Towards Safe Collaboration Between Autonomous Pilots and Human Crews for Intelligence, Surveillance, and Reconnaissance

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Towards Safe Collaboration Between Autonomous Pilots and Human Crews for Intelligence, Surveillance, and Reconnaissance

Today's Presentation

- Motivation
- Scenario Design and Experiment
- Automated Pilot
- Experimental Results
- Conclusions

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Motivation

Autonomous Aircraft

Onboard personnel with minimal AI training

How will mission specialists team with AI and fully Automated Pilots (AP)?

- Most new aircraft will have advanced automation or autonomy capabilities
- Most research focuses on teaming between expert pilots or system operators and advanced automation
- Little work on missions such as medical evacuation, search and rescue, and ISR, that require onboard personnel without piloting or AI expertise

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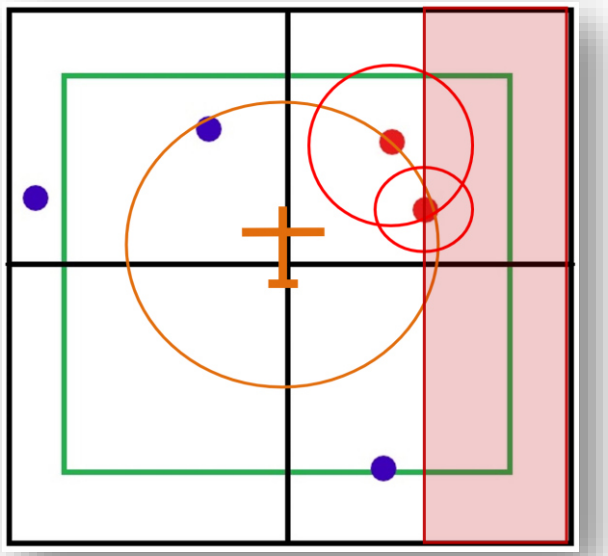
Intelligence, Search & Reconnaissance

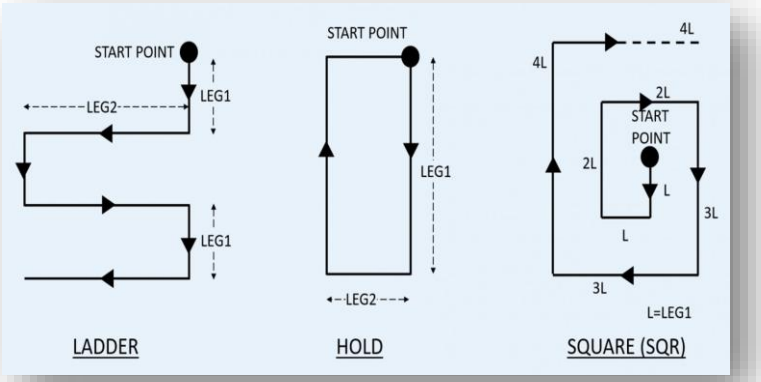
Scenario Description

- Intelligence, Surveillance, Reconnaissance mission over dynamic Surveillance Area (SA).
- Real-time decision making to analyze mission – identify, classify, track, exploit targets.



Human Automation Interactions Planned

- Human Analyst → AI-pilot: predicted path of target, classification & prioritization of targets
- AI-pilot → Analyst: Red threats, aircraft state, sensor degradation, time of arrival, etc.
- Analyst **&** AI-pilot: collaboratively choose best search procedures for optimal mission effectiveness



