m:N ConOps/R&R Remote Simulation

Friday, March 26, 2021

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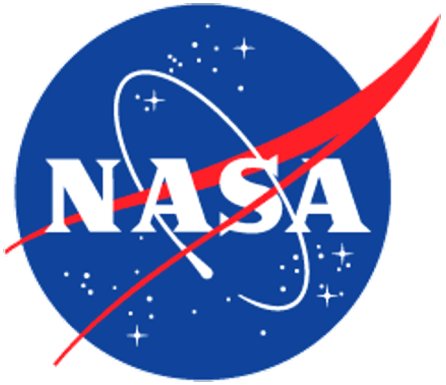
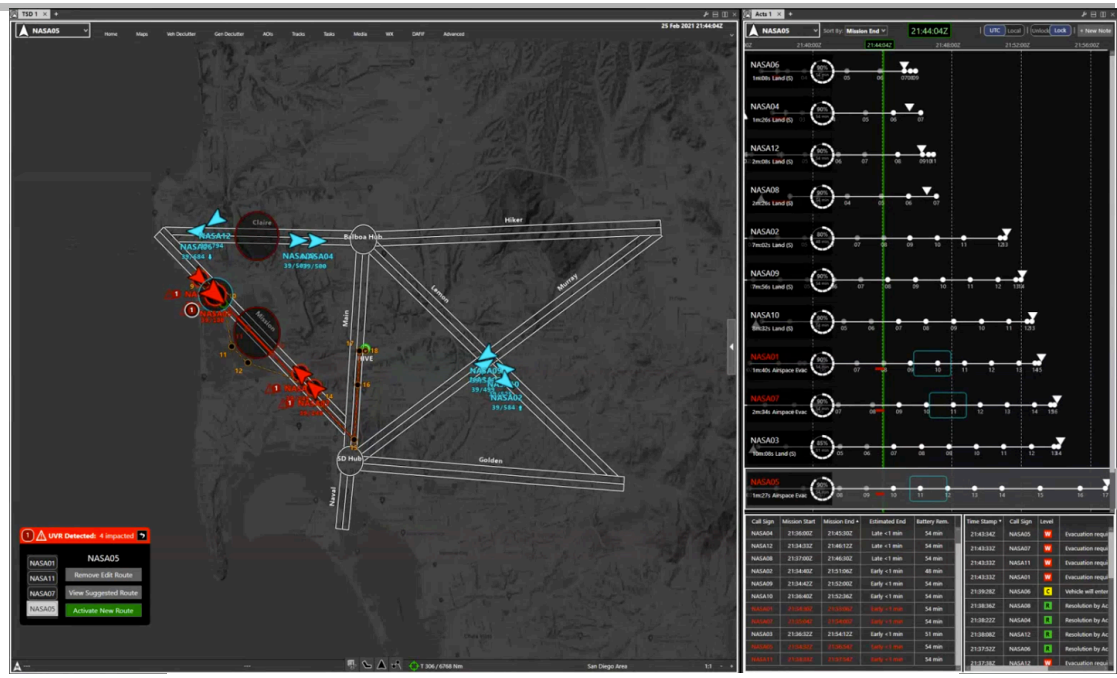


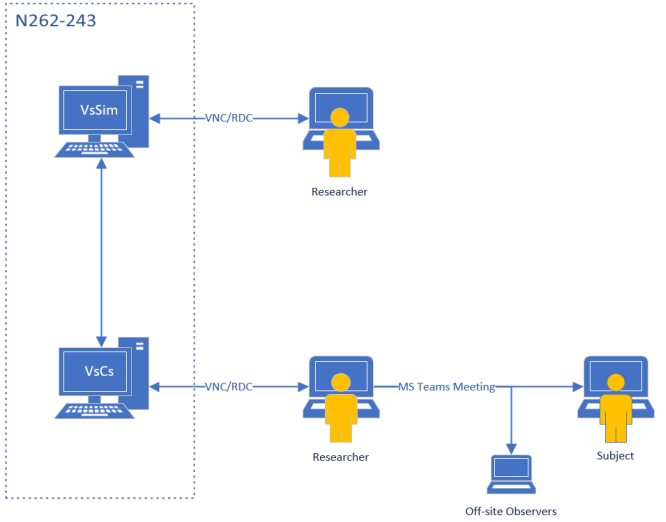
Background

- NASA's Transformational Tools and Technologies (TTT) project seeks state-of-the-art tools and technologies necessary to meet the Aeronautics Research Mission Directorate's (ARMD) strategic needs such as the understanding of innovative control techniques and experimental methods.

- The Human-Autonomy Teaming (HAT) Laboratory is engaged in research to evaluate a concept of operations (ConOps), the roles and responsibilities (R&Rs) of key personnel and ground control station (GCS) displays and interfaces for m:N operations.

