Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

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Manned and unmanned aircraft will be able to routinely operate through all phases of flight in the NAS, based on airspace requirements and system performance capabilities.
Emerging Commercial UAS Operating Environments (OE)

**IFR-LIKE**

UAS will be expected to meet certification standards and operate safely with traditional air traffic and ATM services. (Example Use Case: Communication Relay / Cargo Transport)

**VFR-LIKE**

These UAs will conduct extended operations at altitudes below 10000’ and need to routinely integrate with both cooperative and non-cooperative aircraft. (Example Use Case: Infrastructure Surveillance)

**BVLOS URBAN**

Must interface with dense controlled air traffic environments as well as operate safely amongst the traffic in uncontrolled airspace. (Example Use Case: Traffic Monitoring / Package Delivery)

**BVLOS RURAL**

Low risk BVLOS rural operations with or without aviation services. (Example Use Case: Agriculture)

**RURAL**

Agricultural Aircraft

Helicopters

VLOS

**URBAN**

Terminal Airspace

Airport

VLOS

**TIME (Notional)**

Restricted Access

Routine Access
NASA UAS Airspace Integration Pillars and Enablers

**UAS Technologies:**
- T01 - Airport Operations Technologies
- T02 - Airworthiness Standards
- T03 - Command, Control, Communications Technologies
- T04 - Detect & Avoid (DAA)
- T05 - Flight & Health Mngmt Systems
- T06 - Ground Control Station (GCS) Technologies
- T07 - Hazard Avoidance
- T08 - Highly Automated Architectures
- T09 - Navigation
- T10 - Power & Propulsion
- T11 - Weather Avoidance

**ATM Services & Infrastructure:**
- I01 - Airport Infrastructure
- I02 - Air Traffic Management (ATM) Infrastructure
- I03 - Non-FAA Managed Airspace Infrastructure
- I04 - Radio Frequency (RF) Spectrum Availability
- I05 - Test Ranges & Modeling & Simulation (M&S) Facilities

**Operational Regulations, Policies & Guidelines:**
- P01 - ATM Regulations / Policies / Procedures
- P02 - Airworthiness Regulations / Policies / Guidelines
- P03 - Operating Rules / Regulations / Procedures
- P04 - Safety Risk Mngmt & Methods of Compliance

**Public Acceptance & Trust:**
- A01 - Cyber Security Criteria & Methods of Compliance
- A02 - Legal & Privacy Rules / Guidelines
- A03 - Noise Reductions
- A04 - Physical Security Criteria & Methods of Compliance
- A05 - Public Safety Confidence

The UAS Airspace Integration Pillars enable achievement of the Vision
Provide research findings, utilizing simulation and flight tests, to support the development and validation of DAA and C2 technologies necessary for integrating Unmanned Aircraft Systems into the National Airspace System.

**Technical Challenge-DAA:** Detect and Avoid (DAA)

**Technical Challenge-C2:** Command and Control (C2)

**SIO:**
System Integration and Operationalization for UAS (SIO)
UAS-NAS Phase 2
Project Organization Structure

**Project Leadership**
- Project Manager (PM): Robert Sakahara (Acting), AFRC
- Deputy PM: Davis Hackenberg (Acting), AFRC
- Deputy PM, Integration: Vacant
- Chief Engineer (CE): William Johnson, LaRC

**Project Support: Project Planning & Control**
- Lead Resource Analyst: April Jungers, AFRC
- Resource Analysts: Amber Gregory, AFRC; Warquel Frieson, ARC; Julie Blackett, GRC; Pat O’Neal, LaRC
- Scheduler: Irma Ruiz, AFRC
- Risk Manager: Jamie Turner, AFRC
- Change/Doc. Mgmt: Lexie Brown, AFRC
- Admin Support: Sarah Strahan, AFRC

**Project Support: Technical**
- Deputy CE: TBD, TBD
- Staff Engineer: Dan Roth, AFRC

**Command and Control (C2)**
- Subproject Manager: Mike Jarrell, GRC
- Subproject Technical Lead: Jim Griner, GRC

**Detect and Avoid (DAA)**
- Subproject Manager: Jay Shively, ARC
- Subproject Technical Lead: Confesor Santiago, ARC; Lisa Fern, ARC; Tod Lewis, LaRC

