UAS Integration in the NAS Project
ICAO Visit

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Project Manager, UAS Integration in the NAS Project

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Briefing Outline

• UAS Integration in the NAS Project Alignment within NASA
• Project Overview
• Project Technical Challenges and Technology Development Approach
• 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.
NASA Aeronautics Portfolio

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UAS-NAS Project Lifecycle

<table>
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<tr>
<th>Prior</th>
<th>FY11/12</th>
<th>FY13</th>
<th>FY14</th>
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<tr>
<td>Formulation</td>
<td>Early investment Activities</td>
<td>P2 Portfolio Developed</td>
<td>Flight Validated Research Findings to Inform/Assist Federal Aviation Administration (FAA) Decision Making</td>
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Prior Activities

- External Input
  - Sys Analysis: ConOps, Community Progress, etc.

Key Decision Point (KDP)

Technology Development to address Technical Challenges

- Phase 1 (P1)
  - Initial Modeling, Simulation, & Flight Testing
- Phase 2 (P2)
  - Integrated Modeling, Simulation, & Flight Testing

Technical input from Project technical elements, NASA Research Announcements (NRA)s, Industry, Academia, Other Government Agencies, Project Annual Reviews
UAS-NAS Project Formulation
Key Stakeholders and Influencing Factors

Project Focus:
Unencumbered NAS Access for Civil / Commercial UAS

Key Stakeholders & Influencing Factors

- NASA Aeronautics Centers
- NASA ARMD
- RTCA SC-228
- OSD SAA SARP
- World Radio-communications Conference
- FAA
- Industry
- UAS ARC
- UAS ExCom
- JPDO
- NAC Aeronautics Committee
- UAS Subcommittee
- UAS Meeting of Experts

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
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 are addressing UAS access from an international perspective

FAA Pathway

JPDO

RTCA SC-228

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

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

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

UAS Arc

OSD

SAA

SARP

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 = Technical Challenge
UAS-NAS Project OV-1

IT&E Technical Challenge: Backbone for Integrated Testing

LEGEND
- Sense and Avoid (SAA/DAA Technologies)
- Air Traffic Services
- Control and Nonpayload Communications (CNPC) Network
- Legacy Command and Control (C2) Links

ACRONYMS
- ADS-B: Automatic Dependent Surveillance—Broadcast
- DAA: Detect and Avoid
- TCAS-II: Traffic Alert and Collision Avoidance System
- TRACON: Terminal Radar Approach Control Facility

Small UAS (sUAS)
Mission Support Technologies

UAS vehicle autonomy

Precision agriculture

Human Systems Integration

UAS Restricted Use Certification

Research ground control station

CNPC ground stations

T-34 UAS surrogate CNPC test aircraft

Ikhana UAS DAA test aircraft

CNPC test aircraft

Command and Control

DAA datalink

Beyond line-of-sight link

UAS ground control station

Human Systems Integration

CNPC network

Air traffic services (en route)

Communications satellite

Sense and Avoid

Noncooperative aircraft

Cooperative aircraft

Air traffic services (en route)

Radar

ADS-B and TCAS-II

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**

### SAA Performance Standards
- **Develop SAA Performance Testbed**
- **Develop SAA Interoperability Testbed**

### C2 Performance Standards
- **Develop C2 Prototype System**

### Human Systems Integration
- **Develop Prototype Ground Control Station (GCS)**

### Integrated Test & Evaluation
- **Develop Live Virtual Constructive (LVC) Test Infrastructure**

**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

**Resultant Outcomes**

- **Develop SAA Performance & Interoperability Requirements**
- **Develop SAA Performance Test and MS&A**
- **Develop C2 Performance Test and MS&A**
- **Develop HF Guidelines for SAA, C2 & GCS**
- **Conduct Human Factors (HF) Flight Test and MS&A**
- **Conduct SAA Initial Flight Test Scenarios**
- **Conduct TC Specific Testing**
- **Conduct FT3 Test Scenarios**
- **Conduct FT4 Test Scenarios & Capstone**
- **Conduct IHITL**

**TC**

**SAA**

**C2**

**HSI**

**ITE**

**Develop Live Virtual Constructive (LVC) Test Infrastructure**

**Conduct TC Specific Testing**

**Conduct SAA Initial Flight Test Scenarios**

**Conduct FT3 Test Scenarios**

**Conduct FT4 Test Scenarios & Capstone**

**Conduct IHITL**
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
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
• **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
**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
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

• **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**
Backup Slides
**IT&E Integrated Test Flow**

- **Level 1 Milestone**
- **Reviews**
- **Annual Performance Goal/Indicator**
- **Development Milestones**

**IHITL Development**
- Reqmts Peer Reviews
- SWRR
- ΔFDR
- TRR
- IHITL Sim Complete (8/8/14)

**SAA Initial Flight Tests**
- SAA Initial Flight Tests Start 11/14

**Flight Test-3 Development**
- ΔSRR (FT3/FT4)
- SWRR
- ΔFDR
- Tech Brief
- FT-3 Report (10/15)

**Flight Test-4 Development**
- ΔFDR
- Tech Brief
- Capstone Doc.
- FT-4 Report (5/16)

**Final MOPS Inputs**
- Oct 2015
- May 2016

**Preliminary MOPS Inputs**
- Aug 2014
- July 2015

**SAA Initial Flight Tests Complete (1/15)**

**Ikhana Deployment**
- PDR
- LDR
- ΔFRR (9/5)

**Preliminary MOPS Development**
- FY13 APG LVC Charac. Report (9/30/13)

**Final MOPS Inputs**
- Oct 2015
- May 2016

**Final MOPS**
- July 2016

**IHITL Report**
- (9/14)

**IHITL Sim Complete**
- (8/8/14)

**SAA Initial Fllght Tests Complete**
- (1/15)

**Preliminary MOPS Report**
- FY14 APG

**FT-3 Start**
- 7/14

**FT-3 Report**
- (10/15)

**FT-4 Report**
- (5/16)

**FT-4 Complete**
- Capstone Complete (4/16)

**SAA Initial Flight Tests**
- Partner Intruder Flts

**Tech Brief/AFSRB**
- SAA Initial Ft

**Ikhana Mods**
- (10/22 – 10/31)

**SAA Initial Flight Tests**
- (1/15)

**Preliminary MOPS Inputs**
- Aug 2014
- July 2015

**Final MOPS Input Oct 2015**

**Final MOPS Input May 2016**

**Final MOPS July 2016**

**Preliminary MOPS July 2015**

**SAA Initial Flight Tests**
- Complete

**FT-4 Complete**
- Capstone Complete (4/16)

**FT-4 Report**
- (5/16)

**Final MOPS Inputs**
- Oct 2015
- May 2016

**Final MOPS**
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# Acronyms

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<tr>
<td>ADS-B</td>
<td>Automatic Dependent Surveillance - Broadcast</td>
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<td>APG</td>
<td>Annual Performance Goal</td>
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<td>Annual Performance Indicator</td>
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<td>ARC</td>
<td>Aviation Rulemaking Committee</td>
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<td>ATC</td>
<td>Air Traffic Controller</td>
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<td>ARMD</td>
<td>Aeronautics Research Mission Directorate</td>
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<td>ATM</td>
<td>Air Traffic Management</td>
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<td>BLOS</td>
<td>Beyond Line of Sight</td>
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<td>Command and Control</td>
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<td>Critical Design Review</td>
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<td>CONOPS</td>
<td>Concept of Operations</td>
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<td>Control and Non-Payload Communications</td>
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