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
• Pilot response timeline
  – Derived RADAR Requirements
Simulation Environment: LVC Architecture

SaaProc Input:
- Traffic
- Ownship

SaaProc Output:
- Intruders
- Saa Threat Alerts and Resolutions

SaaProc/JADEM (sensor model)

VSCS Input:
- Intruders
- SAA Threat Alerts

VSCS Output:
- Ownship

LVC Gateway

ATC & PPilots Input:
- Ownship

ATC & PPilots Output:
- Traffic

Stratway Input:
- Intruders
- Ownship

Stratway Output:
- Stratway Bands Msg

Stratway Bands

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

Ownship: • Flt State, • Flt Plan, • Traj. Intent

Intruders: • Flt State
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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NASA

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>
</table>
| ![TCAS RA](image) | TCAS RA          | • **Immediate action required**  
• Comply with RA sense and vertical rate  
• Notify ATC as soon as practicable after taking action | (Driven by TCAS-II)           |                         | “Climb/Desc end”                      |
| ![DAA Warning Alert](image) | DAA Warning Alert | • **Immediate action required**  
• Notify ATC as soon as practicable after taking action | DMOD = 0.75 nmi  
HMD = 0.75 nmi  
ZTHR = 450 ft  
modTau = 35 sec | 25 sec (TCPA approximate: 60 sec) | “Traffic, Maneuver Now”         |
| ![DAA Corrective Alert](image) | DAA Corrective Alert | • On current course, **corrective action required**  
• Coordinate with ATC to determine an appropriate maneuver | DMOD = 0.75 nmi  
HMD = 0.75 nmi  
ZTHR = 450 ft  
modTau = 35 sec | 55 sec (TCPA approximate: 90 sec) | “Traffic, Avoid”                  |
| ![DAA Preventive Alert](image) | DAA Preventive Alert | • On current course, corrective action **should not be required**  
• Monitor for intruder course changes  
• Talk with ATC if desired | DMOD = 1.0 nmi  
HMD = 1.0 nmi  
ZTHR = 700 ft  
modTau = 35 sec | 55 sec (TCPA approximate: 90 sec) | “Traffic, Monitor”                 |
| ![Remaining Traffic](image) | Remaining Traffic | • No action expected | Within surveillance field of regard |                         | N/A                                  |

- **DMOD**: Distance to Minimum Overlap Distance
- **HMD**: Height to Minimum Overlap Distance
- **ZTHR**: Zone Threshold
- **modTau**: Modified Tau Time
- **TCPA**: Time to Point of Avoidance
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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**

Approximate detection range = 8 nm

Approximate detection range = 6 nm

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

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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?