National Aeronautics and Space Administration

UAS Integration in the NAS Project
ICAO Visit

Laurie Grindle

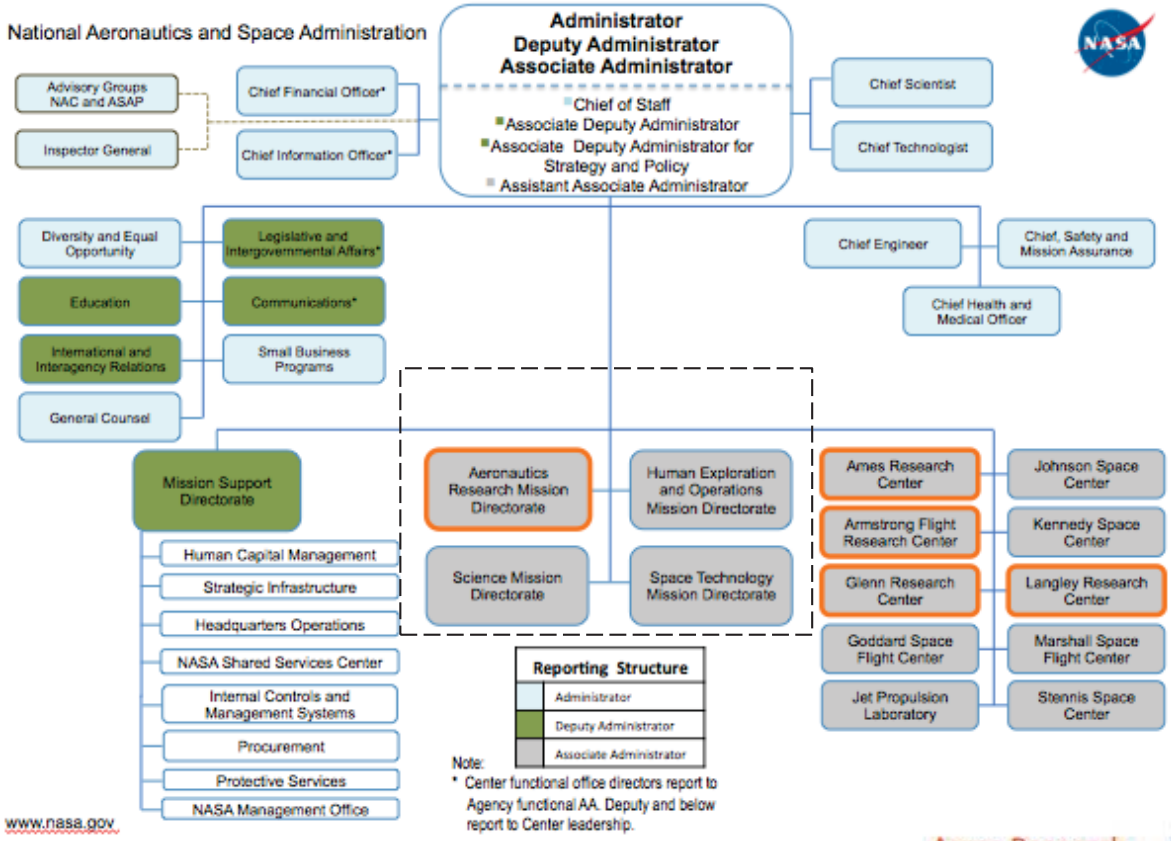
Project Manager, UAS Integration in the NAS Project

December 11, 2014

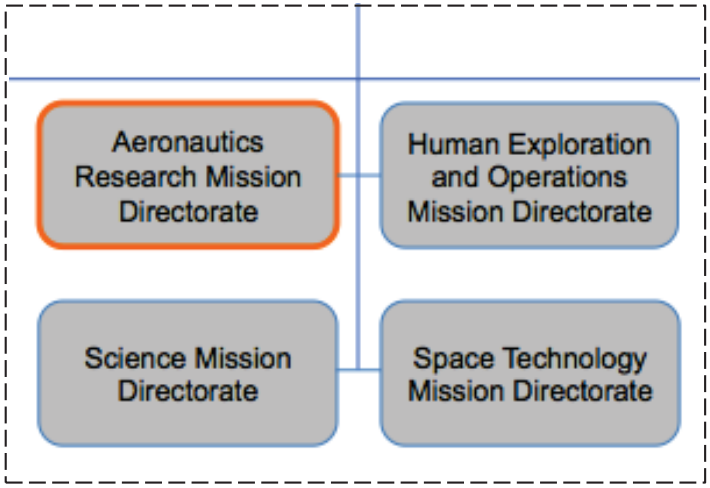
Briefing Outline

- UAS Integration in the NAS Project Alignment within NASA
- Project Overview
- Project Technical Challenges and Technology Development Approach
- FY14 Technical Accomplishments

