NASA UAS Integration Into the NAS Project
Human Systems Integration

AUVSI
May 5, 2016

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Summary of Contributions

• Suggestive Displays
  – Guidance Bands
• Integrated or stand alone*
• Alerting Logic
• Minimum Information tags
• TCAS/DAA interop logic
• Well Clear Recovery logic/display
• Pilot response timeline
  – Derived RADAR Requirements
Simulation Environment: LVC Architecture

**SaaProc Input:**
- Traffic
- Ownship

**SaaProc Output:**
- Intruders
- Saa Threat Alerts and Resolutions

**VSCS Input:**
- Intruders
- SAA Threat Alerts

**VSCS Output:**
- Ownship

**LVC Gateway**

**Stratway Input:**
- Intruders
- Ownship

**Stratway Output:**
- Stratway Bands Msg

**SaaProc/JADEM (sensor model)**

**Ownship:**
- Flt State, Flt Plan, Traj. Intent

**Traffic:**
- Flt State, Flt Plan, Traj. Intent

**SaaProc Output:**
- Intruders
- Saa Threat Alerts and Resolutions

**VSCS Input:**
- Intruders
- SAA Threat Alerts

**VSCS Output:**
- Ownship

**LVC Gateway**

**Adrs (LaRC)**

**Adrs Output:**
- Traffic
- Ownship

**Stratway Bands**

**Gcs (MacS)**

**Gcs Output:**
- Stratway

**Stratway Input:**
- Intruders
- Ownship

**Stratway Output:**
- Stratway Bands Msg

**Atc & Ppilots Input:**
- Ownship

**Atc & Ppilots Output:**
- Traffic
Project Background

• Approach: Conduct a series of iterative human in the loop experiments, in a representative simulation environment, with different display configurations to objectively measure pilot performance when maintaining well clear from scripted conflicts
  – **Key metrics**: pilot response time, losses of well clear, severity of losses of well clear
  – Three simulations have been conducted: PT4, iHITL, PT5
    • Displays are modified/improved/changed based on data/observations
    • Displays are carried through to new HITLs to create anchors or linkages to previous data for comparison
    • New displays are developed for test
    • Test/simulation environment/protocols also updated and improved between HITLs
  – Two “mini-HITLs” (i.e., engineering evaluations)
    • TCAS interoperability
    • Missing Information
Project Background

- **Display Types:**
  - **Informative:** Provides essential information of a hazard that the remote pilot may use to develop and execute an avoidance maneuver. *No maneuver guidance or decision aiding is provided to the pilot.*
  
  - **Suggestive:** *Provides a range of potential resolution maneuvers to avoid a hazard with manual execution.* An algorithm provides the pilot with maneuver decision aiding regarding advantageous or disadvantageous maneuvers.
  
  - **Directive:** *Provides specific recommended resolution guidance to avoid a hazard with manual or automated execution.* An algorithm provides the pilot with specific maneuver guidance on when and how to perform the maneuver.
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DAA Guidance Display

Green Bands

No Green Bands
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Loss of Well Clear Guidance

Horizontal Guidance

Vertical Guidance

Limited Suggestive
Loss of Well Clear: Directional

Horizontal Guidance

Vertical Guidance

Directional
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Latest Display

- **Auditory Alert**
  - RA sense presented aurally
    - (source: TCAS II v7.1)

- **Text Based**
  - RA sense shown in text box next to Baseball Card

- **Vertical Rate Guidance**
  - Presented within VVI
  - Green = desired vertical speed
  - Red = vertical speed to avoid

"CLIMB, CLIMB"
TCAS Interoperability

• A TCAS Interoperability Workshop was held to determine potential display/alerting/guidance issues that could be explored in a NASA “mini” HITL
  – Development of a DAA-TCAS Interoperability concept
  – Prioritized list of independent variables for experimental design
  – Set of use cases to stress TCAS Interoperability

• Main Issues for DAA-TCAS Interoperability
  – TCAS is not aware of all aircraft and so can give guidance that causes conflicts with non-cooperative aircraft
  – DAA system is aware of all aircraft and must conform to TCAS functioning
    • Key interoperability issues with DAA during “well clear recovery”
      – When a loss of well clear can no longer be avoided
    • Urgency of well clear penetration and need to interoperate with TCAS drives a directive or limited suggestive guidance solution
TCAS Interoperability

• DAA-TCAS Interoperability Concept:
  – Any target with an active corrective RA should be removed from all DAA guidance calculations
    • Horizontal DAA guidance will be shown for non-RA aircraft
    • All DAA vertical guidance should be *suppressed* during a corrective RA to prevent showing conflicting guidance to the pilot
  – During a preventive RA, TCAS guidance should be an input to the DAA vertical guidance so that it is consistent
  – Well clear recovery is limited to horizontal only for cooperative intruders
    • Prevents pilots from making maneuvers near the collision avoidance boundary which may degrade TCAS II performance

