Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

ACAS Xu HITL
Overview
**Experiment Objective**

- **Goal**: assess ACAS Xu Run 5 in a HITL setting to measure pilot & system performance
  - RWC alerting and guidance
  - RA alerting and guidance
    - Horizontal-only, vertical-only, and blended RAs
    - Strengthening RAs, reversals and added/removed RAs during blended maneuvers
  - Incorporate realistic sensor noise into the simulation environment
  - Compare pilot and DAA system performance back to NASA’s Phase 1 DAA MOPS V&V HITL

- We leveraged the findings of an engineering analysis conducted in March to help inform how to implement the Xu logic
  - Part 1 focused on how to display horizontal-only, vertical-only and blended RAs
  - Part 2 focused on how to display automated RA responses
Xu Engineering Analysis Results

• Part 1 objectives:
  – Characterize pilot responses to (canned) ACAS Xu RAs in a variety of display configurations
    • With vs. Without text accompaniment
    • Simple vs. ‘Advanced’ aural alerting

• Results
  – Pilots struggled to meet 5 seconds initial response requirement
    • Particularly against horizontal and blended RAs
  – Pilots failed to respond more quickly to secondary RAs
    • Expected response time to subsequent RAs = 2.5 seconds
Xu Engineering Analysis Results

- No clear effect of the different alerting conditions on response times
  - Response times primarily driven by RA type
- Pilots demonstrated high level of compliance with RAs and self-reported Xu alerting and guidance as being acceptable
  - 1/5 reported text as being necessary
  - 4/5 wanted the aural alert to retain the original RA sequence (i.e., issue a follow-on RA second rather than first)
  - 4/5 wanted to retain the “Maintain Heading/Vertical Speed” aural alert in the event that the pilot reached their target response at the time of secondary RA
Based on these results, we decided on the following for the HITL experimental design:

- Incorporated an ‘auto-fill’ feature in Vigilant Spirit that removes the need for pilots to manually enter a heading or altitude for RAs
  - Pilots only have to click ‘Send’ to upload the RA target heading/altitude
- Did **not** include an RA ‘text box’
  - The auto-fill feature largely replaces the purpose of the text box
- Using a combination of the ‘Basic’ and ‘Advanced’ aural alerting
  - In case of blended maneuvers will issue “Maintain Heading/Vertical Rate” if pilot has reached 1\textsuperscript{st} RA target at the time the 2\textsuperscript{nd} RA is issued

Integration and testing with Xu Run 5 also resulted in us adding display logic to modify how horizontal RAs are presented

- Target heading was shown to update at approx. 1 Hz making it difficult for pilots to implement
- Display logic limited horizontal RA strengthening to once every 5 seconds
  - Did not impact timing of reversals, new RAs (i.e., blended), or CoC
Experiment Design

• Independent Variables
  – Display Integration Level (2 levels, **within-subjects**)
    • Integrated – DAA information presented within TSD
    • Standalone – DAA information shown in separate, dedicated display

• Embedded Variables
  – Encounter Type – 6 scripted encounters per trial (4 trials per participant)

<table>
<thead>
<tr>
<th>Threat Level at First Alert</th>
<th>Non-Cooperative (RADAR Only)</th>
<th>Cooperative (ADS-B &amp; RADAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrective DAA Alert</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Resolution Advisory (RA)</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

• 16 total participants (2 per day)
  – All were active UAS pilots
  – 4 experimental trails per pilot (~45min per trial)
• **UAS Routes**
  - Both located in Oakland Center (ZOA 40/41) airspace
    - IFR traffic into/out of SFO and OAK
    - VFR traffic from smaller local airports (KSTS & KAPC)
  - **Fireline**
    - Level at 9000 ft
    - Serving as air asset for California Department of Forestry for fire burning north of Clear Lake
  - **Air Sampling**
    - Starts at 10000’, climbs to 14000’
    - Serving as air asset for California Air Resources Board to measure quality of air east of Santa Rosa
• DAA & CA information **presented separately** from navigation and vehicle control interfaces
• Pilots upload the from the TSD – the heading/altitude will be automatically filled into the steering window
Experiment Design

INTEGRATED CONFIGURATION

- DAA & CA information collocated with navigation and vehicle control interfaces
Test Setup

• Pilot task
  – Maintain of safety of aircraft
    • Manually respond to DAA and RA guidance from Xu (no automation)
  – Coordinate with center controller as appropriate
  – Navigate UAS along pre-filed flight path (navigation only)
  – Respond to scripted chat messages and system failure events

• Ownship configuration
  – Generic MQ-9 model
  – Cruise speed: 160 KTAS
  – Climb/descent rate: 1,000 fpm
  – Turn rate: 3° per second
Encounter Example
Experiment Design

• Dependent Variables
  – DAA and RA response times
  – Loss of DAA well clear/NMAC rate
  – RA compliance rate
  – Alerting behavior
    • Corrective alert duration
    • Instances of RA strengthening/reversals
  – Subjective ratings
    • Acceptability of DAA and RA alerting and guidance
    • ATC acceptability/interoperability ratings
• Data collection wrapped up June 19

• Currently coding pilot interaction data
  – Focusing right now on capturing pilots’ responses to RAs:
    • For each RA, did they upload the target value? If so, how long did it take them to upload it after it was issued?
  – Also capturing pilot responses to Corrective alerts and ATC coordination

• Intend to get preliminary data out to the Xu team in mid August, with a full brief at the September F2F
Questions?