UAS Integration in the NAS: Detect and Avoid

Conrad Rorie for
Jay Shively
Detect and Avoid
Sub-Project Manager
UAS-NAS Phase 2
Project Organization Structure

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

Project Systems Engineering Office
- Deputy Chief Engineer: Clint St. John, AFRC
- SIO Technical Manager: Kurt Swieringa, LaRC

Project Support
- Sr. Advisor: Chuck Johnsons, AFRC
- Staff Engineer: Dan Roth, AFRC
- Lead Resource Analyst: April Jungers, AFRC
- Resource Analysts: Amber Gregory, AFRC; Warquel Frieson, ARC; Julie Blackett, GRC; Pat O'Neal, LaRC; Irma Ruiz, AFRC
- Lead Resource Analyst: April Jungers, AFRC
- Change/Doc. Mgmt: Lexie Brown, AFRC
- Admin Support: Sarah Strahan, AFRC

Project Office Level

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: Gilbert Wu (A)/Confesor Santiago, ARC; Lisa Fern; ARC; Tod Lewis, LaRC

Integrated Test and Evaluation (IT&E)
- Subproject Manager: Mauricio Rivas, AFRC / Jim Murphy, ARC
- Subproject Technical Lead: Ty Hoang, ARC (A) ; Sam Kim, AFRC

SUBPROJECT LEVEL

(A) Acting
UAS-NAS Project Value Proposition

NASA UAS-NAS Project Activities

C2 Performance Standards
- Research C2 SatCom Systems
- Develop C2 Prototype Terrestrial System
- Conduct C2 Flight Test and MS&A
  - Data Link, CNPC Spectrum, CNPC Security, BVLOS/BRLOS, ATC Interoperability
- Develop C2 Requirements

DAA Performance Standards
- Develop DAA Test beds
- Conduct DAA Flight Test and MS&A
  - Human Factors Performance Trade-offs, Low Cost SWaP sensors, Well Clear, Collision Avoidance
- Develop DAA Performance & Interoperability Requirements

Integrated Test & Evaluation
- Develop DAA Prototype System
- Live Virtual Constructive (LVC) Test Infrastructure
- Conduct FT5 Test Scenarios
- Conduct FT6 Test Scenarios
- ACAS Xu FT2
- No Chase COA

Systems Integration and Operationalization
- Develop Robust NASA/Industry Partnership
- Develop certification compliance toolkit(s)
- Integrate Essential Technologies
- Conduct Demo

Key Products
- C2 Performance Requirements to inform C2 MOPS
- DAA Performance Requirements to inform DAA MOPS

Resultant Outcomes
- C2 Technical Standard Order (TSO)
- DAA Technical Standard Order (TSO)
- Generic Certification Compliance Toolkit(s)
Detect and Avoid
<TC-DAA>
Subproject Manager (SPM)
Jay Shively, ARC
Subproject Technical Leads
Gilbert Wu (A), ARC; Lisa Fern; ARC; Tod Lewis, LaRC

DAA Subproject Structure for Project Phase 2

DAA Performance Standards

Develop DAA Test beds

Conduct DAA Flight Test and MS&A
Human Factors
Performance Trade-offs
Interoperability
Self Separation
CONOPs
Well Clear
Collision Avoidance

Develop DAA Performance & Interoperability Requirements

DAA Performance Requirements to inform DAA MOPS

Non-Coop Sensor MOPS
RTCA DAA MOPS
GBDAA MOPS

DAA Technical Standard Order (TSO)
General. When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear.

Piloted “see and avoid” => UAS “detect and avoid”

Pilot vision => surveillance sensors (on- or off- board, or both)

Pilot judgment of well clear => mathematical expression of well clear

Phase 1 DAA well clear defined as:
Horz Miss Distance = 4000ft
Vert Miss Distance = 450ft
modTau = 35sec
DMOD = 4000ft
DAA Operational Environments

Legend
Current Research Areas (FY14 - FY16)
Proposed Research Areas (FY17 – FY20)

60K’ MSL

18K’ MSL

10K’ MSL

MINIMUM ENROUTE ALTITUDE

DAA System for Transition to Operational Altitude (> 10kft MSL)

489

Cooperative Traffic

Non-cooperative Aircraft

HALE aircraft

Alternative DAA Sensors

ACAS Xu

UTM

500’ AGL

Ground Based Radar

GSBAA Data

UAS Ground Control Station

Terminal Area Ops

C2 Datalink

ADS-B & TCAS-II

ACAS Xu

DAA System for Operational Altitudes (> 500ft AGL)

“Tweener” UAS

C2 Datalink

ADS-B & ACAS Xu

Current Research Areas (FY14 - FY16)

Proposed Research Areas (FY17 – FY20)
Phase 1 Accomplishments

RTCA DO-365:
• Minimum Operating Performance Standards for Detect and Avoid Systems

RTCA DO-366:
• Minimum Operating Performance Standards for Air-to Air Radar Traffic Surveillance

FAA Technical Standard Orders:
• TSO-C211, Detect and Avoid
• TSO-C212, ATAR for Traffic Surveillance

NASA DAA Team Contributions:
• Well clear definition
• Alerting
• Guidance
• Displays
• Reference algorithm
• Significant modeling and simulation
• Augmented Well Clear Definitions
  – Terminal
  – Low SWaP
• Low SwaP Sensors
  – RADAR
    • Cooperative agreement with Honeywell
• Flight Tests
  – FY 19 – Low SWaP RADAR
    • Unmitigated encounters
  – FY 20 – Pilot response to new well clear definition; use of Low SWaP RADAR
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name</th>
<th>Pilot Action</th>
<th>DAA Well Clear Criteria</th>
<th>Time to Loss of DAA Well Clear</th>
<th>Aural Alert Verbiage</th>
</tr>
</thead>
</table>
| ![Warning Alert](image) | Warning Alert | • Notify ATC as soon as practicable after taking action | DMOD = 0.66 nmi  
HMD = 0.66 nmi  
ZTHR = 450 ft  
modTau = 35 sec | 25 sec | “Traffic, Maneuver Now” x2 |
| ![Corrective Alert](image) | Corrective Alert | • Coordinate with ATC to determine an appropriate maneuver | DMOD = 0.66 nmi  
HMD = 0.66 nmi  
ZTHR = 450 ft  
modTau = 35 sec | 55 sec | “Traffic, Avoid” |
| ![Preventive Alert](image) | Preventive Alert | • On current course, corrective action should not be required | DMOD = 0.66 nmi  
HMD = 0.66 nmi  
ZTHR = 700 ft  
modTau = 35 sec | 55 sec | “Traffic, Monitor” |
| ![Guidance Traffic](image) | Guidance Traffic | • Traffic generating guidance bands outside of current course | Associated w/ bands outside current course | X | N/A |
| ![Remaining Traffic](image) | Remaining Traffic | • Traffic within sensor range | Within surveillance field of regard | X | N/A |
Phase 1 DAA Suggestive Maneuver Guidance

Remain DAA Well Clear Corrective Guidance
-05

Remain DAA Well Clear Corrective Guidance
11000
10000
9000 ft
8000
7000
Altitude Tape

Remain DAA Well Clear Warning Guidance
00

Regain DAA Well Clear Guidance
11000
10000
9000 ft
8000
7000
Altitude Tape
Multiple human-in-the-loop (HITL) simulations were performed to identify requirements for UAS DAA systems. The following metrics were used to assess pilot and system performance:

- Pilot response times
- Proportion of losses of DAA well clear
- Severity of losses of DAA well clear
- ATC interoperability
- Subjective assessment & workload