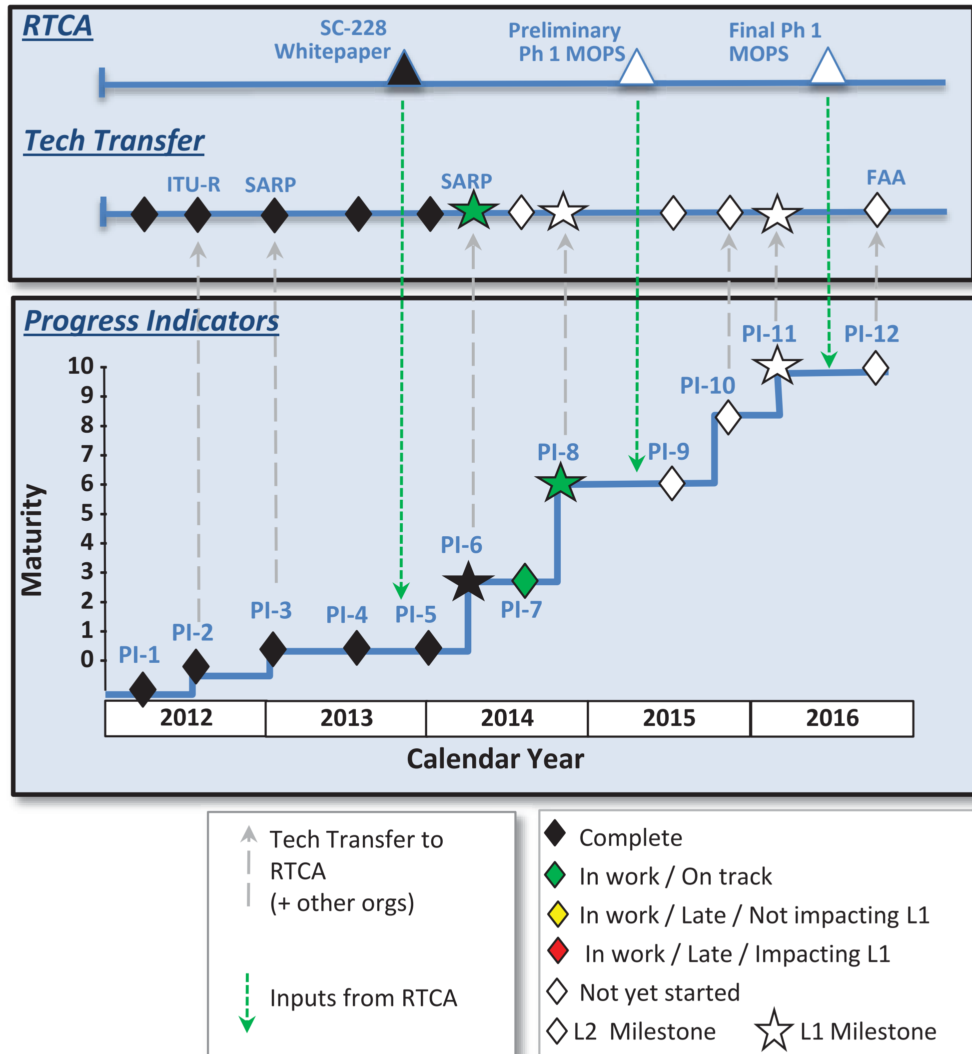
→ **Conduct TC Specific Testing**

- Conduct IHITL
- Conduct SAA Initial Flight Test Scenarios
- Conduct FT3 Test Scenarios
- Conduct FT4 Test Scenarios & Capstone

→ *Re-usable Test Infrastructure*

Progress Indicators

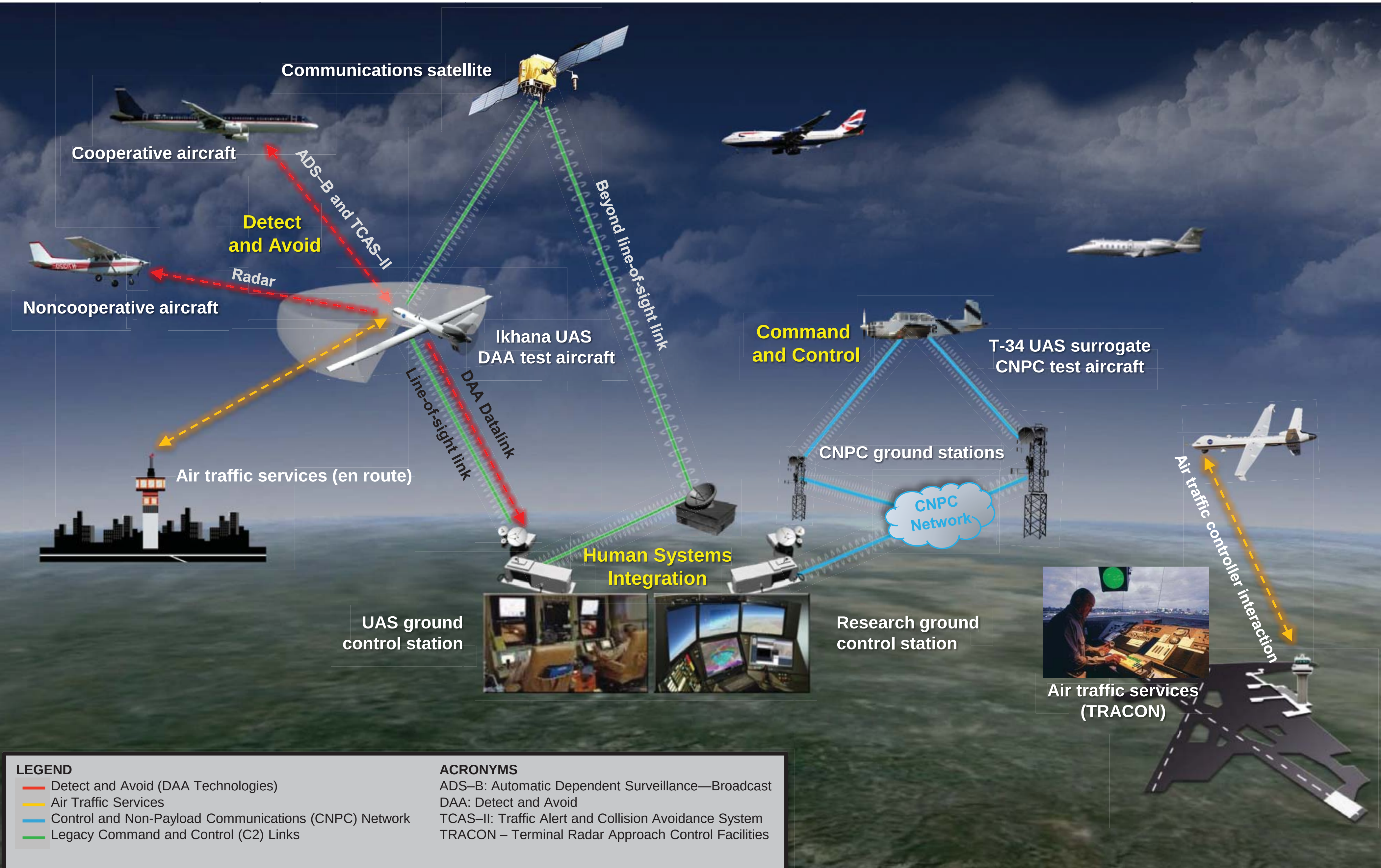
- Technical Challenge progress is tracked by means of Progress Indicators
  - Schedule Package (SP) L2 milestones are the data points for these plots
- Assessed individual contribution towards achieving the overall technical challenge
  - High = 2, i.e. Integrated Tests
  - Moderate = 1, i.e. multiple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



Outline

- UAS-NAS Overview
- TC Performance against the Baseline – Debra Randall
  - TC-SAA
  - TC-C2
  - TC-HSI
  - TC-ITE
- Non-Technical Challenge Work
- Project Control Processes & Governing Documents
- Project Level Performance & FY15 Look Ahead
- Review Summary

UAS-NAS Project Technical Challenge OV-1



TC-SAA: SAA Performance Standards

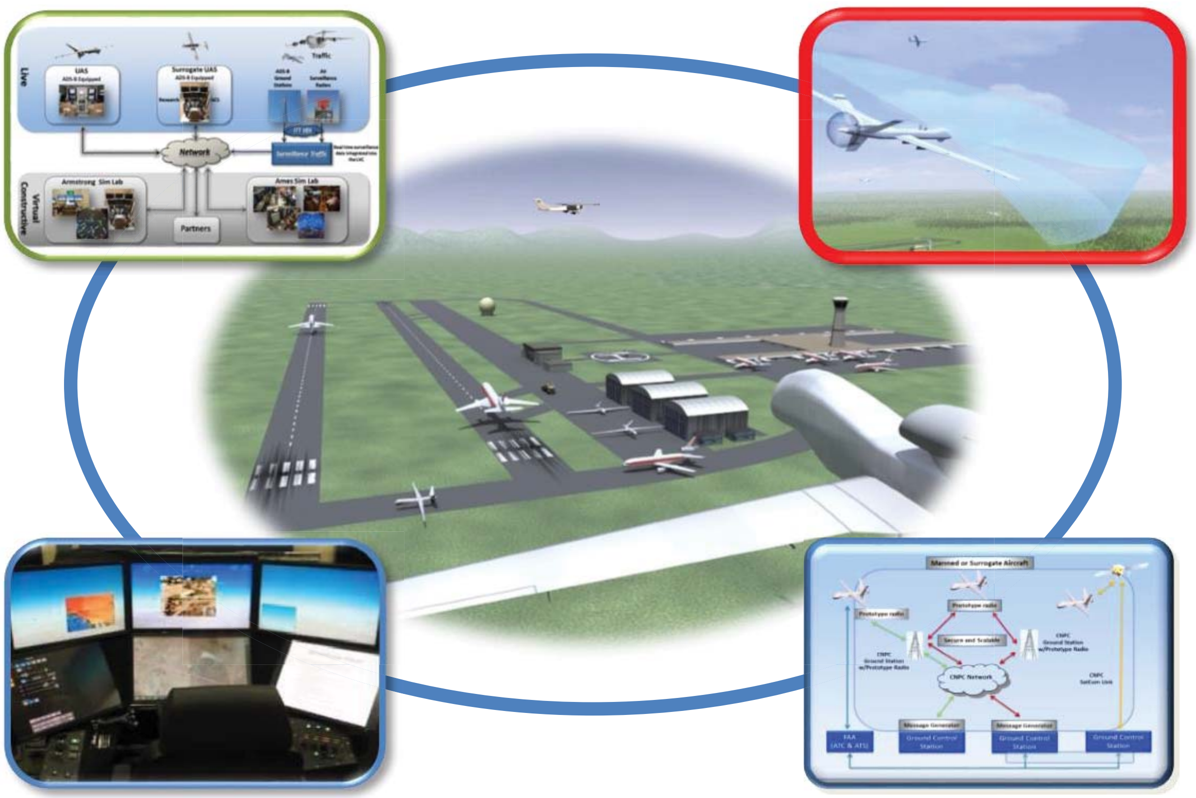
RT1 - UAS Integration

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

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

TC-ITE: Integrated Test & Evaluation

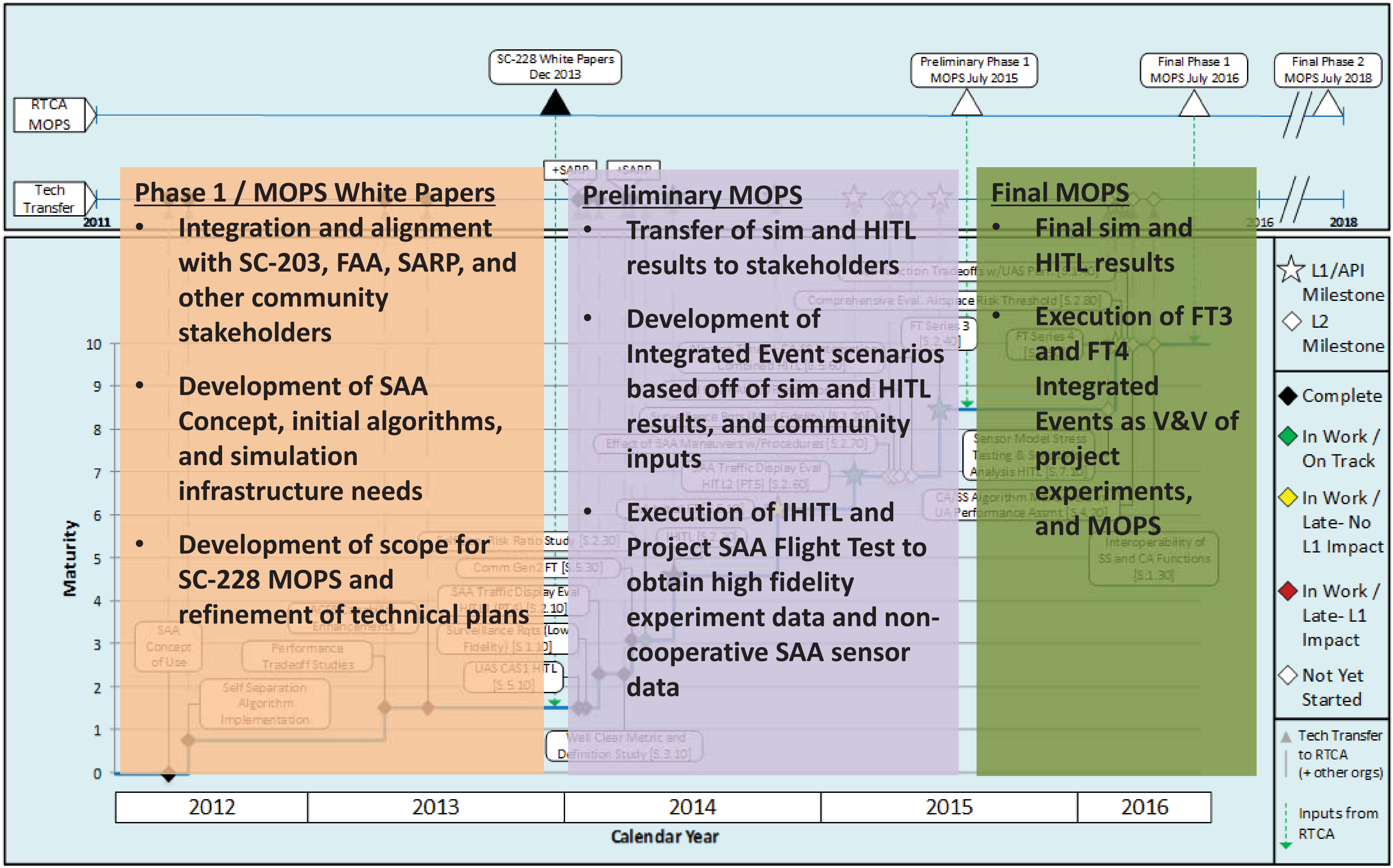
TC-SAA: Sense and Avoid Performance Standards



TC-HSI: Human Systems Integration

TC-C2: Command & Control Performance Standards

TC-SAA: Progress Indicator



Phase 1 / MOPS White Papers

- Integration and alignment with SC-203, FAA, SARP, and other community stakeholders
- Development of SAA Concept, initial algorithms, and simulation infrastructure needs
- Development of scope for SC-228 MOPS and refinement of technical plans

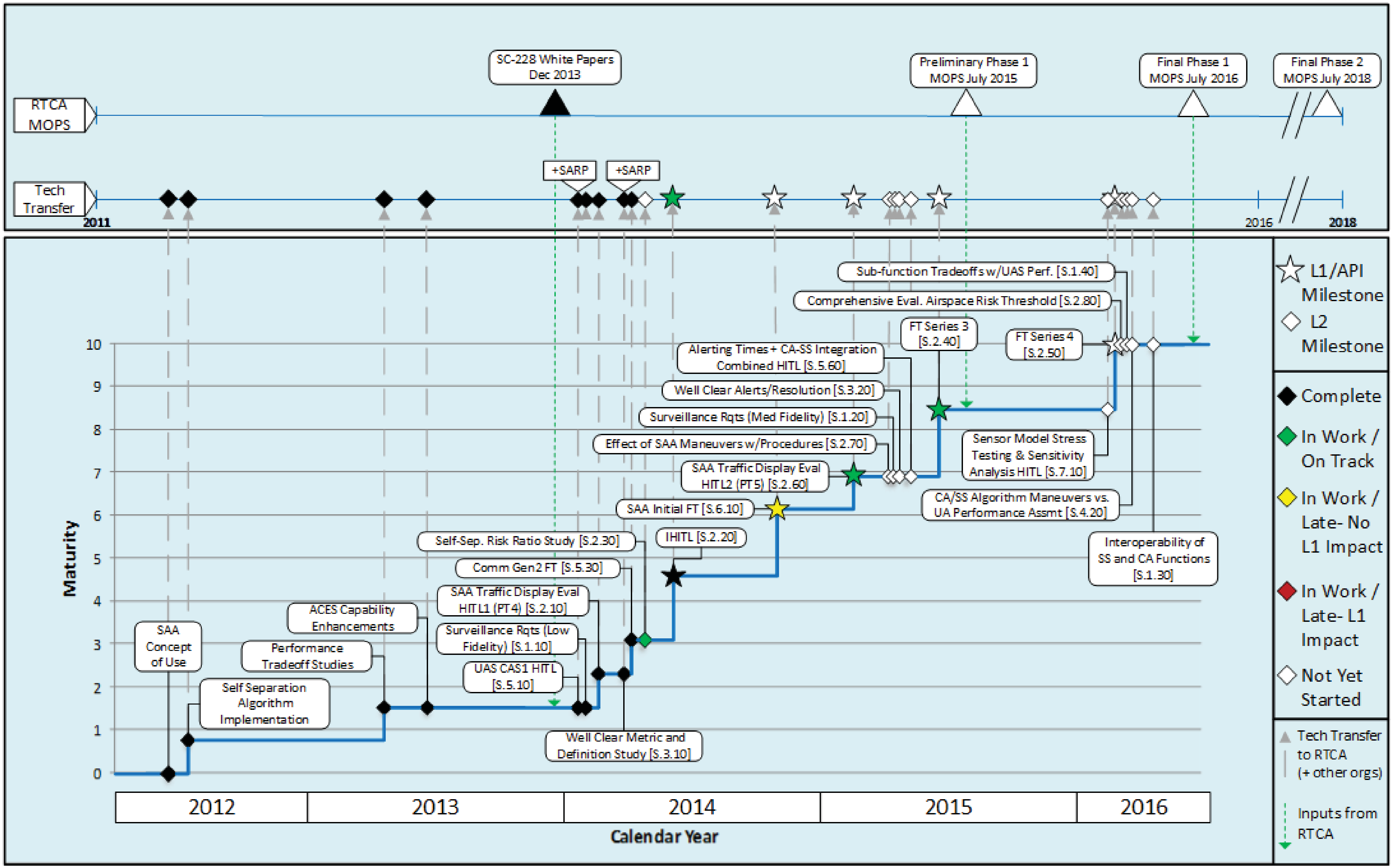
Preliminary MOPS

- Transfer of sim and HITL results to stakeholders
- Development of Integrated Event scenarios based off of sim and HITL results, and community inputs
- Execution of IHITL and Project SAA Flight Test to obtain high fidelity experiment data and non-cooperative SAA sensor data

Final MOPS

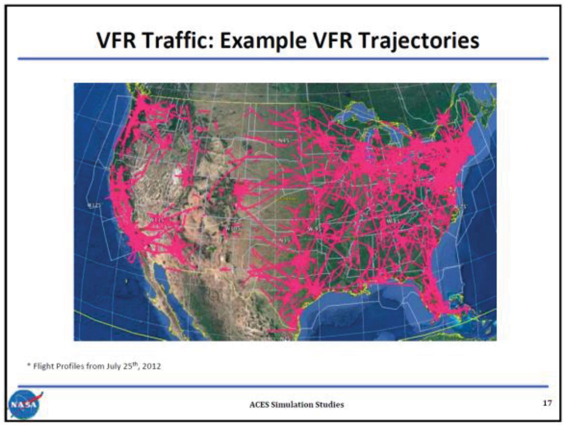
- Final sim and HITL results
- Execution of FT3 and FT4 Integrated Events as V&V of project experiments, and MOPS

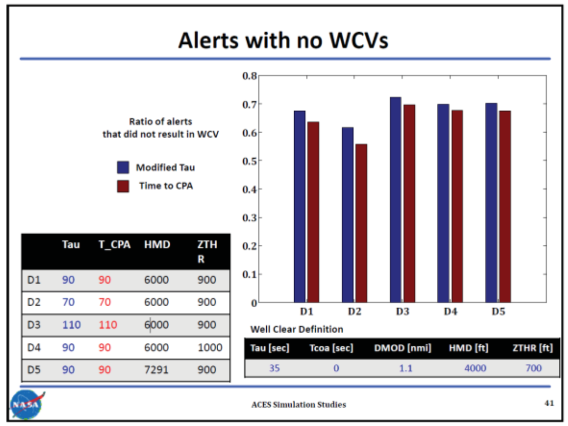
TC-SAA: Progress Indicator



Well Clear Metric and Definition Study

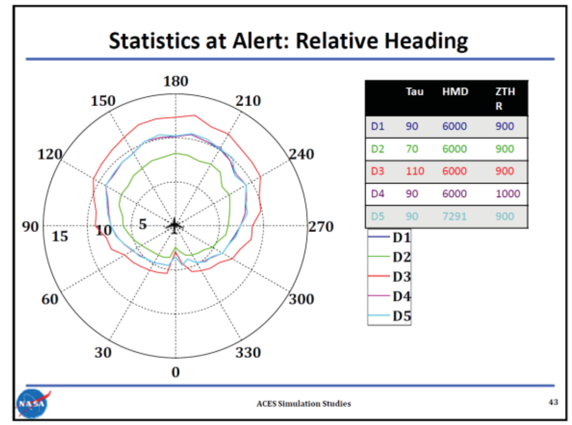
- **Research Activity Objective:**
  - Gather data and develop recommendations for a quantified definition of Well Clear using cooperative Visual Flight Rule traffic that meets target level of safety requirements and NAS-interoperability considerations





	Tau	T_CPA	HMD	ZTHR
D1	90	90	6000	900
D2	70	70	6000	900
D3	110	110	6000	900
D4	90	90	6000	1000
D5	90	90	7291	900

Tau [sec]	Tcoa [sec]	DMOD [nmi]	HMD [ft]	ZTHR [ft]
35	0	1.1	4000	700



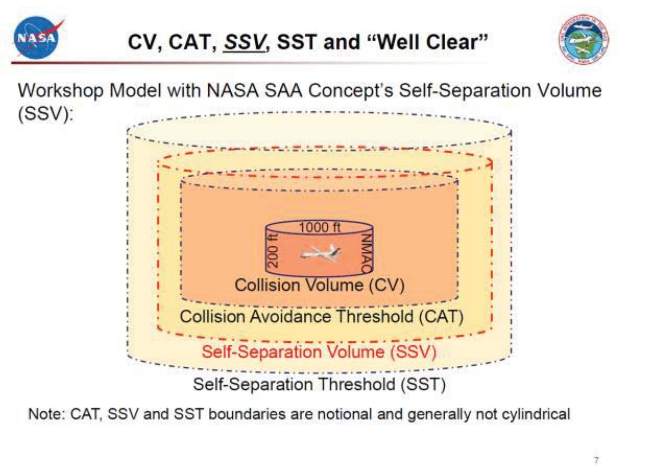
	Tau	HMD	ZTHR
D1	90	6000	900
D2	70	6000	900
D3	110	6000	900
D4	90	6000	1000
D5	90	7291	900

