The High Density Vertiplex Advanced Onboard Automation Overview

DASC 2022
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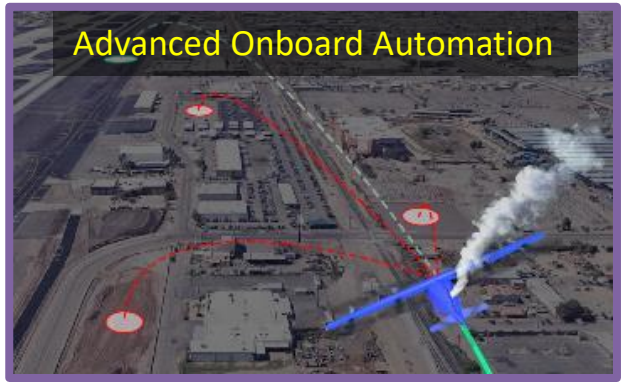
HDV Project Overview

- Two primary thrusts in HDV
  - Prototype and assess representative UAM Ecosystem UML-4
  - Perform testing and safety risk assessments to expand operations and achieve operational credit for NASA techs
    - BVLOS Operations
    - Provides off-ramp to sUAS Part-135 operations
    - Benefits for envisioned UAM vehicles
- Prototype representative UAM Ecosystem including
  - Vertiport automation systems (primary focus)
  - On-board autonomous systems
  - Airspace management systems
  - Ground control/fleet management systems
- Perform coordinated spiral development and test series
  - Each spiral is a schedule work package (~14 months)
  - Ingest NASA techs for specific spiral (AOA, SAO, VO)
  - Apply sim-to-flight test techniques
  - Perform comprehensive safety risk assessments
  - To both support the UAM Ecosystem prototyping/assessment
  - And to generate essential data and results to achieve meaningful operational credit

HDV Schedule Work Packages

FY 21 to 22



FY 22 to 23

FY 23 to 25

AOA Objectives & Success Criteria

Goal Develop reference automation architecture prototypes, integration guidelines, and safety risk assessments that support increasingly autonomous and resilient operations.

Objectives

1. **Development of an UAS automation architecture to support terminal area operations.**
2. **Development of a BVLOS sUAS safety case for urban operations in controlled airspace.**
3. **Demonstration of automated VLOS urban operations in controlled airspace.**

Success Criteria

Minimum Success Criteria: *Development of a UAS automation reference architecture that addresses interoperability of different automation systems and procedures for off-nominal conditions.*

Full Success Criteria: *Collect data to verify the efficacy in terminal area operations of the UAS automation reference architecture through analysis, ground testing and flight testing.*

AOA Simulation Meets Success Criteria

AOA Simulation Partially Meets Success Criteria

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AOA Simulation Meets Success Criteria

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Success Criteria

***Minimum Success Criteria**: Development of an initial hazard analysis and safety case to supporting BVLOS at a NASA test range.*

***Full Success Criteria**: Collect data to support using automation technologies as primary safety mitigations in a BVLOS safety case and ensure safety case aligns with FAA policy and regulations.*

AOA Objectives & Success Criteria

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3. **Demons operatic**

AOA Simulation Meets Success Criteria

AOA Simulation Partially Meets Success Criteria

Success Criteria

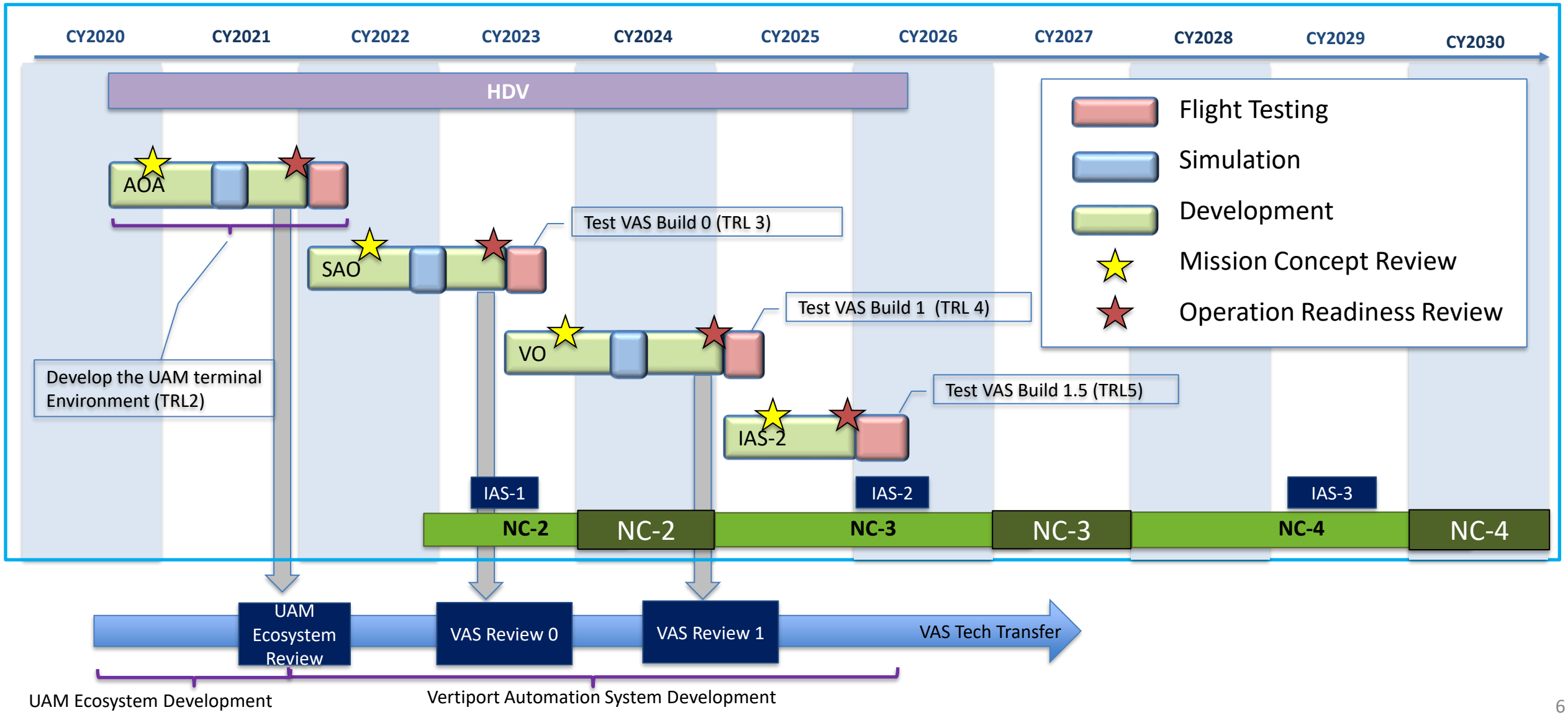
***Minimum Success Criteria**: Develop scenarios that align with partner UAS cargo operations business uses cases.*

