

Uncrewed Aerial System Traffic Management Beyond Visual Line of Sight Multi Operator Technology Assessment Simulation

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Introduction

- Advances in Uncrewed Aerial systems (UAS) technology has enabled complex operations, such as Beyond Visual Line Of Sight (BVLOS) operations, requiring multiple ground services.
- FAA regulation for BVLOS is currently done through waivers but require full review of each application.
- The Near-Term Approval Process (NTAP) can provide safety credit to ground services used in BVLOS waivers.

Background

- UAS Traffic Management (UTM) BVLOS is a NASA sub-project with a goal to enable routine operations through operational ground services.
- These ground services include UAS Service Suppliers (USSs), Surveillance Systems, Detect and Avoid systems, etc.

UTM BVLOS Technical Challenge



Enable routine, safe, extensible BVLOS operations in low altitude Class G airspace through the formalization and operationalization of ground-based services.

Simulation Objectives

- Multi Operator Technology Assessment (MOTA) Simulation had the following objectives:
 - Integrations of MPATH (Measuring Performance for Autonomy Teaming with Humans), a NASA Developed GCS (Ground Control Station), with the NASA USS.
 - Development of a representative simulation that provides a testing environment for UTM enabled operations.
 - Collection and analysis of data on nominal and off-nominal scenarios focused on the remote pilot in command.
 - Includes Human Factor's data and subjective feedback for technology improvement.

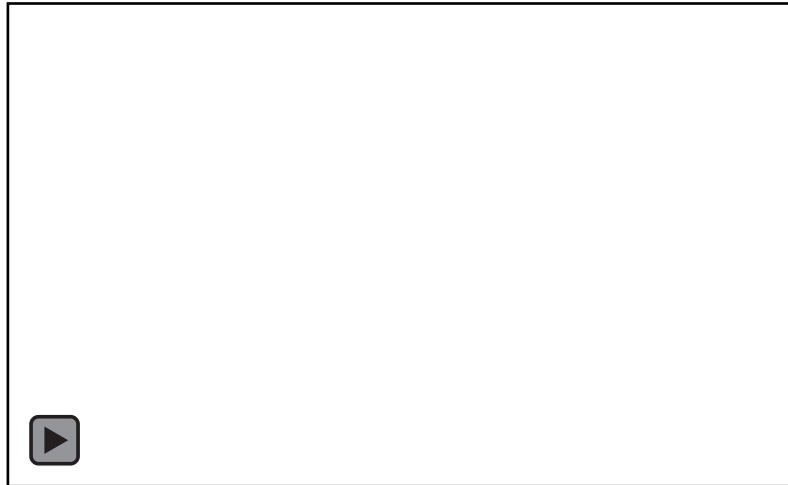
Simulation Evolution – Operations Facilities

➤ Remote Operations for Autonomous Missions (ROAM)

- 3 Remote Pilots in MOTA.
- 12 workstations over two rooms.
- Developed for Research Activities.

➤ Mission Operations & Autonomous Integration Center (MOSAIC)

- 2 Remote Pilots in MOTA.
- 6 workstations in single room.
- Developed for Operational Activities.



Simulation Evolutions – Onboard Autonomy

- NASA Developed Technologies:
 - Integrated Configurable Algorithms for Reliable Operations of Unmanned Systems (ICAROUS).
 - Safe2Ditch.
- Improvements to ICAROUS for MOTA
 - Detection and avoidance of geofence conflicts in return to launch (RTL) mode.
 - Improved transparency on mode for Remote Pilot in Command.
- Improvements to Safe2Ditch for MOTA
 - Can land in any ICAROUS mode.
 - Performs avoidance during emergency landing.

Simulation Evolutions – MPATH Display

The screenshot displays the MPATH simulation interface. The main view is a satellite map showing a flight path in purple and green. The path starts at a landing site (marked with a blue 'X') and proceeds through several loops (Hoop Lake Loop, Hurst Loop E, Bush Rd E, Lewis Loop) before heading towards the Northwest Branch Back River. The interface includes a top navigation bar with a NASA logo and a compass. On the right side, there are several data widgets: a 'VEHICLE STATUS' panel showing 'Ready' and 'Mission' modes, a 'VALUES' panel with metrics like Alt (ft), Ground Speed (ft/s), Flight Time, and Air Speed, a 'MOTORS' panel with a circular motor status indicator, and an 'ONBOARD MESSAGES' panel showing 'Vehicle has well clear'. At the bottom, there is a 'USS Widget' with a 'Takeoff from ground and start the current mission' button and a 'Slide to confirm' slider.