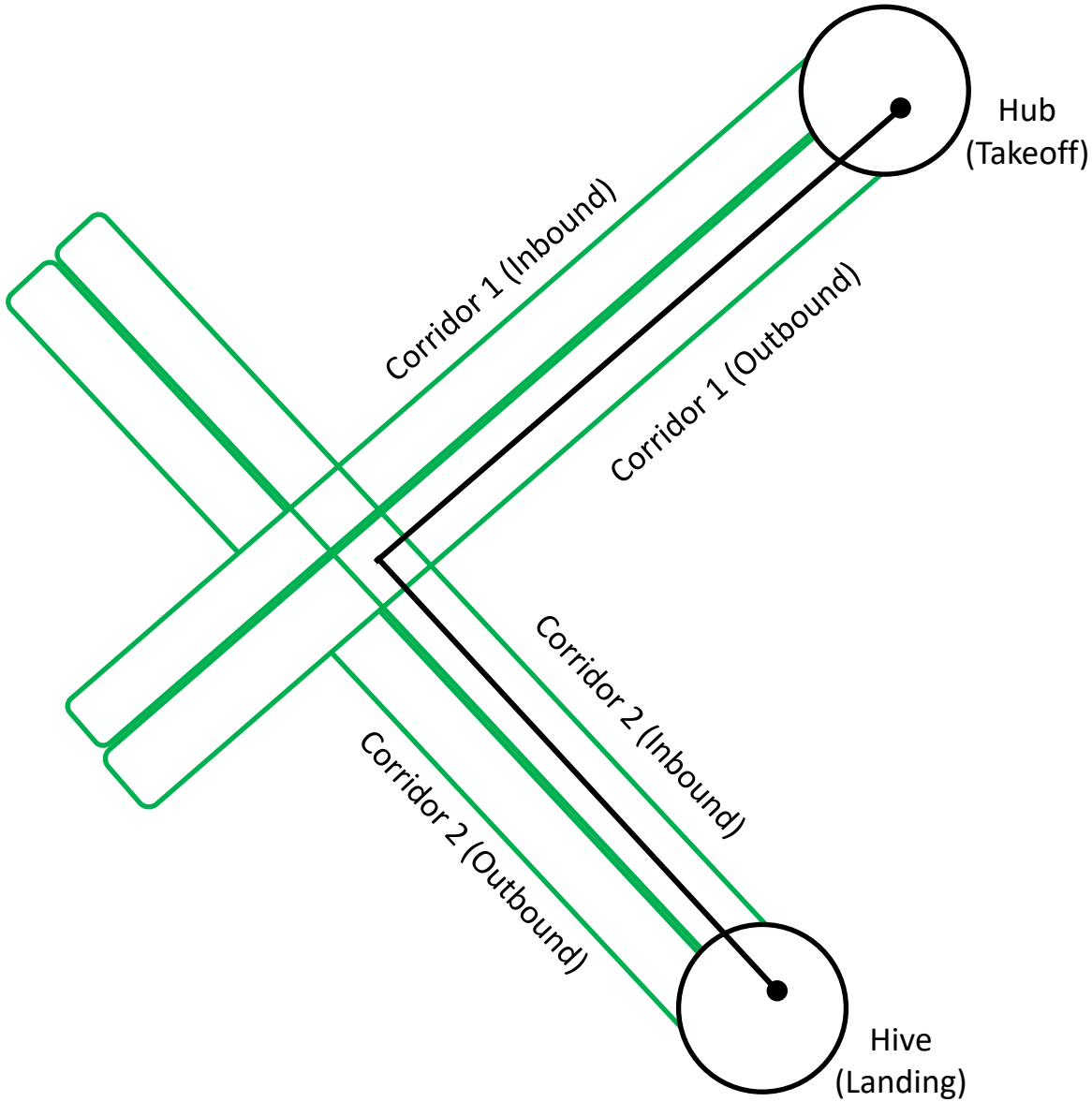
- HAT Lab developed a remote data collection procedure that utilized a verbal communication protocol and "subject-surrogate." Data was collected in February and March 2021.





