UAS Integration in the NAS Project
TAAC 2014

Laurie Grindle
Project Manager, UAS Integration in the NAS Project

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Briefing Outline

• Project Overview
• FY14 Technical Accomplishments
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.

**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.

**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.

**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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UAS-NAS Project Lifecycle

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

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

Prior Activities
- Formulation
- Early investment Activities
  - Sys Analysis: ConOps, Community Progress, etc.

External Input
- Technical input from Project technical elements, NASA Research Announcements (NRA)s, Industry, Academia, Other Government Agencies, Project Annual Reviews

Key Decision Point (KDP)
- Flight Validated Research Findings to Inform Federal Aviation Administration (FAA) Decision Making

Integrated Modeling, Simulation, & Flight Testing to address Technical Challenges

XY11/12 FY13 FY14 FY15 FY16

Technical input from Project technical elements, NASA Research Announcements (NRA)s, Industry, Academia, Other Government Agencies, Project Annual Reviews
The FAA is using several domestic forums, in conjunction with several international forums to lay out the pathway for their priorities and investments.

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

- **World Radio Conference (WRC) and International Civil Aviation Organization (ICAO) UAS Study Group:** Addressing UAS access from an international perspective.

- **Detect and Avoid (DAA) and Command and Control (C2) MOPS Development:** Chartered to develop DAA and C2 MOPS.

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

- **UAS Aviation Rulemaking Committee (ARC):** Developed civil UAS Implementation Plan based on the FAA’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.**
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**
UAS Integration in the NAS Project
Technical Challenge Value Proposition

**NASA UAS-NAS TC Project Activities**

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

**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 Interoperability Testbed
  - Conduct C2 Requirements
- Develop C2 Requirements
- Develop C2 Performance Standards

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

**Integrated Test & Evaluation**
- Develop Live Virtual Constructive (LVC) Test Infrastructure
  - Conduct TC Specific Testing
  - Conduct TC Specific Testing
- Conduct IHITL
- Conduct SAA Initial Flight Test Scenarios
- Conduct FT3 Test Scenarios
- Conduct FT4 Test Scenarios & Capstone

**Key Products**
- SAA Performance Requirements to inform DAA MOPS
- C2 Performance Requirements to inform C2 MOPS
- HF Performance Requirements to inform DAA & C2 MOPS, HF Guidelines
- Re-usable Test Infrastructure

**Resultant Outcomes**
- RTCA
  - DAA MOPS
  - SAA Technical Standard Order (TSO)
  - C2 MOPS
  - C2 Technical Standard Order (TSO)
  - SAA Technical Standard Order (TSO)
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
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

• **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
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

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
• **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

• **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

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**APG/API**

- **Level 1**
- **Level 2**
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