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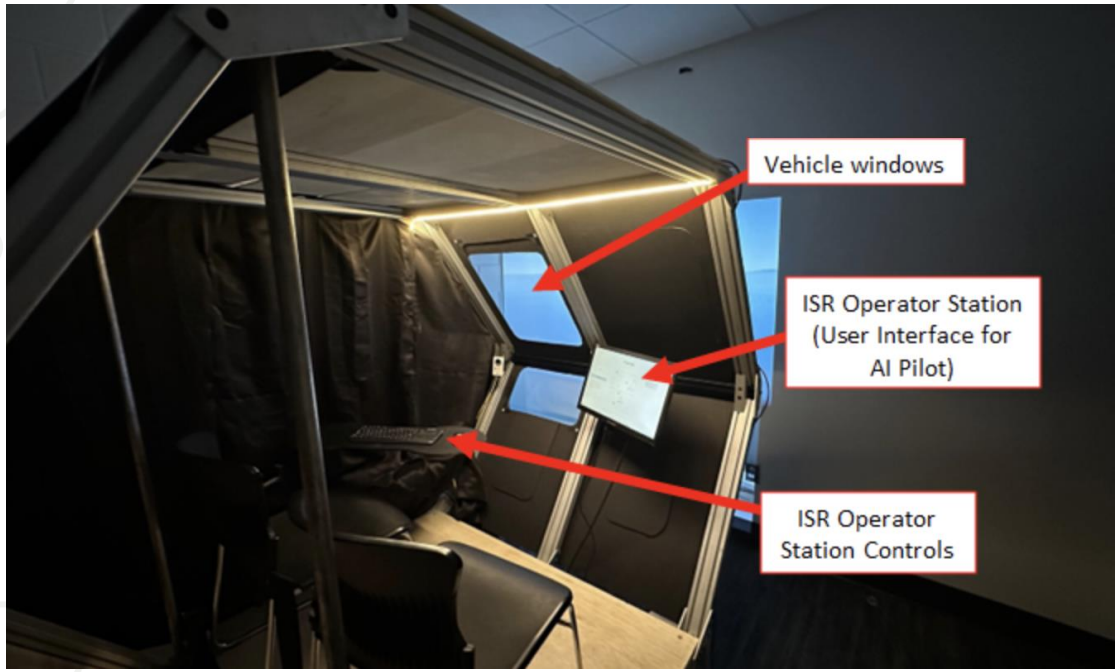
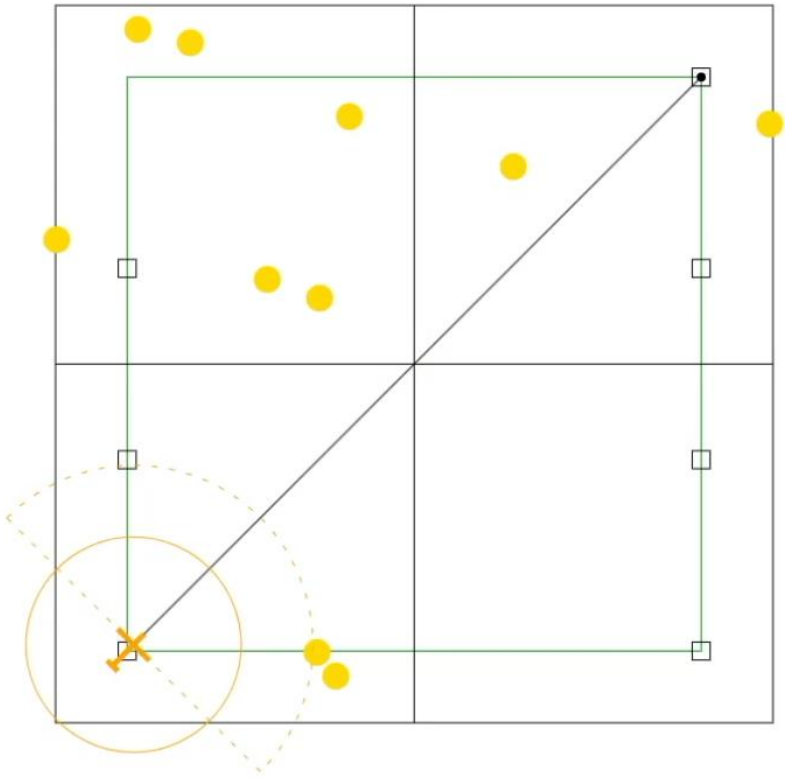
Scenario Design and Experimental Apparatus





- The human operator on-board is tasked to **collaborate** with the aircraft's **Automated Pilot** to **identify and classify ships** in their assigned Surveillance Area while avoiding damage