HITL ConOps

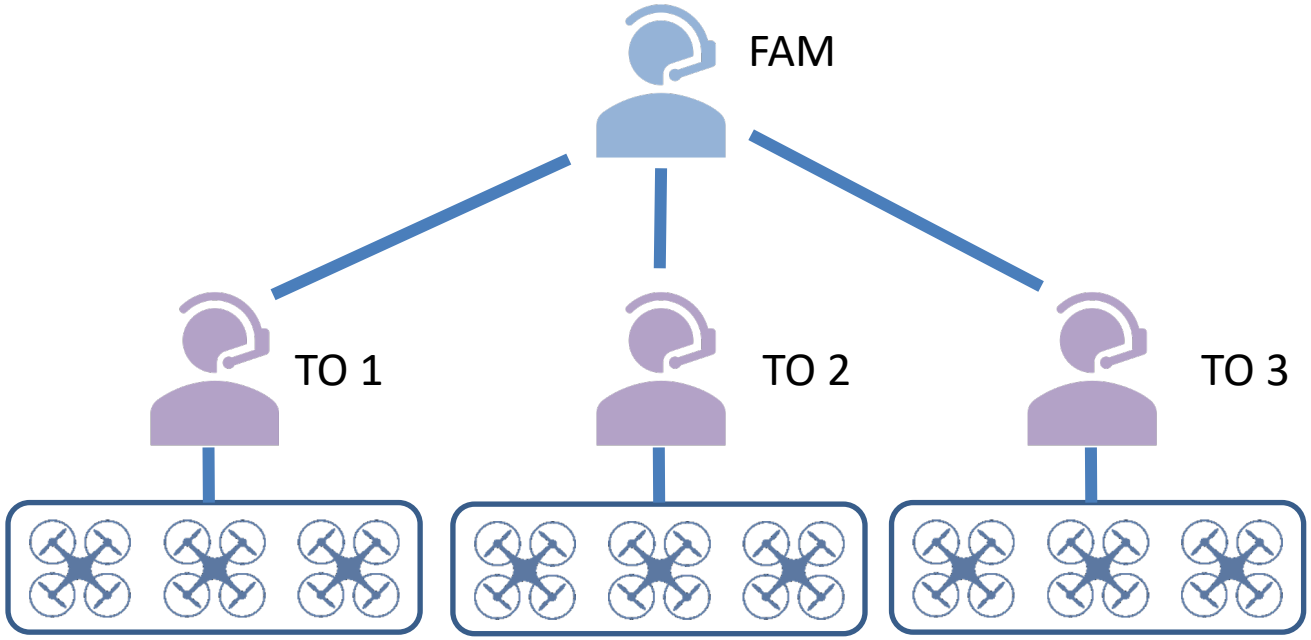
- Food /small package delivery using a fleet of small UAS in San Diego, CA.
- Aircraft follow corridors developed in a simulated Authorized Area of Operation
  - Simulation used a “canned” UAS Service Supplier (USS)
- Each aircraft is remotely monitored by ground operators, and each operator is responsible for multiple aircraft simultaneously.
- Key personnel: the **Tactical Operator** (TO) and Fleet Area Manager (FAM)



Concept of Operations: m:N

- m:N Paradigm
  - Multiple operators managing multiple vehicles, where:
    - m = # of operators
    - N = # of vehicles

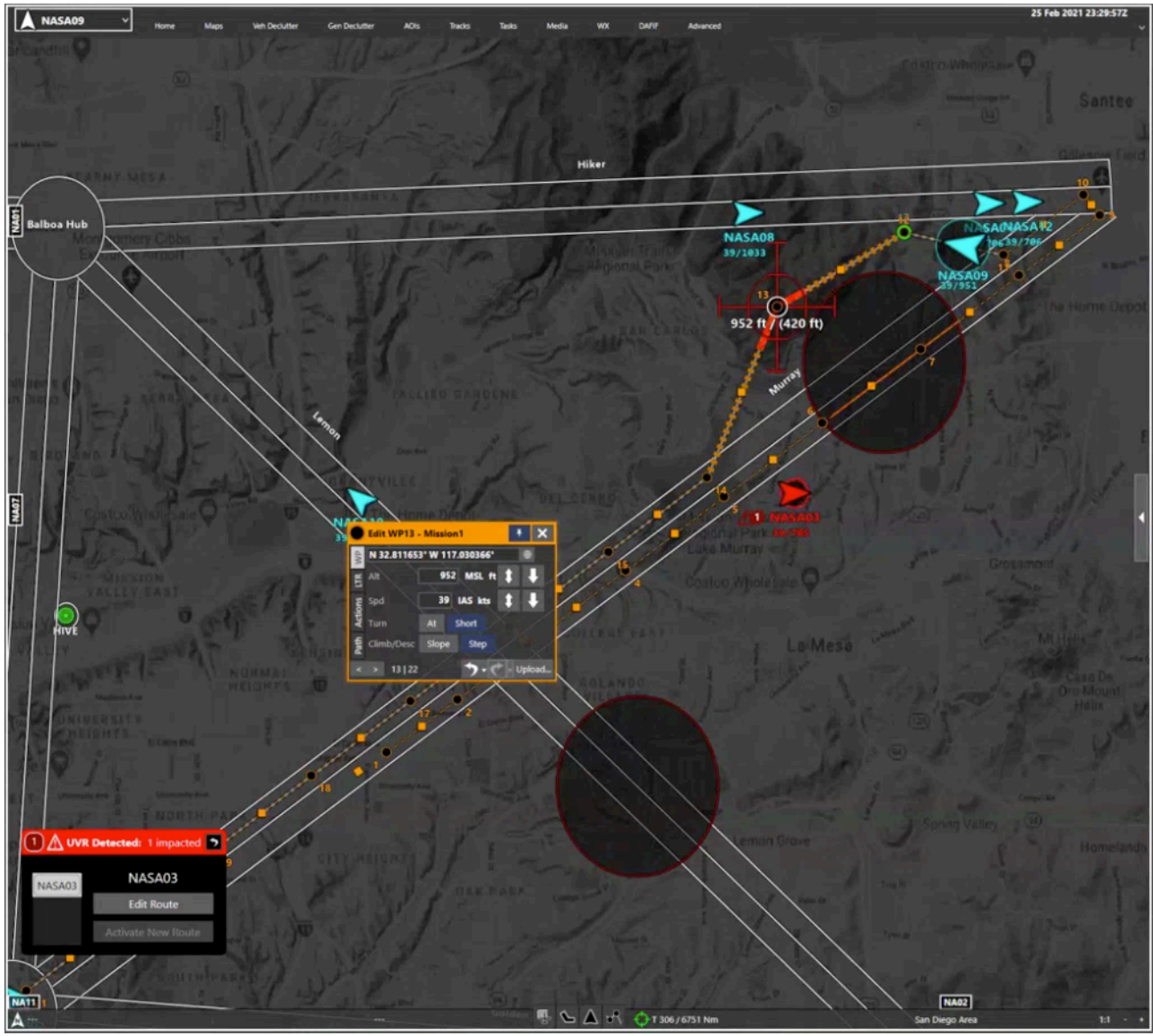
- Roles in m:N operations:
  - Tactical Operator (TO)
    - Pilot-in-Command (PIC) of multiple assets
    - Monitors airspace and hazards
    - Attends to assets
    - **<u>Participant's role</u>** in the study
  - Fleet Area Manager (FAM)
    - Responsible for overseeing a select number of TOs in a specific area
    - Monitors fleet health, monitors system health
    - Evaluates TO performance and workload online
    - Played by researcher confederate



