



*NASA Advanced Air Mobility (AAM) Project
High Density Vertiplex Sub-Project
Scalable Autonomous Operations(SAO) Prototype Assessment HHITL Sim/Flight Test
Jeff Homola: HDV Sub-Project Manager
Jake Schaefer: HDV Tech Lead*

September, 2023

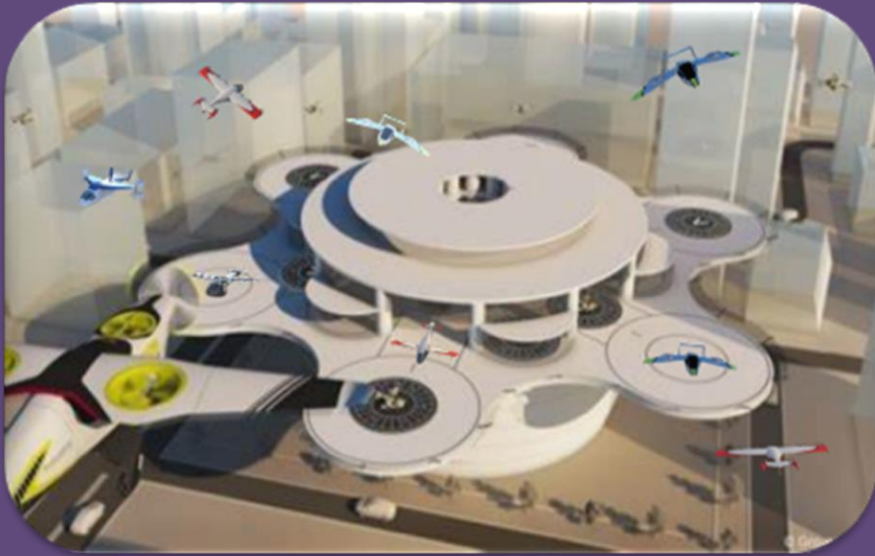


DroneUp Visit Agenda 20230913

1. Meet and Greet in B1268 2120 conf area.
2. Overview of HDV BVLOS Sim (Bryan Petty 15 mins)
3. Time in ROAM going through a few BVLOS Sim scenarios (30 mins)
4. DroneUp Operations and Plans (Andy Thurling, 60 mins)
5. HDV Overview and Plans (Lou Glaab, 30 mins)
6. Collaboration plans (60 mins)
7. ROAM show/follow-up with SAO Flt playbacks (30 mins/tbd as time permits)
8. Stop at CERTAIN R-1 (30 mins/tbd as time permits)



High Density Vertiplex



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.

Schedule Work Package (SWP) Goals:

- **Advanced Onboard Automation (AOA)**: Develop reference automation architecture prototypes, integration guidelines, and safety risk assessments that support increasingly autonomous and resilient operations.
- **Scalable Autonomous Operations (SAO)**: Develop and evaluate concepts, prototypes, procedures and technologies supporting operations at increased scale from a vertiport.
- **Vertiplex Operations (VO)**: Develop and evaluate concepts, procedures and technologies to evaluate system prototypes supporting high density operations in and out of multiple nearby vertiports.



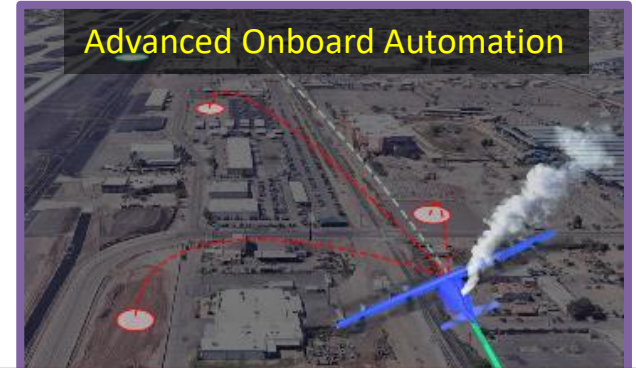
HDV Project Overview

- Two primary thrusts in HDV
 - Prototype and assess representative UAM Ecosystem UML-4
 - Focus on Vertiport Automation System
 - Perform testing and safety risk assessments to expand operations and achieve operational credit for NASA techs
 - sUAS BVLOS Operations
 - Provides valuable off-ramp to sUAS Part-135 operators
- Prototyping representative UAM Ecosystem includes:
 - 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 schedule work package is a spiral (~14 months)
 - Includes HHITL Sim
 - Subsequent flight test
 - Scalable Autonomous Operations (SAO) included vertiport automation system

HDV Schedule Work Packages

FY 21 to 22

Advanced Onboard Automation



FY 22 to 23

Scalable Autonomous Operations



FY 24 to 25

Vertiplex Operations





HDV UML-4 UAM (or UAS?) Ecosystem

Vertiport System

- Manage aircraft in Vertiport Operations Area
- Ensure safe operations

- Vertiport Automation System and Interface
- **Vertiport Manager**

- Representative Onboard Autonomous Systems
- No pilot onboard

Onboard Autonomous Systems



UAM Ecosystem Human Participants



Airspace Management

- PSU

- GCSO system and interface
- **Ground Control System Operator**
- Fleet Manager system and interface
- **Fleet Manager**