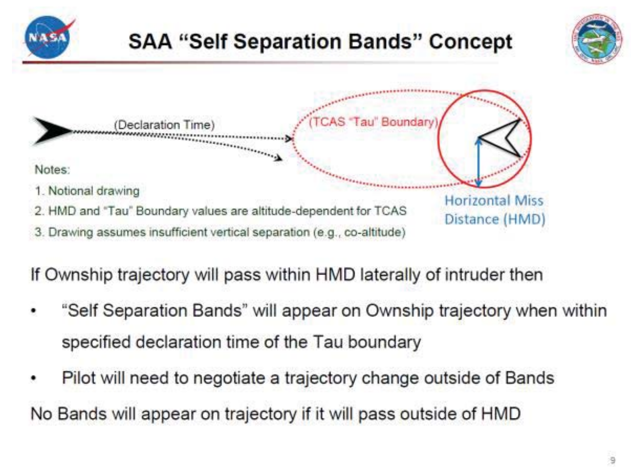
- **Significant Results, Conclusions, and Recommendations:**
  - A minimum 5 nmi range to avoid missed detections
  - 99% of the alerts lie within 10 nmi with a 90 second modified tau alerting threshold
  - Horizontal miss distance and vertical distance criteria will have the largest impact on encounter rates and the closer two aircraft are the more sensitive the encounter rate is to these parameters
  - ~70% of alerts generated using modified Tau or time to co-altitude criteria did not lead to a Well Clear violation

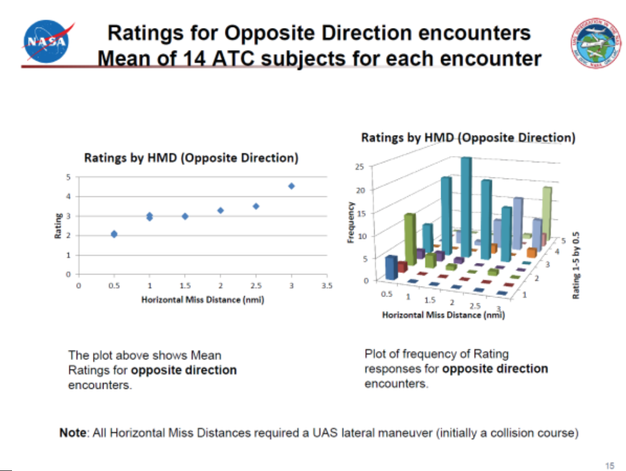
Results Contributed to Well Clear Separation Standard for DAA MOPS

UAS Controller Acceptability Study (CAS)1 HITL

- **Research Activity Objective:**
  - Evaluate the impact of UAS SAA self separation maneuvers resulting for different SAA Well Clear volumes on controller perceptions of safety and efficiency







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

Results Contributed to Well Clear Separation Standard & ATC Interoperability for DAA MOPS

TC-C2: C2 Performance Standards

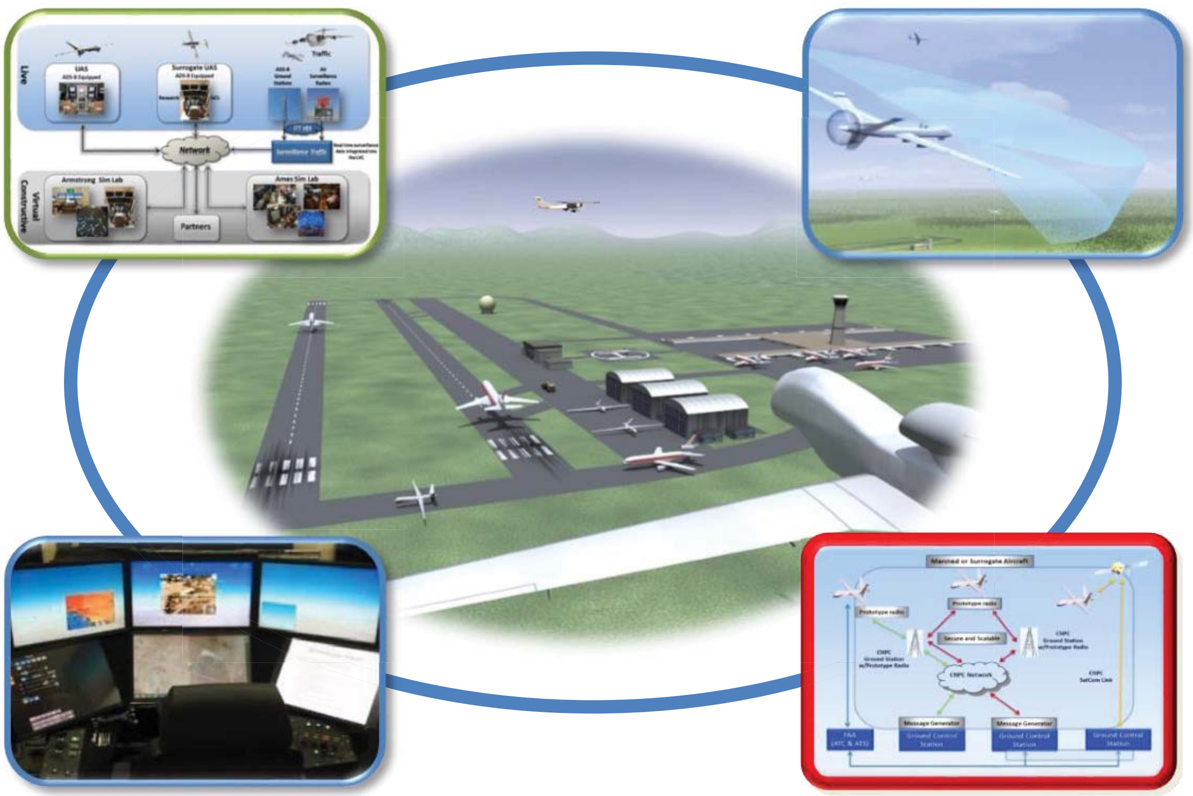
RT1 - UAS Integration

- 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

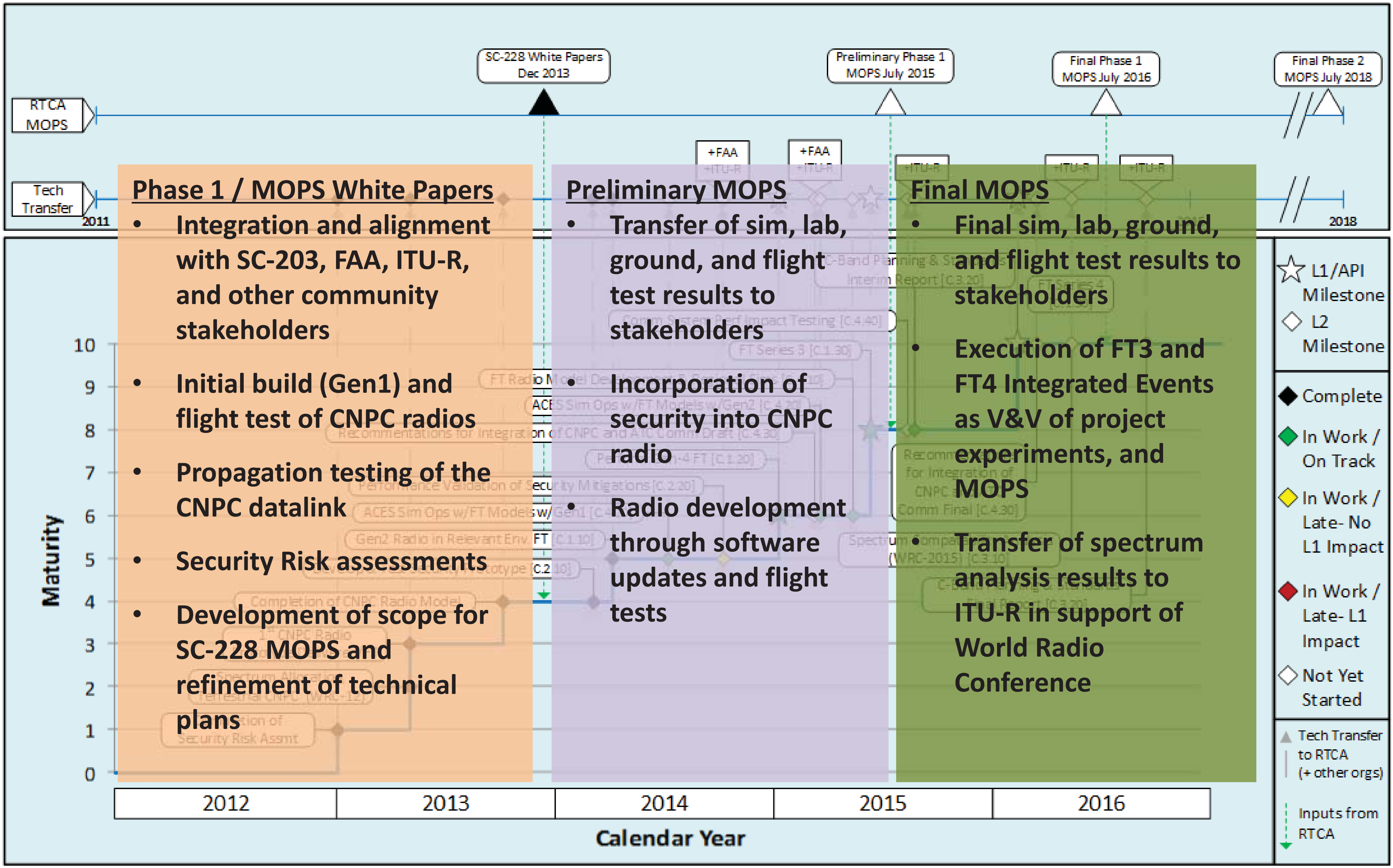
TC-SAA: Sense and Avoid Performance Standards



TC-HSI: Human Systems Integration

TC-C2: Command & Control Performance Standards

TC-C2: Progress Indicator



Phase 1 / MOPS White Papers

- Integration and alignment with SC-203, FAA, ITU-R, and other community stakeholders
- Initial build (Gen1) and flight test of CNPC radios
- Propagation testing of the CNPC datalink
- Security Risk assessments
- Development of scope for SC-228 MOPS and refinement of technical plans

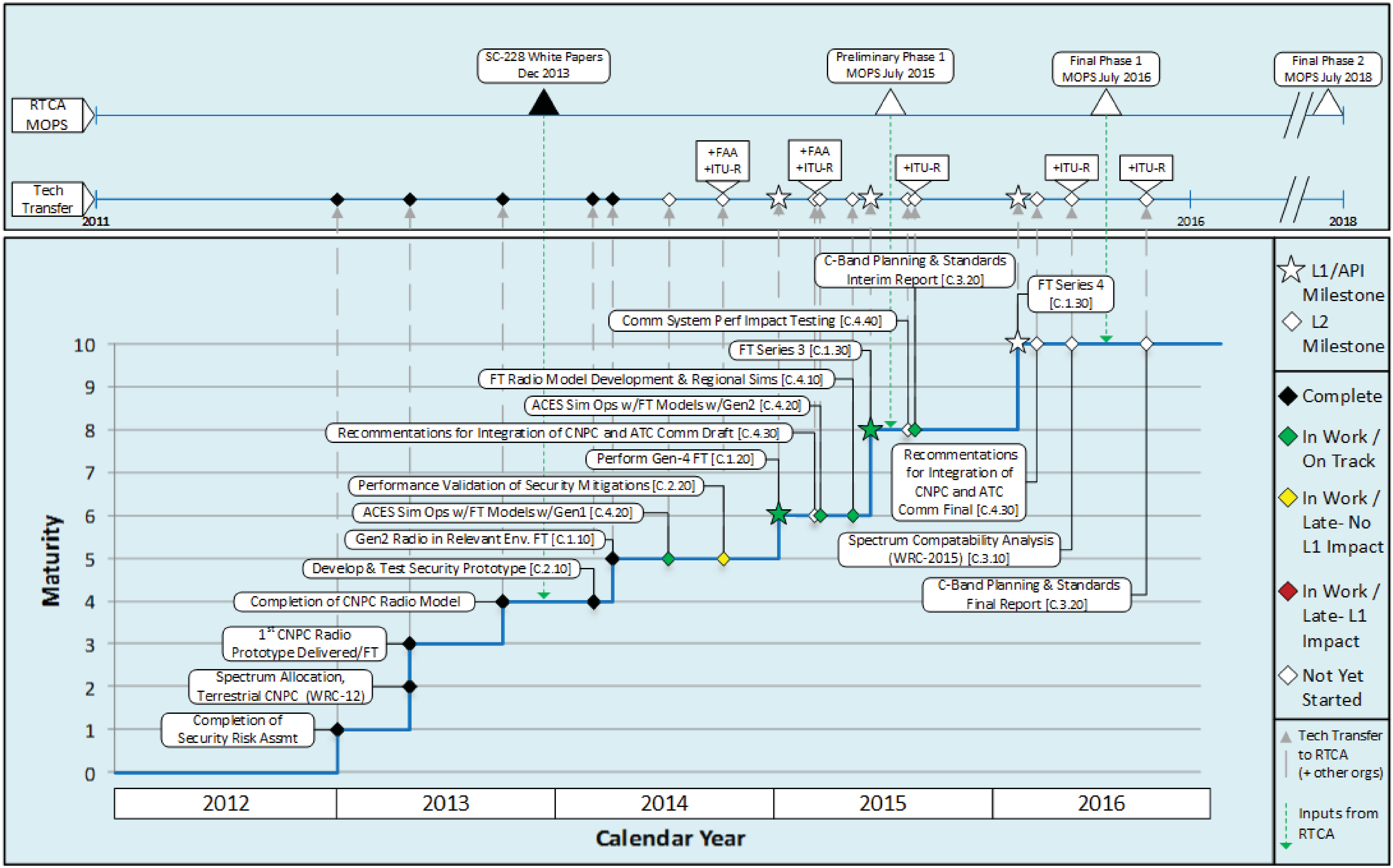
Preliminary MOPS

- Transfer of sim, lab, ground, and flight test results to stakeholders
- Incorporation of security into CNPC radio
- Radio development through software updates and flight tests

Final MOPS

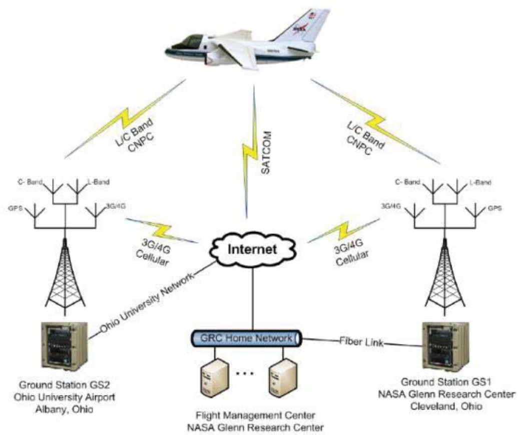
- Final sim, lab, ground, and flight test results to stakeholders
- Execution of FT3 and FT4 Integrated Events as V&V of project experiments, and MOPS
- Transfer of spectrum analysis results to ITU-R in support of World Radio Conference

TC-C2: Progress Indicator



Gen2 Radio in Relevant Environment Flight Test

- **Research Activity Objectives:**
  - Analyze the performance of the second generation C-band CNPC System prototype in a relevant flight environment

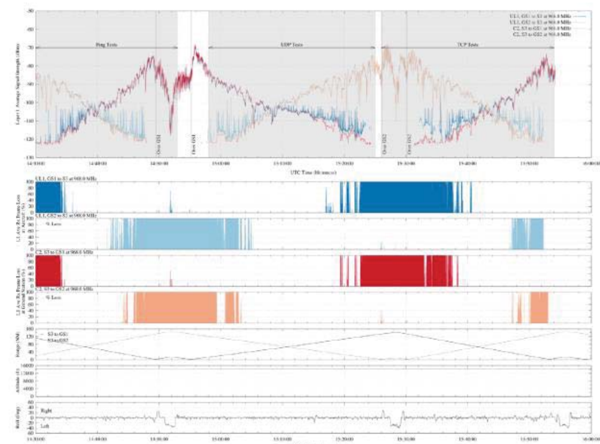


April 11, 2014

GS1 Characterization

April 30, 2014

Two Ground Stations, hand-off and data flow tests

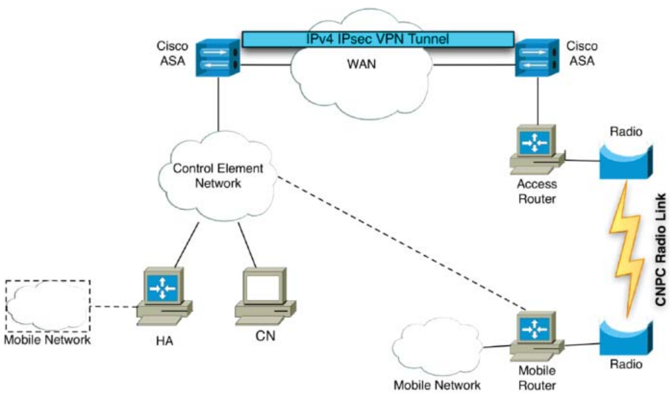


- **Results and Conclusions:**
  - Demonstrated fluid transition “hand-off” of aircraft CNPC signal between two CNPC system ground stations
  - Demonstrated operation of remote CNPC system ground terminals through network
  - Measured data link transmission/reception times
  - Testing of the 2nd generation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

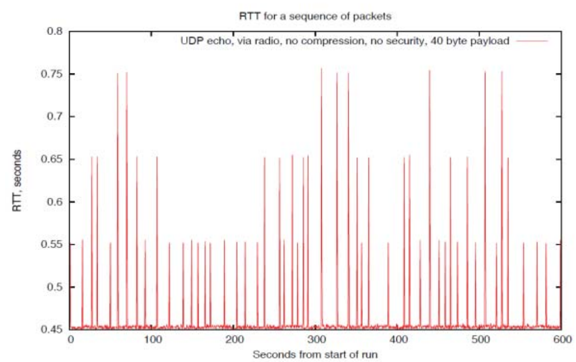
Results Contributed to CNPC Radio for Development and V&V of C2 MOPS

Develop and Test Security Prototype

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



Baseline Latency (UDP)



Results Summary

	Radio, Baseline,	Radio, IPsec	Radio, ROHC	Radio, IPsec, ROHC
UDP, Avg. Bytes/s	262.895	311.147	95.4017	219.03
ICMP RTT Avg., Sec	0.479911	0.490045	0.187938	0.387468
UDP RTT Avg., Sec	0.460836	0.461066	0.159071	0.357333
UDP RTT Min., Sec	0.451063	0.451097	0.151249	0.351076
UDP RTT Max., Sec	0.756798	0.85444	0.455316	0.655391
ICMP Std. Dev.	0.0399578	0.0454718	0.0491613	0.0447224
UDP Std. Dev.	0.0370915	0.0428625	0.0335293	0.0278838

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

Results Contributed to Security Requirements for C2 MOPS

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

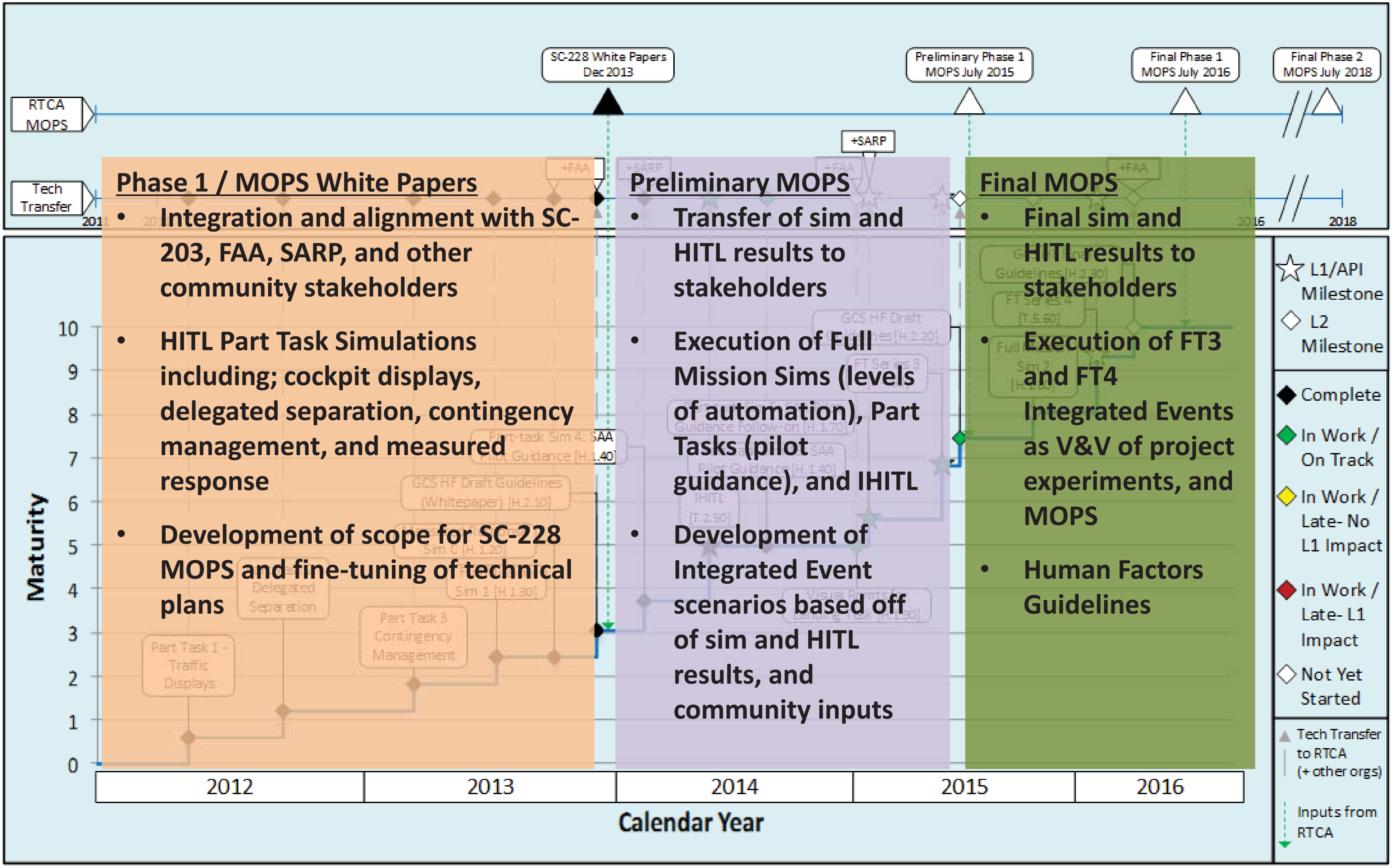
TC-ITE: Integrated Test & Evaluation

TC-SAA: Sense and Avoid Performance Standards

TC-HSI: Human Systems Integration

TC-C2: Command & Control Performance Standards

TC-HSI: Progress Indicator



Phase 1 / MOPS White Papers

- Integration and alignment with SC-203, FAA, SARP, and other community stakeholders
- HITL Part Task Simulations including; cockpit displays, delegated separation, contingency management, and measured response
- Development of scope for SC-228 MOPS and fine-tuning of technical plans