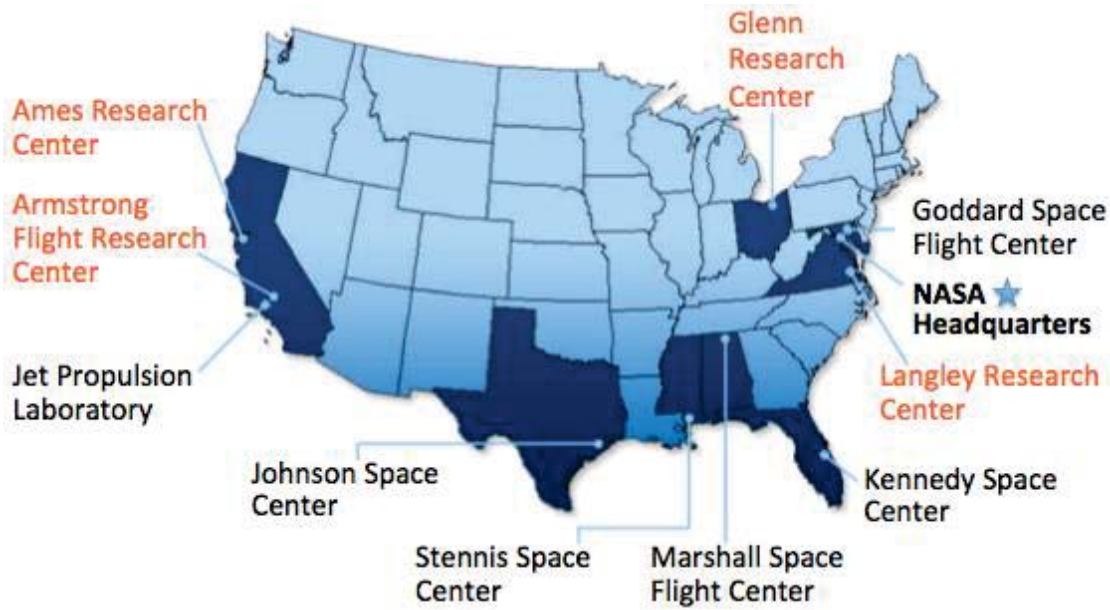
NASA Organizational Structure



Mission Directorates



Aeronautics Research Centers



NASA Aeronautics Portfolio

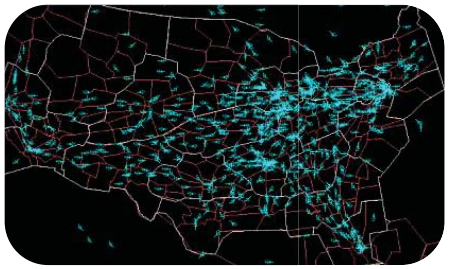


Fundamental Aeronautics Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to enable revolutionary changes for vehicles that fly in all speed regimes.

Integrated Systems Research Program

Conduct research at an integrated system-level on promising concepts and technologies and explore/assess/demonstrate the benefits in a relevant environment

Airspace Systems Program

Directly address the fundamental ATM research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the NAS.


Aviation Safety Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to improve the intrinsic safety attributes of current and future aircraft.



Aeronautics Test Program

Preserve and promote the testing capabilities of one of the United States' largest, most versatile and comprehensive set of flight and ground-based research facilities.

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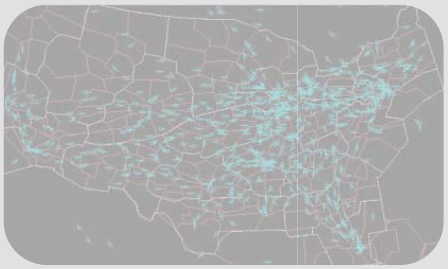

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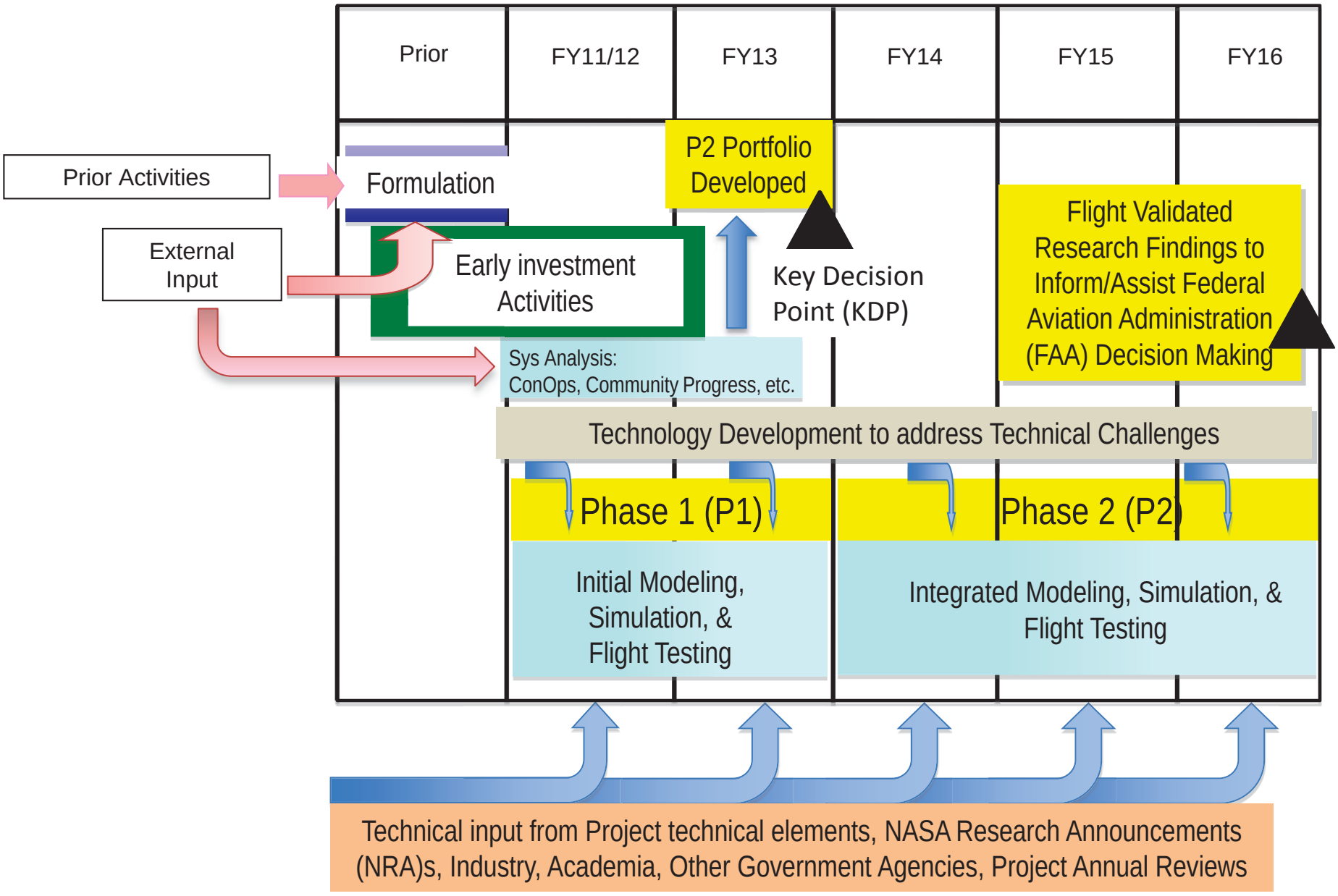
UAS-NAS Project Lifecycle