Objectives and Questions

- Goal:
  - Test and evaluate feasibility of ConOps, roles and responsibilities of the TO
  - Examine meaningful human control under conditions of
    - Elevated workload
    - Varying automation support
  - Gather feedback on how best to manage:
    - Hand-offs between tactical operators and/or the fleet manager (e.g., excessive workload, phase of flight)
    - Potential human-autonomy teaming tools (i.e., 'plays') that could alleviate workload strains while still keeping pilot informed
  - Demonstrate subject-surrogate simulation configuration
  - Evaluate the HAT Lab m:N GCS

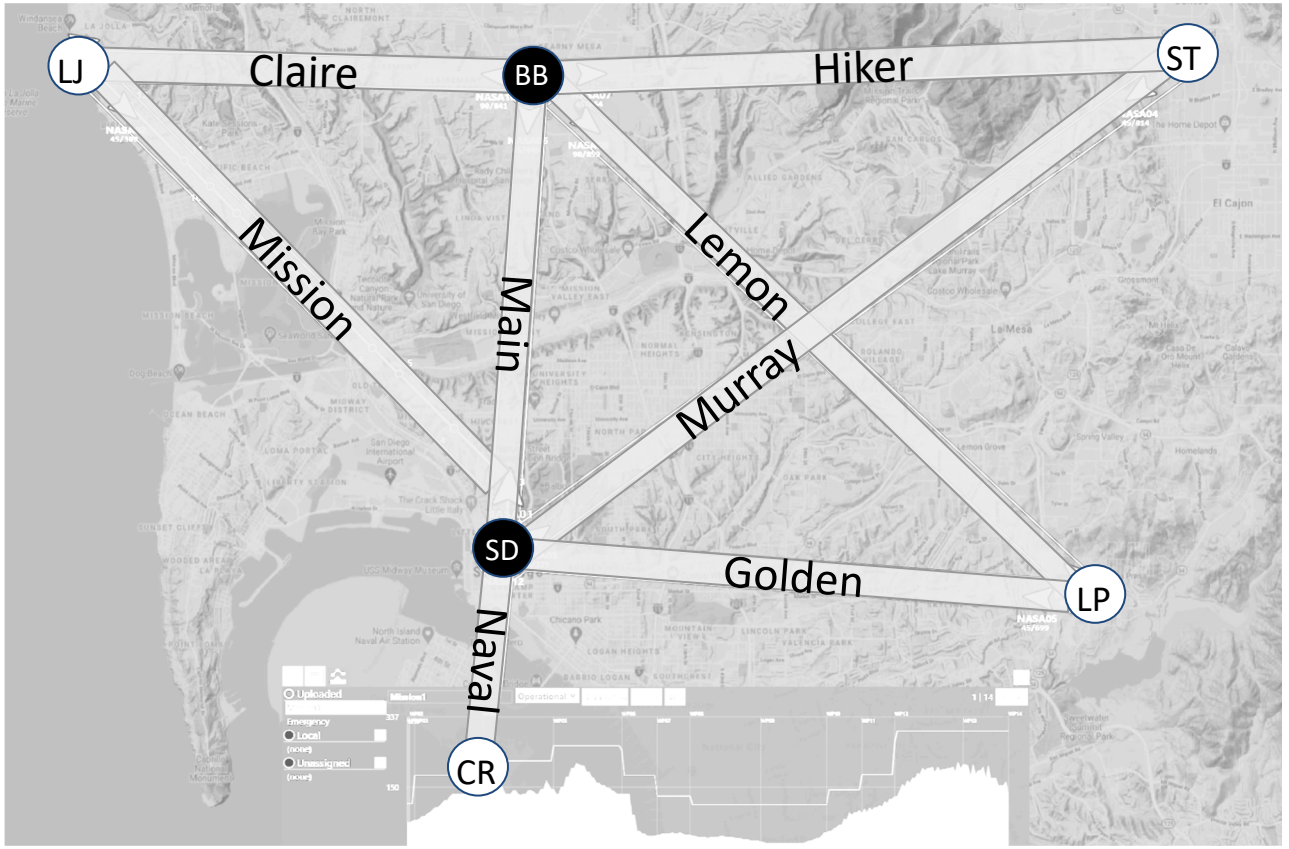
- Research Question
  - To what degree does the presence of automation improve performance?
    - What is the impact or size of the effect as a function of workload and automation support?
  - Will the TO be able to maintain MHC under a 'moderate' vehicle load of 12 UAs?