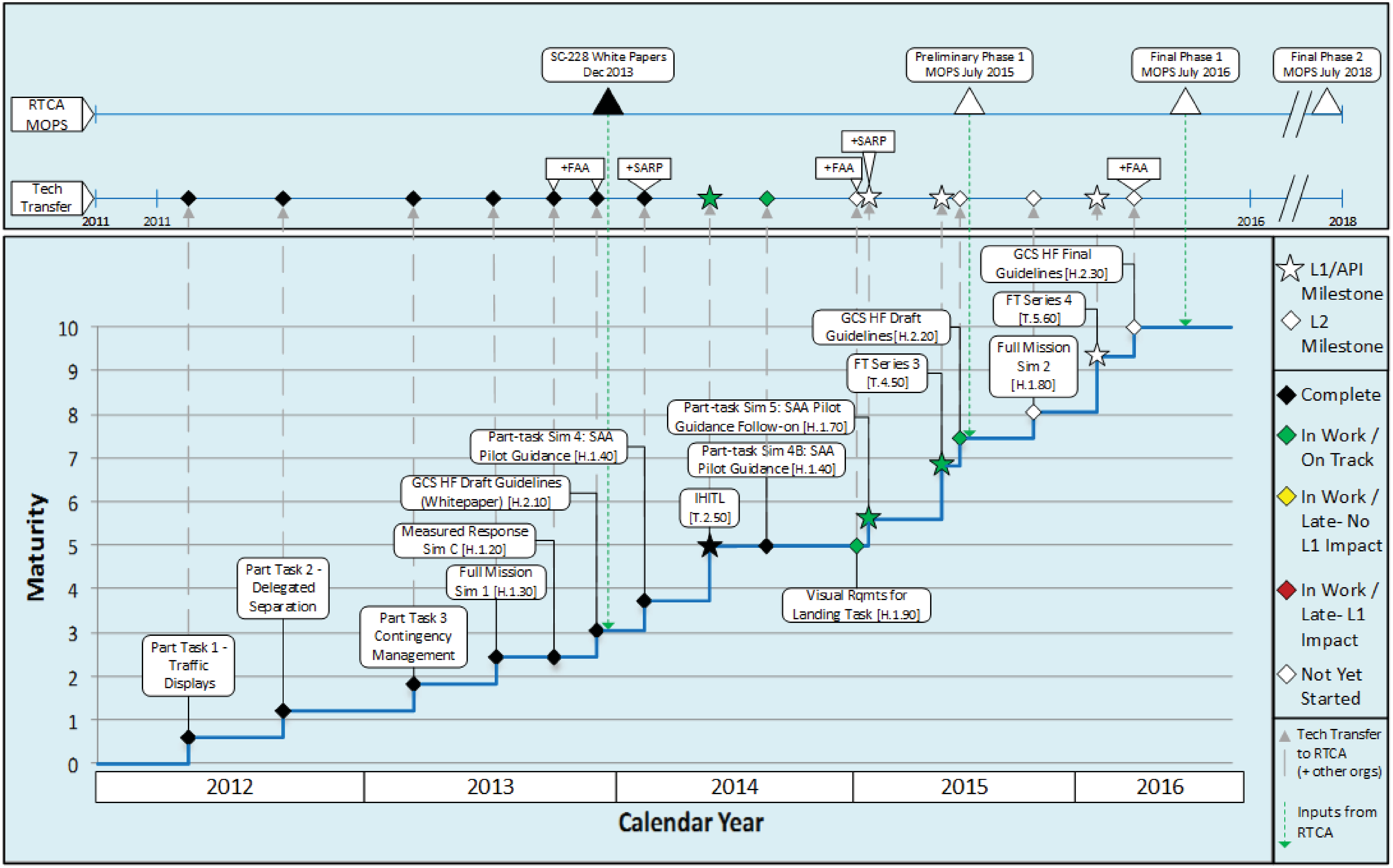
Preliminary MOPS

- Transfer of sim and HITL results to stakeholders
- Execution of Full Mission Sims (levels of automation), Part Tasks (pilot guidance), and IHITL
- Development of Integrated Event scenarios based off of sim and HITL results, and community inputs

Final MOPS

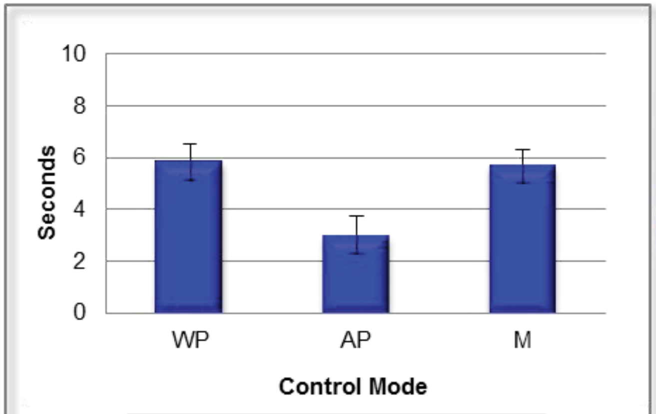
- Final sim and HITL results to stakeholders
- Execution of FT3 and FT4 Integrated Events as V&V of project experiments, and MOPS
- Human Factors Guidelines

TC-HSI: Progress Indicator

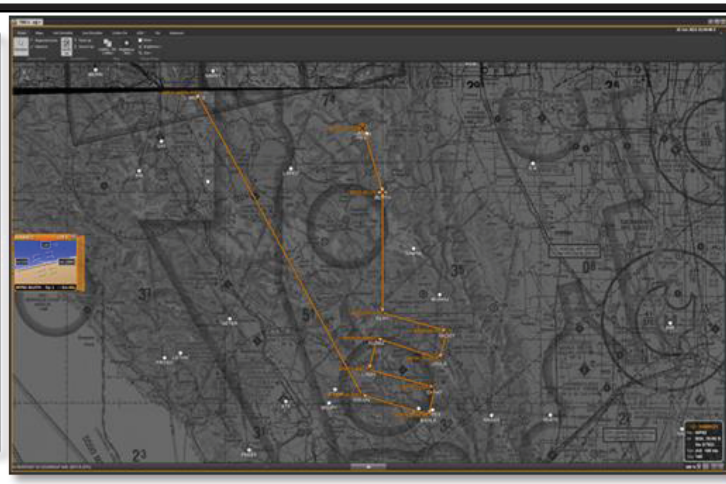


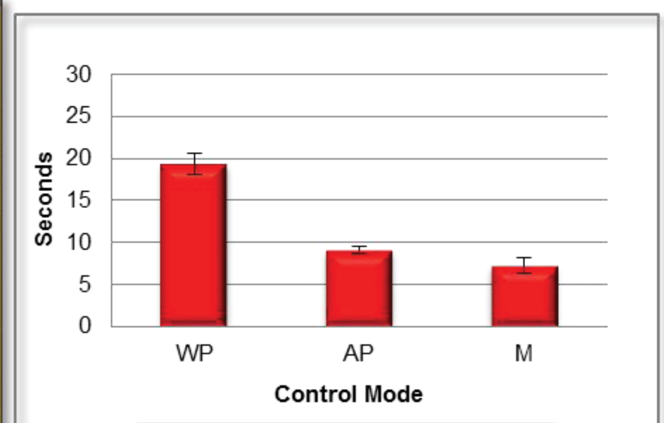
Full-Mission Simulation 1: Levels of Automation

- **Research Activity Objective:**
  - Evaluate pilot response to various events while operating under various levels of UAS automation



Pilot Response Time





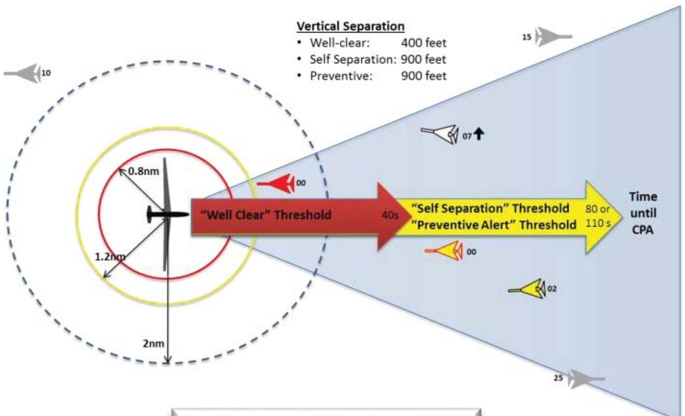
Pilot Edit Time

- **Significant Results, Conclusions, and Recommendations:**
  - Waypoint-to-waypoint control mode demonstrated significant deficits in all of the pilot measured response components compared to Autopilot and Manual control modes
  - Autopilot and Manual control modes had significantly shorter compliance times overall than Waypoint-to-waypoint control mode implying a potential need for a function or mode for quick input to respond the alerts or ATC instructions
  - Initial database of expected pilot response time distributions

Results Contributed to GCS Automation Guidelines/Requirements for DAA & C2 MOPS

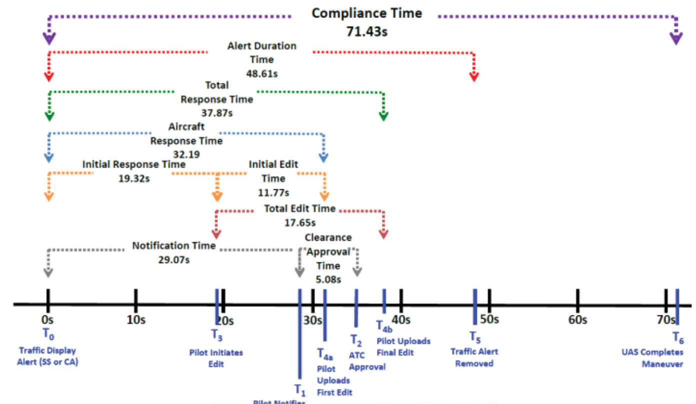
Part-task Simulation 4: SAA Pilot Guidance

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



SAA Thresholds

GCS Display



Timeline

- **Interim Significant Results, Conclusions, and Recommendations:**
  – Consistent advantage seen for Advanced over Basic displays
  – Overall, the Advanced displays had a faster Total Response Time compared to Basic
  – There were no significant differences between the Standalone and Integrated condition
  – Implications to Well Clear Violations and DAA Timeline need to be evaluated

Results Contributed to GCS Minimum Information Guidelines/Requirements for DAA MOPS

TC-ITE: Integrated Test and Evaluation

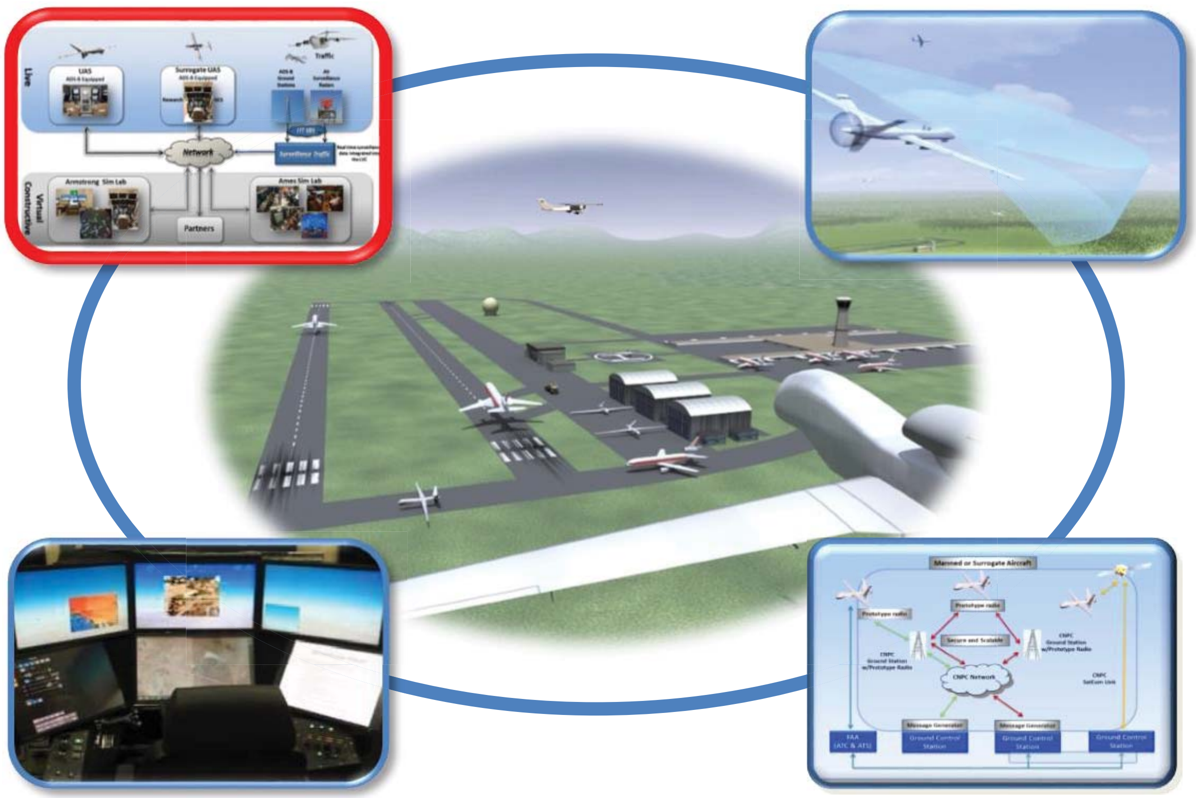
RT2 – Test Infrastructure

- 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

TC-ITE: Integrated Test & Evaluation

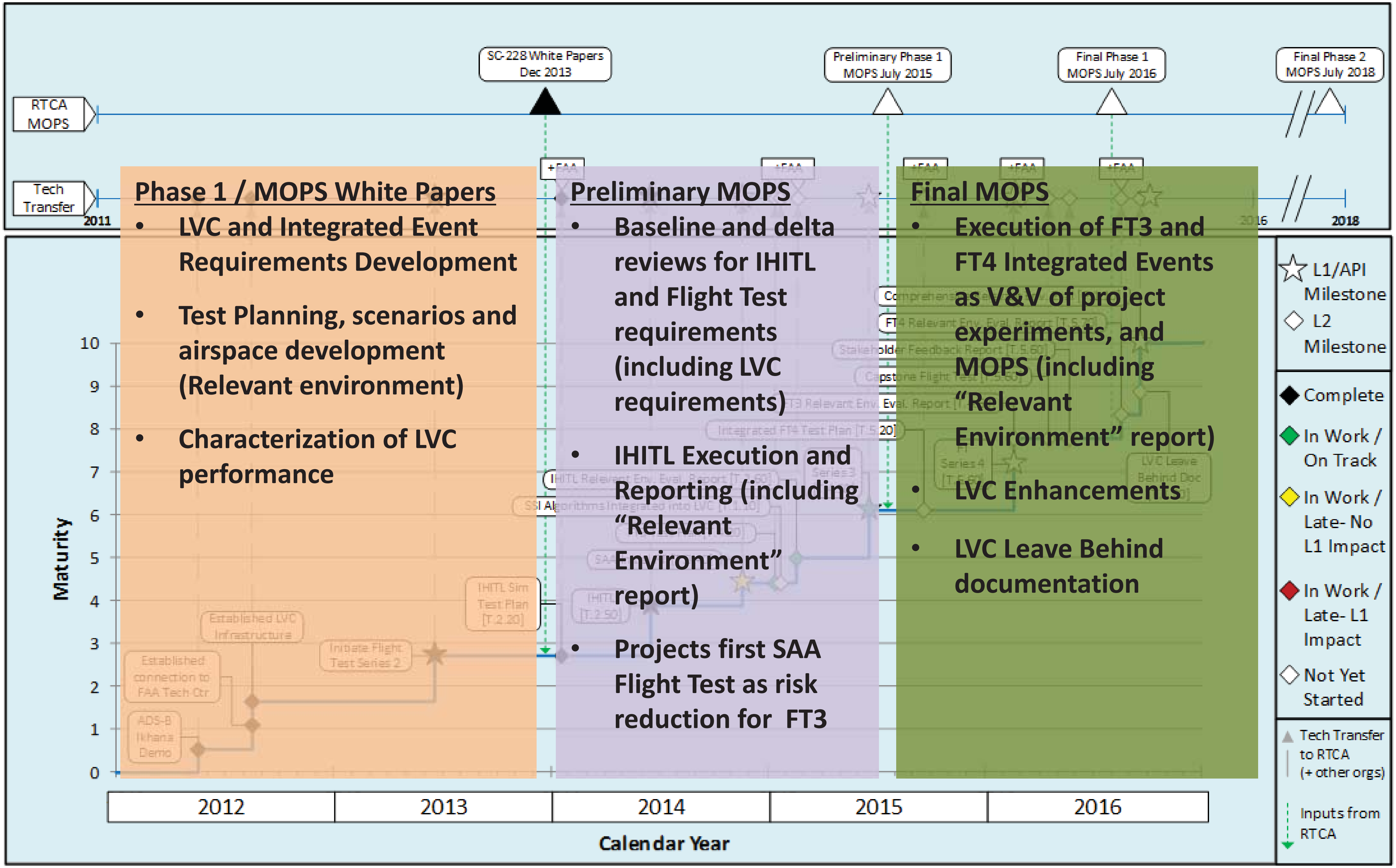
TC-SAA: Sense and Avoid Performance Standards



TC-HSI: Human Systems Integration

TC-C2: Command & Control Performance Standards

TC-ITE: Progress Indicator



Phase 1 / MOPS White Papers

- LVC and Integrated Event Requirements Development
- Test Planning, scenarios and airspace development (Relevant environment)
- Characterization of LVC performance

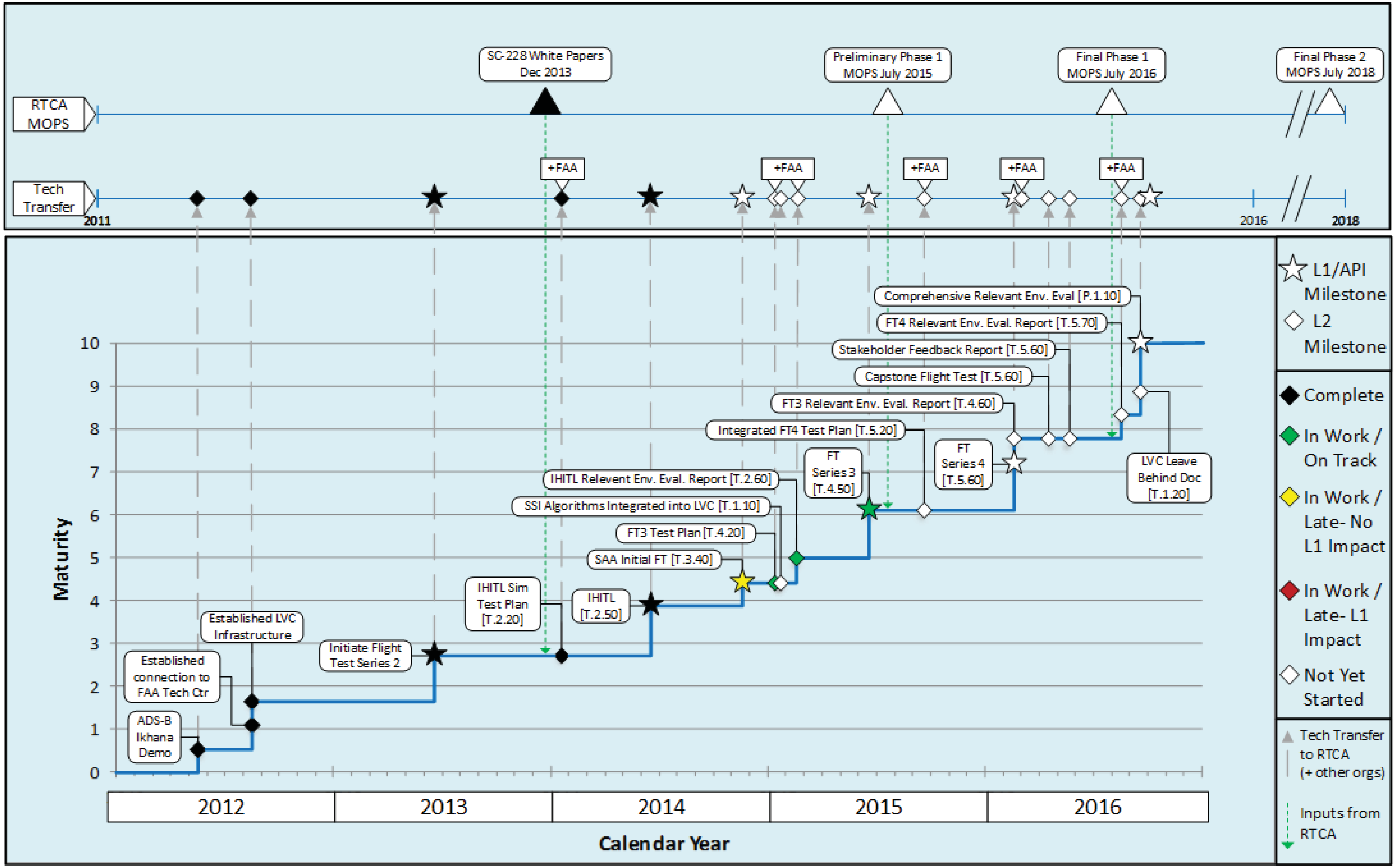
Preliminary MOPS

- Baseline and delta reviews for IHITL and Flight Test requirements (including LVC requirements)
- IHITL Execution and Reporting (including “Relevant Environment” report)
- Projects first SAA Flight Test as risk reduction for FT3

Final MOPS

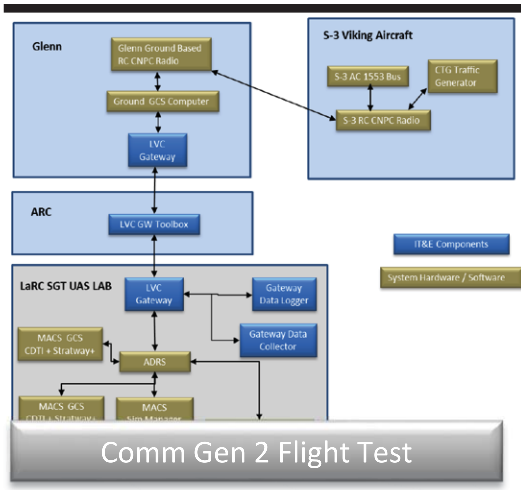
- Execution of FT3 and FT4 Integrated Events as V&V of project experiments, and MOPS (including “Relevant Environment” report)
- LVC Enhancements
- LVC Leave Behind documentation

TC-ITE: Progress Indicator

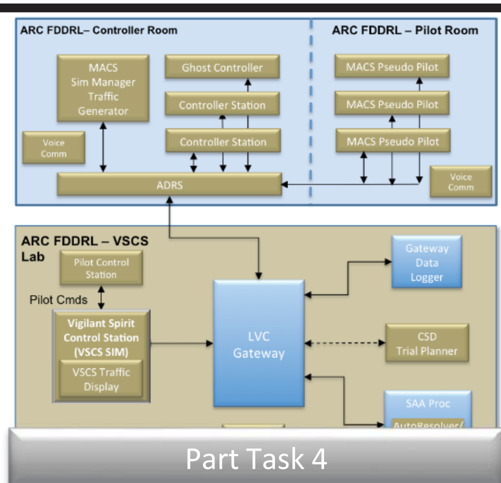


Sim and Demo Planning Support

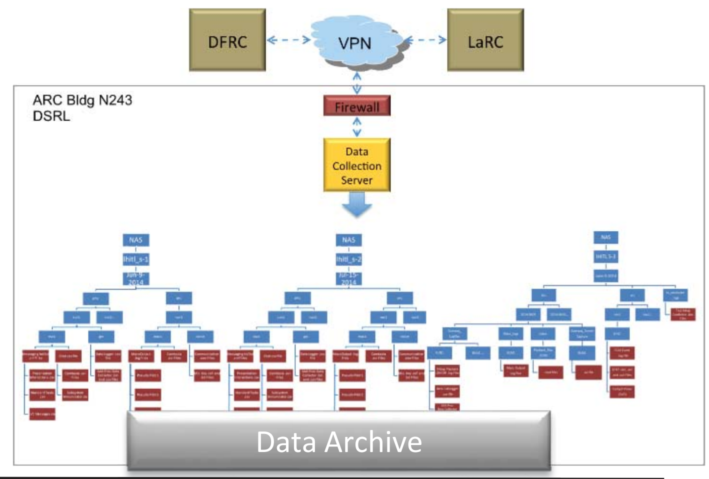
- **Research Activity Objective:**
  - Develop and maintain a relevant test environment to support sub-project research simulations, identify and document the LVC interfaces, and reduce risk for the integrated events by implementing the prototype infrastructure



Comm Gen 2 Flight Test



Part Task 4



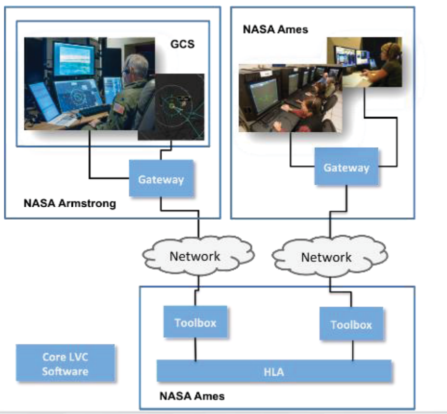
Data Archive

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

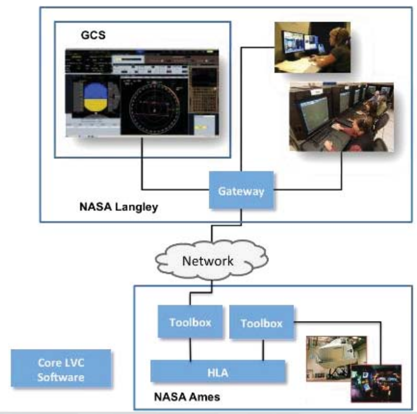
Results Contributed to Test Environment and Support for Draft DAA and C2 MOPS