Active Vehicles

Active Operations

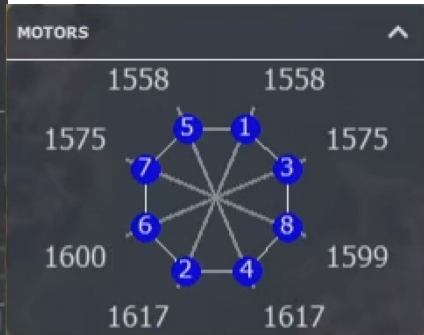
Accepted Operations

Motor Display Widget

Motor Display Widget in flight

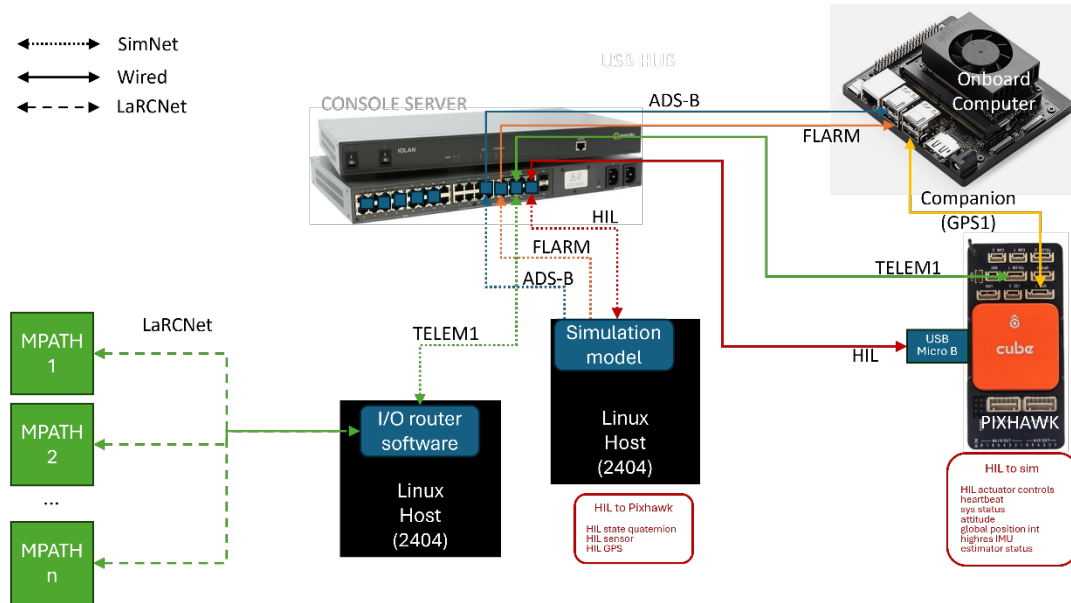
Onboard Autonomy Messages

USS Widget



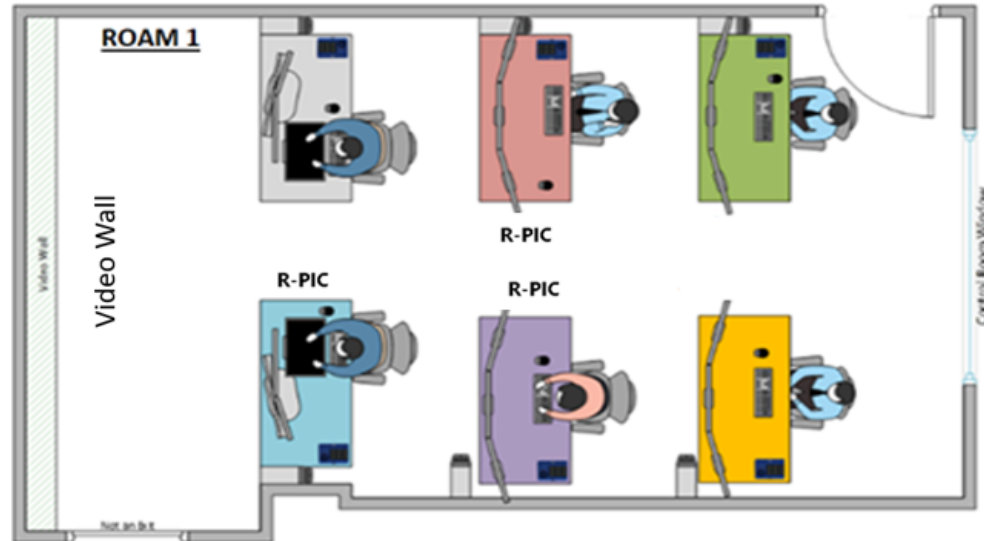
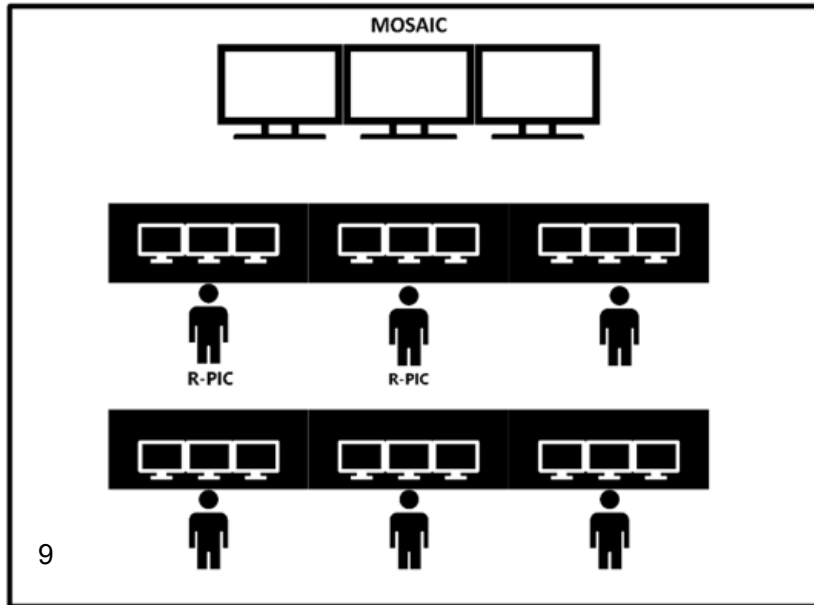
Simulation Setup – Hardware In the Loop

- Hardware In The Loop (HITL) simulators include:
 - Pixhawk Cube Autopilot.
 - Physics model of Octo-rotor UAS.
 - Flight computer for onboard software.
 - Simulated traffic.
- Provides a representative telemetry stream to MPATH for participants in the study.



Simulation Setup – Participants

- Participants selected for this experiment must have completed the simulation portion of the NASA Langley BVLOS training.
- Two participants in MOSAIC and three in ROAM during data collection.
- Data collected on nine participants total with multiple runs.