***Full Success Criteria**: Demonstration of urban operation scenarios using the UAS automation architecture in flight test with at least 3 UAS equipped with NASA-developed automation*

Create environment required to support Vertiport Automation System Development

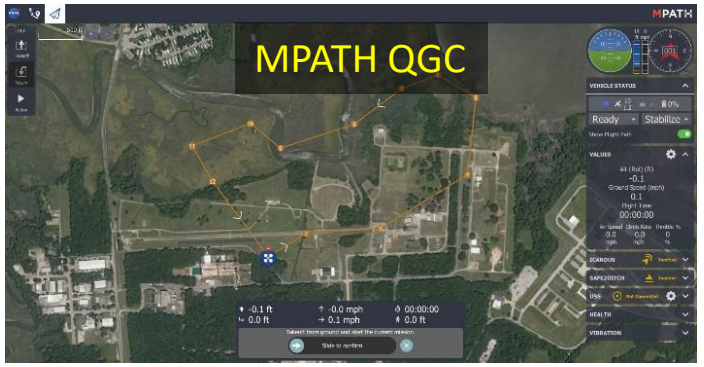
On the road to HDV TC

HDV Technical Challenge: Develop and evaluate a reference automation architecture that addresses scalable and efficient aircraft operations, flight and airspace management procedures, and vertiport operations in high density vertiplex environments.



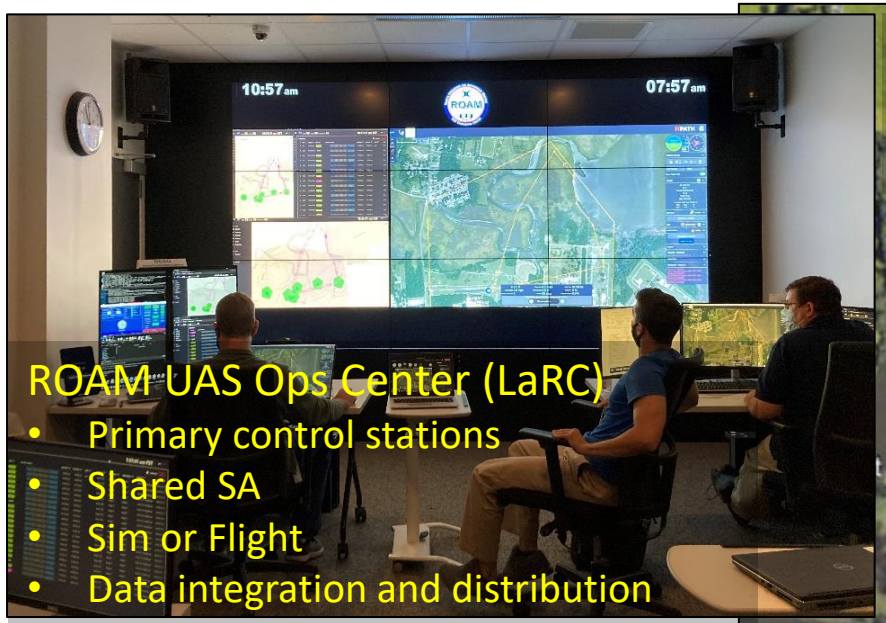
HDV Sim2Flight Methodology

- HDV has invested in human+hardware in the loop simulation capability (HHITL)
  - Provides capability to extensively test autonomous systems
- Simulation characteristics
  - Actual Pixhawk autopilot with sim GPS/IMU/Gyro direct data inputs
  - Same PX-4 firmware sim and flight
  - MPATH QGC
    - Based on QGround Control
    - Modified to integrate ICAROUS/S2D management
    - Can implement and test modifications
  - HelixPro sUAS Simulation model
    - Wind-tunnel derived quadcopter aero model
    - Currently being updated to octocopter
  - Uses same comm links/interfaces as actual sUAS
- High-fidelity test environment for autonomous systems
  - Integration of labs at ARC (AOL/AVAL) and LaRC
  - ICAROUS/Safe2Ditch (S2D)
  - Directly contributes to software verification
- Provides
  - Shakedown testing of flight test routes
  - Training for sUAS operations team prior to testing
  - Serves to complement and extend flight test results
  - Fills critical need for achieving operational credit and BVLOS operations