IHITL Execution

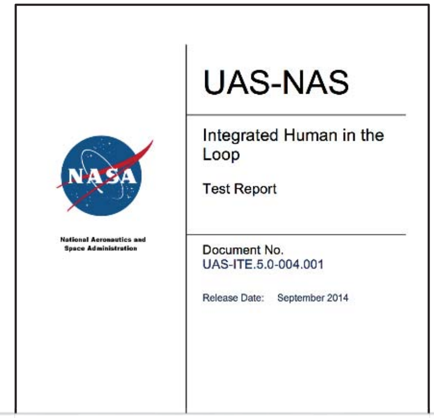
- **Research Activity Objective:**
  - Conduct a HITL simulation integrating the latest SSI algorithms, CNPC System model, and HSI displays using the Live, Virtual, Constructive test environment and document the performance of the simulation infrastructure in meeting the simulation requirements



ARC-AFRC Configuration



ARC-LaRC Configuration



FY14 Annual Performance Goal

- **Interim Significant Results, Conclusions, and Recommendations:**
  - IHITL successfully completed on July 25th
    - Data for each of the tests was successfully collected for all test subjects and archived at NASA Ames for researcher access
    - Distributed LVC test infrastructure thoroughly tested, though some software anomalies were noted, none significantly impacted data collection
    - Required data provided to researchers on schedule
  - The simulation report documenting performance of the simulation infrastructure is on schedule

Results Contributed to Test Environment for V&V of DAA and C2 MOPS

Contributions to Stakeholders

- OSD SAA SARP
  - Provided one of three Well Clear Standards to SARP for assessment
  - Assisted SARP with
    - Definition of selection criteria: operational acceptability metrics
    - Data and analysis of three proposals against operational metrics

- SC-228 DAA and C2 Working Groups
  - Well Clear Definition
    - FAA provided recommended modification to SARP Well Clear criteria
    - FAA recommendation modified vertical dimension nearer to NASA proposal
  - DAA system requirements
  - DAA Verification and Validation requirements
  - GCS minimum display requirements
  - CNPC System performance requirements

- World Radio Conference
  - UAS Spectrum Analysis

Provided High Quality Products Meeting Stakeholders Needs

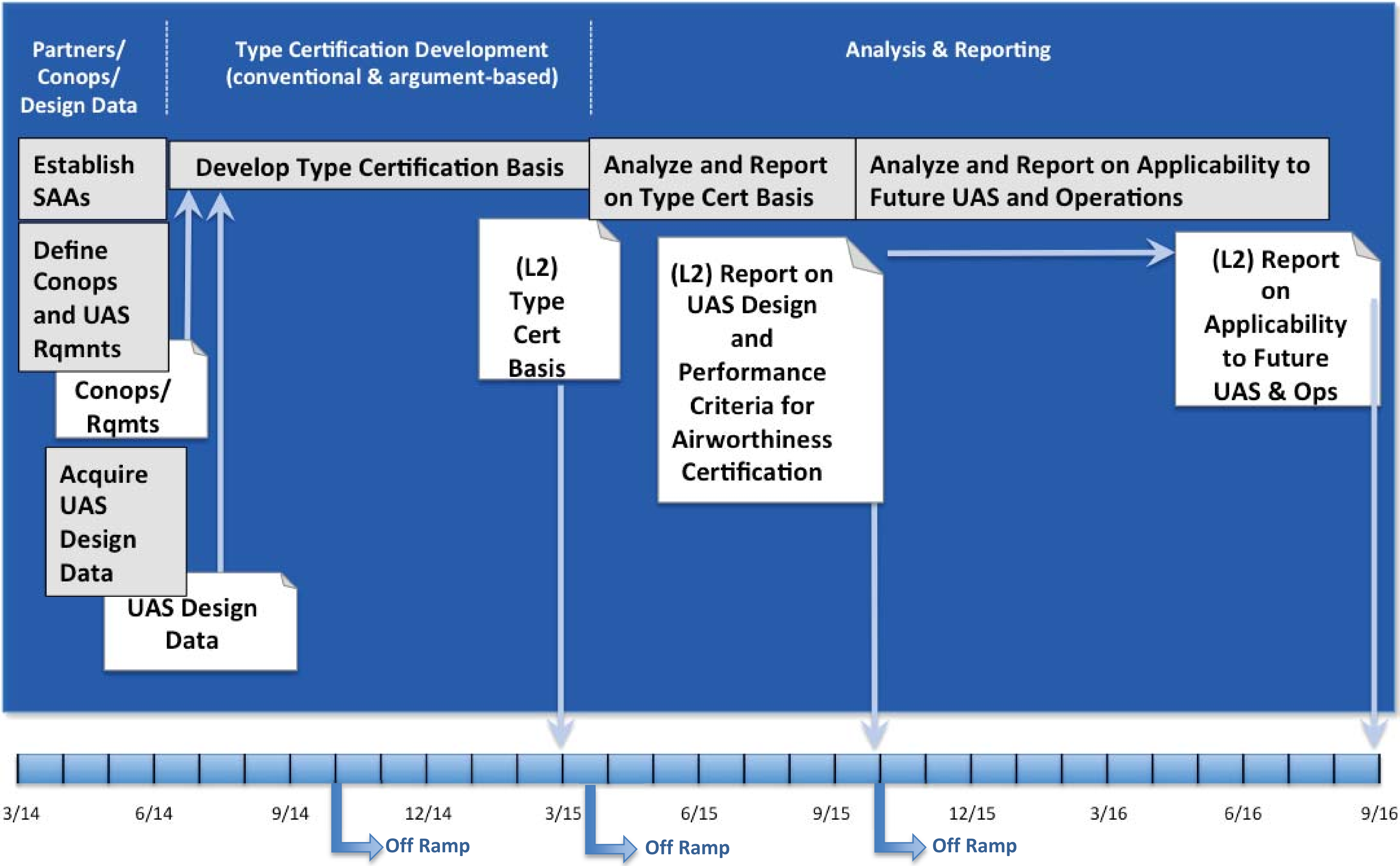
Outline

- UAS-NAS Overview
- TC Performance against the Baseline
- Non-Technical Challenge Work – Davis Hackenberg
  - Certification
  - sUAS
  - USMC
  - Capstone
  - Test Site Visits
  - LVC-DE Enhancements
- Project Control Processes & Governing Documents
- Project Level Performance & FY15 Look Ahead
- Review Summary

Non-Technical Challenge Work

- Non-Technical challenge work is technical work outside the core project focus areas
  - Includes far-reaching/higher risk activities with an emphasis on future (post-project) capabilities
  - Utilizes project management rigor, but to a lesser extent (i.e. No Progress Indicators)
  - Content is not required for min-success of the project
  - Does not have L1 milestones
- Source for resources should TC work encounter unknown risks requiring additional resources for mitigation
- Long term activities have pre-defined off-ramps/on-ramps to facilitate potential TC work needs
  - Off-ramps: Clearly defined breakpoints/stopping places within scheduled activities
  - On-Ramps: New proposed activities that are aligned with the intent of Non-TC work
- Non-TC Work on UAS-NAS Project
  - Certification
  - sUAS
- Management activities with on-ramp implications (being book kept as Non-TC work)
  - USMC
  - Capstone Development
  - Test Sites
  - LVC-DE Enhancements

Certification Plan and Status

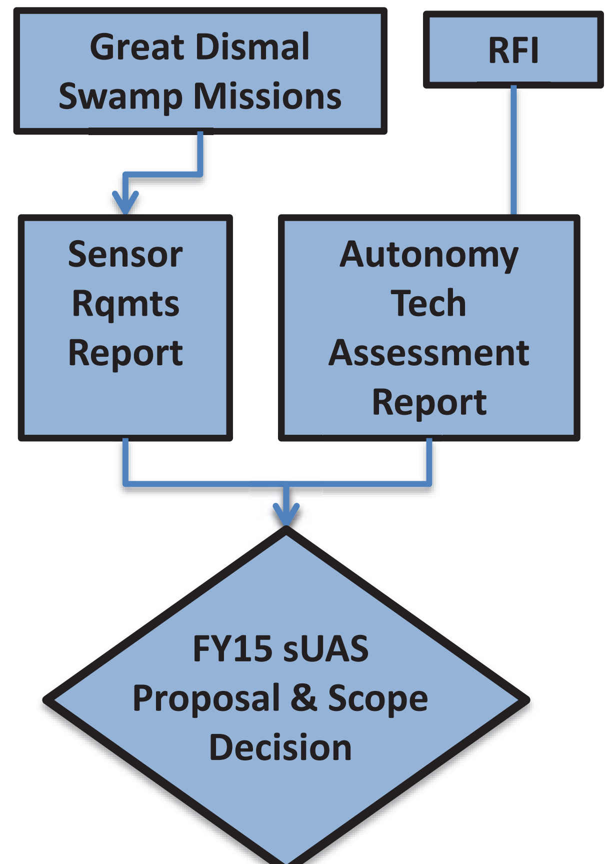


sUAS Plan and Status

- Great Dismal Swamp (GDS) Missions
  - Flights at Smithfield conducted to assess vehicle range and navigation, and sensor performance
  - Agreement with US Fish & Wildlife Service (through Department of Interior) signed to allow flights over GDS
  - Delays in Agreement and the GDS annual proscribed burn schedule caused slip in official Flight Test
  - Execution of GDS Flights (Proscribed Burn) planned to begin on 11/18/14 (Baseline L2 Milestone 8/6/14)
  - Final Report Scheduled to be delivered on 12/19/14 (Baseline L2 Milestone 9/30/14)
- sUAS Vehicle Autonomy RFI
  - Released on 9/8/14 and 42 responses received on 10/17/14
  - Formalized Technology Assessment criteria and scoring
  - Multi-center interest in responses led to a request for ARDs to provide personnel to support a multi-center review team
  - Final Technology Assessment due on 12/19/14
- Next Steps: On-ramp proposal for FY15 work to be evaluated as part of reserve strategy

3-D Robotics Bixler

Army FQM-117B



Marine Corps Space Act Agreement Status

- NASA collaboration with USMC leverages pilots and operational UAS from Yuma Proving Grounds and Twenty-nine Palms
- Primary components include:
  - RQ-7 Shadow UAV
  - Backup UAV
  - Launcher
  - Universal ground control station (UGCS)
  - Shadow ground control station (GCS)
- NASA evaluated systems and pilot responses to provide Human Factors observation and recommendations
- NASA Cockpit Situation Display (CSD) identified as a technology that could provide quality enhancements to the USMC systems
- NAVAIR, the owner of the systems, has received the appropriate demonstrations and is evaluating
- Final Report to be delivered to USMC in November








Capstone Development Status

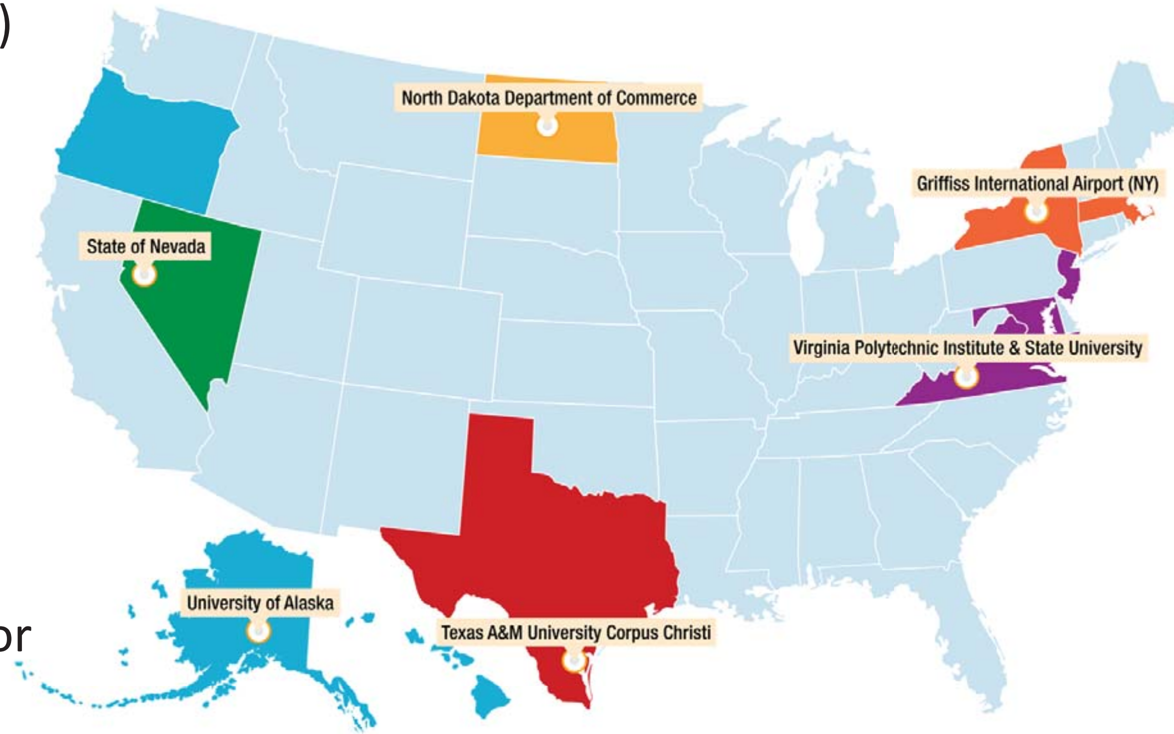
- Current Capstone definition:
  - Two flights of three hours in duration (agreed upon during KDP)
  - Demonstrate the UAS-NAS Project research portfolio relevant to SC-228 Phase 1 MOPS (terrestrial C2 and DAA)
  - Activities are being developed in conjunction with deadlines for FT4 (i.e. Capstone Test Plan feeds the FT4 Test Plan)

- Coordination ongoing with the FAA to acquire a COA and/or exemption by developing a safety case for alternative method for compliance to the appropriate FARs

- Capstone on-ramps are being developed that may include:
  - Leveraging Test Sites for take-off, landing, and other associated operational aspects
  - Leveraging Test Sites or OSD for additional technologies that bridge a gap between P1 and P2 MOPS (e.g. GBSAA, sensor fusion)
  - Other relevant partnerships with external organizations that further demonstrate P1/P2 MOPS technology development

FAA Test Site Visits

- In order to properly understand the skills and core capabilities of the FAA Test Sites the project visited all six FAA test sites
- At each FAA Test Site there was a series of briefing exchanges that generally included:
  - FAA Test Site briefing
  - UAS-NAS project overview briefing
  - UAS Traffic Management (UTM) overview briefing
  - Tours of the Test Site and Facilities
- The Project created a FAA Test Site Catalog for each location
- Path Forward:
  - Project will continue an open dialog with the FAA Test Sites for potential collaboration opportunities (i.e. Capstone, Certification, and sUAS on-ramps)



LVC-DE Enhancement Action

- Action: Investigate modifications to the LVC-DE to be of better use for future autonomous work. Focus on setting up an environment that brings in partners for future work
- Steps Taken:
  - Developed a suite of initial recommendations that were discussed with UAS-NAS/ASP/ISRP at AFRC
  - Discussed future autonomy research with ASP/CTD Project
  - Met with each FAA UAS Test sites to gather simulation and test facility capabilities
  - Incorporated recommendations from UAS SMEs to cover Phase 2 MOPS research areas
  - Utilized "Content Decision Process (CDP)" leveraging autonomy needs from the NRC Report, ICAST, FAA Interagency Planning Office efforts and afore mentioned meetings
- Current Status: Developed process for prioritizing enhancement areas, began developing associated costs

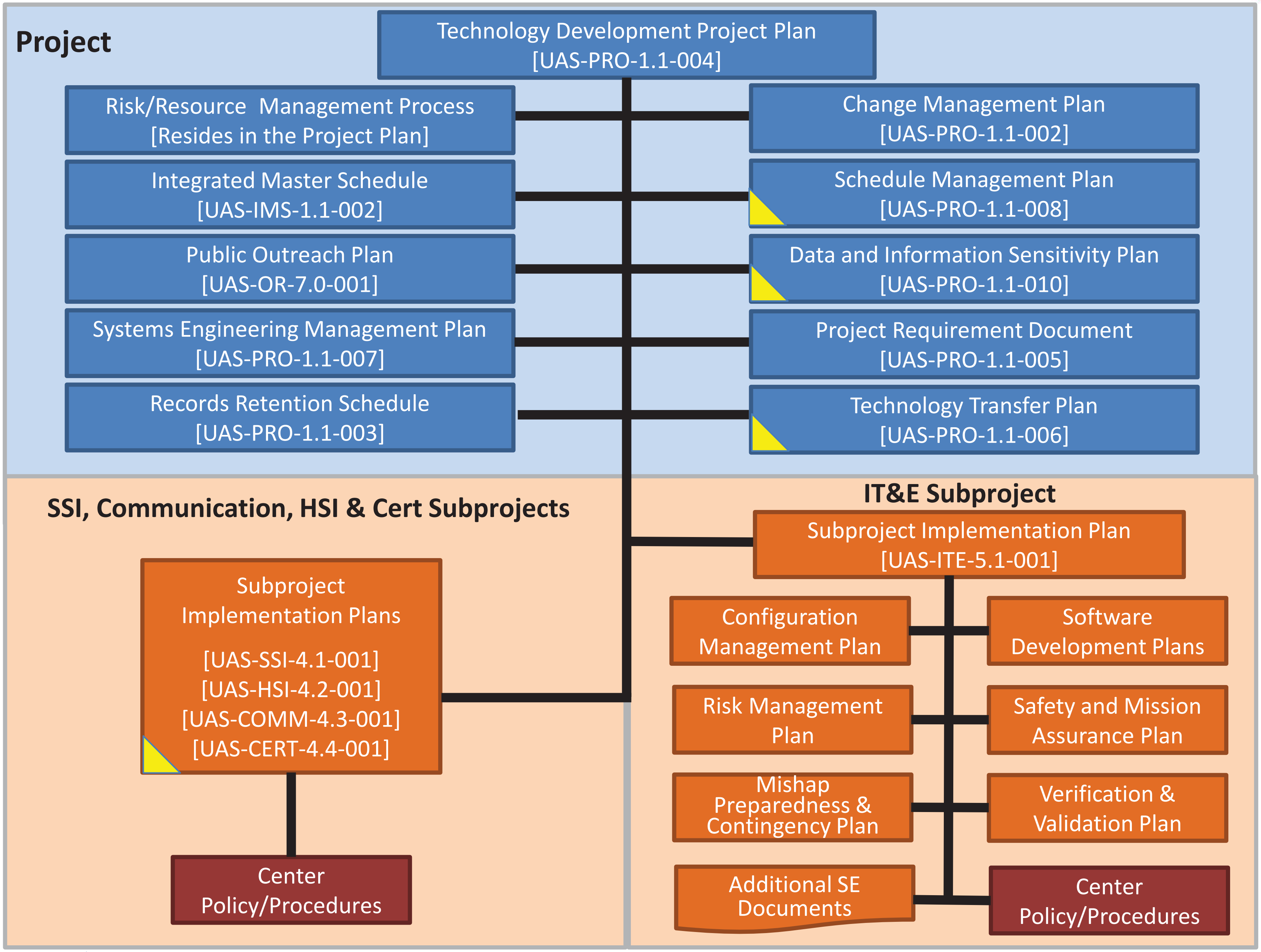
Name (Roll-up of Initial High Priority Enhancements)	Centers
Expand LVC message interface (sensors, legacy systems)	ARC/LaRC/GRC/AFRC
UAS aircraft and trajectory modeling (smalls, rotorcraft)	AFRC/ARC/LaRC
LVC connection and interface robustness (Security, partners)	ARC/LaRC
Data storage and accessibility (data mining, Big Data)	ARC/AFRC
Expand LVC client support (# of aircraft and clients, latencies)	ARC/GRC/AFRC

- Upcoming:
  - Finalize the prioritized list of enhancement areas and associated costs
  - Coordinate full list and priorities with other programs and present to ARMD Associate Administrator
  - Make adjustments to list based on ASP subproject formulation and development

Outline

- UAS-NAS Overview
- TC Performance against the Baseline
- Non-Technical Challenge Work
- Project Control Processes & Governing Documents – Davis Hackenberg
  - Governing Documents
  - Process Changes Since the Baseline
- Project Level Performance & FY15 Look Ahead
- Review Summary

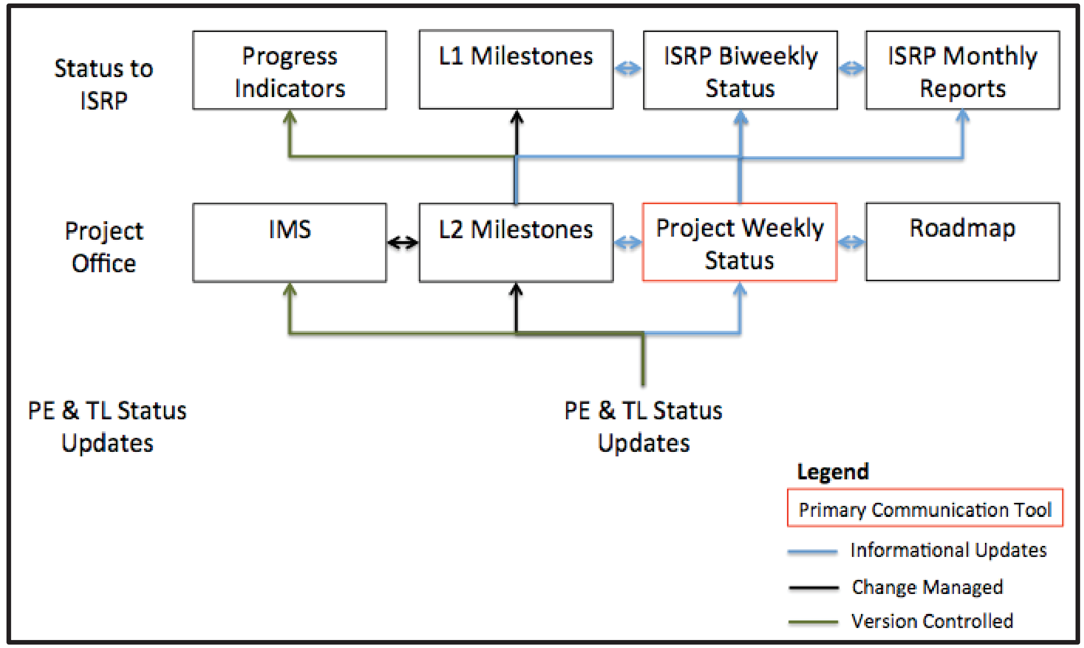
Project Document Tree



Management Impact Changes since Baseline

Schedule Management Plan (SMP)

- Schedule management process is formally documented in the SMP
- Project weekly status is the primary means of information flow, schedule status, and updates
- Schedule Packages and Milestones are the primary means of reporting at the project weekly status



Representative TC Task	M/S Level	Begin Date	End Date	Status/Progress /Concerns
Schedule Package N				Technical, Schedule, Accomplishments, and Issues and Concerns Status
Active Task1		01/01/14	02/15/14	complete
Active Task2		01/20/14	02/28/14	ongoing
Active Task3		02/01/14	03/31/14	ongoing
Deliverable	D	03/15/14	03/15/14	
Milestone	L2	04/01/14	04/01/14	

<u>Changes Since Baseline:</u>

- Project milestone closure process added to SMP

Data Information and Sensitivity

- Purpose
  - UAS-NAS Data and Information Sensitivity Plan is to provide guidance for project personnel and ensure protection of sensitive data and information
- Context
  - Table of identified sensitive information and handling instructions including SBU, company proprietary, and ITAR data

Subproject/Center	Item	Sensitivity Category	Data/Info Owner	NASA POC	Special Handling