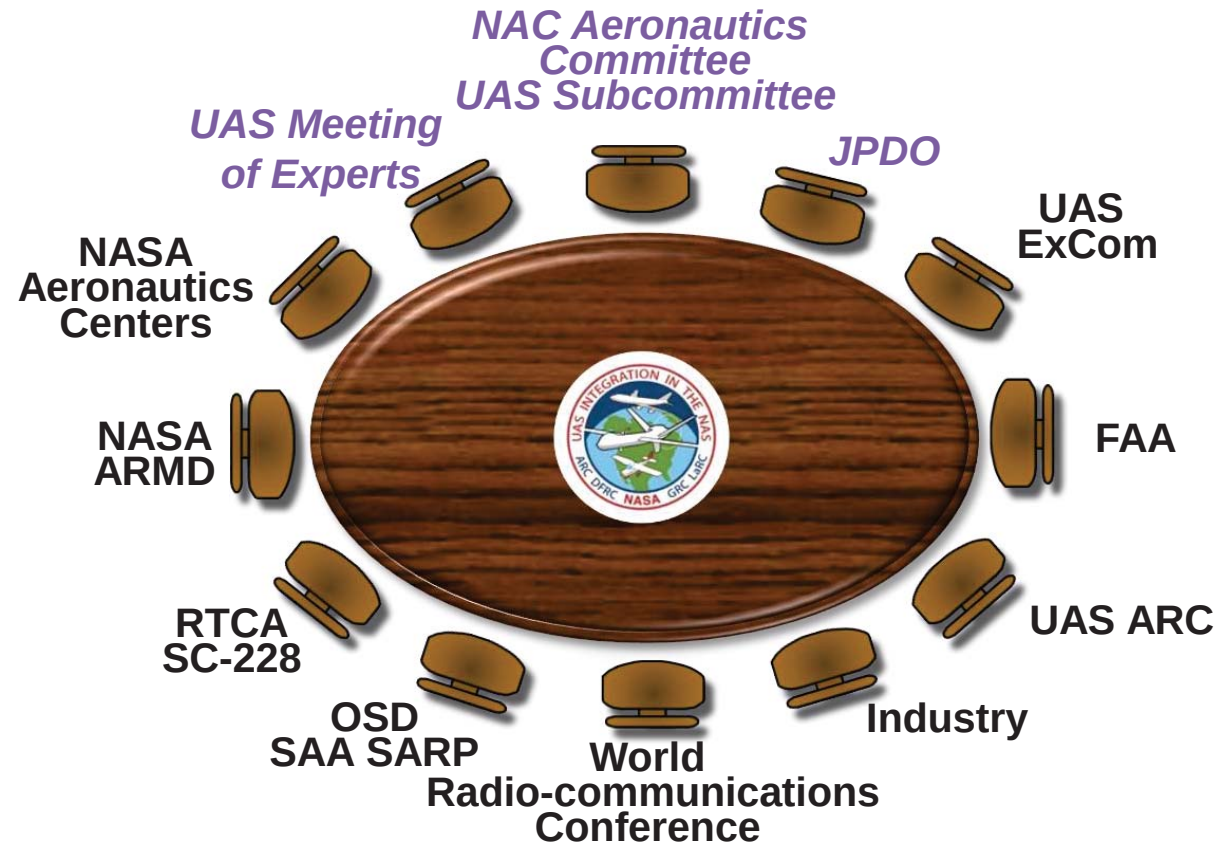
UAS-NAS Project Formulation

Key Stakeholders and Influencing Factors

Project Focus:

Unencumbered NAS Access for Civil / Commercial UAS

Key Stakeholders & Influencing Factors



The NASA UAS-NAS Project is influenced by several key stakeholders within the UAS Community which helped guide it's formulation