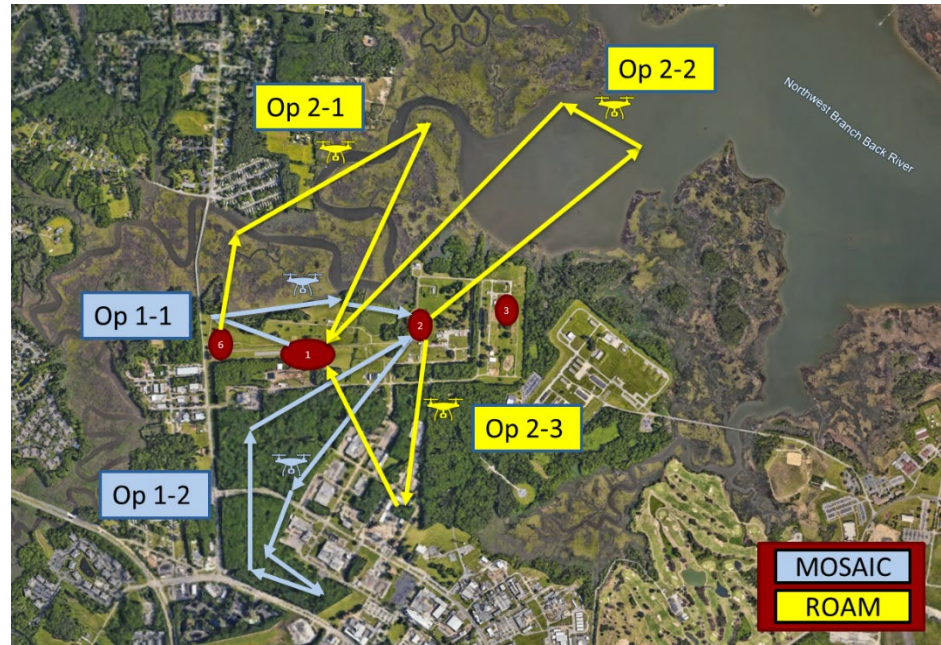
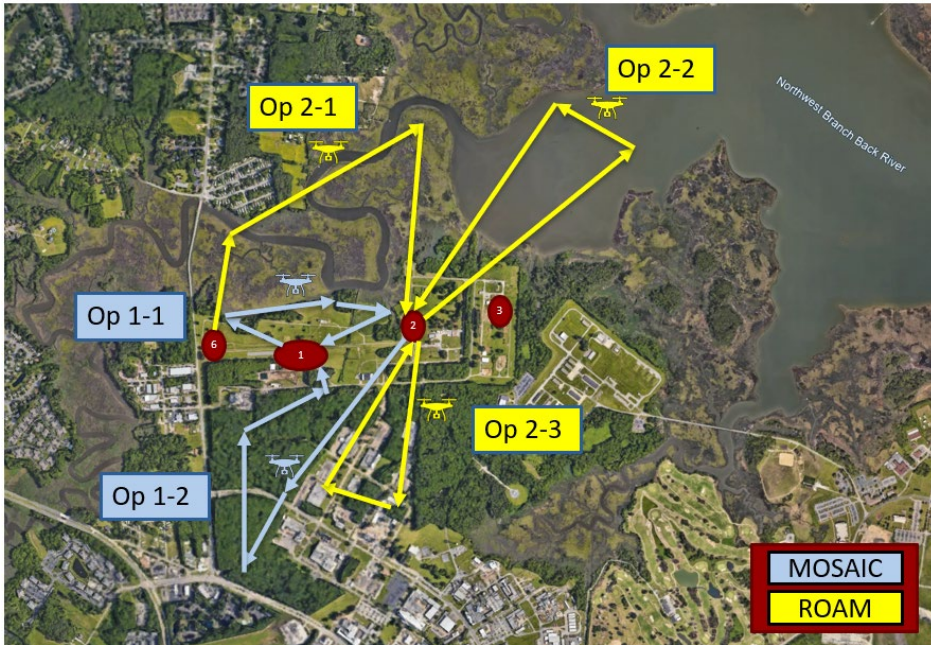
Scenarios

1. Nominal, Nonoverlapping Flight Paths
 - All vehicles fly their mission without issue.
 - No overlapping flight paths, no spatial conflicts.
2. Nominal, Overlapping Flight Paths
 - All vehicles fly their mission without issue.
 - Overlapping flight paths, spatial conflicts but temporal deconflictions.
3. Off Nominal, Overlapping Flight Paths: Safe2Ditch Landing
 - Vehicle requires emergency landing in flight.
 - Causes deviation from preplanned path through another vehicle's path.
4. Off Nominal, Overlapping Flight Paths: Immediate RTL
 - Vehicle requires emergency RTL in flight.
 - Cause deviation from original path, RTL path goes through geofence and another vehicle's path.
5. Off Nominal, Overlapping Flight Paths: Safe2Ditch Landing and Immediate RTL
 - Multiple vehicles deviate from original path in same airspace.