  - Specific paragraph for Ikhana data being "subject to ITAR and is protected under the MQ-1 Predator/MQ-9 Reaper Security Classification/Declassification Guide"
- Additional Information
  - Guidance on providing information to Stakeholders
  - Export control marking language
  - Safeguarding and storage (Physical and Electronic)
  - Mailing and transmission
  - Helpful links

Subproject Implementation Plans

- Subproject specific information such as background, objectives, approach and authority
- Subproject specific control plans detailing how the subproject will be managed, including:
  - Technical, schedule, and cost control plans
  - Safety and Mission Assurance
    - Mishap Plan
  - Other relevant center specific processes
- Center specific security and data retention plans
  - Archiving of research test data
- Lessons learned plan

Relevant Environment Stakeholder Feedback Approach

Created new L1 Comprehensive Relevant Environment Evaluation milestone comprised from three L2 milestones

- Stakeholder Feedback Report (Change to Baseline)
  - Stakeholders
    - FAA Technical Center
    - FAA Subject Matter Experts (SME)s not participating in SC-228
    - SC-228 Working Groups
  - Schedule separate design and objectives reviews with stakeholders for FT3 and FT4
    - Provide stakeholders the opportunity to review the test plan information, address their questions, and request their feedback and comments on relevance of the test environment
    - Conduct review in person to allow for real-time feedback and discussion
  - Consolidate/Disposition feedback from notes taken during meetings
    - IT&E consolidates and dispositions the feedback from the design and objectives meetings
    - Depending on the substantive nature of the comments, a separate meeting with stakeholders to review the comment disposition may be required
  - Added review meetings and feedback integration to IMS as part of Test Plan preparation
- FT4 Relevant Environment Evaluation Report (Baselined)
  - Leverages Air Traffic Controller expertise and feedback during integrated events
- LVC Leave Behind Document (Baselined)
  - Documents LVC Capabilities and Design for future use by other projects

Technology Transfer Coordination (UAS-NAS to Stakeholder)

Annual Coordination

- SC-228
- OSD SAA SARP
- FAA UAS Integration Office
- ITU-R

Stakeholder & Project Annual Meetings

- Strategic Planning
- Project Annual Meetings
- Professional Annual Meetings
- Final Reports/Presentations

Monthly/Quarterly Coordination

- SC-228
- OSD SAA SARP
- FAA UAS Int. Office

Stakeholder Face to Face Meetings

- Cross WG Planning
- Key Issues Resolution
- Results Validation
- Briefings

Daily/Weekly Coordination

Stakeholder Working Groups

- SC-228

UAS TWP Integrated Events

- Sub WG Planning
- Key Issues Resolution
- Technical Exchange
- Briefings

RTCA SC-228

- Baseline PRD Content
- Initial Tech Transfer Briefings
- Final Reports

FAA

- Test Plans
- Final Reports

OSD SAA SARP

- Research Findings

ITU-R

- Spectrum Analysis

Formal UAS-NAS Project Deliverables to Stakeholders

Formal Stakeholder Deliverables Influence UAS-NAS

RTCA SC-228

- White Papers
- Preliminary & Final MOPS

FAA

- Integration Road Maps
- Rules and Regulations

OSD SAA SARP

- Recommendations

ITU-R

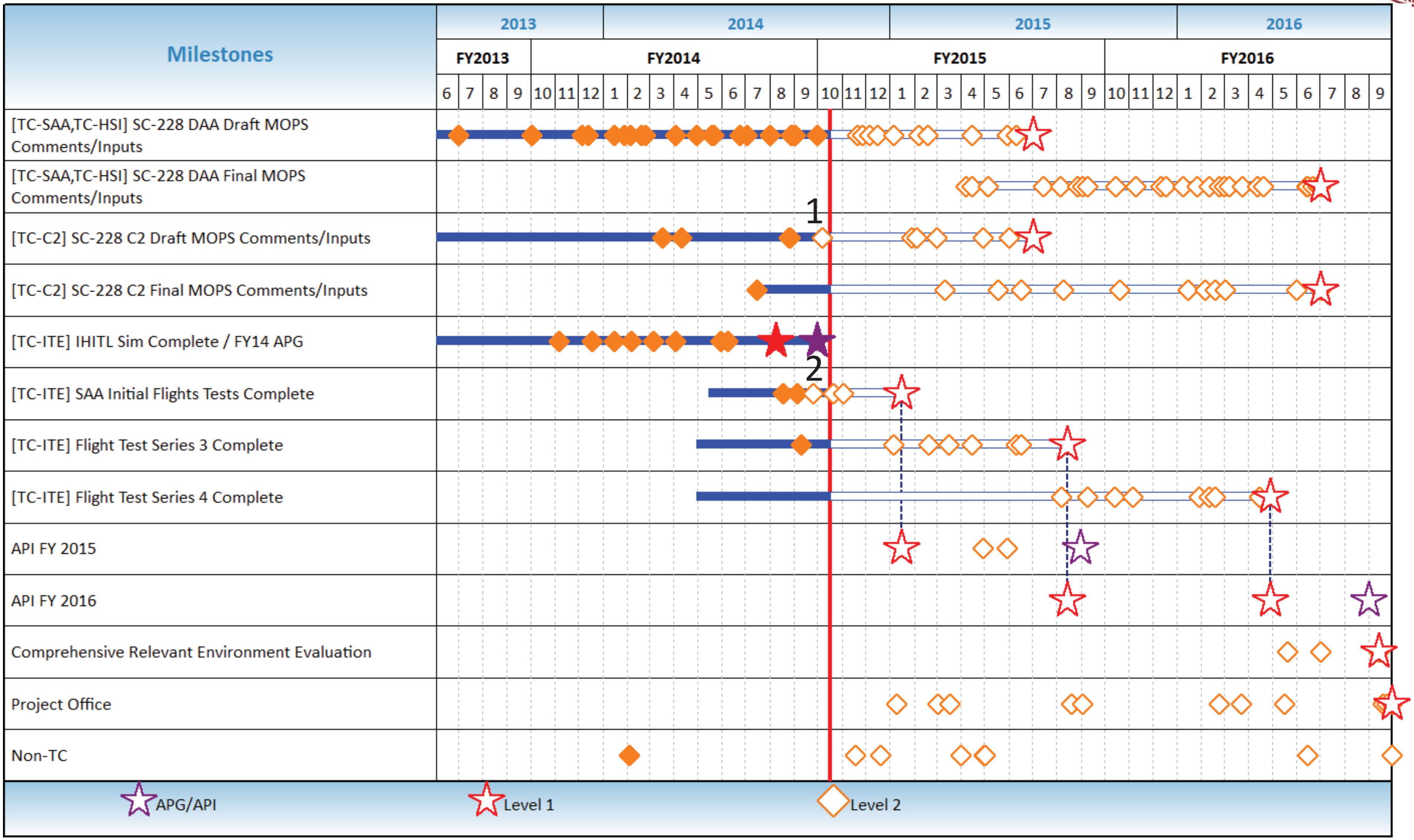
- Authorization

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

Outline

- UAS-NAS Overview
- TC Performance against the Baseline
- Non-Technical Challenge Work
- Project Control Processes & Governing Documents
- Project Level Performance & FY15 Look Ahead – Laurie Grindle
  - Schedule
  - Requirements Summary
  - Partnerships and Collaboration
  - FY14 Accomplishments and FY15 Look Ahead
- Review Summary

UAS-NAS Milestone Summary

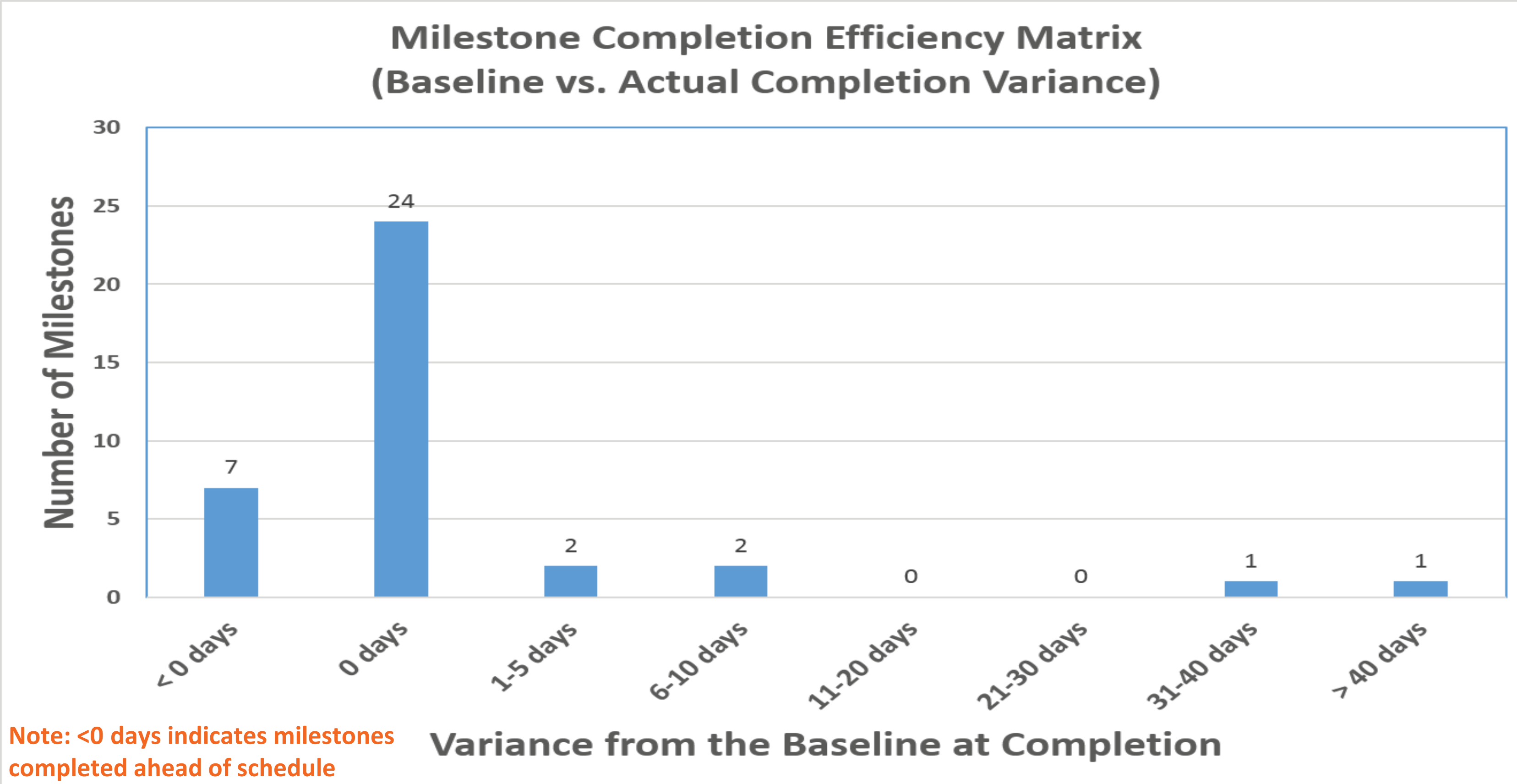


As of 10/16 MRB

Notes:

1. Performance Validation of Security Mitigations Start Execution
   Commitment Date: 10/7/14 Projected Date: 11/3/14
2. Testing of Ikhana GCS and LVC-DE Complete
   Commitment Date: 9/25/14 Projected Date: 10/17/14

Schedule Metrics



- 37 milestones completed (Two Level 1 milestones)
- Four Level 2 milestones were moved to FY15
  - [SP S.2.30] Self-Separation Risk Ratio Study - Brief results to SARP and RTCA
  - [SP H.2.20] GCS HF Draft Guidelines
  - [SP T.3.30] Testing of Ikhana GCS and LVC-DE Complete
  - [SP N.2.10] sUAS Final Integrated Data Analysis Report
- Two Level 2 milestones were reopened and moved to FY15
  - [SP H.1.90] Visual Requirements for Landing Analysis Report
  - [SP N.2.10] sUAS Testing Execution Start

Project Requirements

- Requirement Types:
  - MOPS comments to SC-228: 4
  - Internal Product Transfer or Research Plan: 16
  - Technology Transfers (briefing/report/both): 56
- Project Requirements Completed in FY14
  - Four (4) internal product transfer or research plan
    - SSI IHITL Self-separation algorithm
    - HSI IHITL Final GCS software
    - IT&E IHITL Test Plan
    - IT&E SAA Initial Flight Test Plan (in coordination with FAA)
  - Seven (7) technology transfers (briefing/report/both)
    - SSI Surveillance Requirements (Low Fidelity)
    - SSI SAA Trade-off assessment
    - SSI Comm Gen2 Flight Test Participation
    - C2 Gen2 Radio in Relevant Environment Flight Test
    - HSI Full Mission Simulation: Levels of Automation
    - HSI Measured Response C
    - IT&E conduct and Report on IHITL
- Schedule critical Requirements tracked as Level 1 or 2 Milestones

TWP	Phase 2 Planned	FY14 Completed
SAA	29	4
C2	17	1
HSI	13	3
ITE	13	3
PROJ	4	0
Total	76	11

Current Active Collaborations/Partnerships Status

Partner	Partner POCs	Agreement In Place	In Execution	Collaboration/ Partnership Role
AFRL	Mark Draper	✓ Task Order	✓	Coordinate activities on Vigilant Spirit Control Station. Status: On-going collaboration with AFRL supporting use of VSCS on HSI activities
Dragonfly Pictures	Michael Piasecki	✓ **SAA**	✓	Supporting the UAS certification case study by supplying the design of a UAS rotorcraft **Status: Agreement in place for in-kind work, on-going**
FAA UAS IO	Jim Williams and Chris Swider	✓ MOA	✓	Support by FAA leadership, management, and technical SMEs to validate work being done by the Project Status: On-going coordination of Project deliverables
FAA R&D Integration	Sabrina Saunders-Hodge	✓ MOA	✓	Formal host of partnership agreements and collaborator for Integrated Test Activities Status: On-going coordination of Project deliverables
FAA ACAS Xu PO	Neal Suchy	✓ Software	✓	Coordinating on collaboration for ACAS-Xu software and associated flight tests Status: SAA Initial Flight Tests on schedule
General Atomics	Brandon Suarez	✓ **SAA**	✓	Ikhana equipped with avionics and Proof of Concept SAA system directly supported by UAS-NAS Project **Status: Agreement in place with GA for SAA Initial Flight Test and FT3 and FT4 for in-kind support**
Honeywell	TBD			Sensor data fusion support **Status: Project evaluating necessity of agreement**

Purple text indicates changes since baseline

Current Active Collaborations/Partnerships Status

Partner	Partner POCs	Agreement In Place	In Execution	Collaboration/ Partnership Role
NASA ASP CTD	Parimal Kopardekar	NA	NA	Coordination with ASP on UTM and other activities Status: Continue to coordinate with CTD Project
OSD SAA SARP	Steve Cook and Dallas Brooks	NA	✓	Assess SAA research gaps and generate recommendations to RTCA SC-228. **Status: Project supported development of well clear definition**
Rockwell Collins	John Moore	✓ **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 planned delivery Gen-4 in FY15**
RTCA SC-228	Working Group Leads	NA	✓	Conduct modeling, simulation and analysis to support the development of MOPS Status: On-going support to DAA and C2 working groups
UND	Al Palmer	✓ SAA	✓	Exploring requirements for safe operation of UAS through a series of case studies, experiments and flight evals. Status: On-going collaboration and in-kind support
U.S. Fish and Wildlife Service	Chris Lowie	✓ **IAA**	✓	**Permits flight over the Great Dismal Swamp and associated research activities** **Status: Agreement in place**
USMC VMU2, 1, & 3	LtCol Kain "Chewie" Anderson	✓ SAA	✓	Support for survey of Marine Corps use of Shadow and other UAS and Ground Control Stations **Status: HSI has provided briefing to USMC**

Purple text indicates changes since baseline

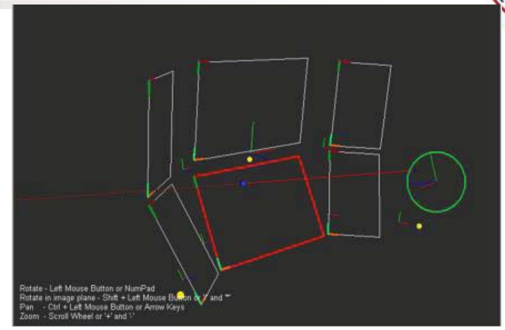
FY14 Accomplishments & FY15 Look Ahead

FY14 Accomplishments

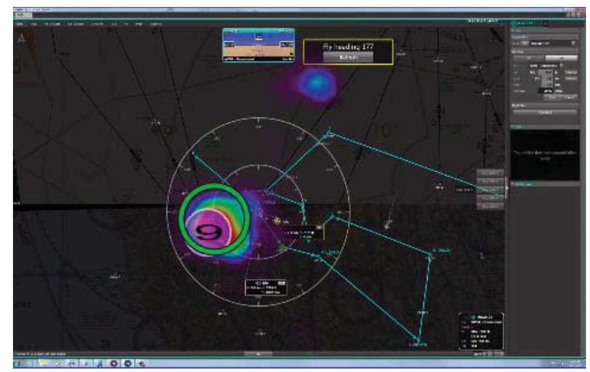
- KDP Follow-on & Baseline Reviews Successfully Completed
- Phase 1 Closeout Completed
- Supported RTCA SC-228 Plenary Sessions, DAA and C2 WGs, and contributed to DAA and C2 White Papers
- Supported the Office of the Secretary of Defense (OSD) SAA Science and Research Panel (SARP) Well Clear Definition Development
- TC-ITE: IHITL Successfully Executed
- TC-HSI: Part Task Simulation 4/4b Successfully Executed
- TC-SAA: UAS CAS 1 HITL Successfully Executed
- TC-SAA: ACES Simulations Successfully Executed
- TC-C2: Gen 2 Flight Test Series Successfully Executed
- Received two NASA Honor Awards: Full Mission Simulation (TC-HSI, TC-SAA, & TC-ITE) and S-3B CNPC Radio Flight Test Execution (TC-C2)
- Non-TC [Cert]: Report on UAS Classification Factors Successfully Completed

FY15 Look Ahead

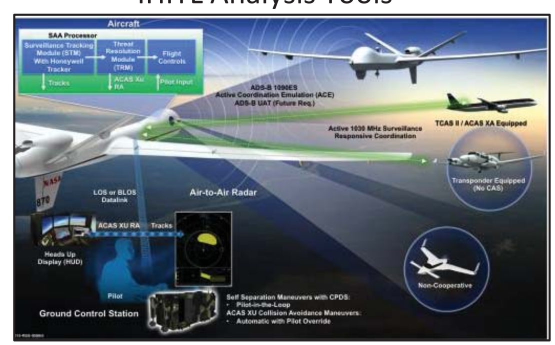
- TC-SAA, TC-HSI, TC-ITE: SAA Initial Flight Test
- TC-C2: CNPC Gen-4 Flight Test
- TC-HSI: Part Task Simulation 5
- TC-SAA, TC-C2, TC-HSI, TC-ITE: Flight Test Series 3



Smart Eye 3D Tracking System



IHITL Analysis Tools



Review Summary

- The Project has provided a programmatic review that addresses the following:
  - ✓ Showed alignment of the project's goal and Technical Challenges (TC) to the NASA and ARMD Strategy
  - ✓ Briefed multiple key highlights and accomplishments that meet the Project's technical challenges
    - Consistent progress towards technical challenge completion
  - ✓ Presented FY14 Project performance against the Project baseline
    - Changes against baseline, cause of the changes, and resulting impacts were minimal
    - Appropriate controls (schedule, risk, and technical) in place for successful execution
    - Consistent resource (personnel, facilities, and equipment) allocation and utilization
    - Progress establishing partnerships/collaborations achieved
  - ✓ Identified key activities, milestones, and "storm clouds" for FY15
  - ✓ Addressed actions from Baseline Review
    - Reviewed and refined management approach of reserves
    - Appropriate balance of rigor and technical accomplishments
    - Plan developed for formal stakeholder buy-in on the LVC-DE as a relevant environment

Delivering research findings and critical products integral to the UAS Community on schedule and within budget

UAS-NAS Overview
Backup Slides

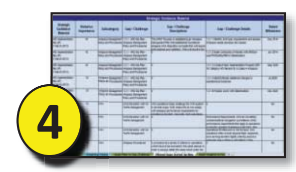
Phase 2 Content Decision Process

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

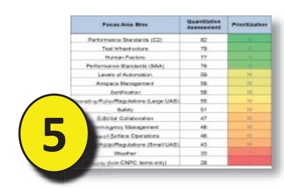
- **Step 2: Define and Apply Filters**
  - Filters were selected to assess which community needs were relevant to NASA, ARMD, and the Project
  - Filters: *NASA & ARMD Mission, ARMD Skills/Capabilities, Project Time Frame*

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

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



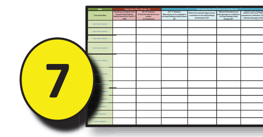
- **Step 5: Applying Weight Criteria and Prioritization**
  - Prioritization used to identify lower priority community needs that the Project should not pursue for Phase 2
    - Weighting Criteria: *Community Needs, Appropriate Organization, Ability to Complete, Complexity & Testing, Public Outreach/Acceptance*



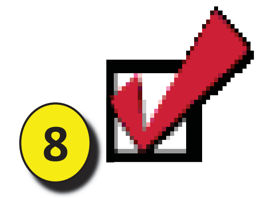
Phase 2 Content Decision Process (cont.)