**Integrated Test and Evaluation (IT&E)**
- Subproject Manager: Heather Maliska, AFRC
- Subproject Technical Lead: Jim Murphy, ARC; Sam Kim, AFRC

**Technical Work Packages (TWP):**
- **Terrestrial Extensions, Ka-band Satcom, Ku-band Satcom, C-band Satcom**
- **Alternative Surveillance, Well Clear, ACAS Xu, External Coordination, Integrated Events**
- **Integration of Technologies into LVC-DE, Simulation Planning and Integration, Integrated Flight Test**
Develop Detect and Avoid (DAA) operational concepts and technologies in support of standards to enable a broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to detect and avoid manned and unmanned air traffic.

**Technical Challenge-DAA:** Detect and Avoid (DAA)

**Technical Challenge-C2:** Command and Control (C2)

**SIO:**
System Integration and Operationalization for UAS (SIO)
Detect and Avoid (DAA) Operational Environments

Legend
Previous Research Areas (FY14- FY16)

Proposed Research Areas (FY17 – FY20)

60K' MSL

18K' MSL

10K' MSL

500' AGL

DAA System for Transition to Operational Altitude

MINIMUM ENROUTE ALTITUDE

DAA System for Operational Altitudes (> 500ft AGL)

Ground Based Radar
gbdAA Data

UAS Ground Control Station

Terminal Area Ops

Cooperative Traffic

Non-cooperative Aircraft

HALE aircraft

Airborne Radar

ADS-B & TCAS-II ACAS Xu

ADS-B & ACAS Xu

Alternative DAA Sensors

“Mid-sized” UAS

C2 Datalink

C2 Datalink

Legend
Previous Research Areas (FY14- FY16)

Proposed Research Areas (FY17 – FY20)
**DAA: Overview**

**Description:** The Detect and Avoid (DAA) effort will work with the Unmanned Aircraft System (UAS) community through **concepts and technology development** of DAA technologies applicable to a **broad range of aircraft with low cost size, weight, and power (SWaP) availability**. The DAA system will detect other aircraft in their vicinity, **predict** if the aircraft trajectories will be in conflict with each other, and **determine the appropriate guidance** to display to the UAS pilot in command. Pilot responses to the system will be assessed in order to **validate standards** being developed for UAS within **RTCA SC-228**. Robust safety and collision risk assessments, algorithm development, and ground control station display development will be performed in **collaboration with other government agencies and industry stakeholders** to support the broad needs of detect and avoid for the UAS community.

**Objectives**

- Develop and validate UAS DAA requirements for Low-SWaP airborne DAA systems to support standardization through the evaluation of commercial and engineering prototype DAA systems that enable a broader set of UAS operations
- Implement state of the art DAA technologies into an UAS and test in operationally relevant scenarios
- Obtain FAA approval to demonstrate SC-228 Phase 1 DAA MOPS technologies on an unmanned aircraft in the NAS as an alternative means of compliance to FAR Part 91 “see and avoid” rules (i.e. No Chase COA)

**Approach**

- Develop Concept of Operations and performance standards in coordination with RTCA and FAA
- Solicit industry partnerships to develop DAA technologies
- Perform modeling and simulation to Characterize the trade space of the DAA system for critical areas
- Flight Test and V&V of DAA technologies for performance standard requirements, and DAA system technology builds
- Leverage Phase 1 DAA MOPS developed technologies to obtain FAA approval to fly the DAA system in the NAS with as few restrictions as possible (No Chase COA)

**Deliverables**

- RTCA Standards Inputs:
  - DAA Phase 2 MOPS
  - Sensor Phase 2 MOPS
  - ACAS Xu MOPS
- Technical papers & presentations to technical and regulatory organizations
- Candidate DAA guidance, displays, & alerting
- Integrated design documents for each integrated event
Develop Command and Control (C2) operational concepts and technologies in support of standards to enable the broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to leverage allocated protected spectrum.
Command and Control (C2) Operational Environments