Phase 1 only Influences

FAA Pathway to UAS Access

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

Chartered to develop Detect and Avoid (DAA) and Command and Control (C2) MOPS

Joint Planning & Development Office (JPDO): Forum where collaboration for NextGen research occurs across gov't agencies and industry

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

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

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

Office of Secretary of Defense (OSD) Sense and Avoid (SAA) Science and Research Panel (SARP): Chartered by OSD to identify SAA Research Gaps

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

UAS-NAS International Collaboration

- Communications
  - International Telecommunications Union (ITU) – WRC-15 AI 1.5
    - 2015 World Radiocommunication Conference – Agenda Item 1.5
  - ICAO Aeronautical Communications Panel
    - Participating in Working Group F (Spectrum)
    - Participating in Working Group S (Surface Air-Ground Datalink Communication System)
- Human Factors
  - ICAO Remotely Piloted Aircraft Systems (RPAS) Panel Support
  - North Atlantic Treaty Organization (NATO)
    - Human Factors and Medicine (HFM) working group 247
- John Walker (Contractor)
  - ICAO
    - Supports RPAS Panel as member of the FAA Team as a Subject Matter Expert
    - Supports preparation for ICAO RPAS Symposium/March 2015
    - Supports ICAO Regional forums (as required)
  - As required
    - NATO Flight Into Non-Segregated Airspace (FINAS) Work Group
    - Joint Authorities for Rulemaking on Unmanned Systems (JARUS)
    - Single European Sky Research (SESAR)
    - EUROCAE Work Group 73 & 93: UAS Standards Development
    - Civil Air Navigation Service Organizations (CANSO)
    - Mid Air Collision Avoidance System (MIDCAS) Consortium

Project Goal, Research Themes, & Technical Challenges

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

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

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

TC-ITE: Integrated Test & Evaluation

TC-SAA: Sense and Avoid (SAA) Performance Standards

TC-HSI: Human Systems Integration

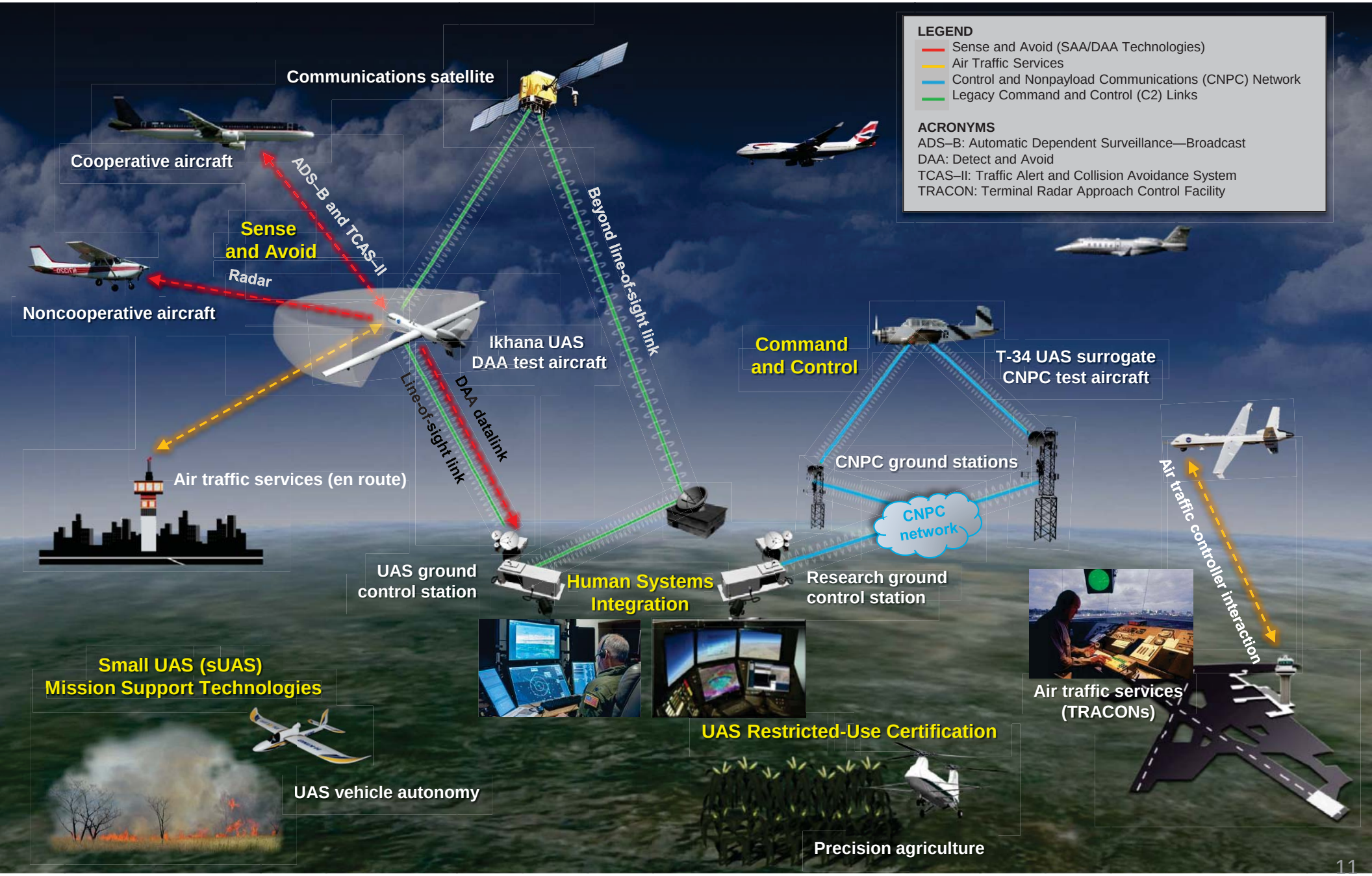
TC-C2: Command & Control (C2) Performance Standards

