NASA UAS Integration Into the NAS Project
Human Systems Integration

AUVSI
May 5, 2016

Jay Shively (Robert.J.Shively@NASA.GOV)
NASA Ames Research Center
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

ATC & PPilots Input:
- Ownship

ATC & PPilots Output:
- Traffic

SaaProc/JADEM (sensor model)

Stratway Bands

ATC & Pseudo Pilot System (MACS)

Stratway Output:
- Stratway Bands Msg

Stratway Input:
- Intruders
- Ownship

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.
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
DAA Guidance Display

- Green Bands
- No Green Bands
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
Loss of Well Clear Guidance

Horizontal Guidance

Vertical Guidance

Limited Suggestive
Loss of Well Clear: Directional

Horizontal Guidance

Vertical Guidance

Directional
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
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”
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
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
<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               | • **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     | • **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  | • 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  | • 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     | • No action expected                                                             | Within surveillance field of regard |                         | N/A                  |
Video Demo
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
Self-Separation Timeline

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

**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
Pilot-DAA Timeline

Tight Display Alert (SS or CA)

Pilot Notifies ATC

ATC Approval

Pilot Initiates Edit

Pilot Uploads First Edit

Pilot Uploads Final Edit

Traffic Alert Removed

UAS Completes Maneuver

T0

T1

T2

T3

T4a

T4b

T5

T6

Alert Duration Time

Compliance Time

Total Response Time

Aircraft Response Time

Initial Response Time

Clearance Approval Time

Initial Edit Time (First Upload)

Total Edit Time (Final Upload)

Approval vs Upload Time

Notify vs Upload Time

Aircraft Response Time

Notification Time

Total Response Time

Initial Edit Time (First Upload)
Summary

• 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
• 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?