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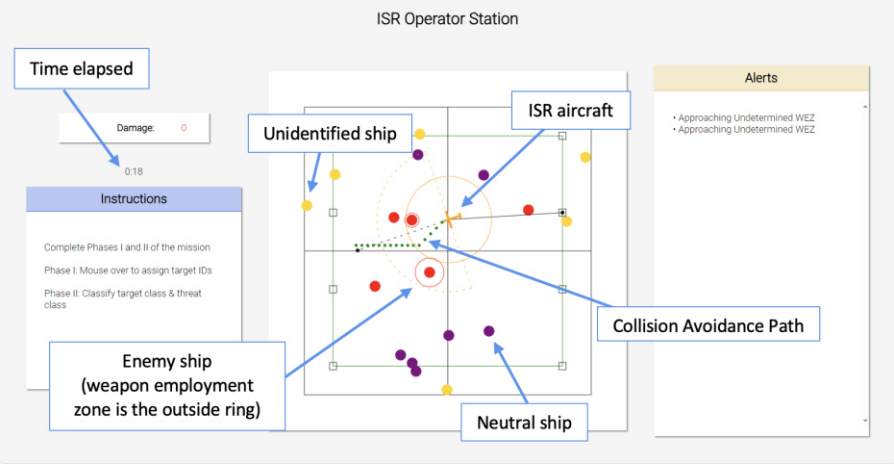
Automated Pilot (AP)

The **AP aviates, navigates and communicates** while the human classifies the ships.

Two different APs were compared:

- **Waypoint tracking AP**: Human intervention required to prevent damage to the aircraft
- **Collision Avoidance AP**: Control Barrier Functions (CBFs) proactively prevent the aircraft from being damaged



Waypoint AP

AP behavior:

- The baseline Waypoint AP flies an automated search pattern. At any time, the human operator can override the AP's automated search pattern waypoint by clicking on a point on the screen to cast a vector to a new operator designated waypoint.
- The AP flies one of two programmed search patterns:
  - 1) Hold which resembles a rectangular orbit or
  - 2) Ladder which stair steps horizontal scans across the surveillance area.
- In this mode, the human operator has complete authority over aircraft navigation and responsibility for avoiding enemy ships

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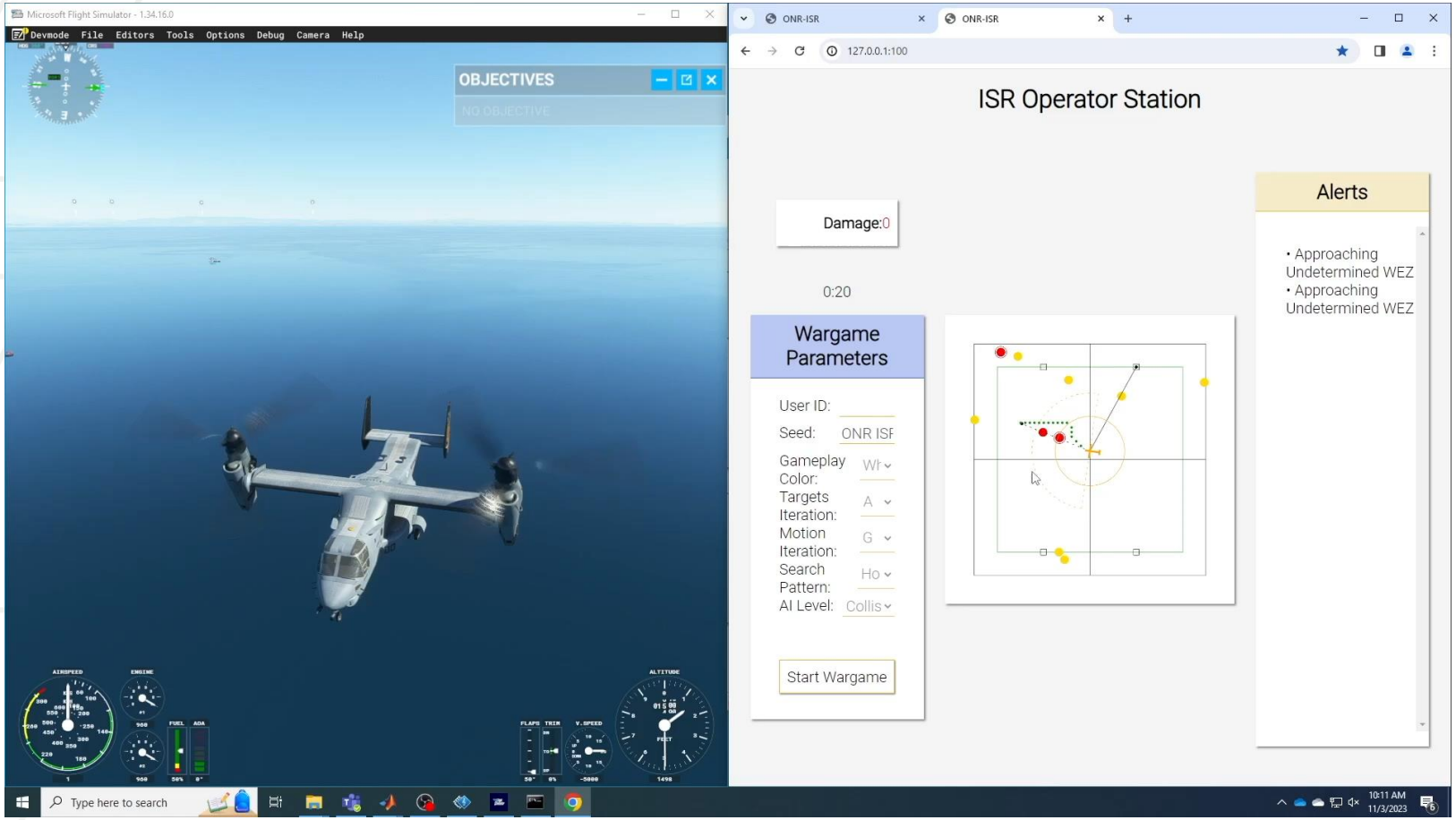
Collision Avoidance AP