Scenarios – Nominal

Non-overlapping flight paths

Overlapping flight paths



  Operator 1 Path

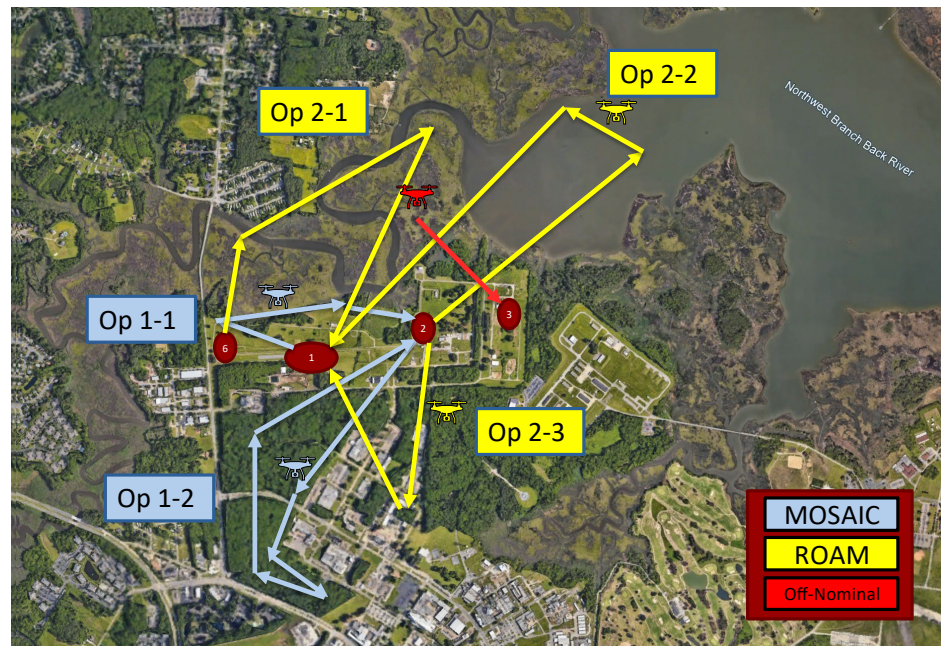
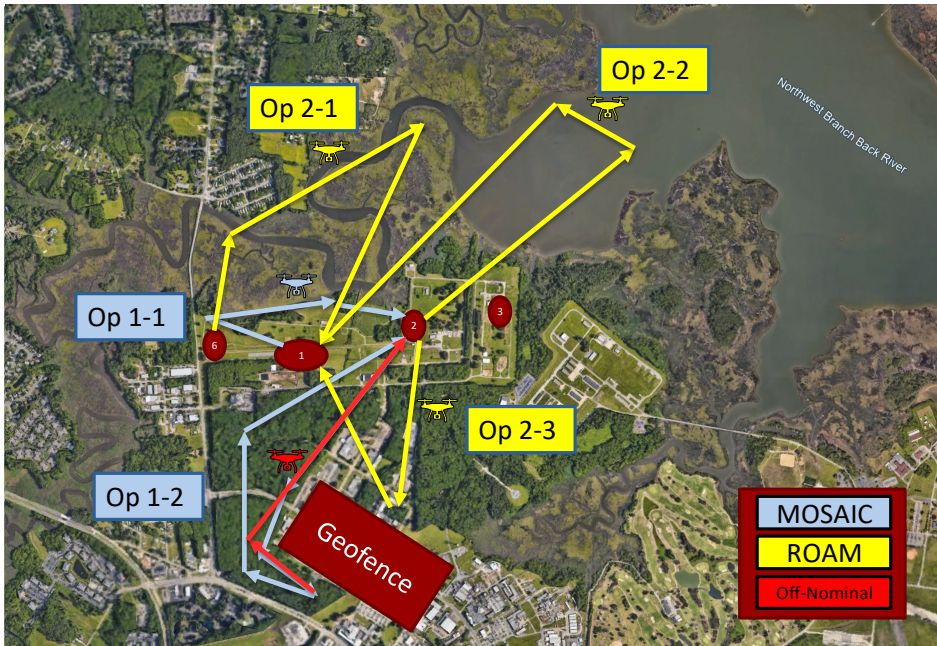
  Operator 2 Path


