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

**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

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

(A) Acting
DAA Subproject Structure for Project Phase 2

Detect and Avoid
<TC-DAA>
Subproject Manager (SPM)
Jay Shively, ARC
Subproject Technical Leads
Gilbert Wu (A), ARC; Lisa Fern; ARC; Tod Lewis, LaRC

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 CONOPS Well Clear Interoperability Self Separation Collision Avoidance
Develop DAA Performance & Interoperability Requirements
DAA Performance Requirements to inform DAA MOPS

RTCA DAA MOPS GBDAA MOPS
Non-Coop Sensor 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
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
## 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>![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>![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>![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>![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>![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 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