- Human pilot is only required to provide **waypoints for navigation** on the interface
- **CBFs** modify the aircraft trajectory to **avoid flying over weapon engagement zones** from enemies

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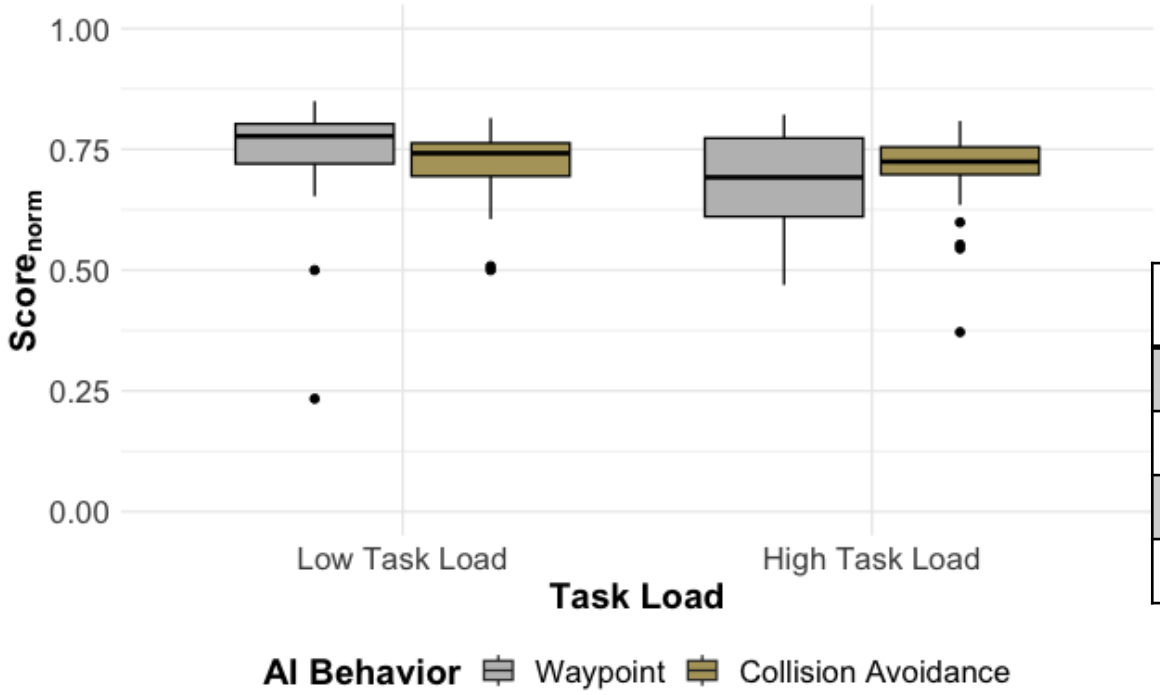
Mission Effectiveness

Assessed by **participant's damage and time** to complete each trial:

$Score_{norm} = \frac{2-\left(\frac{D}{D_{max}}+\frac{T}{T_{max}}\right)}{2} \in [0,1]$. According to this formula, ***higher is better***.