    Vertiports

Scenarios – Off Nominal

ICAROUS RTL Around Geofence



Safe2Ditch Emergency Landing



  Operator 1 Path

  Operator 2 Path

    Vertiports

  Off-Nominal Path

MOSAIC
ROAM
Off-Nominal

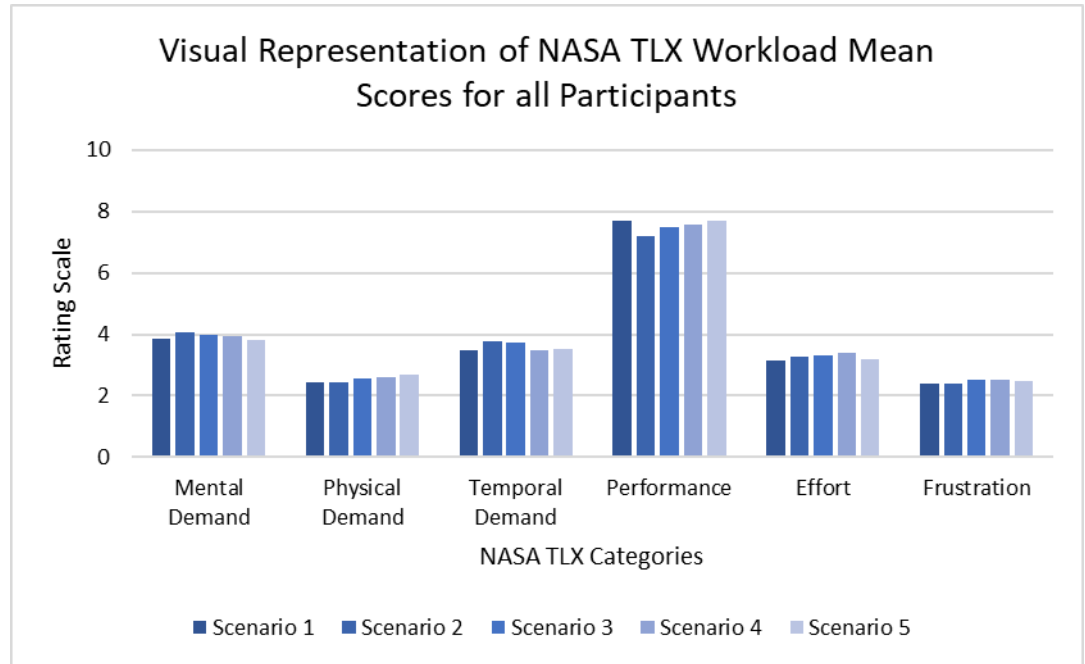
MOSAIC
ROAM
Off-Nominal

Human Factors – Method of Collection

- Capture of subjective data on participants.
 - Five scenarios a day over two weeks of data collection.
 - Two groups of participants, one per week.
- Each participant filled out the following subject questionnaire.
 - Post scenario questionnaire after scenario.
 - End of day questionnaire.
 - End of experiment questionnaire.
- Questions on workload, situation awareness, performance, and perceived risk during each presented scenario.
- Combination of Likert scale rating and open-ended questions.

Human Factors – Workload Results

- NASA Task Load Index assess participant's subjective workload over six categories.
- Captured scores across all test days for each participant.
- Overall, low levels of workload observed with a high performance from the participants.
- Slight increase in workload as scenarios became more complex.



- Scenario 1 – Nominal non-overlap
- Scenario 2 – Nominal overlap
- Scenario 3 – Off-Nominal Safe2Ditch
- Scenario 4 – Off-Nominal RTL
- Scenario 5 – Combined

Human Factors – Situation Awareness

- Likert Scale Rating (1 to 7) on awareness in the scenarios.
- Participants had good awareness of vehicles, particularly due to the USS.
- Negatives impacts to situation awareness due to lack of secondary or tertiary tasks and previous familiarity with the GCS display and simulation that may have caused a lack of focus.

Question: “I had good situation awareness of all UAS aircraft in my control.”

Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
5.79	+/-1.20	5.69	+/-0.86	5.62	+/-1.04	5.86	+/-0.80	5.82	+/-1.01

Question: “I had good situation awareness of all other aircraft in the surrounding area.”

Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
5.77	+/-0.78	5.67	+/-0.98	5.56	+/-1.02	5.58	+/-1.00	5.68	+/-0.90

Human Factors – Perceived Risk

- Likert Scale Rating (1 to 7) on perceived risk in the scenarios.
- Overall, scenarios are perceived as low risk but could be due to the participants knowledge of the simulation.
- Perceived risk does seem to increase as scenarios become more complex but offers a large standard deviation on the mean than situation awareness.

Question: “The probability of real-world operations like the last scenario going poorly is low.”

Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
5.03	+/-1.74	5.21	+/-1.38	5.03	+/-1.60	5.00	+/-1.53	5.29	+/-1.35

Question: “Introducing real-world operations like the last scenario will not have negative ramifications for the future.”

Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
5.62	+/-1.31	5.36	+/-1.35	5.13	+/-1.54	5.33	+/-1.39	5.11	+/-1.62

Human Factors – General Perceptions

- Participants noted that, while the USS information is useful for situation awareness, it made the GCS display feel cluttered.
 - Suggestion to have the ability to toggle the USS information to have it disappear when not needed.
 - Desire for better warnings when vehicles were out of their intended flight path.
 - Requested pilot information or callsign associated with each vehicle.
- Comments on unexpected onboard autonomy responses.
 - Vehicle performing detect and avoid actions towards a geofence.
 - Vehicle not honoring geofence during RTL.

Conclusion and Follow On Work

- Participants felt that their workload was low and situation awareness was high.
 - Scenarios conducted in order, not randomly, so results are preliminary and exploratory.
- Simulation helped identify improvements to technologies that enables BVLOS operations.
 - Display feedback on the GCS.
 - Defects identified within the onboard autonomy.
 - Better GCS integration with the USS.
- Best practices learned will help support future operations.
 - Data collection during given scenarios in flight
 - NTAP enabled operations

Questions?

Thank You!

For any questions or follow-ups, please contact:

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