NASA UAS Integration Into the NAS Project
Human Systems Integration

AUVSI
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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
  – Derived RADAR Requirements
Simulation Environment: LVC Architecture

SaaProc/JADEM (sensor model)

- SaaProc Input:
  - Traffic
  - Ownship
- SaaProc Output:
  - Intruders
  - Saa Threat Alerts and Resolutions

Traffic: Flt State, Flt Plan, Traj. Intent
Intruders: Flt State

VSCS Input:
- Intruders
- SAA Threat Alerts

VSCS Output:
- Ownship

LVC Gateway

ADRS (LaRC)

- ADRS Input:
  - Ownship & Traffic
- ADRS Output:
  - Stratway Bands

GCS (MACS)

- GCS Input:
  - Ownship
- GCS Output:
  - Traffic

ATC & Pseudo Pilot System (MACS)

- ATC & PPIlots Input:
  - Ownship
- ATC & PPIlots Output:
  - Traffic

Stratway Input:
- Intruders
- Ownship

Stratway Output:
- Stratway Bands Msg
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
    • 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/Desc end”</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  HMD = 0.75 nmi  ZTHR = 450 ft  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  HMD = 0.75 nmi  ZTHR = 450 ft  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  HMD = 1.0 nmi  ZTHR = 700 ft  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>
Video Demo
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- Pilot response timeline
  - Derived RADAR Requirements
**Self-Separation Timeline**

- **Time until CPA**
  - Aircraft Maneuver Time (~35 sec)
  - Well Clear Threshold (~35 sec)

**Pilot Response Time** (~15 sec)

**Aircraft Maneuver Time** (~30 sec)

**Approximate detection range = 6 nm**

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

**Approximate detection range = 8 nm**
Pilot-DAA Timeline

Compliance Time

Alert Duration Time

Total Response Time

Aircraft Response Time

Notification Time

Initial Response Time

Clearance Approval Time

Initial Edit Time (First Upload)

Total Edit Time (Final Upload)

T_0: Traffic Display Alert (SS or CA)
T_1: Pilot Notifies ATC
T_2: ATC Approval
T_3: Pilot Initiates Edit
T_4a: Pilot Uploads First Edit
T_4b: Pilot Uploads Final Edit
T_5: Traffic Alert Removed
T_6: UAS Completes Maneuver

Notify vs Upload Time

Approval vs Upload Time

Aircraft Response Time

Total Edit Time

Approval Time vs Upload Time

Clearance Approval Time

Initial Edit Time

Total Edit Time (Final Upload)

Notification Time

Initial Response Time

Compliance Time

Total Response Time

Aircraft Response Time

Total Edit Time (Final Upload)

Approval vs Upload Time

Notify vs Upload Time

Initial Edit Time (First Upload)

Initial Response Time

Compliance Time

Total Response Time

Aircraft Response Time

Total Edit Time (Final Upload)

Approval 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?