Non-TC: UAS Restricted Use Certification

Non-TC: Small UAS Mission Support Technologies

TC = Technical Challenge

UAS-NAS Project OV-1
IT&E Technical Challenge: Backbone for Integrated Testing



UAS Integration in the NAS Project

Technical Challenge Value Proposition

NASA UAS-NAS TC 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 Ground Control Station (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

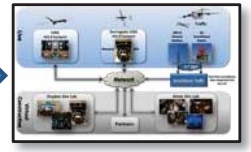
HF Performance Requirements to inform DAA & C2 MOPs, HF Guidelines

RTCA DAA MOPS, RTCA C2 MOPS → SAA Technical Standard Order (TSO), C2 Technical Standard Order (TSO)

TC ITE — Integrated Test & Evaluation

- Develop Live Virtual Constructive (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



FY14 Technical Accomplishments

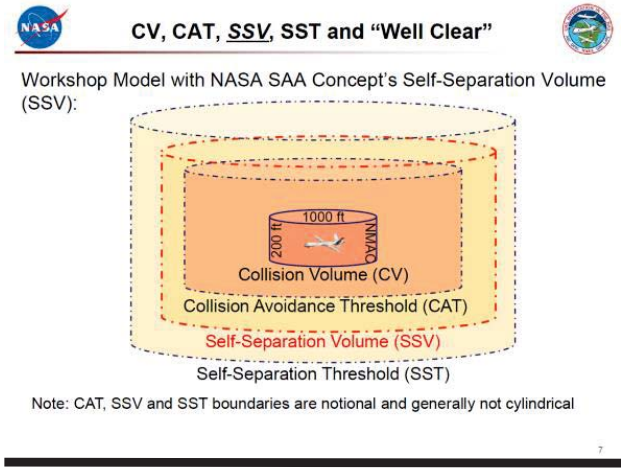
Major Contributions to Stakeholders

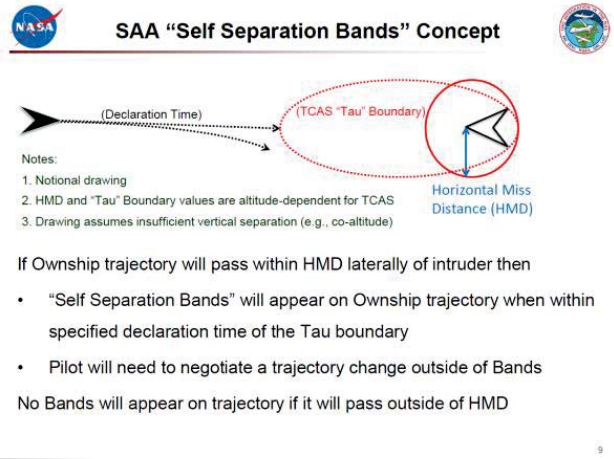
- Office of the Secretary of Defense (OSD) Sense and Avoid (SAA) Science and Research Panel (SARP)
  - Provided one of three Well Clear Standards to SARP for assessment
  - Assisted SARP with
    - Definition of selection criteria: operational acceptability metrics
    - Data and analysis of three proposals 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

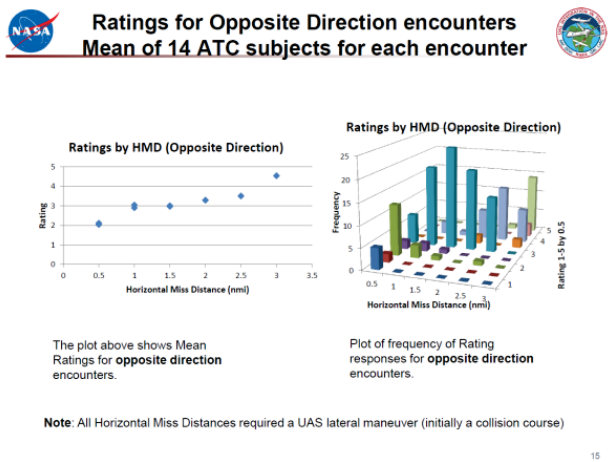
Providing High Quality Products Meeting Stakeholders Needs

TC-SAA
UAS CAS1 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





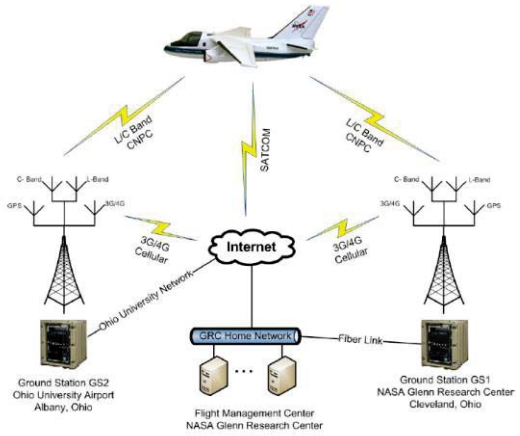


- **Interim Significant Results, Conclusions, and Recommendations:**
  - A horizontal miss distance of ~1.5 nmi appears to be optimal for ATC acceptability (away from the airport vicinity)
  - Horizontal miss distance of 1.5 nmi is 150% larger than the TCAS resolution advisory horizontal miss distance 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
Gen2 Radio in Relevant Environment Flight Test

