UAS Integration in the NAS Project
Ideal Aerosmith Brief

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Briefing Outline

• Project History and Overview
• Integrated Test & Evaluation
Briefing Outline

• Project History and Overview
  – ARMD Programmatic Structure
  – UAS-NAS Project Lifecycle
  – FAA Linkages
  – Content Decision Process
  – UAS-NAS Portfolio – Technical vs. Non-Technical
  – Project OV-1

• Integrated Test & Evaluation
ARMD Programs Overview

MISSION PROGRAMS

- Airspace Operations and Safety Program (AOSP)
  - Safe, Efficient Growth in Global Operations
  - Real-Time System-Wide Safety Assurance
  - Assured Autonomy for Aviation Transformation

- Advanced Air Vehicles Program (AAVP)
  - Ultra-Efficient Commercial Vehicles
  - Innovation in Commercial Supersonic Aircraft
  - Transition to Low-Carbon Propulsion
  - Assured Autonomy for Aviation Transformation

- Integrated Aviation Systems Program (IASP)
  - Flight research-oriented, integrated, system-level R&T that supports all six thrusts
  - X-planes/test environment

SEEDLING PROGRAM

- Transformative Aeronautics Concepts Program (TACP)
  - High-risk, leap-frog ideas that support all six thrusts
  - Critical cross-cutting tool development
Integrated Aviation Systems Program

Coordinates long-term ongoing research with other ARMD programs as done by the Integrated Systems Research Program. Continues the Environmentally Responsible Aviation and UAS in the NAS projects and includes the flight test portion of the former Aeronautics Test Program.

Conducts research on promising concepts and technologies at an integrated system level

Explores, assesses, and demonstrates the benefits of promising technologies in a relevant environment

Conducts research into environmentally responsible aviation and unmanned system integration into the national airspace

Supports flight research needs across the ARMD strategic thrusts, programs and projects

Completes flight demonstrations

Projects
- Environmentally Responsible Aviation
- UAS Integration in the NAS
- Flight Demonstrations and Capabilities
UAS-NAS Project Lifecycle

Prior Activities

Early investment Activities

Sys Analysis: ConOps, Community Progress, etc.

Technology Development to address Technical Challenges

Key Decision Point (KDP)

P2 Portfolio Developed

Flight Validated Research Findings to Inform Federal Aviation Administration (FAA) Decision Making

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
The FAA is using several domestic forums, in conjunction with several international forums to lay out the pathway for their priorities and investments. NASA has a leadership role within the domestic forums and participates in the international forums.
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.
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
  - Interoperability
  - Well Clear
  - Self Separation
  - Collision Avoidance
- Develop SAA Performance & Interoperability Requirements

**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

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

**Integrated Test & Evaluation**
- 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

**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**
- Re-usable Test Infrastructure
- DAA MOPS
- C2 MOPS
- SAA Technical Standard Order (TSO)
- C2 Technical Standard Order (TSO)
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-HSI: Human Systems Integration
TC-SAA: Sense and Avoid (SAA) Performance Standards
TC-C2: Command & Control (C2) Performance Standards
Non-TC: UAS Restricted Use Certification
Non-TC: Small UAS Mission Support Technologies

TC = Technical Challenge
Briefing Outline

• Project History and Overview
• Integrated Test & Evaluation
Live, Virtual, Constructive – Distributed Environment

Jim Murphy: UAS-NAS Integrated Test and Evaluation Project Engineer
TC-ITE: Integrated Test and Evaluation

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

- 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.
**Purpose**
- Evaluates and measures the acceptability of algorithms and pilot guidance displays with ATC operations with increased simulation fidelity by adding CNPC time delay, a proof of concept GCS, and VFR cooperative and non-cooperative traffic.

**Approach**
- 2 LVC configurations to be tested (Config1 & Config2)
  - Config1: Ames/Armstrong connectivity (ATC and Pilot test set-ups)
  - Config2: LaRC/Ames connectivity (SAA-CA interoperability)
  - Scenarios - Class E airspace operations near major TRACONs

**Test Duration**
- Jun – Jul 2014
  - Config1 Test Set-up 1: ATC – 3 weeks (15 Controllers)
  - Config1 Test Set-up 2: UAS pilots – 2 weeks (10 pilots)
  - Config2 Test Set-up: ATC – 3 weeks (6 Controllers)

**Tech Transfer**
- Validated SAA, C2, HSI performance requirements and guidelines
- Community insight into LVC Infrastructure capabilities

**Project Benefit**
- Validates Project models
- Risk reduction for ACAS Xu Flight Test Series and Flight Test Series 3
- Foundational infrastructure integrated test supports ACAS-Xu, FT3, & FT4
Purpose
• Evaluate SAA Algorithm performance with actual sensor data
• Demonstrate SAA 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 (CA and SS)

Test Duration
Nov 2014 – Jan 2015 (13 flights/2 backups)
• Nov 2014: ACAS-Xu CA (UAS vs. Manned)
• Nov – Dec 2014: Self Separation (UAS vs. Manned)
• Dec 2014 – Jan 2015: ACAS-Xu CA (UAS vs. UAS)

Tech 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
• LVC/DE connectivity to Ikhana GCS established
General Research Test Objectives