Test Setup and Scenario Design

- Participants (sUAS Part 107 pilots)
  - 4 pretest subjects
  - 12 data collection subjects

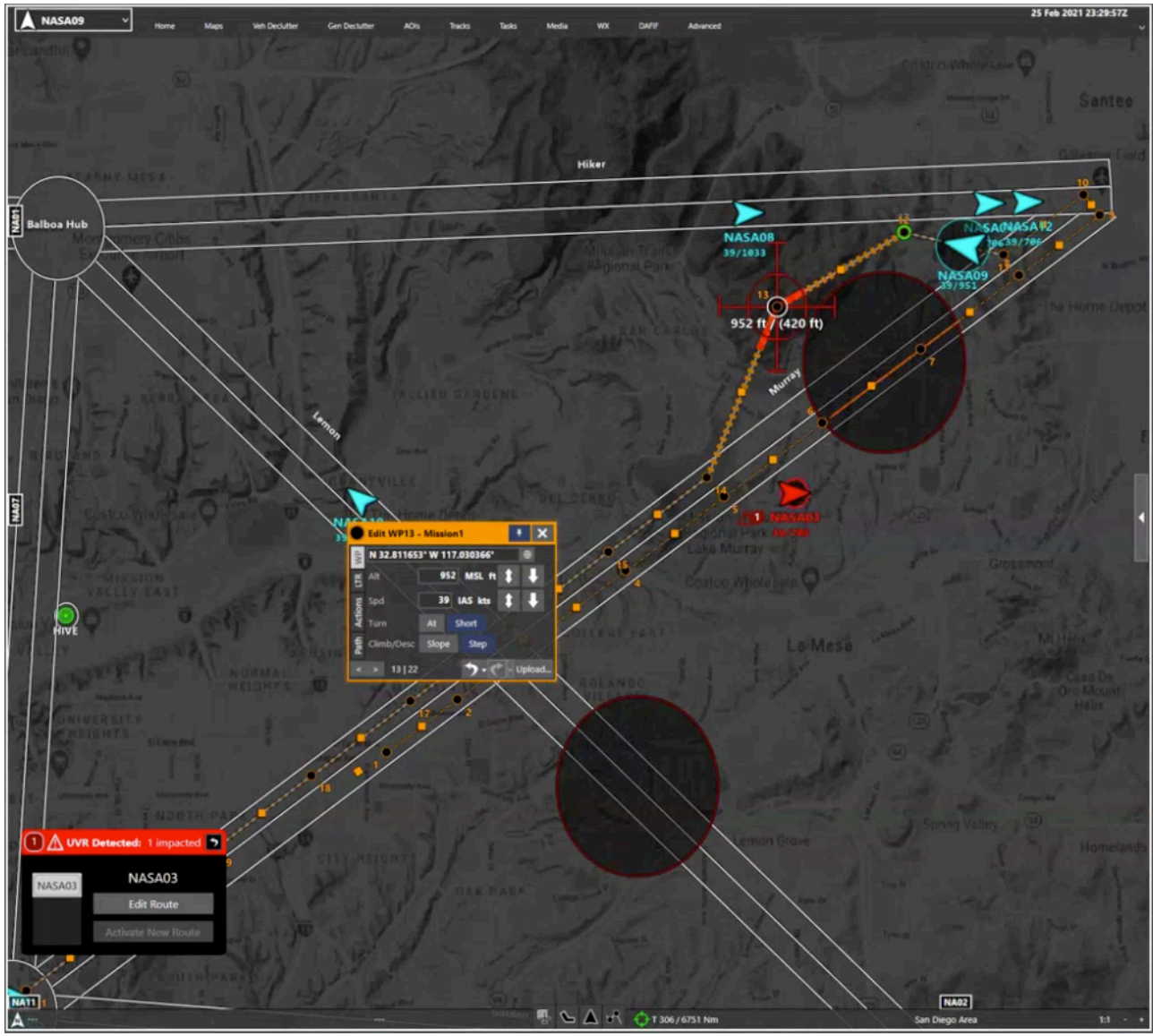
- Experimental Trials
  - 4 experimental trails per pilot
  - ~15-minute trial duration
  - Simulate 1:12 delivery operations
    - San Diego area
    - 8 pre-authorized corridors
    - 1 Hive
    - 2 Restaurant Hubs
    - 4 delivery sites
  - Participant Tactical Operator
    - Maintain safety and conformance for aircraft under control/supervision
    - Resolve scripted contingency (1/scenario)
      - UVR requiring replanning for multiple UAs
  - Researcher will played role of the Fleet Area Manager