Legend

Previous Research Areas (FY14 - FY16)

Proposed Research Areas (FY17 - FY20)

SATCOM C2 Data Link

Ka/Ku SATCOM Link

Communications Satellite

Cooperative Traffic

60K' MSL

18K' MSL

10K' MSL

500' AGL

Terrestrial C2 Data Link

Terrestrial C2 Data Link Network

CNPC Ground Stations

UAS Ground Control Station

SATCOM Transmitter

Land Line

"Mid-sized" UAS

C-Band SATCOM Link

SATCOM/BLOS Link

Cooperative Traffic

CNPC Network

Terrestrial C2 Data Link

Terrestrial C2 Data Link

UAS Ground Control Station

UAS Ground Control Station
**TC-C2: Overview**

**Description:** The Command and Control (C2) effort will work with the UAS community on concept and technology development of C2 systems that are consistent with national regulations, standards, and practices. C2 will develop and analyze robust datalinks in designated spectrum and propose security recommendations for civil UAS control communications. All of the identified activities will be accomplished by collaborating with other government agencies and industry partners to address the technical barriers.

**Objectives**

- Develop and validate UAS C2 requirements to support C2 standardization through the evaluation of engineering prototype Networked C-Band Terrestrial radio systems
- Develop and validate UAS C2 requirements and radio spectrum allocation decisions to support C2 standardization through the evaluation of commercial and engineering prototype Ka/Ku Satcom radio systems
- Provide system design studies (payload and earth station) and system design requirements of C-band Satcom systems for C2 standardization

**Approach**

- Develop Concept of Operations to be leveraged for initial requirements for C2 partnerships, and coordination with RTCA and FAA
- Jointly develop performance standards with RTCA and FAA throughout lifecycle of concept and technology development
- Solicit industry partnerships to develop radio technologies
- Flight Test and V&V of radio technologies for performance standard requirements, and radio technology builds

**Deliverables**

- RTCA Standards Inputs
  - CNPC Link MASPS
  - CNPC Link MOPS
- Technical papers & presentations to technical and regulatory organizations
RTCA SC-228 Phase 2 MOPS Terms of Reference

- RTCA SC-228 ToR defined a path forward to develop MOPS
  - Phase 2 MOPS included in the original ToR, but had several TBDs
  - ToR development team defined Phase 2 DAA and C2 scope broad enough to fully enable the operating environments for relevant UAS (e.g., instrument flight rules [IFR] and visual flight rules [VFR]-like)
- Phase 2 MOPS ToR scope
  - C2: Use of satellite communication (SATCOM) in multiple bands and terrestrial extensions as a C2 data link to support UAS and address networking interoperability standards for both terrestrial and satellite systems
  - DAA: Extended UAS operations in Class D, E, and G, airspace, and applicability to a broad range of civil UAS capable of operations beyond visual line of sight (BVLOS)
System Integration and Operationalization (SIO) for UAS

**SIO: System Integration and Operationalization for UAS**

Integrate state of the art DAA and C2 technologies into Unmanned Aircraft Systems (UAS) to ensure sufficient aircraft level functional and operational requirements, and perform demonstrations in the NAS to inform Federal Aviation Administration creation of policies for operating UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations.

- **Definition of “Operationalization”**
  - A process for measuring operational concepts with empirical methods, particularly concepts that are complex and difficult to measure without empirical data
- **NASA’s UAS-NAS Project use of “Operationalization”**
  - A process to mitigate one or more implementation barriers by addressing one or more of the UAS Airspace Integration Pillars and Enablers through TRL 6+ demonstration/testing in an operationally relevant environment
Summary

- UAS-NAS Project has developed significant capabilities and infrastructure for the development of DAA, non-cooperative surveillance sensor, and C2 technologies.

- Significant work remains ensuring DAA and C2 technology are interoperable with the entire National Airspace System.

- Project is dedicated to driving the community toward robust and innovative solutions that apply to DAA, C2, and other necessary vehicle technologies.
Questions?

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