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

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

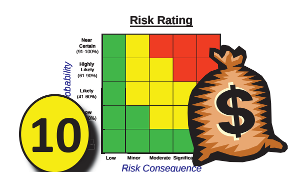


- **Step 8: Project Office Validate Proposed Technical Work Packages**
  - The Project Office reviewed the proposed TWPs supplied by the team and evaluated them according to many factors including: Consistency with existing Phase 1 plans, lessons learned, and Phase 2 Drivers



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

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



TC-SAA Performance against the Baseline
Backup Slides

TC-SAA: Research Activity Contribution to MOPS Development

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP S.4.10] UAS - SAA Trade-off Assessments - Final	12/18/2013	• Determine the trade-off space between UAS performance and DAA algorithm performance	• Results: • Provide insight into the performance trade space between UAS and SAA systems to support defining UAS non-cooperative sensor and algorithm-agnostic UAS maneuverability requirements • Inform the development of SAA performance requirements in relation to the performance characteristics of unmanned vehicles • Inform the SAA maneuver time requirements for a spanning set of aircraft performance models over a broad range of encounters
[SP S.5.10] UAS CAS1 HITL	1/28/2014	• Evaluate the impact of UAS SAA SS maneuvers resulting for different SAA Well Clear volumes on controller perceptions of safety and efficiency	• Results inform: • Understanding of air traffic controller operational acceptability of UAS Stratway+ self-separation concept/capability • Understanding of air traffic controller operational acceptability of quantifying the definition of Well Clear • Understanding of air traffic controller workload in the presence of a UAS with Stratway+ self-separation concept/capability operating in the NAS • Understanding of interoperability of UAS Stratway+ self-separation concept/capability and TCAS II

TC-SAA: Research Activity Contribution to MOPS Development

<table>
<tr><th>TC-SAA Test/Simulation</th><th>Baselined Execution Start Date</th><th>Test/Simulation Objective</th><th>Contribution to SC-228 MOPS</th></tr>
<tr><td>[SP S.1.10] Surveillance Requirements (Low Fidelity) (ACES Simulation)</td><td>2/5/2014</td><td>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 (SS algorithm)</td><td>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</td></tr>
<tr><td>[SP S.2.10] SAA Traffic Display Evaluation HITL1 (joint w/ HSI Part Task Sim 4)</td><td>2/24/2014</td><td>Evaluate integrated SAA system under perfect sensor conditions
Evaluate the pilot’s ability to remain clear as a function of SS threshold
Evaluate the pilot’s acceptability of recommended Autoresolver maneuvers to avoid well-clear
Evaluate the utility of two different trial planner capabilities that aid an UAS in remaining well-clear of other traffic</td><td>Results:
Inform SAA system display requirements to include trial planning capabilities
Contribute to defining performance characteristics for UAS human-automation systems
Provide estimates for the impact of UAS (pilot, traffic displays, SAA algorithm/concept/displays) operations on NAS safety over a range of UAS mission profiles
Provide estimates for number of Well Clear violations, pilot acceptability of autoresolver SAA maneuvers, pilot acceptability of alerting criteria, encounter characteristics if/when autoresolver fails to recommend a Well Clear maneuver, and Well Clear maneuver characteristics, pilot/air traffic controller negotiation times</td></tr>
</table>

TC-SAA: Research Activity Contribution to MOPS Development

TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP S.3.10] Well Clear Metric and Definition Study	4/3/2014	• Gather data and develop recommendations for a quantified definition of "Well Clear" using cooperative Visual Flight Rule traffic that meets target level of safety requirements and NAS-interoperability considerations	• Results: • Inform the development of a quantified Well Clear definition and SAA concept with multiple UAS mission profiles and NAS traffic estimates using perfect surveillance state information of cooperative VFR traffic • Contribute to the definition of Well Clear time and/or distance dimensions • Generate Well Clear maneuver resolution characteristics for UAS and cooperative VFR traffic for multiple definitions of Well Clear • Provide estimates for risk ratio as a function of self-separation threshold and Well Clear definition, number/rate of Well Clear violation, number/rate of NMAC, number of generated TCAS RAs, number/rate of UAS-to-VFR traffic conflicts to the self-separation threshold
[SP S.5.30] Comm Gen2 Flight Test Participation & Data Collection	4/11/2014	• Analyze Stratway+ performance during simulated SS encounters using a live UAS surrogate aircraft and virtual intruder traffic	• Results: • Continue the development of the Stratway+ SAA concept by verifying Stratway+ self-separation algorithm performance in a flight test environment, including the CNPC radio and real winds, matches observations from simulation experiments • Provide risk reduction for the IT&E subproject live, virtual, constructive distributed test environment

TC-SAA: Research Activity Contribution to MOPS Development

<table>
<tr><th>TC-SAA Test/Simulation</th><th>Baselined Execution Start Date</th><th>Test/Simulation Objective</th><th>Contribution to SC-228 MOPS</th></tr>
<tr><td>[SP S.2.30] Self-Separation Risk Ratio Study</td><td>4/30/2014</td><td>Gather data indicating the degree to which SS systems mitigate the probability that an encounter to the SS threshold will proceed to a Well Clear violation (SS Airspace Safety Threshold)</td><td>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</td></tr>
</table>

TC-SAA: Research Activity Contribution to MOPS Development

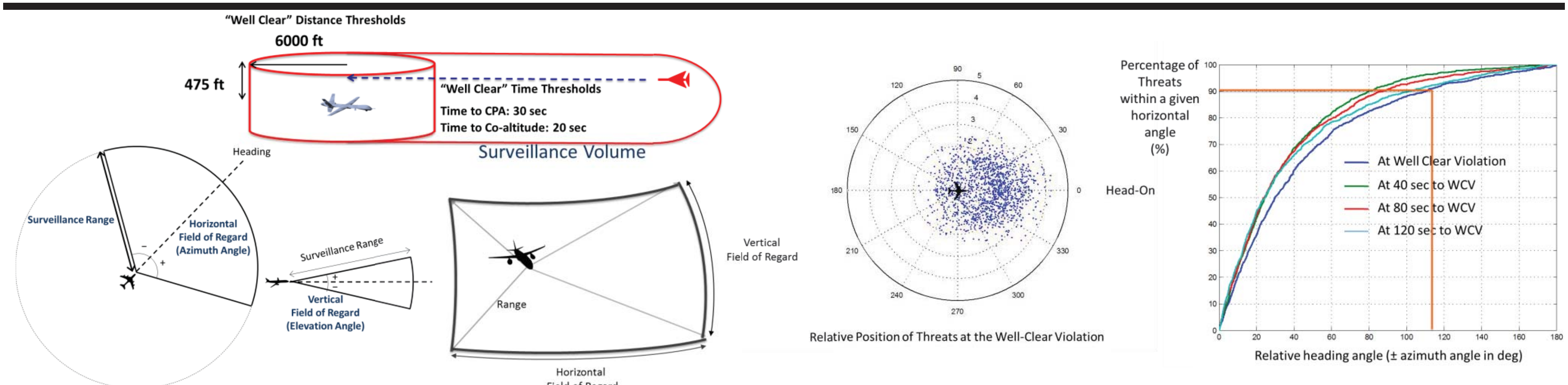
TC-SAA Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP S.2.20] IHITL Participation & Data Collection	6/9/2014	• Evaluate air traffic controller acceptability of UAS maneuvers in response to SAA advisories and pilot performance for remaining "Well Clear"	• Results inform and support understanding of: • Air traffic controller acceptability of UAS maneuvers in response to SAA advisories • UAS pilot's performance at remaining Well Clear modeling non-cooperative sensor range, elevation, and azimuth performance as part of an SAA system • Existing air traffic control procedures and operations in the presence of a UAS • Interoperability between UAS pilot and air traffic controller • Sensor performance on UAS pilot's ability to perform SAA functions and maintain Well Clear • Impact of realistic estimate of CNPC system latency impact on UAS pilot and air traffic controller operations and performance • Well Clear as a airborne separation standard for UAS • Air traffic controller ability to recognize/correct a Well Clear violation • UAS pilot workload

TC-SAA: Research Activity Contribution to MOPS Development

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	6/9/2014	• Assess SAA-to-Traffic Alert and CA System interoperability and the impact of CNPC system delay on the execution of UAS pilot SS 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
[SP S.6.10] SAA Initial Flight Test Participation w/ IT&E	11/3/2014	• 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

Surveillance Requirements (Low Fidelity) (ACES Simulation)

- **Research Activity Objective(s):**
  - 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)

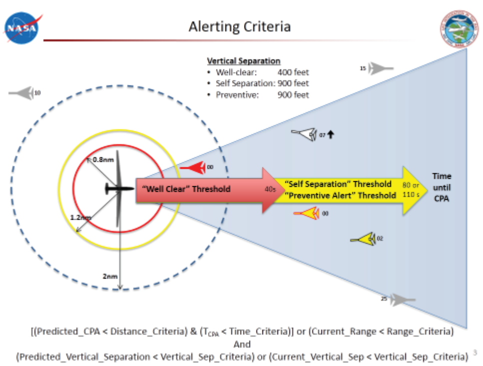


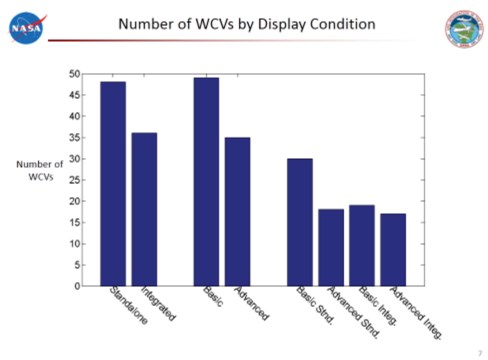
- **Significant Results, Conclusions, and Recommendations:**
  - Analyzed Well Clear violations between UAS and VFR traffic providing system designers a method to conduct trade space analysis among surveillance parameter values to meet overall system safety metrics
  - Observed the ratio of undetected Well Clear Violations was substantially affected by horizontal field of regard
  - Observed the time to Well Clear Violations was most sensitive to surveillance detection range

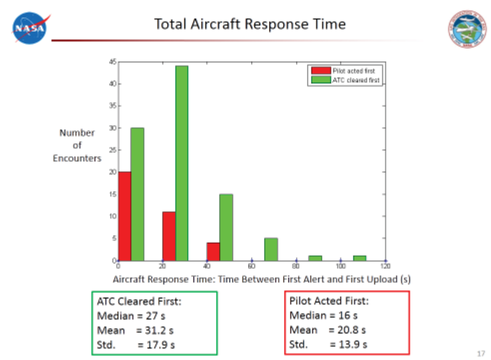
Results Contributed to Sensor Requirements & Unmitigated DAA System Performance for DAA MOPS

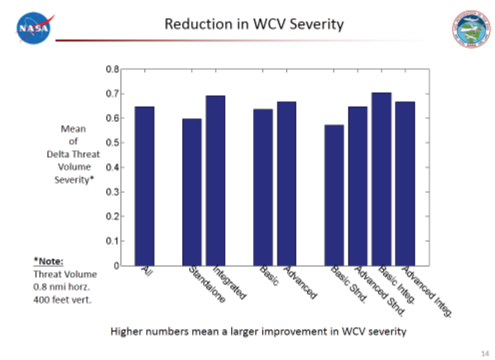
SAA Traffic Display Evaluation HITL1 (joint w/ HSI Part Task Sim 4)

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







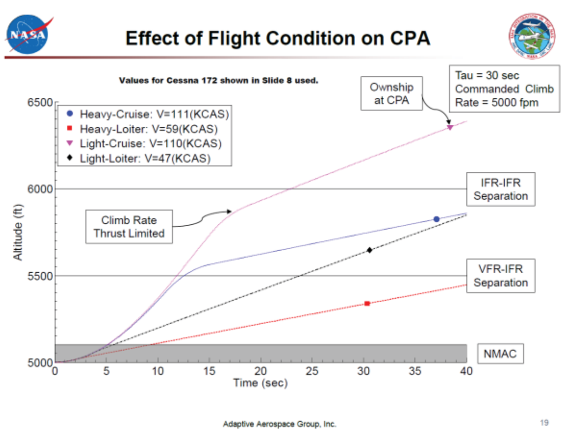


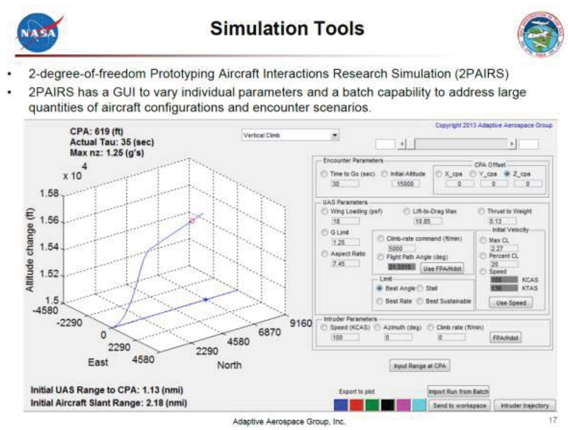
- **Significant Results, Conclusions, and Recommendations:**
  - Well Clear Violation results provided increased understanding of:
    - Effect of time to violation at first alert
    - Effect of display type on Well Clear violations
    - UAS time spent within Well Clear volume
    - Comparison of closet point of approach to predicted distance
    - Time from first alert to UAS maneuver initiation
    - Time to closet point of approach at UAS maneuver initiation

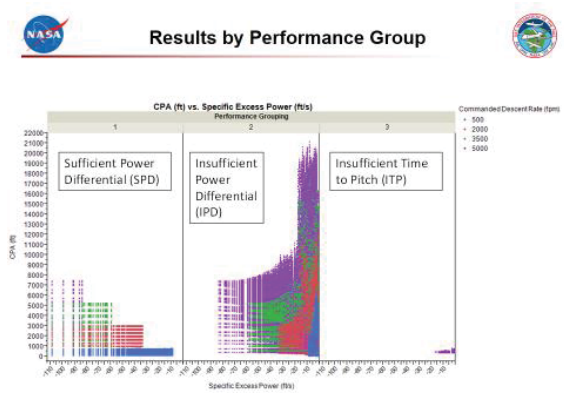
Results Contributed to DAA Displays & Well Clear Separation Standard for DAA MOPS

UAS - SAA Trade-off Assessments - Final

- **Research Activity Objective:**
  - Determine the trade-off space between UAS performance and DAA algorithm performance







- **Interim Significant Results, Conclusions, and Recommendations:**
  - Achievable closest point of approach depends on encounter geometry, airplane design parameters, and initial flight condition
  - Three performance groups were developed:
    - Sufficient Power Differential group has predictable closest point of approach performance
    - Insufficient Power Differential group has less predictable closest point of approach performance
    - Insufficient Time to Pitch group only occurred with very small times to closet point of approach
  - Tool available for ongoing work supporting MOPS development

Results Contributed to UA - DAA System Performance Trade Space for DAA MOPS

IHITL Participation & Data Collection

- **Research Activity Objective:**
  - Evaluate air traffic controller acceptability of UAS maneuvers in response to SAA advisories and pilot performance for remaining Well Clear


MACS GCS Display


VSCS Display

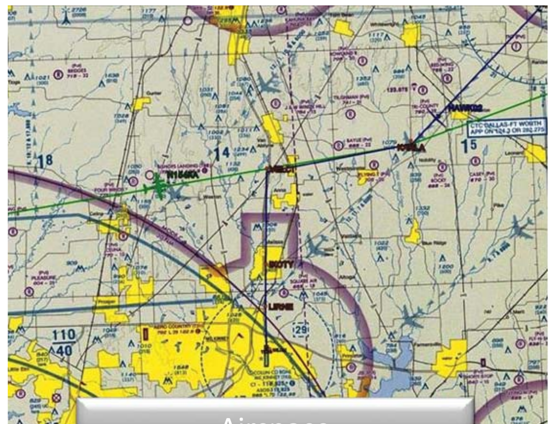
- **Interim Significant Results, Conclusions, and Recommendations:**
  - Testing successfully accomplished in June 2014
  - Analysis in progress

Results Contributed to ATC Interoperability Requirements for DAA MOPS

Langley Support & Participation in IHITL

- **Research Activity Objective:**
  - Assess SAA-to-Traffic Alert and CA System interoperability and the impact of CNPC system delay on the execution of UAS pilot Self Separation tasks

Boeing 747



Airspace

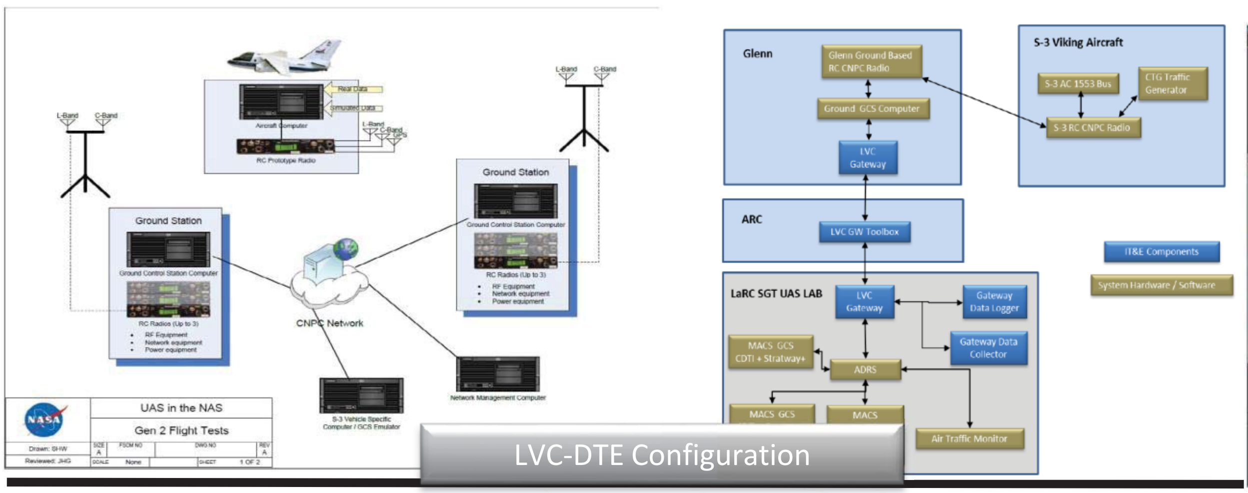
MACS GCS Stratway+

- **Interim Significant Results, Conclusions, and Recommendations:**
  - Testing successfully accomplished in June and July 2014
  - Analysis in progress

Results Contributed to DAA – TCAS & ATC Interoperability Requirements for DAA MOPS

Comm Gen2 Flight Test Participation & Data Collection

- **Research Activity Objective:**
  - Analyze Stratway+ performance during simulated self separation encounters using a live UAS surrogate aircraft and virtual intruder traffic



LVC-DTE Configuration

GCS Display

- **Significant Results, Conclusions, and Recommendations:**
  - Successfully demonstrated end-to-end capability of a distributed flight test
  - CNPC radio worked well; good stress test of data capabilities
  - Highlighted some minor software discrepancies and some network interaction deficiencies
  - Live, virtual, constructive distributed test environment setup and reliability is not currently sufficient for flight test
    - Constant need to reset the test environment connections between each scenario run on both ends

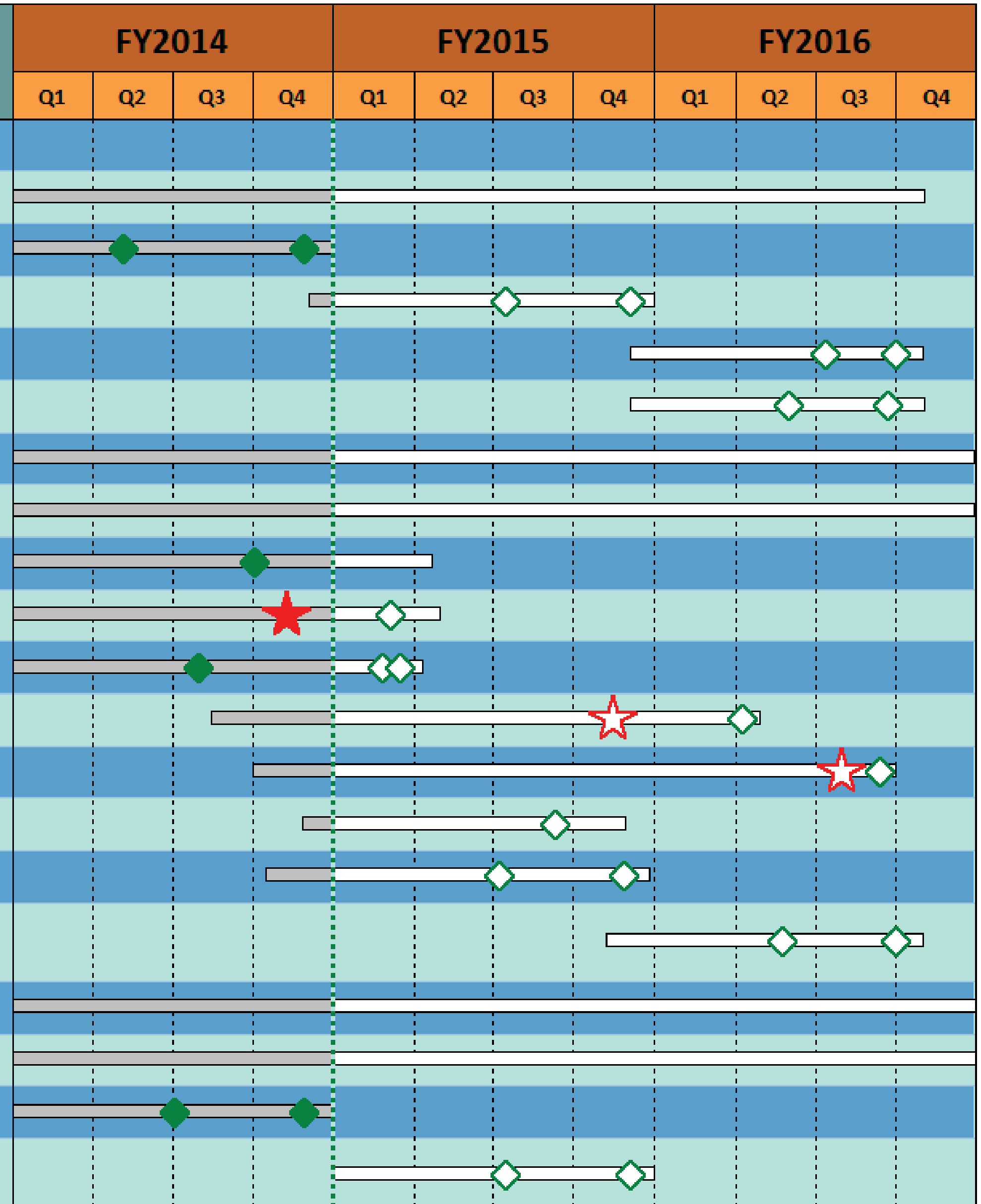
Results Contributed to DAA System for Development and V&V of DAA MOPS

TC-SAA: Schedule

Name

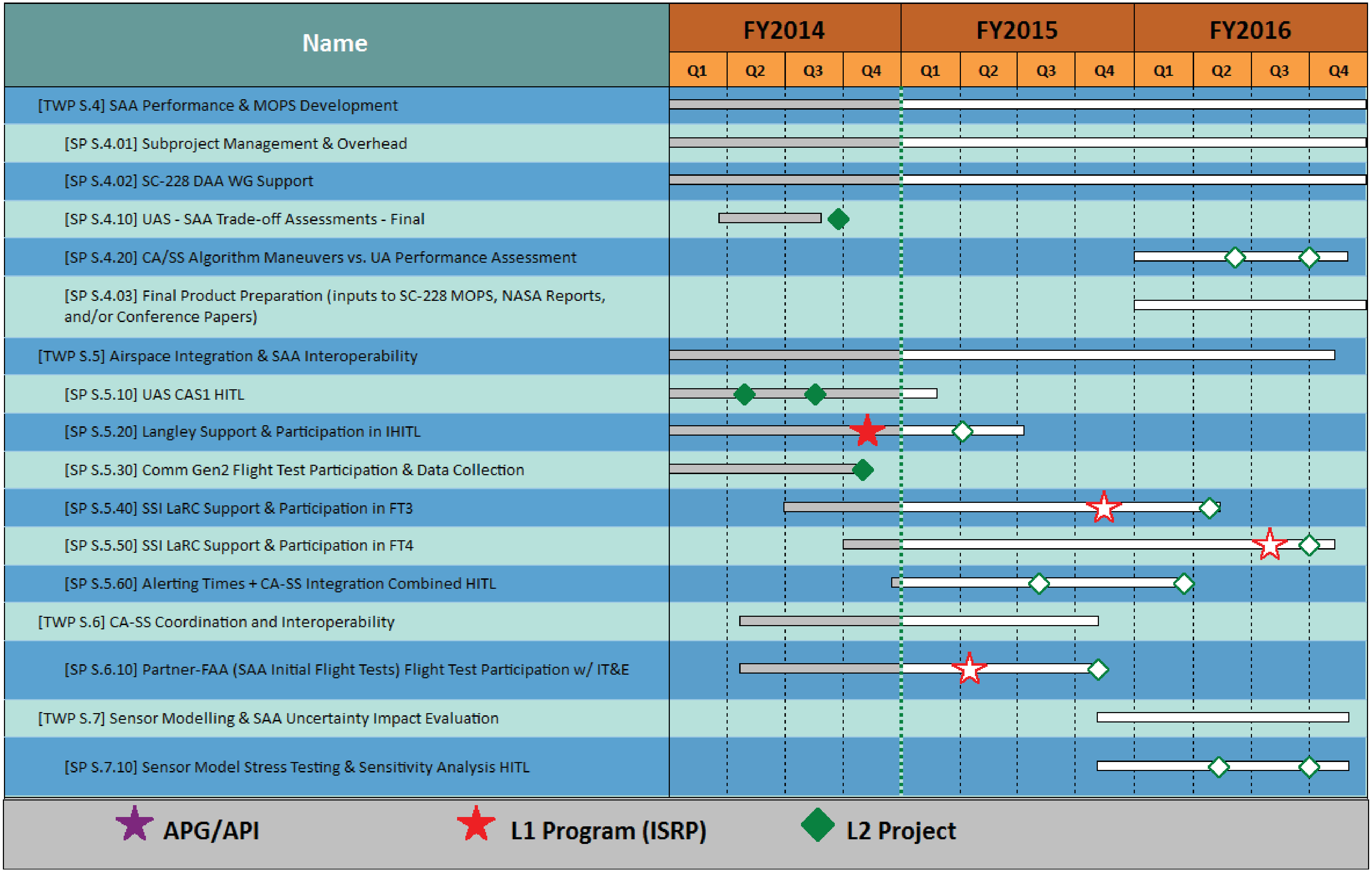
TC - SAA Performance Standards

- [TWP S.1] SAA Sub-function Tradeoffs and Requirements
  - [SP S.1.10] Surveillance Requirements (Low Fidelity) (ACES Simulation)
  - [SP S.1.20] Surveillance Requirements (Medium Fidelity) (ACES Simulation)
  - [SP S.1.30] Interoperability of SS and CA Functions (ACES Simulation)
  - [SP S.1.40] Sub-function Tradeoffs w/ UAS Performance (ACES Simulation)
- [TWP S.2] Interoperability and Impact of SAA-Equipped UAS on the NAS
  - [SP S.2.01] ACES Software Development & Support
  - [SP S.2.10] SAA Traffic Display Evaluation HITL1 (joint w/ HSI Part Task Sim 4)
  - [SP S.2.20] IHITL Participation & Data Collection
  - [SP S.2.30] Self-Separation Risk Ratio Study
  - [SP S.2.40] FT3 Participation & Data Collection
  - [SP S.2.50] FT4 Participation & Data Collection
  - [SP S.2.60] SAA Traffic Display Evaluation HITL2 HITL (joint w/ HSI Part Task Sim 5)
  - [SP S.2.70] Effect of SAA Maneuvers with Procedures (ACES Simulation)
  - [SP S.2.80] Comprehensive Evaluation of Airspace Risk Threshold (ACES Simulation)
- [TWP S.3] Well Clear Definition and SAA Concept of Operations
  - [SP S.3.01] SC-228 Collaboration
  - [SP S.3.10] Well Clear Metric and Definition Study
  - [SP S.3.20] Well Clear Alerts/Resolutions with VFR and Pilot/Controller (ACES Simulation)



★ APG/API ★ L1 Program (ISRP) ◆ L2 Project

TC-SAA: Schedule (cont.)