- Collision Avoidance resulted in lower damage, albeit an increased mission duration.
- Collision Avoidance decreased the interquartile range of the participant's mission effectiveness.

Task Load	Behavior	$Score_{norm}$ Interquartile Range
Low	Waypoint	0.083
Low	Collision Avoidance	0.069
High	Waypoint	0.163
High	Collision Avoidance	0.057

Main takeaway: As the AP exercised more control over the flight trajectories, the team's **mission effectiveness was more predictable**.

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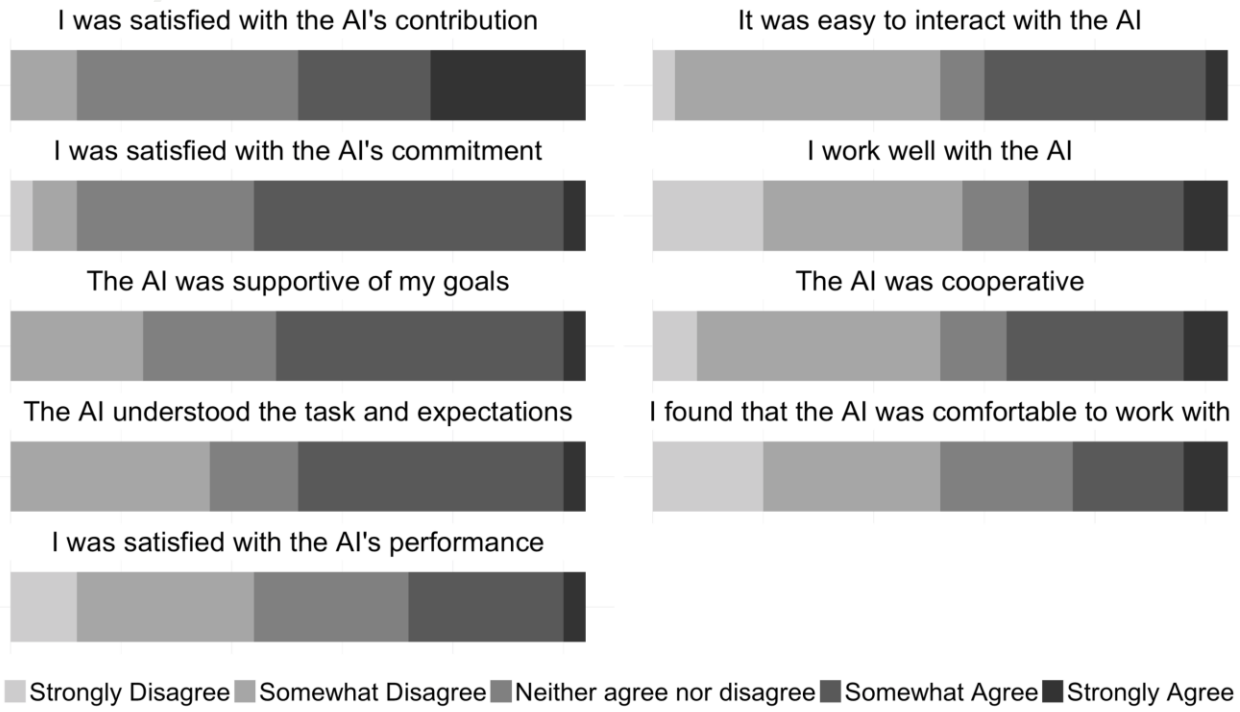
Perception of the AP and User Experience



Debrief interviews:

- Most aspects perceived neutrally
- Positive feedback for Collision Avoidance AP
- Lack of transparency and the slow response to human inputs were perceived negatively

Questionnaires:

- Users were satisfied with the AI's teammate commitment and contribution
- A majority of users felt that the AI was not comfortable to interact with.

