Helicopter Pilot Evaluations of the Airborne Collision Avoidance System Xr in a High-Fidelity Motion Simulation

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Background

- Hazard Perception and Avoidance: tools for tactical conflict management for NASA's Advanced Air Mobility (AAM) project
  - Electric vertical take-off and landing (eVTOL) aircraft, onboard pilot
  - Airborne Collision Avoidance System for Rotorcraft (ACAS Xr) as tool
- ACAS Xr alerting types
  - Detect and Avoid (DAA): caution-level and suggestive
    - Intended to provide remote pilots with ability to comply with 'see and avoid' requirements
  - Resolution Advisories (RAs): warning-level and directive
    - Vertical RAs command a target vertical speed
    - Horizontal RAs command a target track
    - Blended RAs command a target track and target vertical speed simultaneously

Background

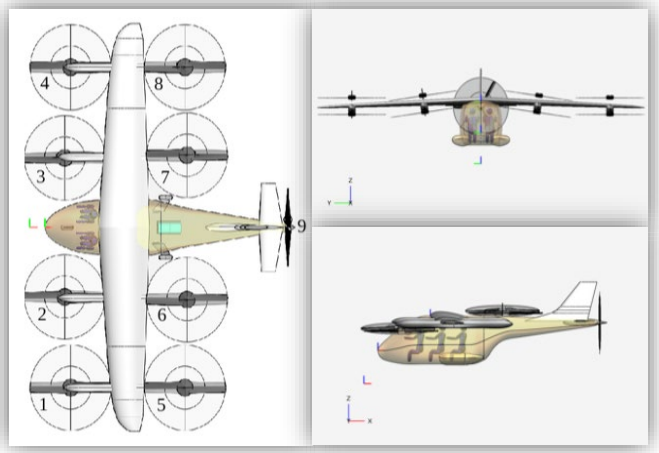
Two Configurations Proposed for ACAS Xr v2

- Collision Avoidance System (CAS)
  - Similar to current Traffic alert and Collision Avoidance System (TCAS II)
  - Low Altitude: No Descend RAs below 750 ft
  - Terminal Areas: Pilot switches to Traffic Advisory (TA)-Only mode
- Detect and Avoid (DAA)
  - Meets uncrewed DAA requirements
  - Low Altitude: No cut-off altitude, terrain handled similar to intruders
  - Terminal Areas: No Caution-level alerting or Horizontal RAs

Traffic	Configuration	
	CAS Alert Structure	***DAA Alert Structure***
	<u>Resolution Advisory (RA)</u> • Comply within 5 seconds • Directive banding • Aural Cues: “Climb, Climb”	<u>Resolution Advisory (RA)</u> • Comply within 5 seconds • Directive banding • Aural Cues: “Climb, Climb”
	<u>Traffic Advisory (TA)</u> • Monitor for possible RA • No Maneuver Guidance • Aural Cues: “Traffic, Traffic”	<u>Corrective DAA Alert</u> • Action required to remain well-clear • Suggestive banding • Aural Cues: “Traffic, Avoid”
	N/A	<u>Preventive DAA Alert</u> • Monitor for increase in severity • No Maneuver Guidance • Aural Cues: “Traffic, Monitor”
	N/A	<u>Guidance Traffic</u> • Monitor for increase in severity • No Maneuver Guidance • No Aural Cues
	<u>Basic Traffic</u> • No Pilot Actions • No Maneuver Guidance • No Aural Cues	<u>Basic Traffic</u> • No Pilot Actions • No Maneuver Guidance • No Aural Cues

Test Setup: First Study

- Participants: 12 helicopter pilots
- Fixed-Base Simulator
  - Lift Plus Cruise (LPC), eVTOL model
  - Simplified airspace environment
  - No out of window traffic
  - No air traffic control (ATC) coordination



Test Setup: Current Study

- Participants: 6 helicopter pilots
- Vertical Motion Simulator (VMS)
  - LPC model
  - 6 degrees of motion
  - Higher-fidelity displays
  - Terrain detection
  - Out-of-window traffic provided
  - No ATC coordination

Experimental Design

- Independent Variables
  - ACAS Xr Configuration (2 levels; within-subjects): CAS & DAA
  - Phase of Flight (3 levels; within-subjects)
    - Cruise – cruise speed of 110 kts, starting altitude 500-1500 ft MSL
    - Hover – hover speed of 10 kts, starting altitude 500-1500 ft MSL
    - Approach – straight-in approach, speed 70 kts, starting altitude 700-1100 ft MSL, 6° glide slope

- Dependent Variables: Effectiveness, Acceptability, Usefulness, & Preference
  - Post-Encounter Questionnaire after each encounter
  - Post-Trial Questionnaire after 10 encounters within a Phase of Flight
  - Post-Block Questionnaire, after 30 encounters within all Phases of Flight
  - Post-Simulation Questionnaire after 60 encounters with Phase of Flight & Configuration
  - Debrief at the end of simulation

Results: Ratings

- Effectiveness
  - DAA (*M* = 4.50, *SE* = 0.22)
  - CAS (*M* = 3.83, *SE* = 0.40)
- Acceptability
  - DAA (*M* = 4.35, *SE* = 0.18)
  - CAS (*M* = 4.35, *SE* = 0.17)
- Usefulness
  - Most useful for DAA alerting and guidance
    - Aural cues (*M* = 4.67, *SE* = 0.21)
    - Vertical DAA banding (*M* = 4.33, *SE* = 0.21)
    - Horizontal DAA banding (*M* = 4.17, *SE* = 0.48)
  - Most useful for CAS/RAs
    - Aural cues (*M* = 4.67, *SE* = 0.42)
    - Horizontal RAs (*M* = 4.67, *SE* = 0.21)
    - Blended RAs (*M* = 4.67, *SE* = 0.21)
    - Vertical RAs (*M* = 4.50, *SE* = 0.34)

* Results from a 5-point scale: 1 = "Strongly Disagree"; 5 = "Strongly Agree"

Results: Alerting and Guidance Preferences

- Alerting and Guidance Preferences
  - Cruise: DAA and RA (5 out of 6 pilots [5/6])
  - Hover:
    - TAs and RAs (3/6)
    - RAs Only (3/6)
  - Approach:
    - TA and RA (2/6)
    - RA Only (2/6)
    - DAA Only (1/6)
    - DAA and RA (1/6)
  - Pilots' Overall Choice:
    - DAA (3/6)
    - CAS (3/6)

Results: General Comments

- Hover procedure was too confusing and time consuming
- Level-Off RAs failed to generate adequate separation (Hover & Approach)
  - Should instead be climbs or descends
- TA-Only alerting in terminal areas was considered insufficient

Level-Off RA

Conclusions

- Pilots rated ACAS Xr as effective, acceptable, and useful for both CAS and DAA configurations
- Hover and Approach scenarios require more development
  - Refine terminal-area alerting
  - Investigate when to use Level-Off RAs
- Results were used to inform live helicopter flight tests in 2023 with Integration of Automated Systems (IAS) project
- Additional ACAS Xr work occurring under NASA ATM-X's Pathfinding for Autonomous Airspace and Vehicles (PAAV) subproject

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Questions

For additional questions, please contact
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