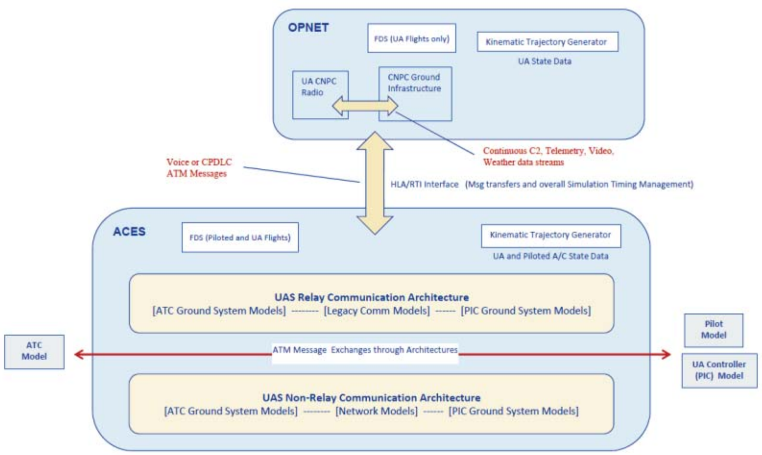
TC-C2 Performance against the Baseline
Backup Slides

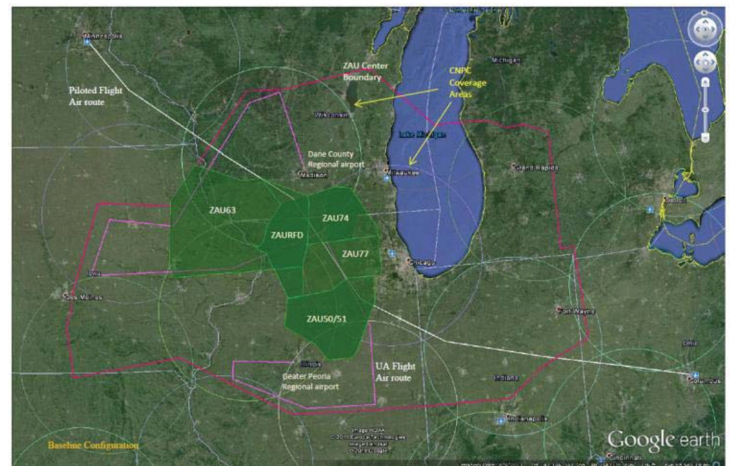
TC-C2: Research Activity Contribution to MOPS Development

TC-C2 Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP C.2.10] Develop and Test Prototype	3/17/2014	• Define CNPC security recommendations for civil UAS operations based on analysis of laboratory test results	• Results inform understanding of CNPC system security architecture performance
[SP C.1.10] Gen2 Radio in Relevant Environment Flight Test	4/11/2014	• 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
[SP C.4.20] ACES Sim Operations w/ Flight Test Models	7/16/2014	• 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
[SP C.2.20] Performance Validation of Security Mitigations - Relevant Flight Environment	10/7/2014	• Determine CNPC security recommendations for civil UAS operations based on analysis of flight test results	• Results: • Inform CNPC system security design requirements • Inform control and non-payload security architecture performance • Contribute to validation of security mechanisms designed to mitigate risks and vulnerabilities of CNPC system as incorporated in performance standards • Inform understanding of CNPC system performance during hand-off between communication system ground stations and edge of coverage events

ACES Sim Operations w/ Flight Test Models

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

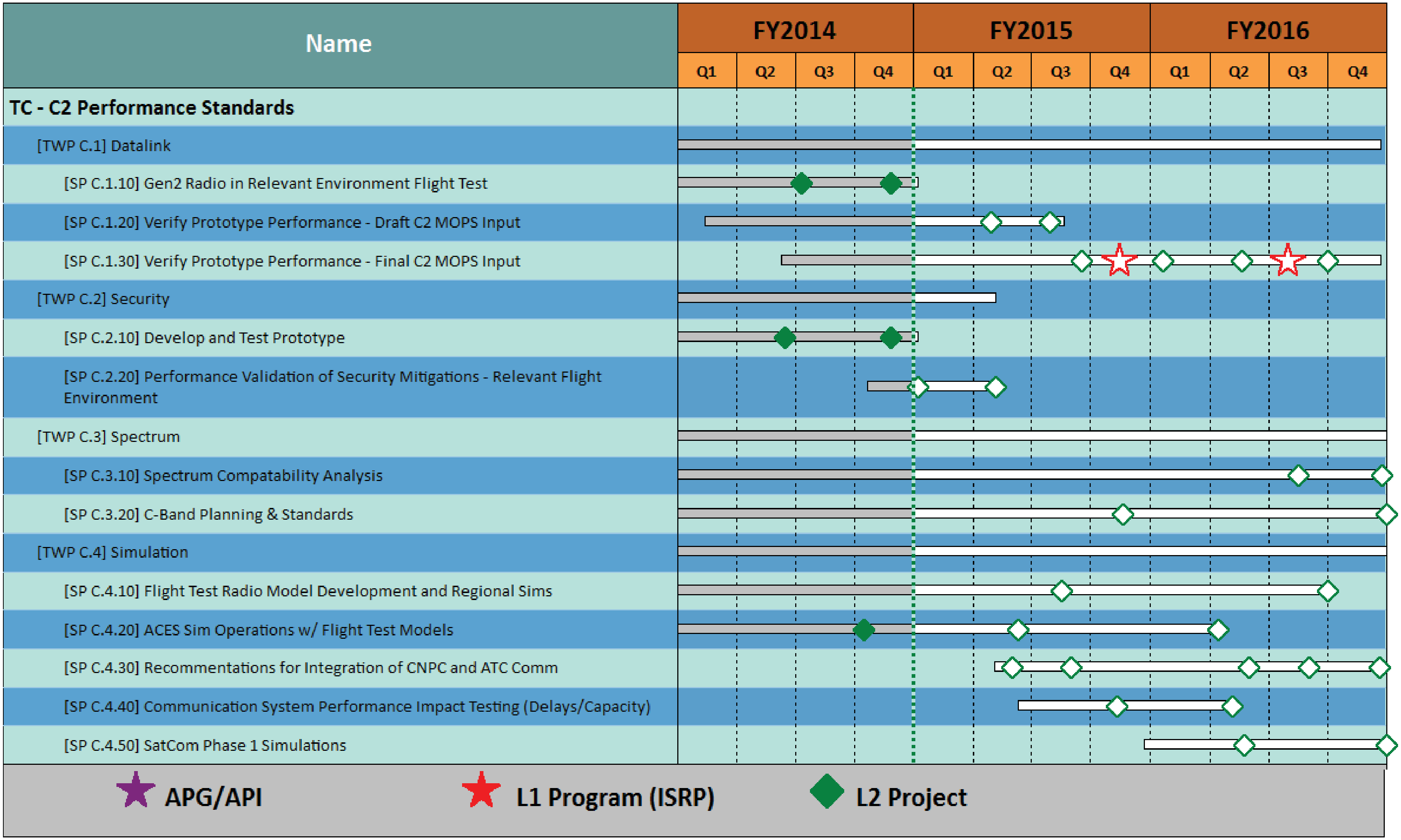




- **Interim Results, Conclusions, and Recommendations:**
  - Validated Gen-2 Radio model using flight test data
  - Completed initial evaluation on the scalability of CNPC system to meet UAS traffic projections – results indicate system is scalable

Results Contributed to NAS-Wide Communication Simulation for Development and V&V of C2 MOPS

TC-C2: Schedule



TC-HSI: Performance against the Baseline
Backup Slides

TC-HSI: Research Activity Contribution to MOPS Development

TC-HSI Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP H.1.30] Full-Mission Simulation 1: Levels of Automation	7/1/2013	• Evaluate pilot response to various events while operating under various levels of UAS automation	• Results inform understanding of: • UAS pilot acceptability of varying level of ground control station automation (manual, knobs, waypoint navigation) • UAS pilot-to-air traffic controller response times in the presence of varying levels of ground control station automation
[SP H.1.20] Measured Response Simulation C	10/2/2013	• Investigate the effects of number of UAS per sector and types of UAS on GCS information requirements	• Results inform understanding of ground control station automation levels and the number of UAS per NAS sector and types of UAS in the sector
[SP H.1.90] Visual Requirements for Landing Task (support for CSUN)	10/9/2013	• Evaluate nose camera video display requirements for manual takeoff and landing, and determine the minimum C2 bandwidth that still enables the safe execution of the takeoff and landing tasks	• Results inform: • Requirements for visual displays for landing (e.g., resolution, frame rate, color) • CNPC system bandwidth requirements to support acceptable visual displays for landing
[SP H.1.40] Part-task Simulation 4: SAA Pilot Guidance	2/24/2014	• Evaluate efficacy of minimum information SAA displays, potential improvements for advanced information features and pilot guidance, and integrated vs. stand-alone GCS SAA displays	• Results inform ground control system display requirements associated with display class (integrated, stand alone), level of information (basic, advanced), and self-separation alerting threshold.

TC-HSI: Research Activity Contribution to MOPS Development

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	5/29/2014	• 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

HSI IHITL Participation & Data Collection

- **Research Activity Objective:**
  - Evaluate an instantiation of the prototype GCS in relevant environment

MACS GCS Display

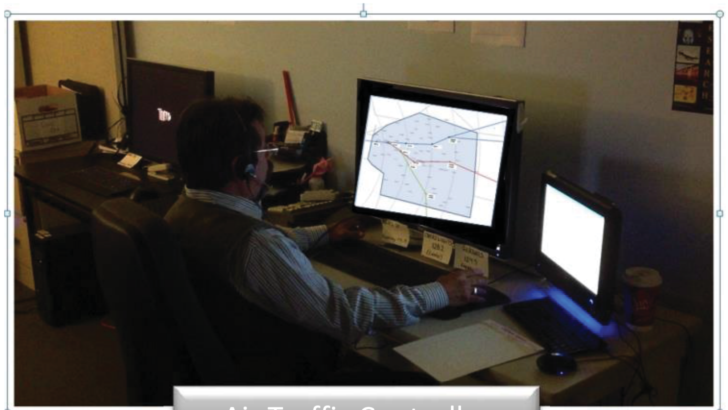
VSCS Display

- **Interim Significant Results, Conclusions, and Recommendations:**
  - Testing successfully accomplished in June 2014
  - Analysis in progress

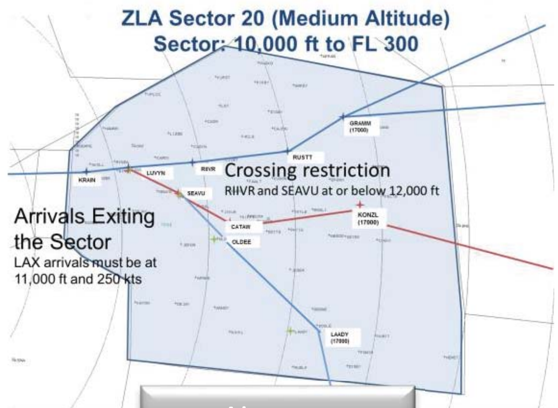
Results Contributed to GCS Information Guidelines/Requirements for DAA MOPS

Measured Response Simulation C

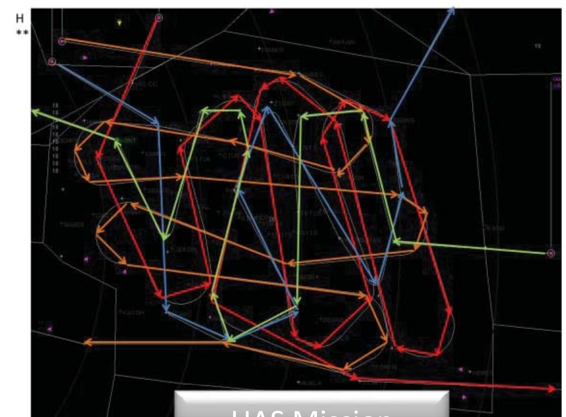
- **Research Activity Objective:**
  - Investigate the effects of number of UAS per sector and types of UAS on GCS information requirements



Air Traffic Controller



Airspace

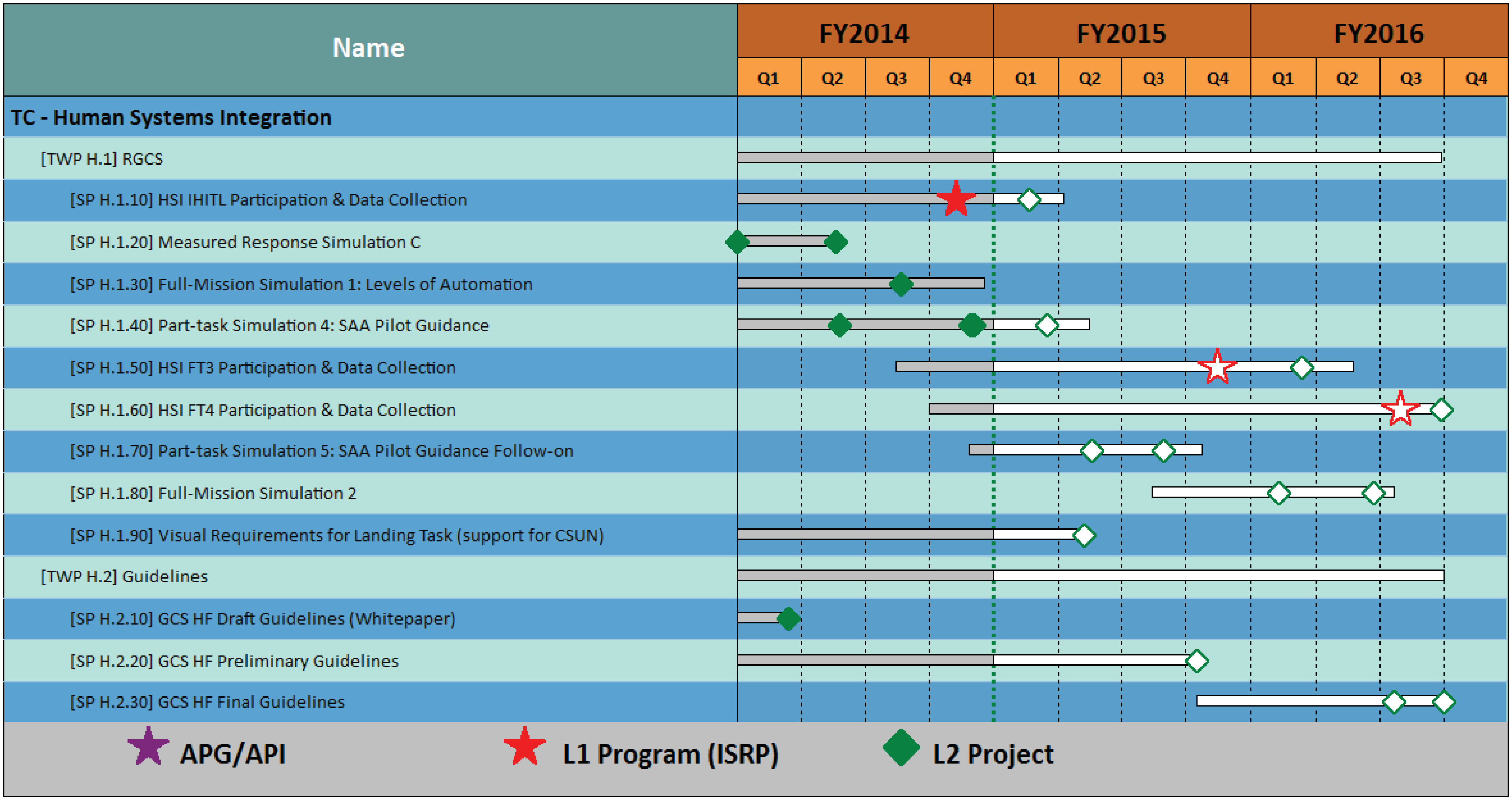


UAS Mission

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

Results Contributed to GCS Information Guidelines/Requirements for DAA MOPS

TC-HSI: Schedule

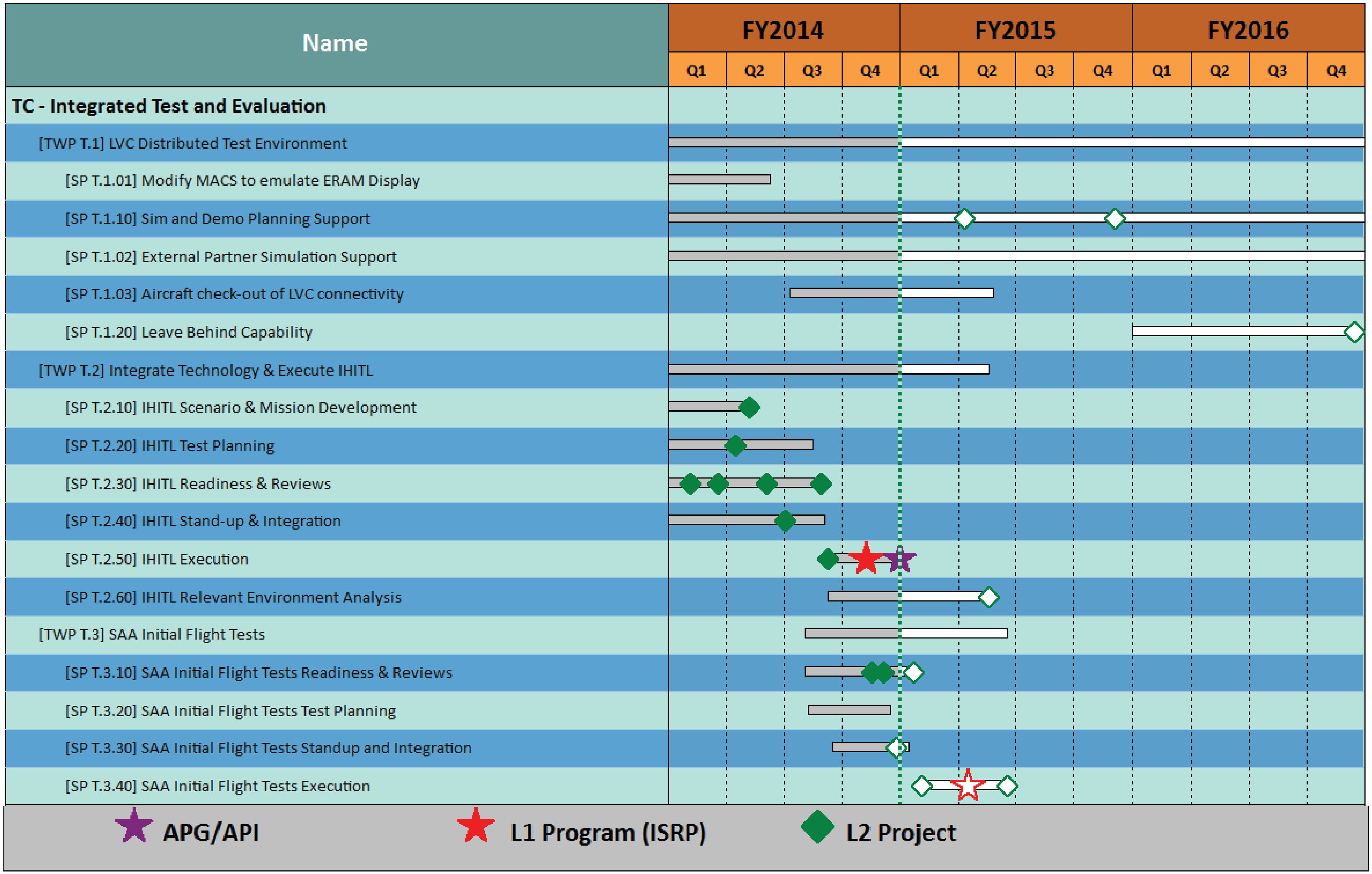


TC-ITE Performance against the Baseline
Backup Slides

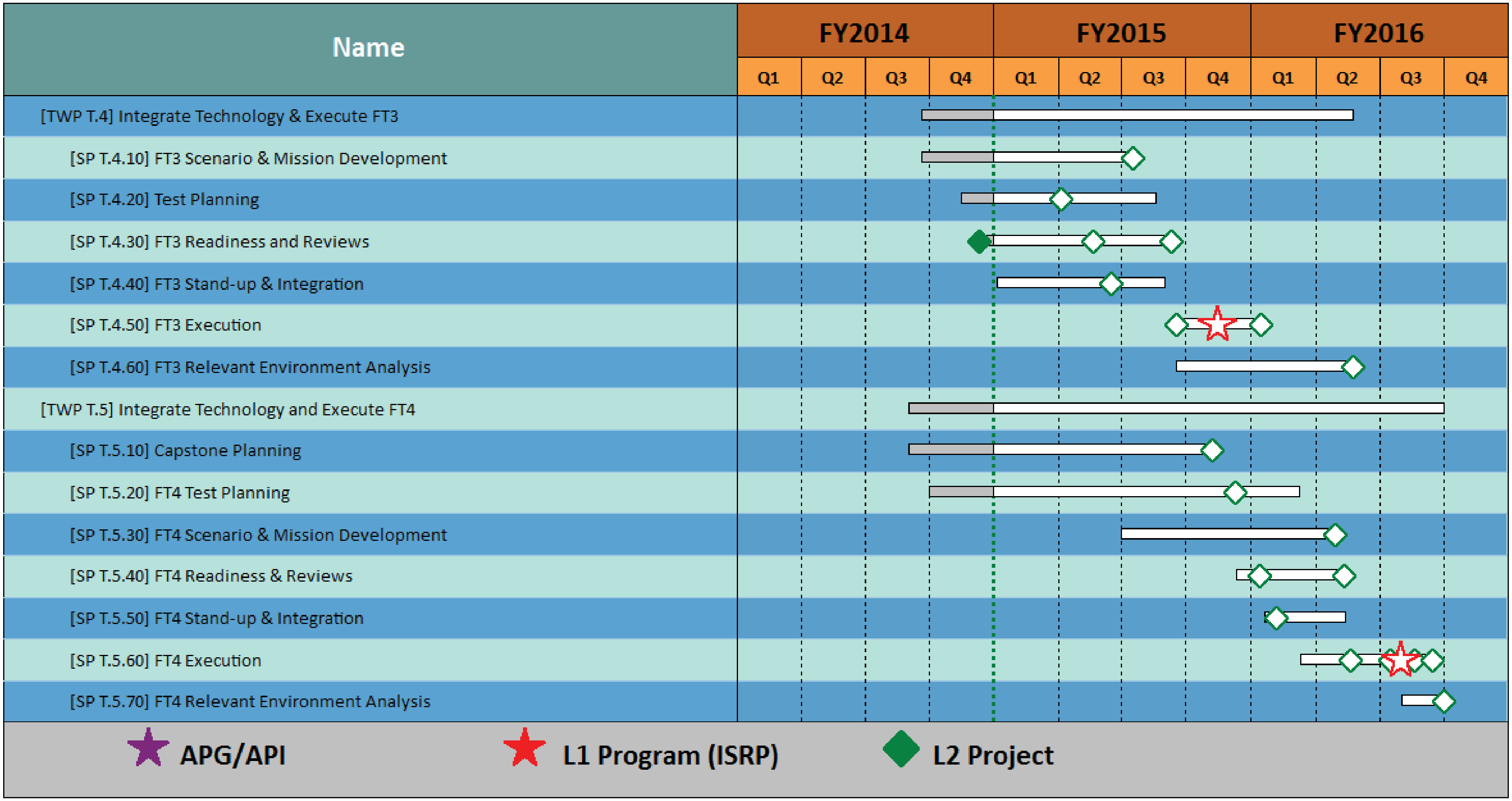
TC-ITE: Research Activity Contribution to MOPS Development

TC-ITE Test/Simulation	Baselined Execution Start Date	Test/Simulation Objective	Contribution to SC-228 MOPS
[SP T.2.50] IHITL Execution	6/9/2014	• Conduct a HITL simulation integrating the latest SSI algorithms, CNPC System model, and HSI displays using the Live, Virtual, Constructive test environment and document the performance of the simulation infrastructure in meeting the simulation requirements	• Results inform acceptability of the live, virtual, constructive distributed test environment as a realistic representation of the NAS, air traffic control, and unmanned aircraft system environment for use in verifying and validating MOPS
[SP T.3.40] SAA Initial Flight Test Execution	11/3/2014	• Conduct SAA Initial Flight Test using the Live, Virtual, Constructive test environment and document the performance of the test infrastructure in meeting the flight test requirements	• Results inform acceptability of the live, virtual, constructive distributed test environment as a realistic test environment for use in verifying and validating MOPS

TC-ITE: Schedule



TC-ITE: Schedule (cont.)