User experience:

- Argus Science ETVision eye trackers did not identify significant trends on users' gaze

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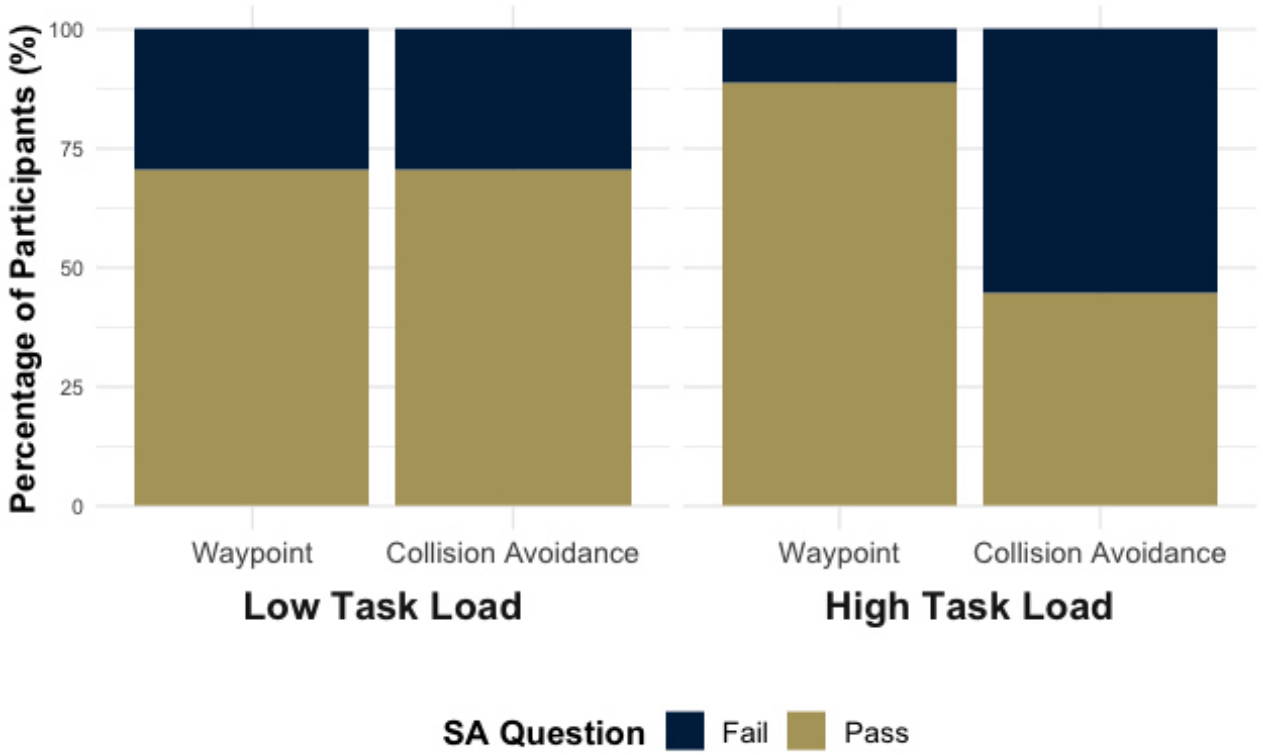
Situation Awareness



- Collision Avoidance AP showed the safety benefits of more predictable and consistent performance.
- However, the **operators were less engaged causing the situation awareness to drop** under the high-task load conditions:
  - **70.3 %** of the participants passed the SA question using the **Waypoint AP**
  - **44.4 %** of the participants passed the SA question using the **Collision Avoidance AP**

Key takeaway:

An **adaptive AP encouraging human engagement** is key to both guarantee safety and improve performance, but also **maintain high levels situation awareness** allowing the human to intervene and overrun the AP when necessary.

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Conclusions & Discussion

Main take aways:

- **Collision Avoidance AP** resulted in **less aircraft damage** and more **predictable** team performance, albeit **longer mission times**.
- **Situation awareness decreased** with **task load level**
- Under high task load, Situation awareness decreased with AP complexity
- Participants perceived **positively** the **AP successes**
- Participants **calibrated** their **trust** after AP failures

- AI-based APs as a hallmark for safe collaboration between automated pilots and human crew
- AP assures a minimum expectation of mission effectiveness
- Operator over reliance on the AP and low situation awareness can mission and safety failure
- The sensitivity of the mission should serve as guidance for the level of AP and authority sharing scheme

Thanks for your attention!

Any questions?

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