UAS Integration in the NAS: Detect and Avoid

Conrad Rorie for
Jay Shively
Detect and Avoid
Sub-Project Manager

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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
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- 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
- Scheduler: Irma Ruiz, AFRC
- Risk Manager/Outreach: Jamie Turner, AFRC
- Change/Doc. Mgmt: Lexie Brown, AFRC
- Admin Support: Sarah Strahan, 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: 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

(A) Acting
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

Alternate
Surveillance
Requirements

Well Clear
Alerting
Requirements

ACAS Xu

External
Collaborations

Integrated Events

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

RTCA

Non-Coop
Sensor MOPS

DAA MOPS
Rev A/B

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)

UTM

500’ AGL

Terminal Area Ops

Ground Based Radar

GBSAA Data

UAS Ground Control Station

HALE aircraft

Cooperative Traffic

Non-cooperative Aircraft

ADS-B & TCAS-II

ACAS Xu

Alternative DAA Sensors

“Tweener” UAS

DAA System for Operational Altitudes (> 500ft AGL)

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
Phase 2
FY 18 - 20

• 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
## Phase 1 DAA Alerting

<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>
<tbody>
<tr>
<td><img src="image.png" alt="Symbol" /></td>
<td>Warning Alert</td>
<td>• Notify ATC as soon as practicable after taking action</td>
<td>DMOD = 0.66 nmi HMD = 0.66 nmi ZTHR = 450 ft modTau = 35 sec</td>
<td>25 sec</td>
<td>“Traffic, Maneuver Now” x2</td>
</tr>
<tr>
<td><img src="image.png" alt="Symbol" /></td>
<td>Corrective Alert</td>
<td>• Coordinate with ATC to determine an appropriate maneuver</td>
<td>DMOD = 0.66 nmi HMD = 0.66 nmi ZTHR = 450 ft modTau = 35 sec</td>
<td>55 sec</td>
<td>“Traffic, Avoid”</td>
</tr>
<tr>
<td><img src="image.png" alt="Symbol" /></td>
<td>Preventive Alert</td>
<td>• On current course, corrective action should not be required</td>
<td>DMOD = 0.66 nmi HMD = 0.66 nmi ZTHR = 700 ft modTau = 35 sec</td>
<td>55 sec</td>
<td>“Traffic, Monitor”</td>
</tr>
<tr>
<td><img src="image.png" alt="Symbol" /></td>
<td>Guidance Traffic</td>
<td>• Traffic generating guidance bands outside of current course</td>
<td>Associated w/ bands outside current course</td>
<td>X</td>
<td>N/A</td>
</tr>
<tr>
<td><img src="image.png" alt="Symbol" /></td>
<td>Remaining Traffic</td>
<td>• Traffic within sensor range</td>
<td>Within surveillance field of regard</td>
<td>X</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Phase 1 DAA Suggestive Maneuver Guidance

Remain DAA Well Clear Corrective Guidance

Remain DAA Well Clear Warning Guidance

Regain DAA Well Clear Guidance
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

**Pilot-Air Traffic Control Interaction Timeline & Metrics**

- $T_0$: Onset of DAA Alert
- $T_1$: Pilot Notifies ATC
- $T_2$: ATC Responds to Pilot
- $T_3$: Pilot Initiates Change in GCS
- $T_{4A}$: Pilot Sends First Upload to UA
- $T_{4B}$: Pilot Sends Final Upload to UA

**Metrics**:
- Total Response Time
- Aircraft Response Time
- Initial Response Time
- Initial Edit Time
- Total Edit Time
- Final Edit Time