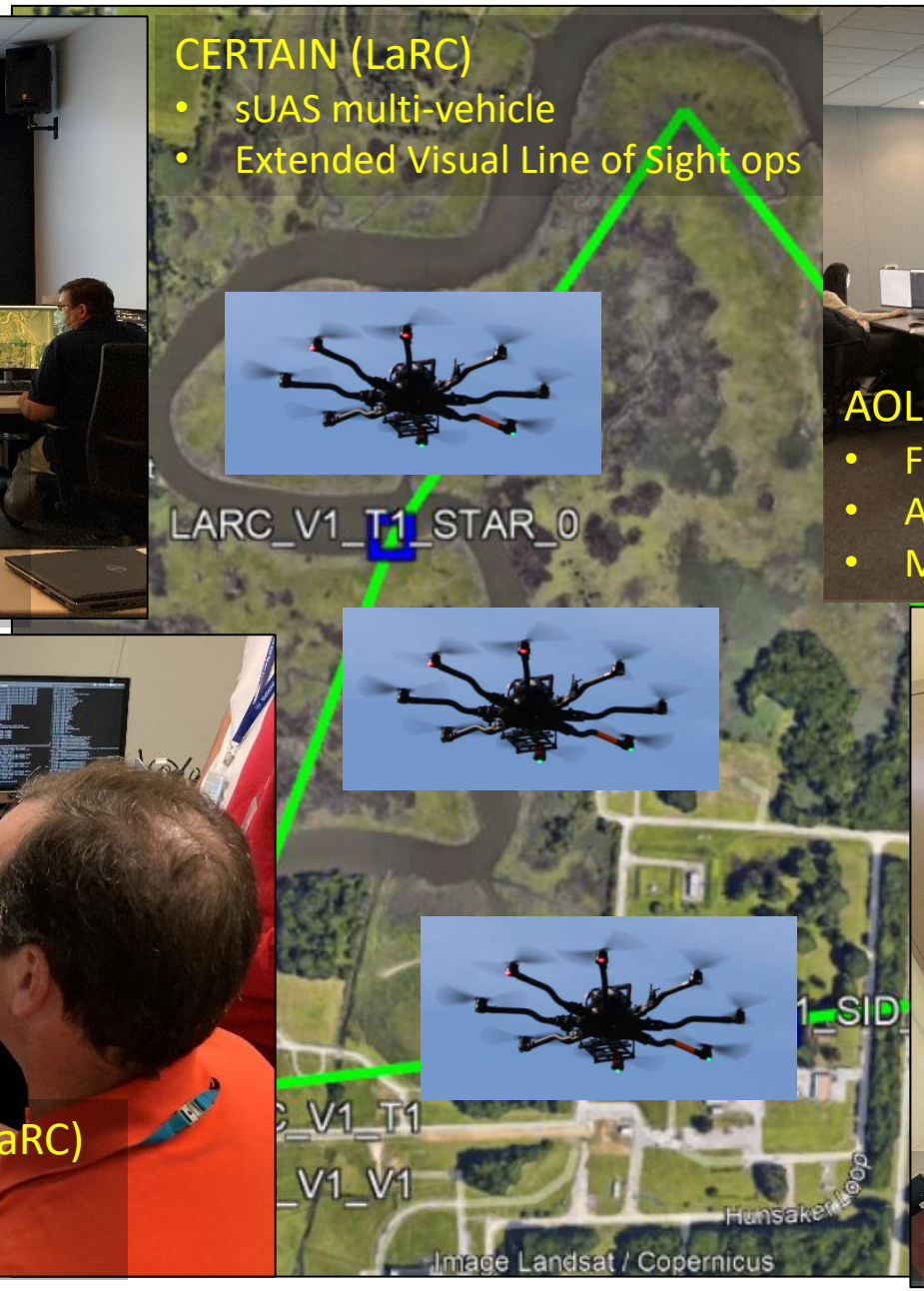
Decoder ring: ICAROUS: Independent Configurable Architecture for Reliable Operations of UAS. S2D: Safe 2 Ditch. MPATH: Measuring Performance for Autonomy Teaming with Humans. ROAM: Remote Operations for Autonomous Missions. IMU: Inertial Measurement Unit. QGC: Qground Control. AOL: Airspace Operations Lab. AVAL: Autonomous Vehicle Applications Lab. BVLOS: Beyond Visual Line of Sight

AOA Simulation and Flight Testing (Coast to Coast)

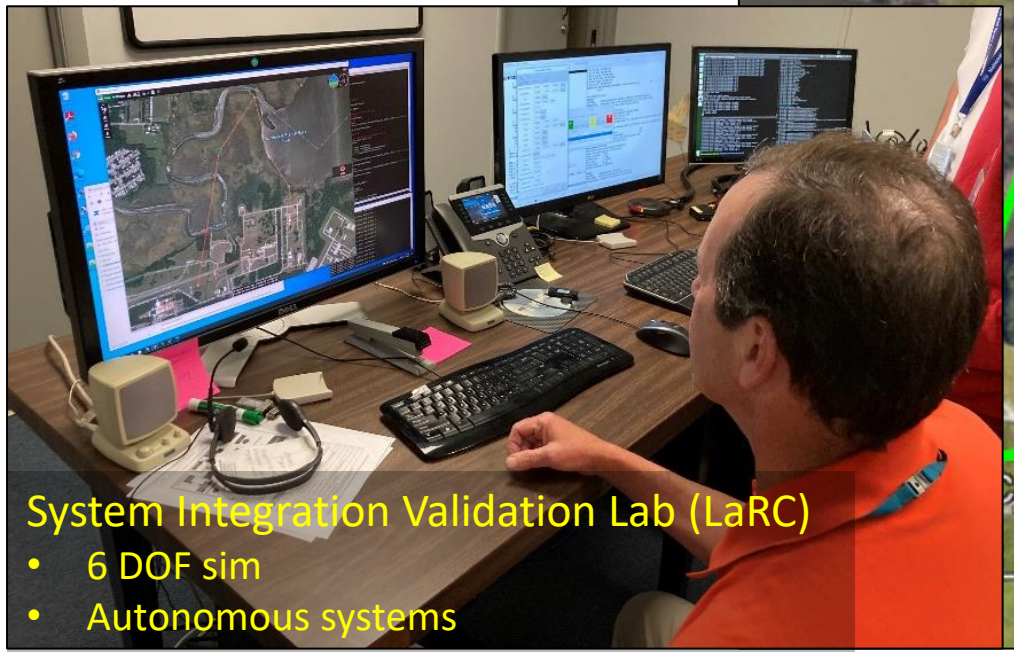


ROAM UAS Ops Center (LaRC)
- Primary control stations
- Shared SA
- Sim or Flight
- Data integration and distribution

CERTAIN (LaRC)
- sUAS multi-vehicle
- Extended Visual Line of Sight ops



AOL (ARC)
- Fleet manager
- ATM-X Provider of Services UAM interface
- Multi Aircraft Control System Sim