- Integrate and evaluate the state of UAS concepts and supporting technologies defined within the scope of the UAS in the NAS Project.
  - Evaluate and measure the effectiveness and acceptability of the SAA systems (algorithms and displays) to inform and advise UAS pilots
  - Evaluate and measure the interoperability and operational acceptability of UAS integration concepts in the NAS
- Characterize the test environment and identify areas of future research and development emphasis and reduce risk for the flight tests and capstone event

- Conduct flight test risk reduction activities for FT3 and FT4
- Demonstrate Live, Virtual, Constructive (LVC) distributed test environment
- Demonstrate self-separation Concept of Operations (CONOPS) through real world scenarios
- Evaluate sense and avoid (SAA) algorithm performance with actual sensor data

- Validate results previously collected during simulation testing (UAS CAS 2, IHITL, PT5) with live data.
- Test fully integrated UA system with components of SSI, HSI, and Comm in a relevant live test environment
  - End to end (Aircraft sensor/winds/etc. to RGCS) traffic encounter test of pilot guidance generated by SS algorithm (Stratway+, AutoResolver)
  - Conduct flight test of prototype Communication system in relevant environment
  - Collect data in support of the preliminary MOPS draft for C2 and DAA

- Validate C2 and DAA MOPS
  - Challenging encounter geometries with 2 or more live aircraft
  - Negotiation between UAS pilot and ATC in complex/busy airspace
  - UAS capable of autonomous SA during lost link contingency

- Assess operational utility of UAS separation assurance and sense and avoid algorithms, ground control and air traffic display concepts
  - UAS line pilot flying surrogate or partner UAS
  - Mission-oriented, not test oriented
Simulation Conops

- Live: Real people operating real assets
- Virtual: Real people operating simulated assets
- Constructive: Simulated people operating simulated assets
- Distributed Environment: Brings simulation to the LVC assets increasing external partner options

T-34C UAS Surrogate

Live Intruder
- ADS-B/TCAS II Equipped
- High speed

Virtual/Constructive Intruders

ADS-B Out

CNPC Data Link
- C2
- Voice
- H&S
- Video
- Traffic

UAS Pilot

Research GCS

Displays of Proximal Traffic

Research GS

Virtual/Constructive Intruders

Target Generation

ATC

VPN
LVC Client Assets

• Live
  – Ikhana (NASA’s MQ-9)
  – T-34C (Manned Intruder)
  – S-3B Viking (Surrogate UAS)

• Virtual
  – Ikhana Sim
  – B747 Flight Simulator
  – Ground Control Station
  – Multi-Aircraft Control System (MACS) ATC Emulator

• Constructive
  – MACS Pseudo Pilot
Ikhana MQ-9 Predator B at NASA Armstrong
T-34C at NASA Glenn
S-3B Viking at NASA Glenn
Ikhana Simulator at NASA Armstrong
B747 Flight Simulator at NASA Ames
UAS Ground Control Station at NASA Armstrong

Lab Layout for Flight Test

Pilot Control Station Layout for Flight Test
ATC and Pseudo Pilots at NASA Ames and NASA Langley

Pseudo Pilot Control

Air Traffic Control
Multi-Aircraft Control System (MACS)

- Active/Ctrl AC List
- Pseudo Pilot Control
- Air Traffic Control
Distributed Connectivity Demonstration

Initial test of distributed simulation capability among multiple participants

Flight Test 3: Configuration 1 (Pairwise at AFRC) – Low Speed Ownship

Live Ownship

Live Intruder(s)

Ikhana Data Link
- CZ
- Voice
- Health & Status
- Video
- Intruders

ADS-B Out
Mode 3/10C

ADS-B Data
ASR Data

AFTC
Bldg. 1440

AFTC/AFRC
Alliance Link
Bldg. 4800

MSCT
Multi-Source
Correlator

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UAS-NAS FT3 System Engineering Discussions
Flight Test 3: Configuration 1 (Pairwise at AFRC) – High Speed Ownship

Live Ownship

Live Intruder(s)

CNPC Data Link
- C2
- Voice
- Health & Status
- Video
- Intruders

CNPC Gmd Station
- CNPC Radio
- Gmd Station Computer

ADS-B Data
ASR Data

AFTC
Bldg. 1440

AFTC/AFRC
Alliance Link
Bldg. 4800

MSCT
Multi-Source Correlator

3/5/2015
UAS-NAS FT3 System Engineering Discussions
Voice Communication Architecture – Baseline Plan
FT3 Full Mission at AFRC

Desirable

Joshua (VHF)
Virtual ATC Mission Discrete (VHF)
CNPC (Voice)
TC/SPORT Mission Discrete (VHF)

CNPC Ground Station
CNPC Radio
Ground Station Computer

Pilot Station
Voice Comm System (DICES III)
AFRC RGCS LAB

Network Management
Virtual ATC
VSM Voice I/O

Radio 1
Radio 2
Radio 3
DICES III/Channel Bank/ACE-RIU Bridge

AFRC Comm Bldg

AFRC SAF
Voice Comm System (DICES III)
Test Conductor
Test Director

TC/SPORT Joshua
Ghost

AFRC

ARC

3/5/2015
UAS-NAS FT3 System Engineering Discussions