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

Xu Engineering Analysis Results

- 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 1st RA target at the time the 2nd 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)

Threat Level at First Alert	Non-Cooperative (RADAR Only)	Cooperative (ADS-B & RADAR)
Corrective DAA Alert	1	3
Resolution Advisory (RA)	1	1

- 16 total participants (2 per day)
  - All were active UAS pilots
  - 4 experimental trails per pilot (~45min per trial)

Experiment Design

- 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)
  - <u>Fireline</u>
    - Level at 9000 ft
    - Serving as air asset for California Department of Forestry for fire burning north of Clear Lake
  - <u>Air Sampling</u>
    - Starts at 10000’, climbs to 14000’
    - Serving as air asset for California Air Resources Board to measure quality of air east of Santa Rosa

Experiment Design

STANDALONE CONFIGURATION

- 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

Update

- 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?