System Integration Validation Lab (LaRC)
- 6 DOF sim
- Autonomous systems

AVAL (ARC)
- Vertiport Manager

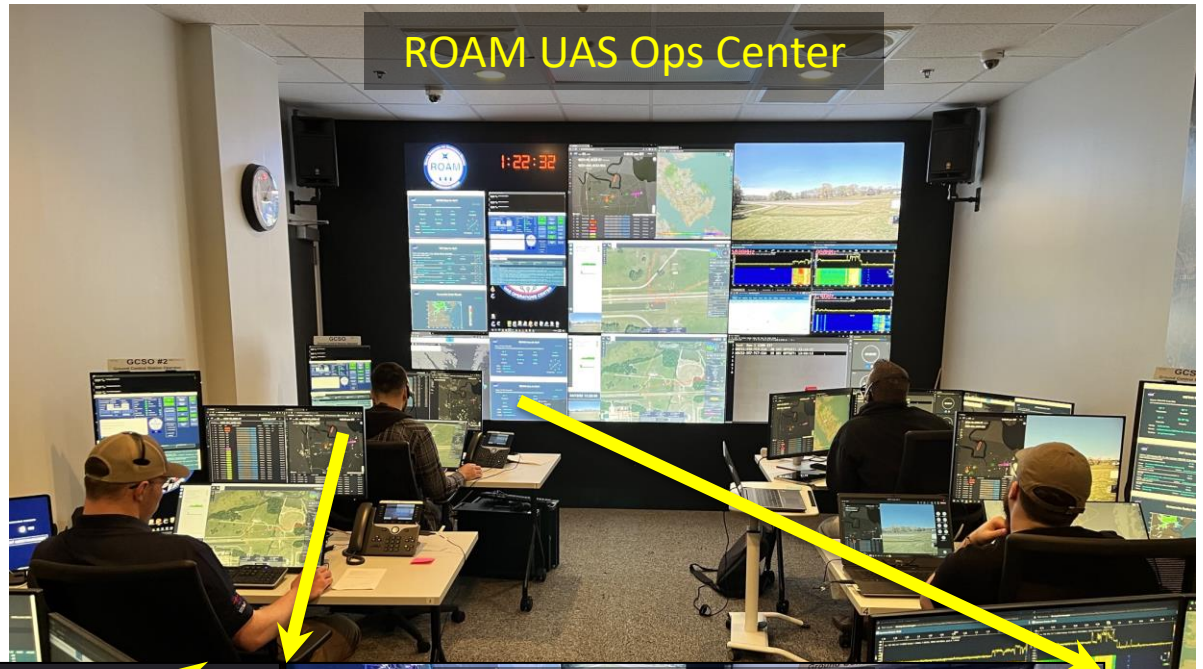
AOA Sim & Flight Test Matrix

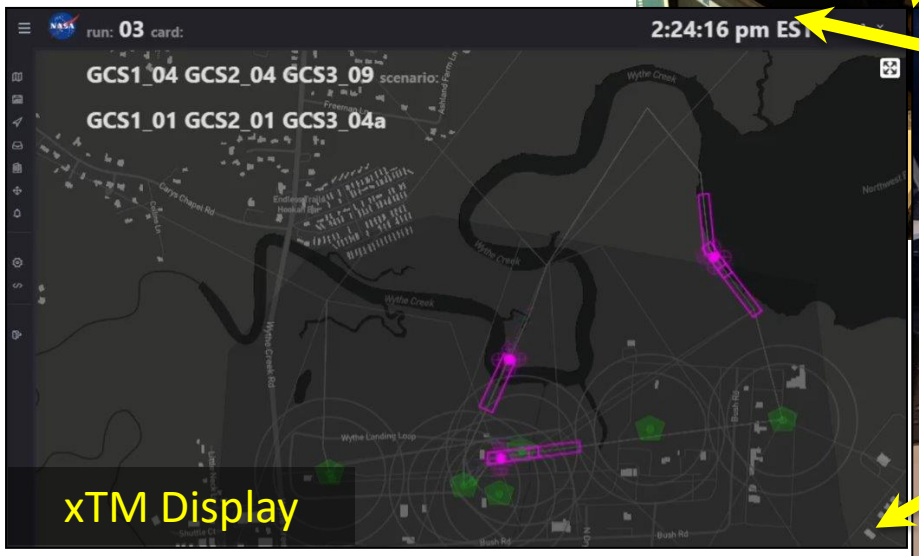
Id	Name	Description	Ops/Hr	Vehicles
1	Nominal flight	Flight(s) are executed per flight plan	20	1/2/3
2a	Tactical ownship conflict conformant	Flight path deviation needed to address traffic incursion: sUAS. This scenario could be due to scenario 3a low-conflict	20	1/2
2b	Tactical ownship conflict non-conformant	Flight path deviation needed to address traffic incursion: sUAS. This scenario could be due to scenario 3b high conflict	20	1/2
3a	Emergency re-route S2Dmanual	Flight path deviation needed to address vehicle health issues manually triggered. Single alternate landing location vertistop (lowconflict).	20	1/2
3b	Emergency re-route S2Dmanual	Flight path deviation needed to address vehicle health issues manually triggered. Single alternate landing location vertiport (high-conflict).	20	1/2
4	Re-route for non-emergency reasons	Needed to simulate/assess vertiport closures. Fleet managertriggered to a Vertiport.	20	1/3
5a	Geofence test (BVLOS)	Test vehicle encounter with geofence	20	1
5b	Vehicle Control	Test GCSOs knowledge of creating a flight plan and geofence in MPATH	--	1
5c	Emergency Descent	Test GCSOs knowledge of observing a straight vertical descent mid-flight	--	1