- **Research Activity Objectives:**
  - Analyze the performance of the Gen2 C-band CNPC System prototype in a relevant flight environment

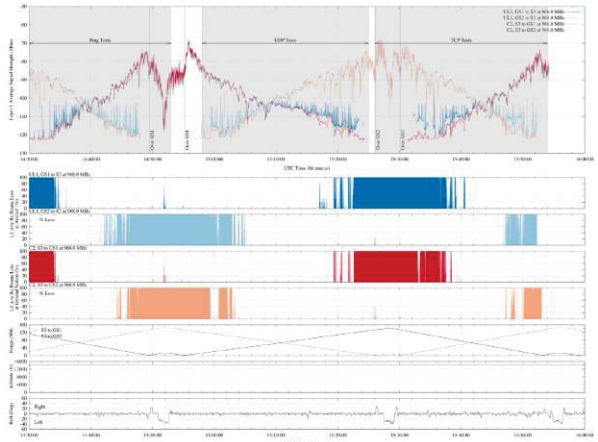


April 11, 2014

GS1 Characterization

April 30, 2014

Two Ground Stations, hand-off and data flow tests

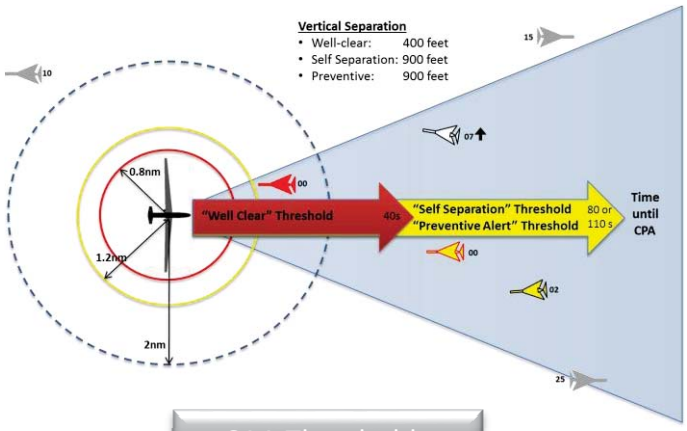


- **Results and Conclusions:**
  - Demonstrated fluid transition “hand-off” of aircraft CNPC signal between two CNPC system ground stations
  - Demonstrated operation of remote CNPC system ground terminals through network
  - Measured data link transmission/reception times
  - Testing of the Gen2 CNPC 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

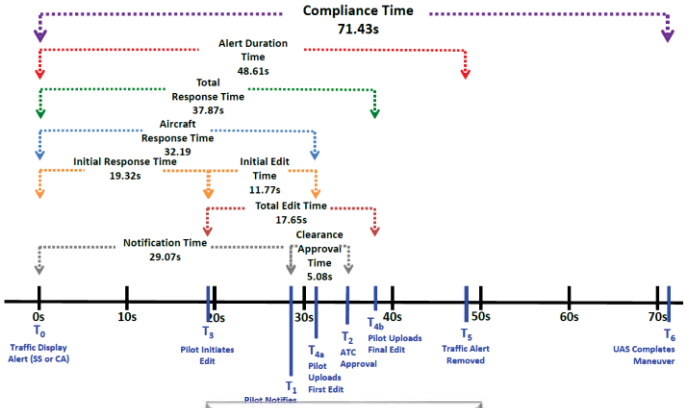
TC-HSI
Part-Task Simulation 4: SAA Pilot Guidance

- **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



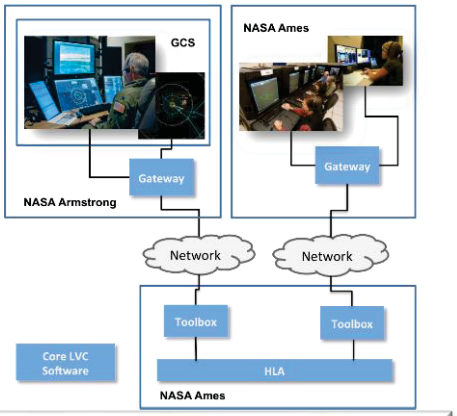
Timeline

- **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

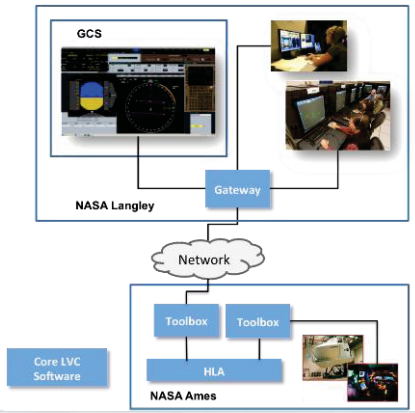
Results Contributed to GCS Minimum Information Guidelines/Requirements for DAA MOPS