Simulation Area and Corridors

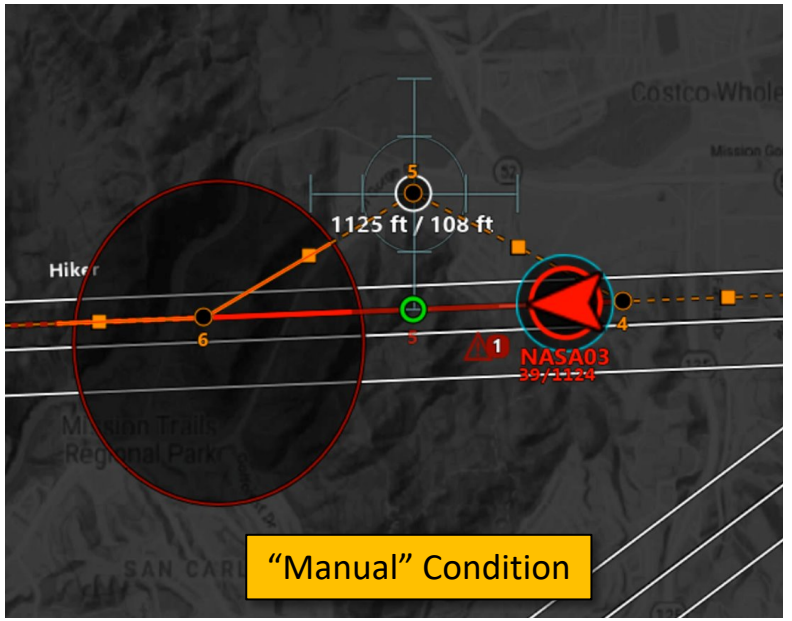
Experimental Task

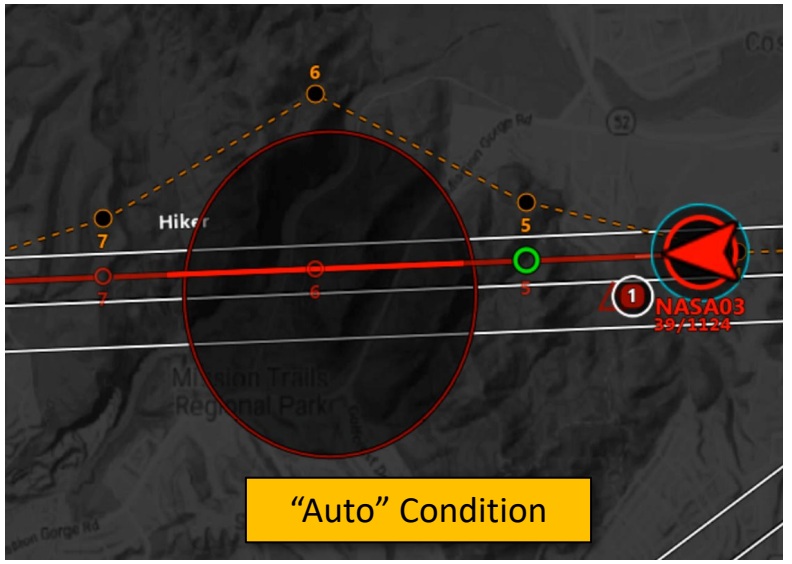
- Each participant, as the TO, monitored 12 assets on delivery missions in San Diego, CA.
- Participants responded to sudden, high-priority contingency events in the form of UAS Volume Reservations (UVRs, 2 per trial)
- Upon issuance of a UVR, pilots were responsible for rerouting affected aircraft around the restricted airspace
  - Automation support and workload were manipulated
  - Some vehicles required special considerations for terrain as part of the reroute
- Participants performed actions through coordination with the subject-surrogate
- Throughout trials, participants communicated with a FAM (played by researcher) who queried TOs with secondary tasks