Scenarios tested: only in sim, only in flight, both sim & flight

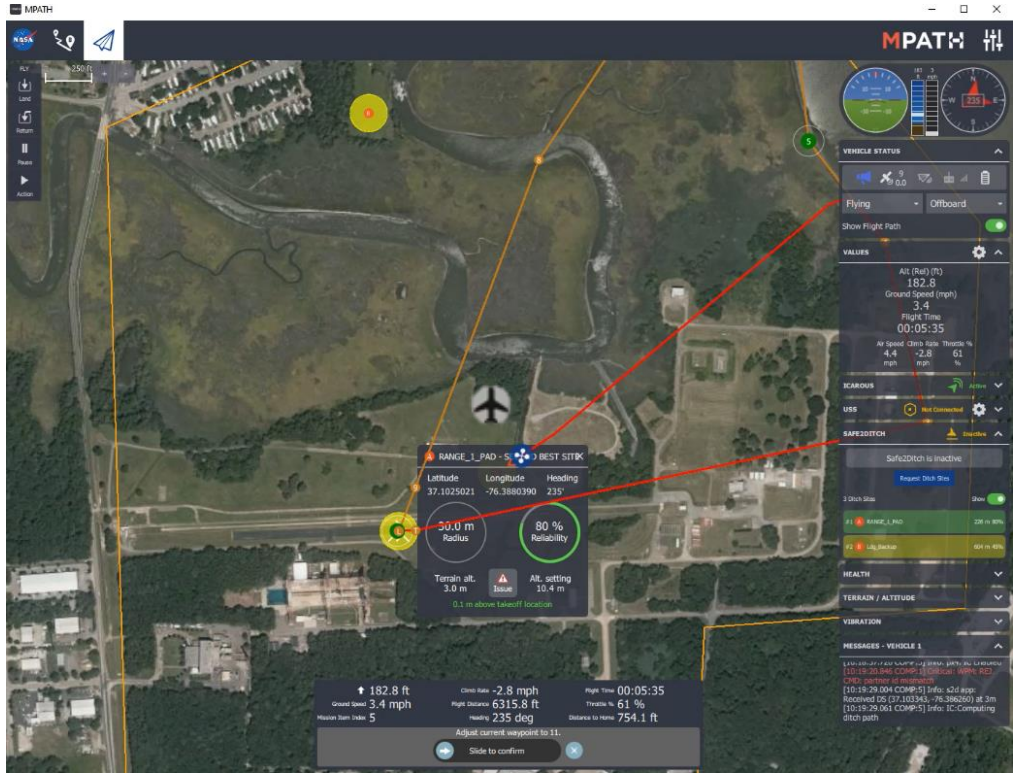
GCSO Display Environment

1. Forward video wall including
   - All GCSO MPATH displays (up to 3)
   - Internet-based ADS-B
   - Weather METAR
2. Head Down
   - MPATH
   - xTM
   - Flight schedule
   - METAR
   - HF questionnaire

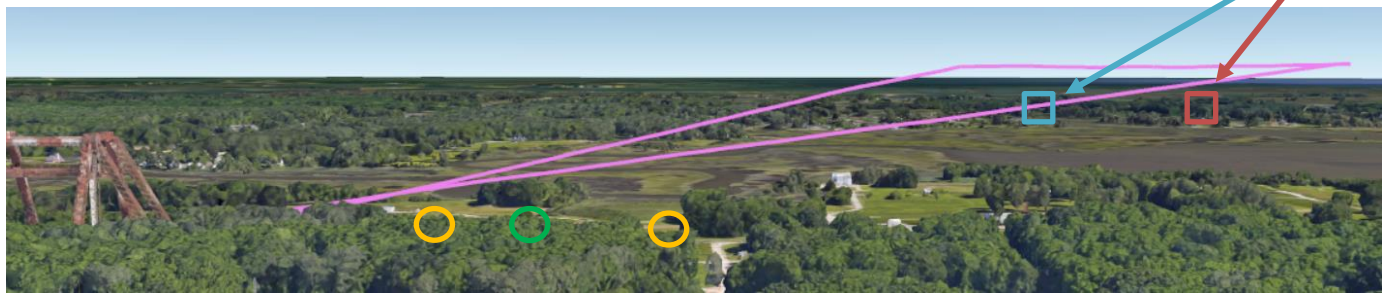




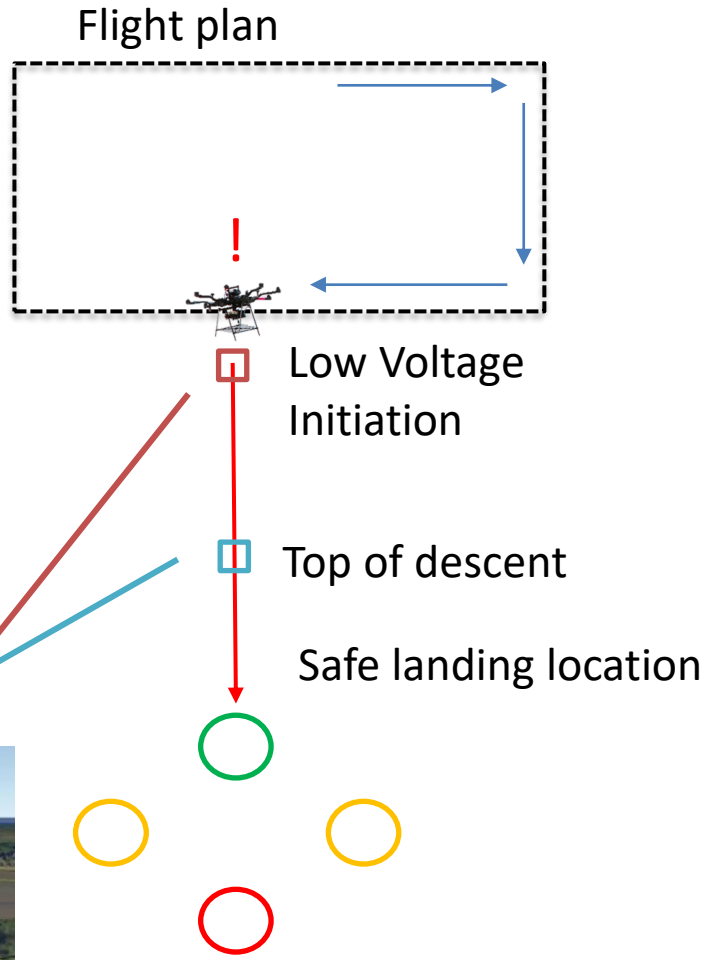
Scenario 3b: Emergency S2D re-route to Vertiport (high conflict)