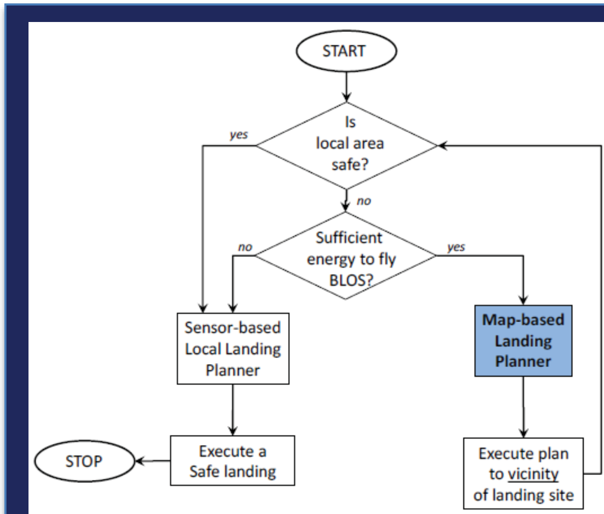


Non-Technical Challenge Work
Backup Slides

University of Michigan NRA FY14 Accomplishments

- NRA Goal: identify and assess risks imposed by small UAS operating in the NAS, especially unique failures, hazards, and mitigations

- Primary Effort:
  - risk mitigation for the unexpected low battery energy condition (critical hazard for small UAS)
  - investigated 2 emergency landing planning strategies to mitigate low battery energy hazard for operations over populated areas
    - sensor-based and map-based planning



Safe Landing Planning as a Risk Mitigation Strategy to Unexpectedly Low Energy

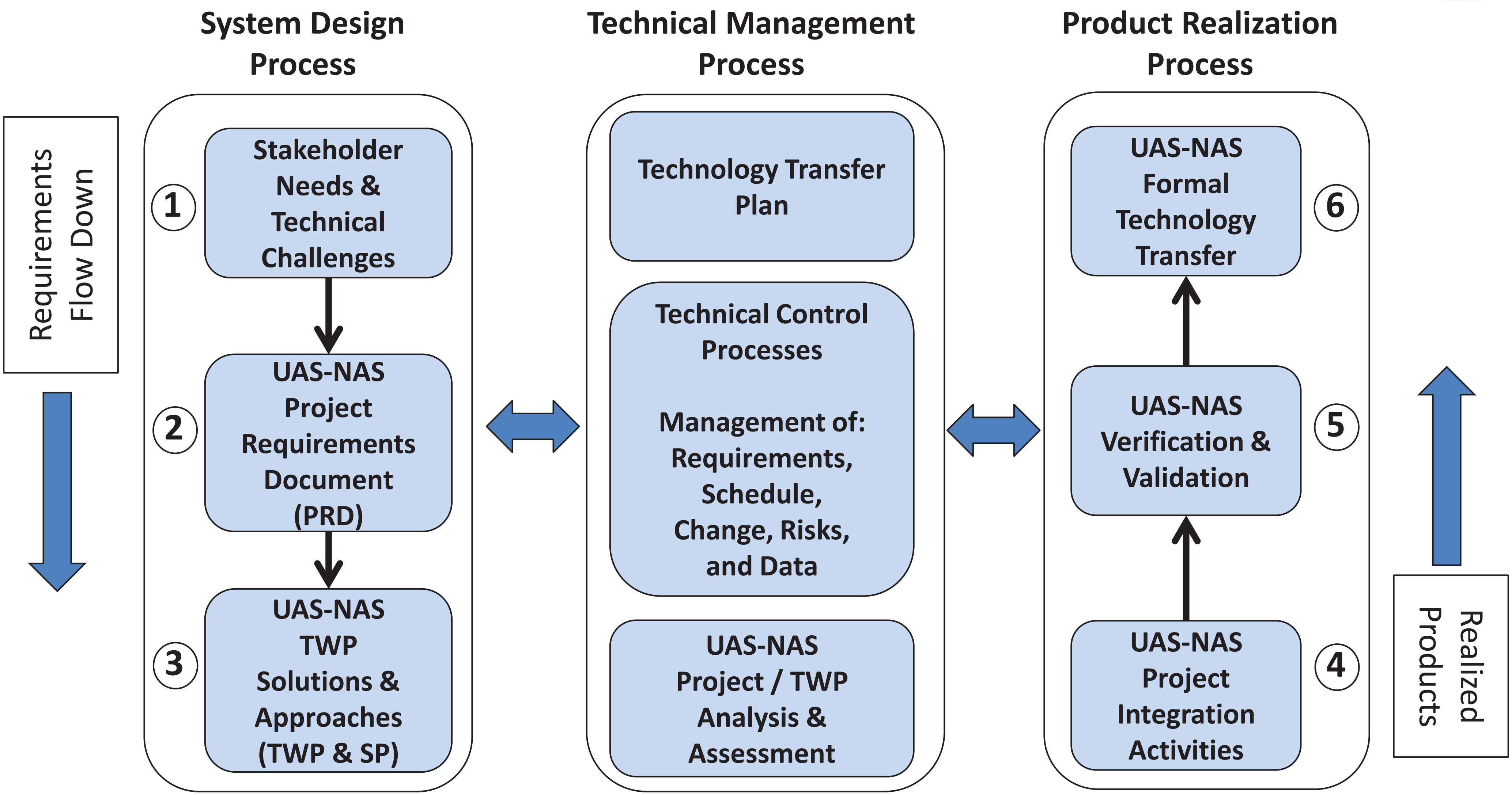
- Accomplishments:
  - Olson, I., Ten Harmsel, A., and Atkins, E., "Safe Landing Planning for an Energy-Constrained Multicopter," *International Conference on Unmanned Aircraft Systems (ICUAS),* Orlando, FL, May 2014
  - Atkins, E. M., "Autonomy as an Enabler of Economically Viable, Beyond-Line-of-Sight, Low- Altitude UAS Applications with Acceptable Risk," *AUVSI North American Conference*, Orlando, FL, May 2014
  - Luxhøj, J.T., sUAS Handbook for Hazard and Safety Risk Modeling, ver. 4.0, August 2014

- FY15-16 Goal: develop a specific risk mitigation capability for electronic geofencing for small UAS

Control Processes and Governing Documentation Backup Slides

Technical Management

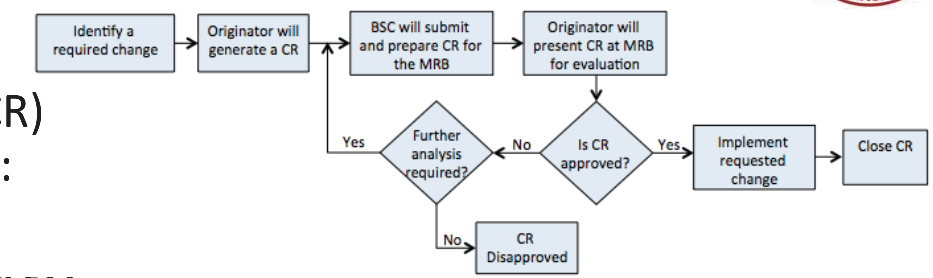
(note: follows 7123.1B SE Engine)



- SE Processes leverage existing Project processes
  - Schedule management, change management, risk management, and PE/TL Status at the UAS weekly telecon
- Technical management process is formally documented in the SEMP

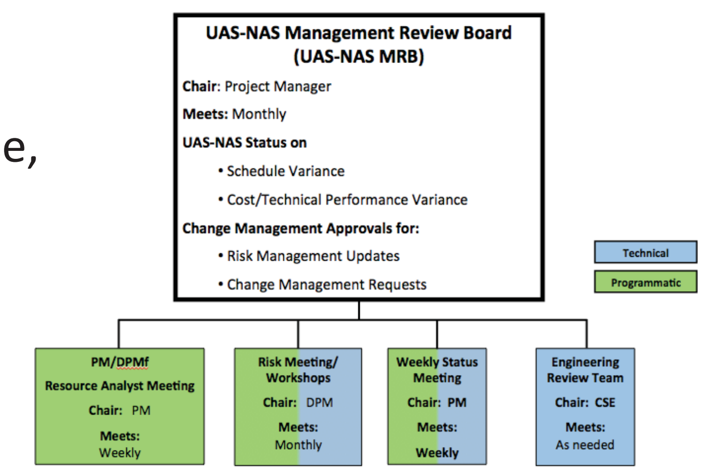
Key Phase 2 Control Processes

- Change Management
  - Standard process utilizing Change Requests (CR) to manage changes to the following elements:
    - L1 and L2 Milestones
    - Project Goals, Objectives, and Technical Challenges
    - Technical Baseline, i.e. SP objective, approach, deliverables
    - Project Requirements
    - Project Budget



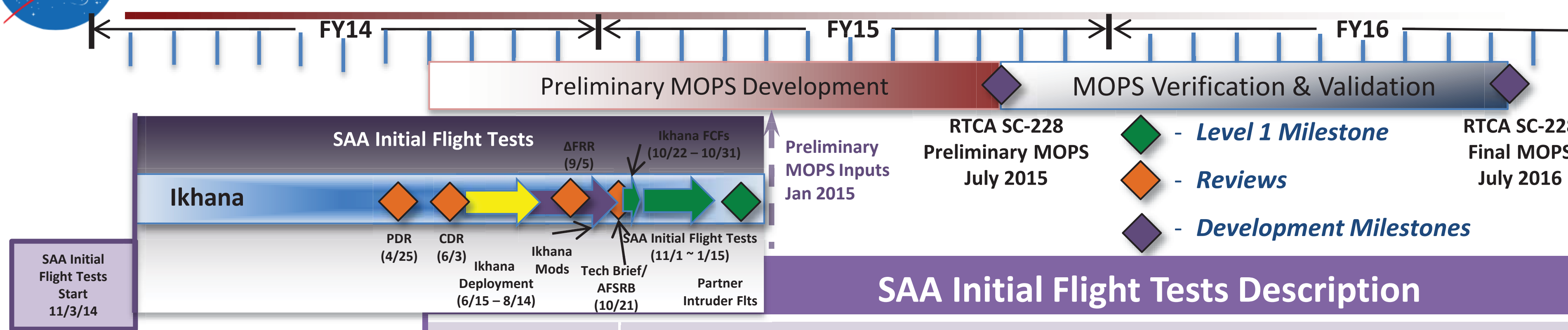
- Risk Management
  - Utilizes a Continuous Risk Management (CRM) process to identify, analyze, plan, track, and control risks
    - Risk Workshops and Risk Review meetings conducted monthly
    - Risks communicated at ISRP Risk Management Board, AFRC & Partner Center CMCs

- Resource Management
  - TWP, Budget roll up, and travel spreadsheets used in conjunction with standard tools (PMT, Business Warehouse, and SAP) to generate phasing plans and monitor status
- Management Review Board (MRB)
  - Monthly meeting where CRs and Risks are assessed/ approved and resource status and schedule status are presented



Project Level Performance
Backup Slides

SAA Initial Flight Tests



SAA Initial Flight Tests Description

Primary Partners	• FAA Aircraft Collision Avoidance System (ACAS) Xu Program • General Atomics Aeronautical Systems Inc. (GA-ASI)
Purpose	• Evaluate SAA Algorithm performance with actual sensor data • Demonstrate SAA Concept of Operations (CONOPS) in real-world scenarios • Demonstrate LVC distributed test environment
Approach	• Ikhana UAS modified with Proof of Concept DAA system (Prototype Air-to-Air Radar, SAA Processor, TCAS, ADS-B, Sensor Fusion) • Multiple encounter geometries (ACAS Xu Collision Avoidance (CA) and SS)
Test Duration	Nov 2014 – Jan 2015 (13 flights/2 backups) • ACAS Xu CA Flight Tests: UAS vs. Manned and UAS vs. UAS • Self Separation (SS) Flight Tests (UAS vs. Manned)
Technology Transfer	• DAA CONOPs and Algorithm flight demonstration • Data for validation of sensor models, well clear definition, and SS-CA interoperability
Project Benefit	• Conduct flight test risk reduction activities for FT3 and FT4 • Project’s 1st live flight test for SAA algorithms and pilot guidance displays for real sensor data/uncertainties, real environmental factors • Distributed test environment with GA-ASI

GENERAL ATOMICS AERONAUTICAL

Honeywell

BAE SYSTEMS

SAA Initial Flight Tests

EAFB Restricted Airspace R-2515

FY14 Project Deliverables

Phase 1 Closeout - sUAS	Date	Type of Deliverable
Concept of Operations and Guidelines of sUAS in the NAS	Apr-14	Report
Making the case for New Research to Support the Integration of sUAS in the NAS	Apr-14	Report
Survey Responses by ATC Manned Aircraft Pilots and UAS Pilots	Apr-14	Report
The Ability of RC Pilots to Maintain Visual Line-of-Sight of Their Vehicle	Jun -14	Report

Phase 2 Technical Challenge Deliverables - SAA	Date	Type of Deliverable
UAS Controller Acceptability Study 1 (UAS-CAS1) Test Plan	Nov-13	Paper
SAS Surveillance Performance Requirements for UAS	Nov-13	Paper
A Well-Clear Volume Based on Time to Entry Point	Dec-13	Report
Interim Report From UAS and SAA System Performance Trade Study	Jan-14	Interim Paper
UAS CAS1 May 13, 2014	May-14	Brief
UAS Controller Acceptability Study 2 (UAS-CAS2) and IHITL Test Plan	May-14	Report
IHITL Experiment Plan-Controller Subjects (aka Configuration 1, test setup 1)	May-14	Brief
Traffic Advisory and Safety Alerting Threshold Simulation Test Plan (TASATSTP)	Nov-13	Report
Investigating Effects of Well Clear Definitions on UAS SAS Operations Slides	May-14	Brief
UAS and SAA Performance Trade Study (SSI1)	May-14	Brief
Experiment Title- Study of Surveillance Range and Self-Separation Thresholds for DAA System with Various Resolution Criteria	May-14	Brief

FY14 Project Deliverables

Phase 2 Technical Challenge Deliverables – SAA (Continued)	Date	Type of Deliverable
Investigating Detect and Avoid Surveillance Performance for Unmanned Aircraft Systems	May-14	Report
Exploration of the Trade Space Between UAS Descent Maneuver Performance and SAA System Performance Requirements	May-14	Report
UAS-CAS1	May-14	Brief
Report -A Family of Well-Clear Boundary Models for the Integration of UAS in the NAS	Aug-14	Report
PT4 Detect and Avoid Results Presentation	Aug-14	Brief
Briefing - Investigating Detect and Avoid Surveillance Performance for UAS	Aug-14	Brief
AIAA Aviation 2014 Exploration of the Trade Space Between UAS Descent Maneuver Performance and SAA System Performance Requirement	Aug-14	Report
Paper - Investigating Detect and Avoid Surveillance Performance for UAS	Aug-14	Report
Final Overview of ACES Sim for Evaluating SARP Well Clear Definitions	Aug-14	Brief
Briefing - A Family of Well Clear Boundary Models for the Integration of UAS in the NAS	May-14	Brief
ACES Mitigated Results Supporting Selection of SARP Well-Clear Definition Maneuver Initiation Point MIP	Aug-14	Brief

FY14 Project Deliverables (cont.)

Phase 2 Technical Challenge Deliverables – C2	Date	Type of Deliverable
Security Test Plan for Lab Prototype	Jan-14	Report
Spectrum Element C-Band Planning and Standards Dev Plan	Jan-14	Paper
UAS CNPC System Developing and testing	Apr-14	Brief
Control and Non-Payload Communications (CNPC) Prototype Radio – Generation 2 Flight Lab Security Test	Aug-14	Report
GRC Spectrum Update - Briefing	Aug-14	Brief
CNPC Prototype Radio Development Generation 2 Flight Test Program Overview - Briefing	Aug-14	Brief
CNPC Security Architecture Prototype - Briefing	Aug-14	Brief
Comm Modeling and Simulation Status - Briefing	Aug-14	Brief
Phase 2 Technical Challenge Deliverables – HSI	**Date**	**Type of Deliverable**
Human Factors of UAS Ground Control Stations-The Development of Human Factors Guidelines	Jan-14	Paper
UAS Contingency Management The Effect of Different Procedures on ATC in Civil Airspace Operations	May-14	Report
HSI Full Mission Simulation Final Results	May-14	Brief
UAS Response to Air traffic Control Clearances- Measured Responses	May-14	Report
Measured Response For UAS-NAS	Jul-14	Report
UAS Measured Response: The Effect of GCS Control Mode Interfaces on Pilot Ability to Comply with ATC Clearances	Aug-14	Report
PT4: DAA Display Evaluation-Prelim Results	Aug-14	Brief

FY14 Project Deliverables (cont.)

Phase 2 Technical Challenge Deliverables – IT&E	Date	Type of Deliverable
UAS-NAS IHITL Simulation Test Plan	Jan-14	Paper
FY14 APG IHITL Test Report	Sept-14	Report

Phase 2 Non-Technical Challenge Deliverables – Cert	Date	Type of Deliverable
A Review of Current and Prospective Factors for Classification of Civil Unmanned Aircraft Systems	Aug-14	Report

Acronym List

AA	Associate Administrator
ACAS	Airborne Collision Avoidance System
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
AIAA	American Institute of Aeronautics and Astronautics
APG/I	Annual Performance Goal/Indicator
ARC	Ames Research Center/Aviation Rule Making Committee
ARD	Aeronautics Research Director
ARMD	Aeronautics Research Mission Directorate
ASRS	Aviation Safety Reporting System
ASP	Airspace Systems Program
ATC	Air Traffic Controller
ATO	Air Traffic Organization-FAA Organization
ATOL	Air Traffic Operations Lab
AUVSI	Association for Unmanned Vehicle Systems International
BLOS	Beyond Line of Sight
C2	Command and Control
CA	Collision Avoidance
CAS	Collision Avoidance System
CAT	Collision Avoidance Threshold
CDP	Content Decision Process
CDR	Critical Design Review

Acronym List

CM	Change Management or Contingency Management
CMC	Center Management Council
CNPC	Control and Non-Payload Communications
COA	Certificate or Waiver of Authorization
ConOps	Concept of Operations
CPDS	Conflict Prediction and Display System
CR	Change Request
CRM	Continuous Risk Management
CSD	Cockpit Situation Display
CSUN	Cal State University Northridge
CTD	Concepts and Technology Development Project
DAA	Detect and Avoid
DER	Designated Engineering Representative
DoD	Department of Defense
DPM	Deputy Project Manager
DPMf	Department Project Manager for
EL	Elevation
EO	Electro Optical
ERT	Engineering Review Team
ExCom	UAS Executive Committee
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FL	Flight Level
FRR	Flight Readiness Review
FT	Flight Test

Acronym List

FTE	Full Time Equivalent
FY	Fiscal Year
GA	General Aviation
GA-ASI	General Atomics Aeronautical Systems Inc.
GCS	Ground Control Station
GDS	Great Dismal Swamp
GRC	Glenn Research Center
GSN	Goal Structuring Notation
HCII	Human Computer Interaction International
HF	Human Factors
HITL	Human-In-The-Loop
HMD	Horizontal Miss Distance
HSI	Human Systems Integration Subproject
IAA	Inter-Agency Agreement
IAI	Intelligent Automation Inc.
ICAST	Inter Center Autonomy Study Team
IFR	Instrument Flight Rules
IH	In House
IHITL	Integrated Human-In-The-Loop
IMS	Integrated Master Schedule
IO	Integration Office
IPO	Inter-agency Planning Office
IR	Infrared
IRP	Independent Review Panel
ISRP	Integrated Systems Research Program

Acronym List

ITAR	International Traffic in Arms Regulations
IT&E	Integrated Test and Evaluation Subproject
ITU-R	International Telecommunication Union-Radiocommunication Sector
KDP	Key Decision Point
L1	Level 1
L2	Level 2
LaRC	Langley Research Center
LOS	Line of Sight
LVC	Live Virtual Constructive
LVC-DE	Live Virtual Constructive Distributed Environment
MIPR	Military Interdepartmental Purchase Request
MIT/LL	Massachusetts Institute of Technology Lincoln Labs
MOA	Memorandum of Agreement/Methods of Assessment
MOPS	Minimum Operational Performance Standard
MR	Measured Response
MRB	Management Review Board
MUSIM	Multiple UAS Simulation
NAS	National Airspace System
NRA	NASA Research Announcement
OPNET	OPNET Technologies
OSD	Office of the Secretary of Defense
P1	Phase 1
P2	Phase 2
PDR	Preliminary Design Review
PE/Co-PE	Project Engineer/Co-Project Engineer

Acronym List

PI	Progress Indicator
PM	Program Manager or Project Manager
PMT	Project Management Tool
PO	Project Office
PRD	Project Requirements Document
PRP	Performance Review Panel
PT	Part Task Simulation
RA	Resolution Advisory
RFI	Request for Information
RFP	Request for Proposal
RGCS	Research GCS
RTCA	RTCA
SA	Situational Awareness or Separation Assurance
SAA	Sense and Avoid or Space Act Agreement
SARP	Science and Research Panel
SBIR	Small Business Innovative Research
SC	Special Committee
SME	Subject Matter Expert
SMP	Schedule Management Plan
SP	Schedule Package
SRR	System Requirements Review
SS	Self-Separation
SSG	Senior Steering Group
SSI	Separation Assurance/Sense and Avoid Interoperability Subproject

Acronym List

SST	Self-Separation Threshold
SSV	Self-Separation Volume
sUAS	small Unmanned Aircraft System
TASATS	Traffic Advisory and Safety Alerting Threshold Simulation
TBD	To Be Determined
TC	Technical Challenges
TCAS	Traffic Alert and Collision Avoidance System
ToR	Terms of Reference
TPWG	Test Plan Working Group
TRACON	Terminal Radar Approach Control Facilities
TWP	Technical Work Package
UA	Unmanned Aircraft
UAS	Unmanned Aircraft Systems
UAV	Unmanned Aircraft Vehicle
UGCS	Universal Ground Control Station
USMC	U.S. Marine Corps
UTM	UAS Traffic Management
V&V	Verification and Validation
VFR	Visual Flight Rules
VSCS	Vigilant Spirit Control Station
WBS	Work Breakdown Structure
WG	Working Group
WYE	Work Year Equivalent