TC-ITE
IHITL Execution

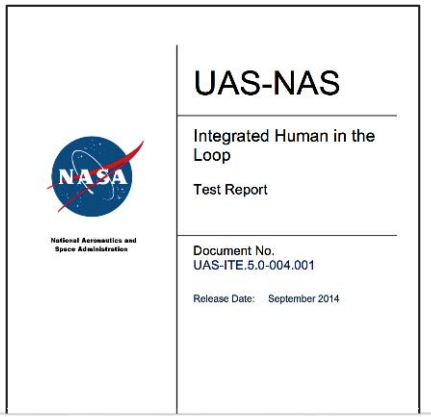
- **Research Activity Objective:**
  - Conduct a HITL simulation integrating the latest SSI algorithms, CNPC System model, and HSI displays using the Live, Virtual, Constructive test environment and document the performance of the simulation infrastructure in meeting the simulation requirements



ARC-AFRC Configuration



ARC-LaRC Configuration

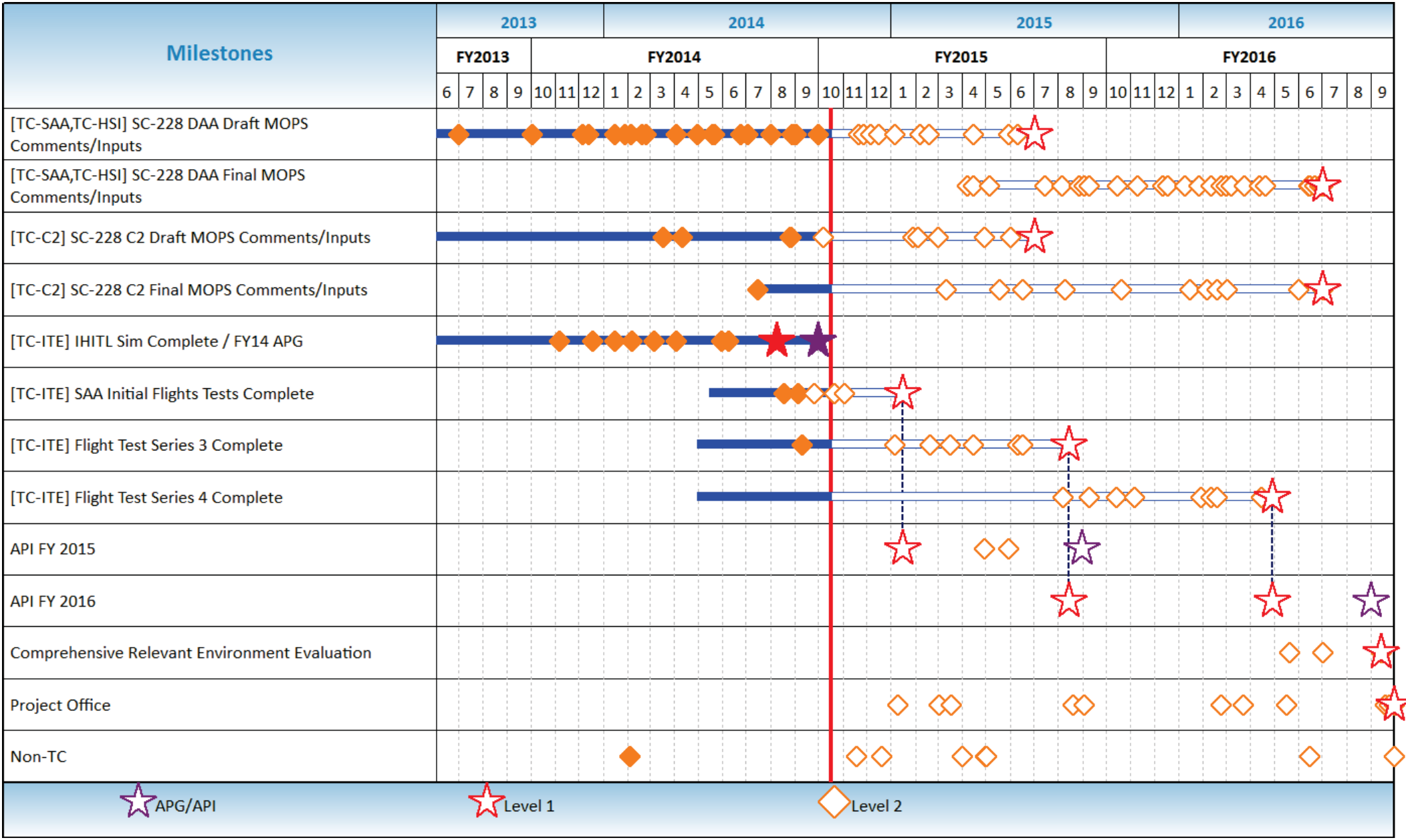


FY14 Annual Performance Goal

- **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

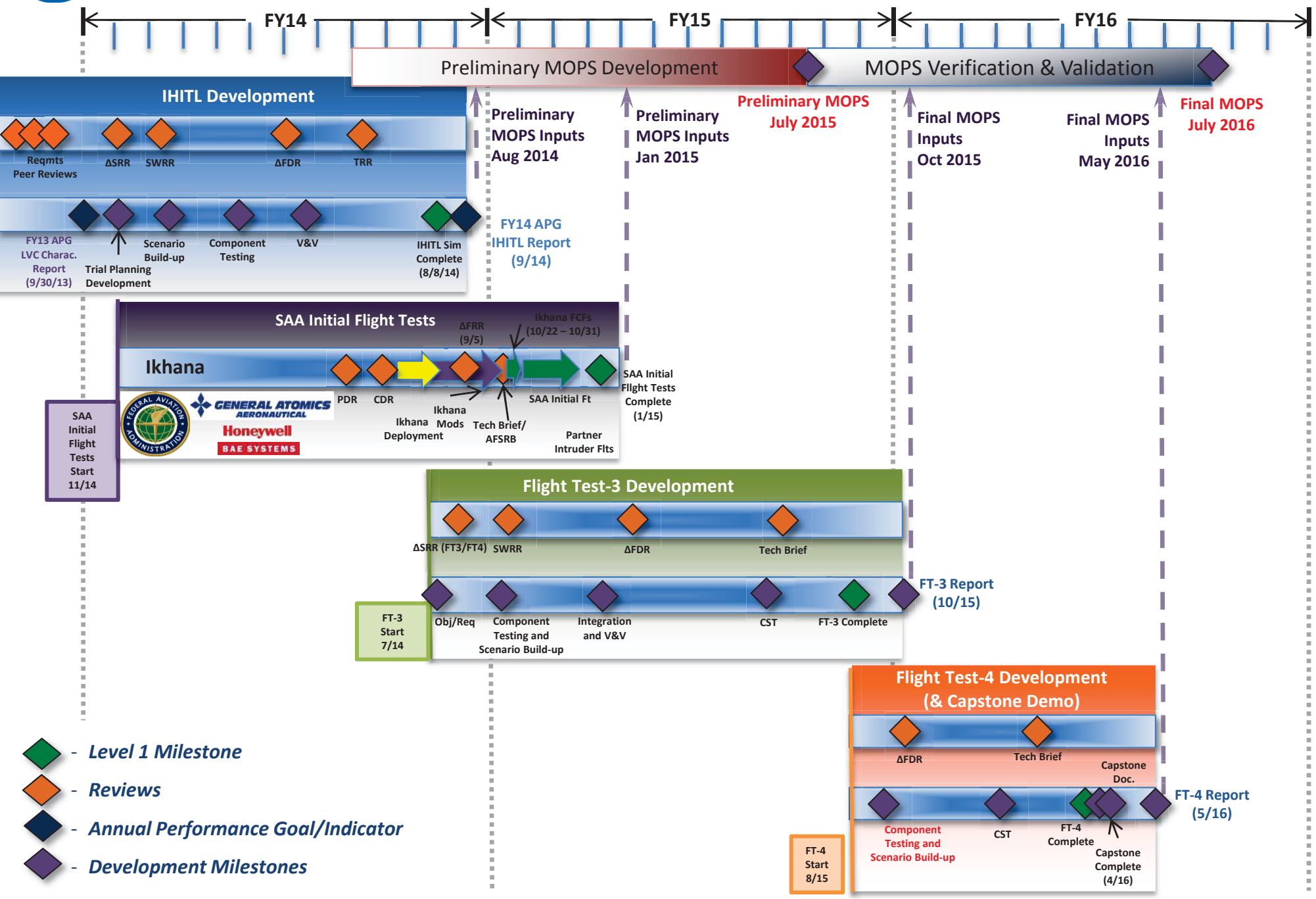
Results Contributed to Test Environment for V&V of DAA and C2 MOPS

UAS-NAS Milestone Summary



Backup Slides

IT&E Integrated Test Flow



Acronyms

ADS-B	Automatic Dependent Surveillance - Broadcast
APG	Annual Performance Goal
API	Annual Performance Indicator
ARC	Aviation Rulemaking Committee
ATC	Air Traffic Controller
ARMD	Aeronautics Research Mission Directorate
ATM	Air Traffic Management
BLOS	Beyond Line of Sight
C2	Command and Control
CDR	Critical Design Review
CANSO	Civil Air Navigation Service Organizations
CONOPS	Concept of Operations
CNPC	Control and Non-Payload Communications
DAA	Detect and Avoid
ExCom	Executive Committee