AOA Simulation Emergency Landing Test Scenario

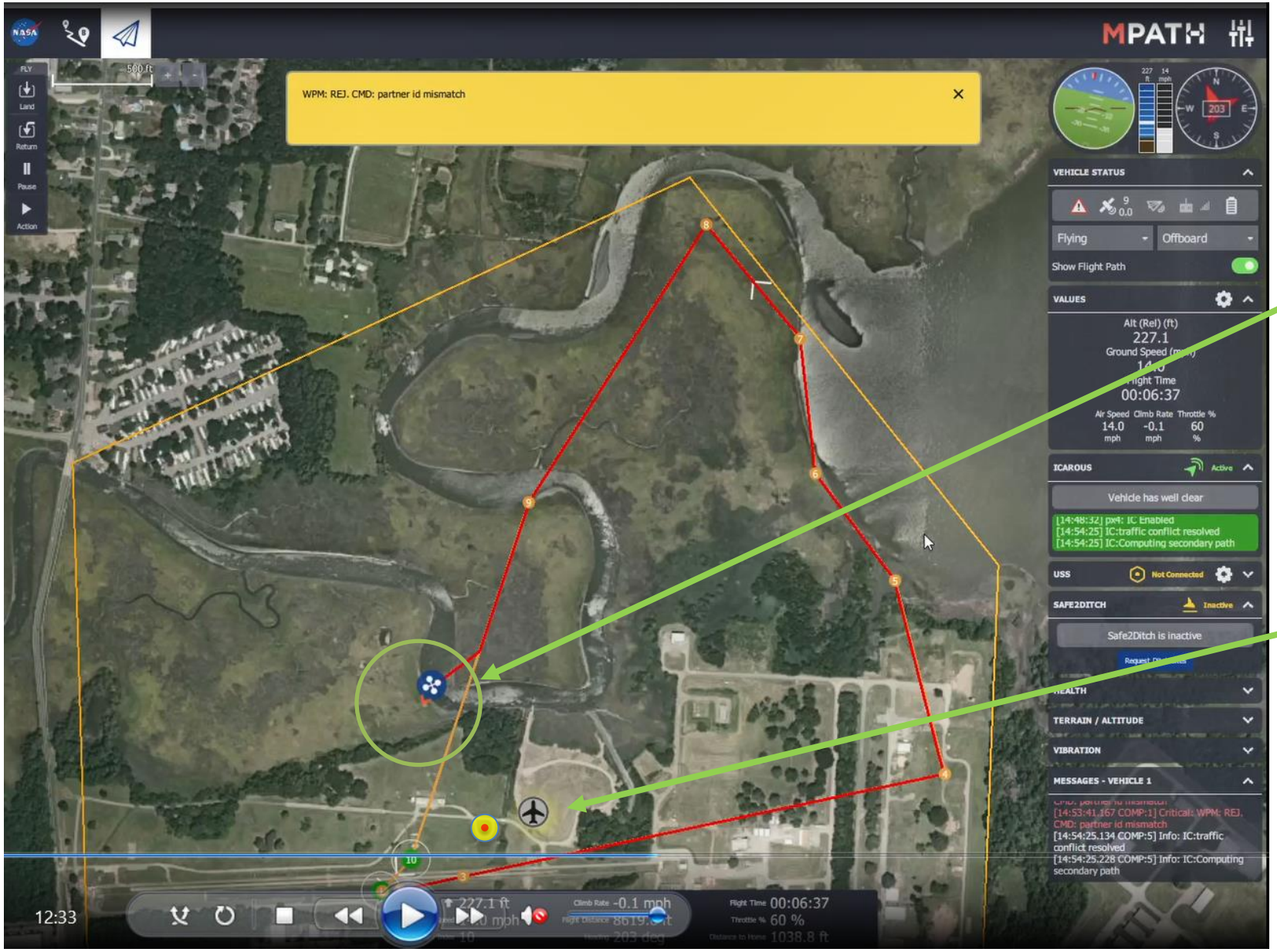


AOA Emergency Landing Test Flight Path

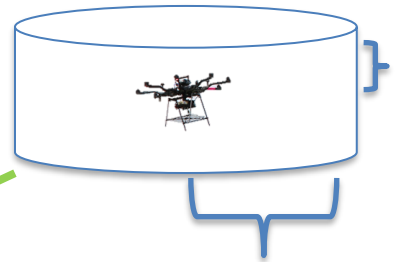


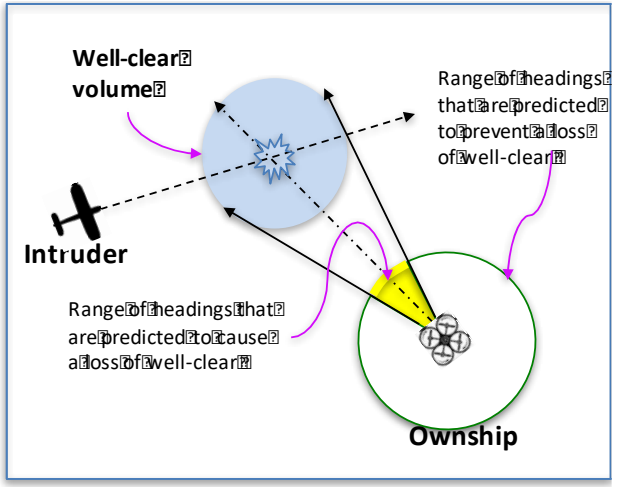
13 Test Runs Conducted

Scenario 2a/3a: Tactical ownship conflict conformant



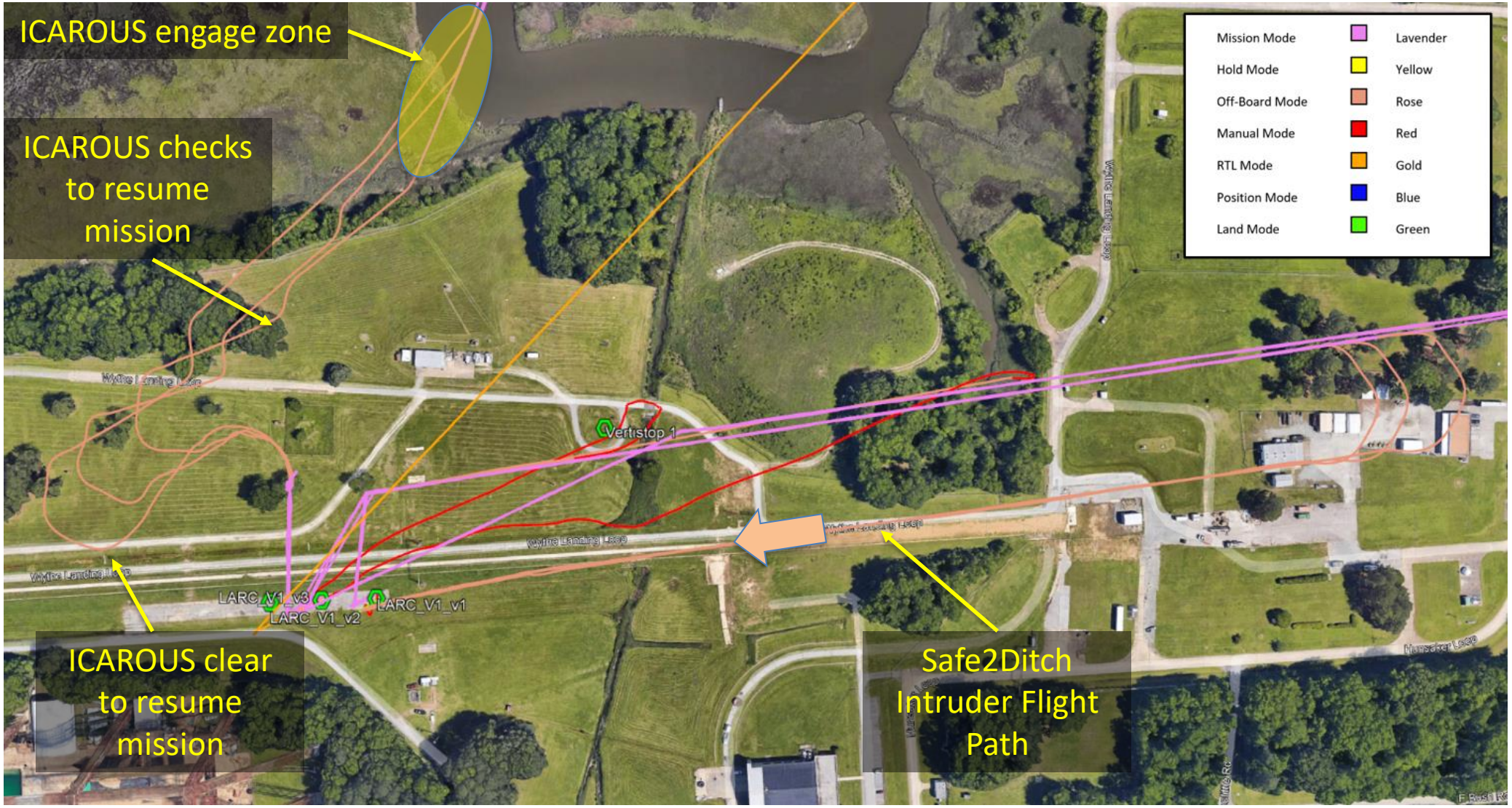
Well-clear Volume



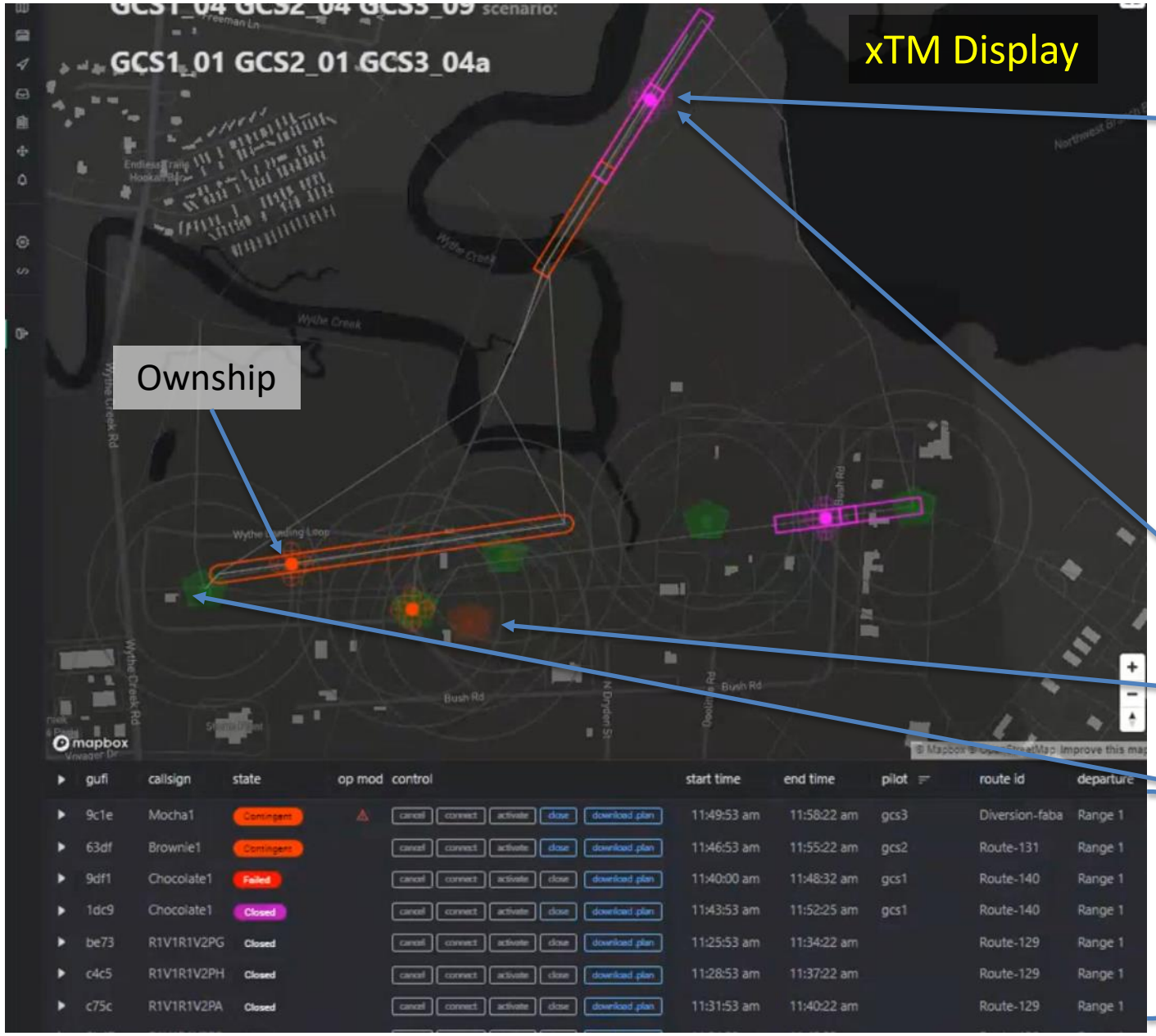


16 Test Runs Conducted

Scenarios 2b/3b: Tactical ownship conflict non-conformant



Scenaio 4b: Re-route for non-emergency reasons



N556NU Re-Routed from Vertiport 1 to Vertiport 6 in flight

Vertiport 1 Closed with ownship inbound

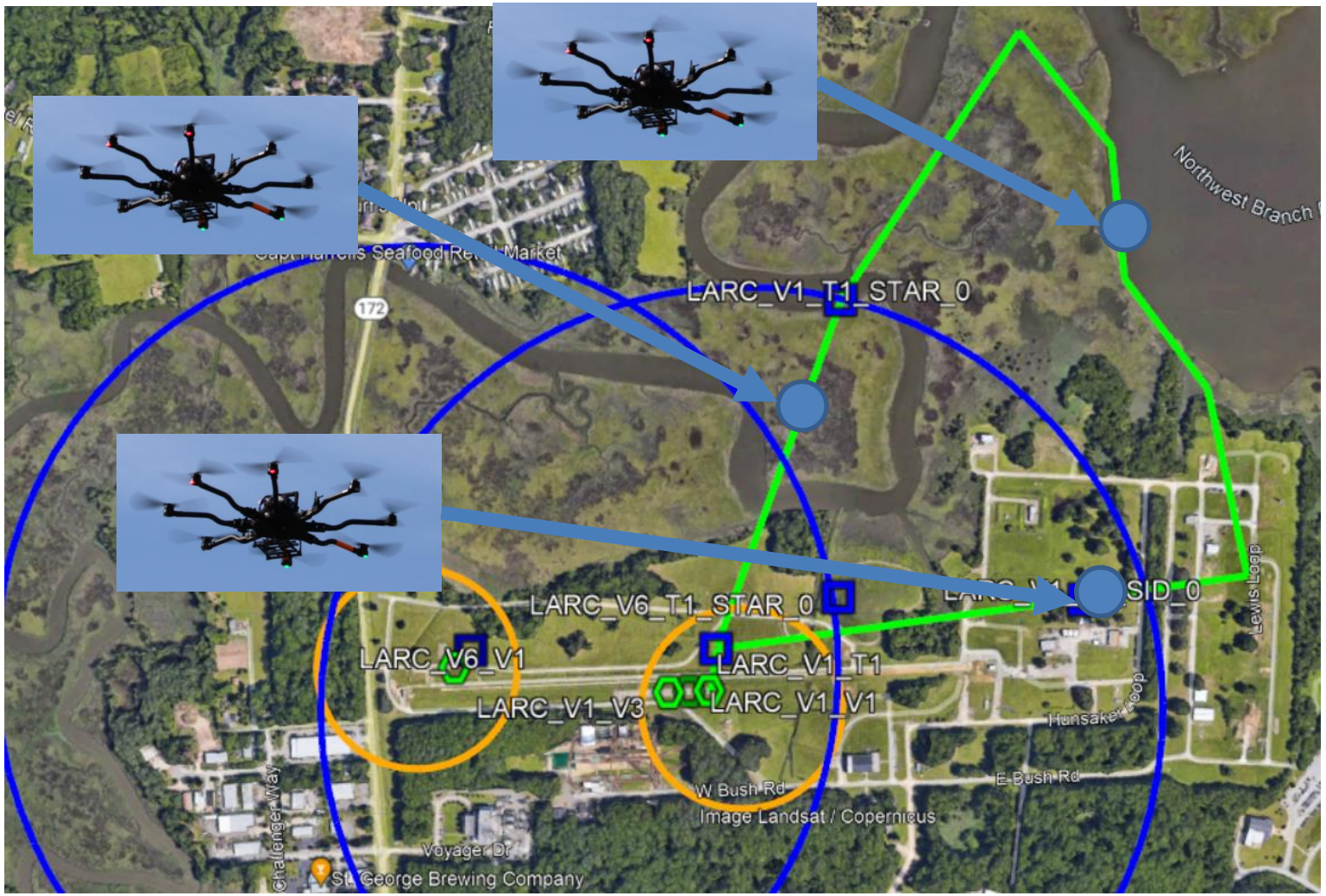
Vertiport 6

Schedule operations