• Purpose of HITL:
  1. Examine performance difference for different methods of showing well clear recovery and DAA guidance
  2. Test overall suitability of interoperability concept
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# DAA-TCAS Alerting Structure

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name</th>
<th>Pilot Action</th>
<th>Buffered Well Clear Criteria</th>
<th>Alerting Time Threshold</th>
<th>Aural Alert Verbiage</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="TCAS RA" /></td>
<td>TCAS RA</td>
<td>• <strong>Immediate action required</strong>&lt;br&gt;• Comply with RA sense and vertical rate&lt;br&gt;• Notify ATC as soon as practicable after taking action</td>
<td>(Driven by TCAS-II)</td>
<td>x</td>
<td>“Climb/Descend”</td>
</tr>
<tr>
<td><img src="image" alt="DAA Warning Alert" /></td>
<td>DAA Warning Alert</td>
<td>• <strong>Immediate action required</strong>&lt;br&gt;• Notify ATC as soon as practicable after taking action</td>
<td>DMOD = 0.75 nmi&lt;br&gt;HMD = 0.75 nmi&lt;br&gt;ZTHR = 450 ft&lt;br&gt;modTau = 35 sec</td>
<td>25 sec (TCPA approximate: 60 sec)</td>
<td>“Traffic, Maneuver Now”</td>
</tr>
<tr>
<td><img src="image" alt="DAA Corrective Alert" /></td>
<td>DAA Corrective Alert</td>
<td>• On current course, <strong>corrective action required</strong>&lt;br&gt;• Coordinate with ATC to determine an appropriate maneuver</td>
<td>DMOD = 0.75 nmi&lt;br&gt;HMD = 0.75 nmi&lt;br&gt;ZTHR = 450 ft&lt;br&gt;modTau = 35 sec</td>
<td>55 sec (TCPA approximate: 90 sec)</td>
<td>“Traffic, Avoid”</td>
</tr>
<tr>
<td><img src="image" alt="DAA Preventive Alert" /></td>
<td>DAA Preventive Alert</td>
<td>• On current course, corrective action <strong>should not be required</strong>&lt;br&gt;• Monitor for intruder course changes&lt;br&gt;• Talk with ATC if desired</td>
<td>DMOD = 1.0 nmi&lt;br&gt;HMD = 1.0 nmi&lt;br&gt;ZTHR = 700 ft&lt;br&gt;modTau = 35 sec</td>
<td>55 sec (TCPA approximate: 90 sec)</td>
<td>“Traffic, Monitor”</td>
</tr>
<tr>
<td><img src="image" alt="Remaining Traffic" /></td>
<td>Remaining Traffic</td>
<td>• No action expected</td>
<td>Within surveillance field of regard</td>
<td>x</td>
<td>N/A</td>
</tr>
</tbody>
</table>

TCAS RA (Driven by TCAS-II)
Video Demo
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Self-Separation Timeline

- Time until CPA:
  - Well Clear Threshold (~35 sec)
  - Aircraft Maneuver Time (~30 sec)
  - Pilot Response Time (~15 sec)
  - ATC Interaction Time (~10 sec)

- Latency

TOTAL RESPONSE TIME:
- Detect Intruders
- Pilots Determine Resolution
- Negotiate Clearance with ATC and uplink maneuver to aircraft

Approximate detection range = 8 nm
Approximate detection range = 6 nm

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Pilot-DAA Timeline

- **Traffic Display Alert (SS or CA)**: $T_0$
- **Pilot Notifies ATC**: $T_1$
- **ATC Approval**: $T_2$
- **Pilot Initiates Edit**: $T_3$
- **Pilot Uploads First Edit**: $T_{4a}$
- **Pilot Uploads Final Edit**: $T_{4b}$
- **Traffic Alert Removed**: $T_5$
- **UAS Completes Maneuver**: $T_6$

**Key Times:**

- **Initial Response Time**
- **Clearance Approval Time**
- **Total Response Time**
- **Alert Duration Time**
- **Compliance Time**
- **Total Edit Time (Final Upload)**
- **Initial Edit Time (First Upload)**
- **Notification Time**

**Time Differences:**

- **Notify vs Upload Time**
- **Approval vs Upload Time**

**Activities:**

- **Pilot Uploads**
- **ATC Approval**
- **Traffic Display Alert**

**Event Blocks:**

- **Compliance Time**
- **Alert Duration Time**
- **Total Response Time**
- **Aircraft Response Time**

**Notes:**

- **Total Edit Time (Final Upload)**
- **Approval vs Upload Time**
- **Notify vs Upload Time**
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RTCA SC 228

• Phase 1 MOPS – Final Aug 2016
  – Alerting
  – Guidance
  – Displays
Next Steps

• Support SC 228 Phase 2 MOPS
  – Terminal Areas
  – ACAS-Xu
  – Alternative Sensors
  – GBSAA
  – Mid-size A/C
• Support ICAO – RPAS - Human In The System (HITS) working group
• “Common” GCS
• GCS Guidelines
Questions?