FAA	Federal Aviation Administration
FINAS	Flight Into Non-Segregated Airspace
FRR	Flight Readiness Review
FT	Flight Test
FY	Fiscal Year
HF	Human Factors
HFM	Human Factors and Medicine

Acronyms

HITL	Human in the Loop
HSI	Human Systems Integration
ICAO	International Civil Aviation Organization
IHITL	Integrated Human in the Loop
ITE	Integrated Tests and Evaluation
ITU	International Telecommunications Union (ITU)
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
JPDO	Joint Planning and Development Office
KDP	Key Decision Point
LOS	Line of Sight
LVC	Live Virtual Constructive
MOPS	Minimum Operational Performance Standards
MS&A	Modeling Simulation and Analysis
NATO	North Atlantic Treaty Organization (NATO)
NRA	NASA Research Announcements
OSD	Office of the Secretary of Defense
P1	Phase 1
P2	Phase 2
PDR	Preliminary Design Review
RPAS	Remotely Piloted Aircraft Systems
SAA	Sense and Avoid
SARP	Science and Research Panel

Acronyms

SC	Special Committee
SST	Self Separation Threshold
TC	Technical Challenge
TCAS	Traffic Alert and Collision Avoidance System
TRACON	Terminal Radar Approach Control Facilities
TSO	Technical Standard Order
UAS	Unmanned Aircraft Systems
V&V	Verification and Validation
WRC	World Radio Conference