Experimental Design

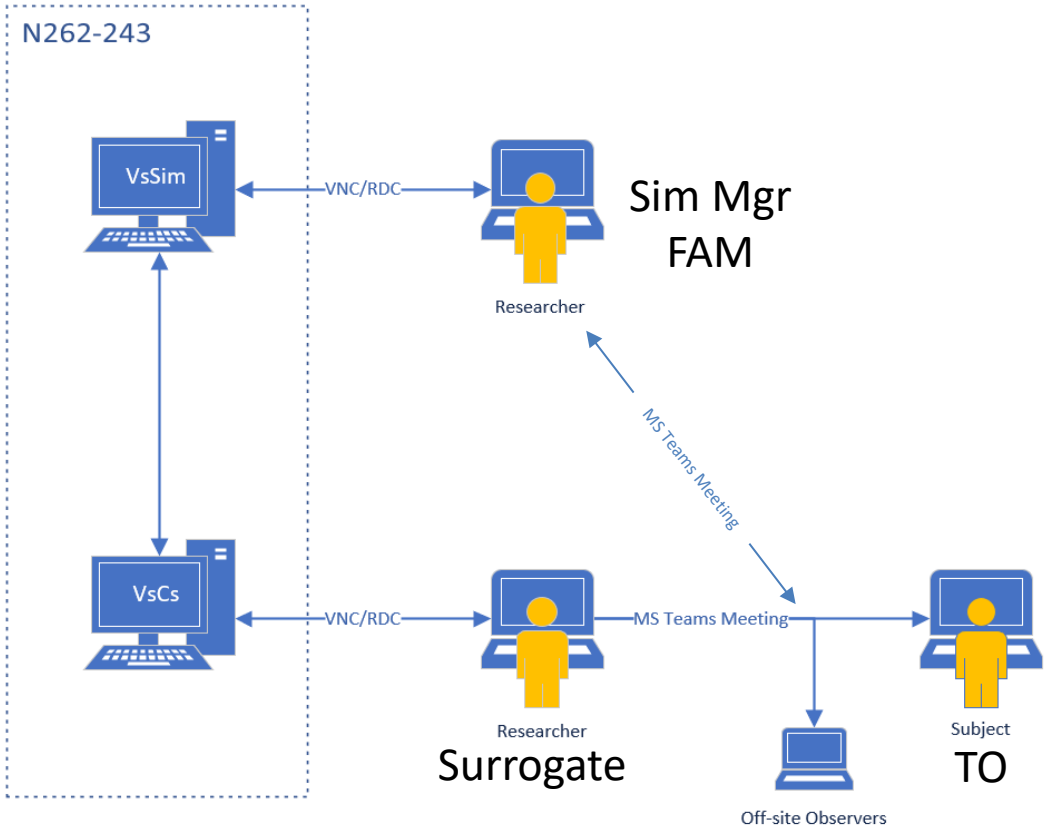
- Two UVR contingency events in each trial
- Independent Variables
  - Workload: Number of contingency-affected vehicles (2 levels, within-subjects)
    - Low: 2 affected vehicles per UVR (4 affected vehicles total per trial)
    - High: 4 affected vehicles per UVR (8 affected vehicles total per trial)
  - "Automation" support (2 levels, within-subjects)
    - Manual contingency solution
    - Recommended solution provided
- Independent variables intended to force either interactions with FAM or automation support
- Embedded Variables
  - Terrain consideration: 25% of UVR aircraft in each scenario require consideration of terrain when rerouting around UVRs.
- Dependent Variables
  - Response times*
  - Workload*
  - Correctness/appropriateness of responses
  - Meaningful Human Control
  - Debrief/open ended responses





Remote Data Collection

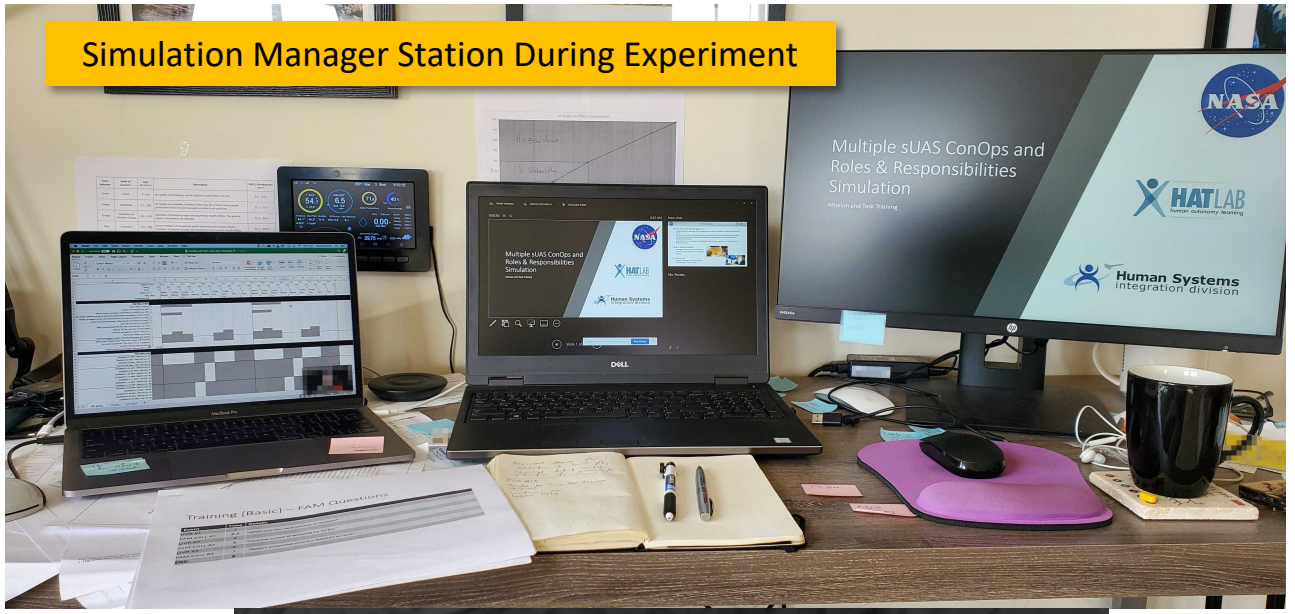
- **<u>Access restricted due to COVID-19</u>**
  - All participation (subjects/staff) was remote
- Cybersecurity policies prevented external control of GCS by participants
- Remote researcher connections:
  - Simulation Manager & FAM remote connection Vigilant Spirit Sim, Teams
  - Subject-Surrogate remote connection to Vigilant Spirit Control Station, Teams
  - Teams Broadcast for observers
- Remote subject on Teams conveys actions to Subject-Surrogate using verbal protocol