Scenario 1 and 4a: Single and Triple aircraft

AOA Flight Test Completed 12 Flights for Triple Aircraft Operations:

- Scenario 1 (10)
- Scenario 4A (2)
  - Last vehicle in train performed re-route to Vertiport 6
- 3-minute separation
- Last scenario performed for AOA Flt



HDV AOA Summary

- AOA Sim and AOA Flt conducted
  - AOA Sim: Q1 FY-22, AOA Flt: Q3 Fy-22
- HDV reports in DASC 2022
  1. Glaab, L: *The High Density Vertiplex Advanced Onboard Automation Overview*
  2. Unverricht, J: *Eye Glance Behaviors of Ground Control Station Operators in a Simulated Urban Air Mobility Environment*
  3. Suzuki, A: *A Flight Replanning Tool for Terminal Area Urban Air Mobility Operations*
  4. Gaug, N: *Lightweight Surveillance and Target Acquisition Radar Characterization for High Density Veriplex Beyond Visual Line of Sight Operations*
  5. Hoddel, G: *Usability Evaluation of eXtensible Traffic Management Client*
- UAM Ecosystem prototype created
  - Onboard autonomous systems
  - Ground Control/Fleet Management.
  - Airspace Management Systems
  - MBSE modelling completed for HDV UAM Ecosystem
- Establishes environment for Vertiport Automation System development and testing
  - Scalable Autonomous Operations (SAO) SWP underway
  - SAO Sim Q2/Q3 FY-23
  - SAO Flt Q4 FY-23

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HDV Sizzle

Please contact Lou Glaab for video:
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