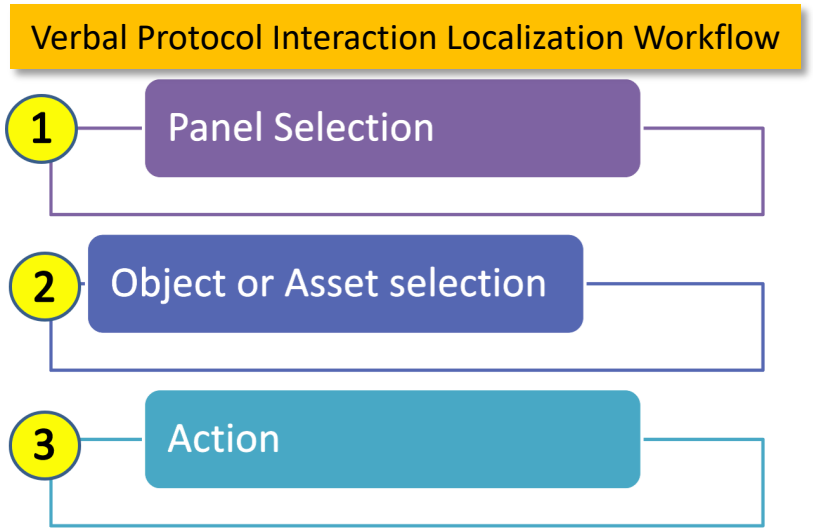


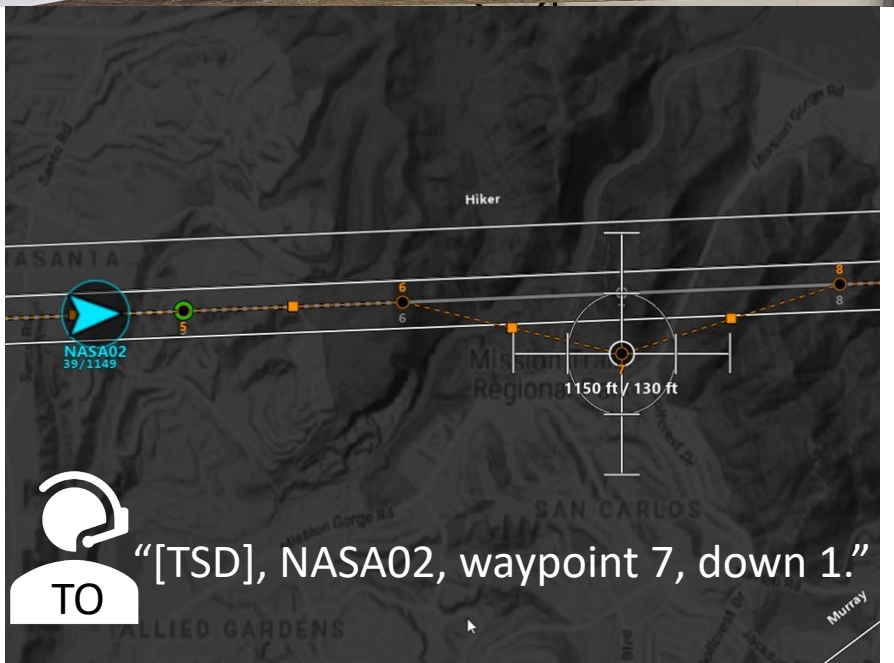
Subject-Surrogate Data Collection

- Simulation managed, executed by remote researchers

- Subjects convey actions through the Subject- Surrogate
  - Surrogate controls GCS
  - Shared vocabulary for verbal instructions







Data Analysis

- Objective Metrics
  - Time to resolve UVR conflicts
  - Time to resolve terrain conflicts
  - Number of UVR violations
  - Number of terrain collisions
  - Path efficiency of rerouted vehicles
- Subjective Metrics
  - Subjective performance ratings
    - Ability to manage vehicles
    - Ability to minimize impact of UVR
  - Interface ratings
  - Workload (NASA TLX)
  - Meaningful human control ratings
- Methodological impacts of remote/surrogate study
  - Connection lag/latency
  - Participant display size
  - Surrogate workload (NASA TLX)
  - "Messy" surrogate interactions
    - Miscommunications/stepped on comms
    - Departures from verbal protocol
    - UI/surrogate fumbles
  - Participant qualitative feedback on remote data collection, surrogate design
- Plan to brief results at next Multi-Vehicle Control (m:N) WG meeting!

Thanks!

Questions?

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