Ground Control Station / Fleet Management

Develop environment to support Vertiport Automation System design and UAM Ecosystem Prototype Assessment



HDV Integrated Test and Evaluation (Coast to Coast)

ROAM I/II UAS Ops Center (LaRC)

- Primary control stations
- Shared SA
- Data integration and distribution
- Sim or Flight

CERTAIN (LaRC)

- sUAS multi-vehicle
- Extended Visual Line of Sight ops
- BVLOS operations



Google Earth

AOL (ARC)

- Fleet manager
- ATM-X Provider of Services UAM interface
- Multi Aircraft Control System Sim

AVAL (ARC)

- Overall test quality monitoring
- Trial planning tool testing and development

SIVL Lab (LaRC)

- 6 DOF sim
- Autonomous system integration



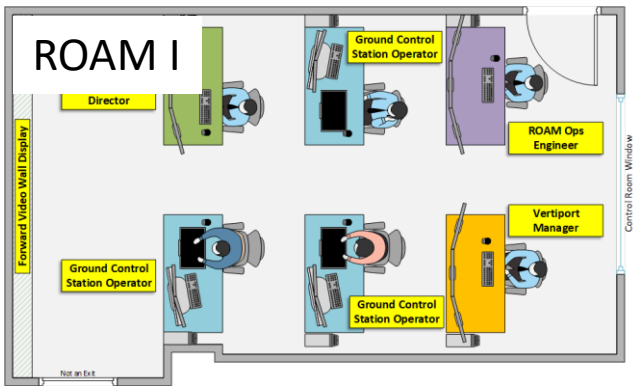
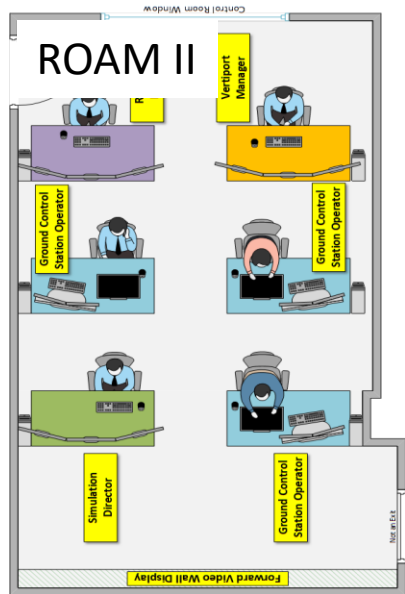
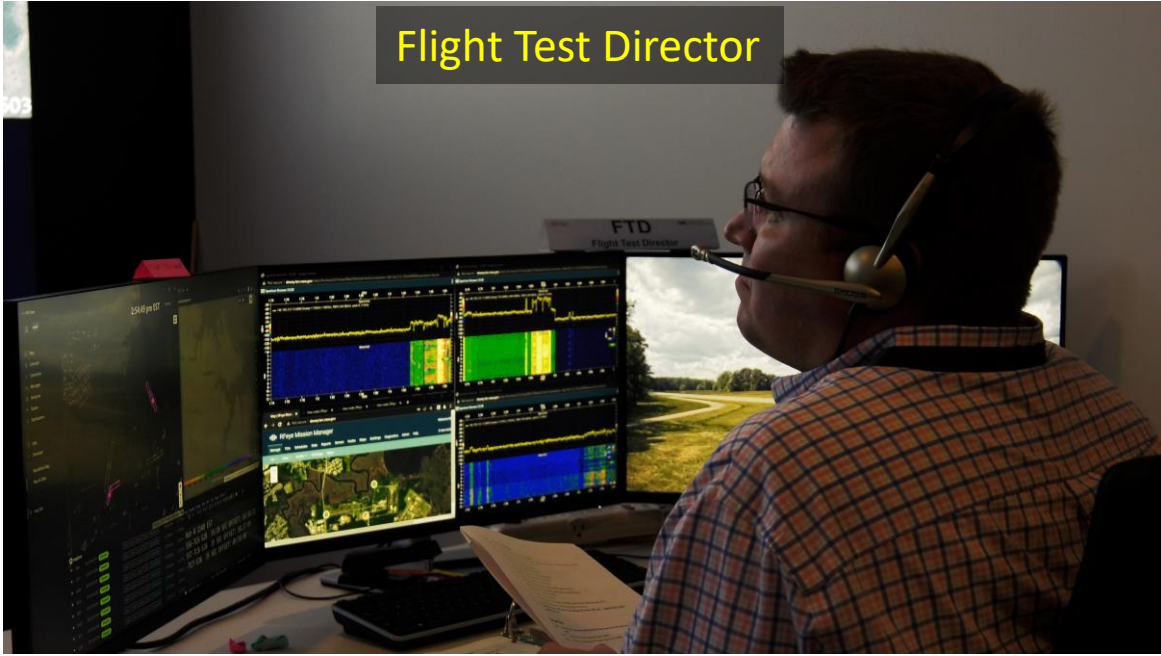
Fleet Manager Station (AOL)

- Monitors vehicles progress
- Receives messages from VM/VAS
- Issues speed change commands
- Performs trial planning to complete divers to nearby vertiport





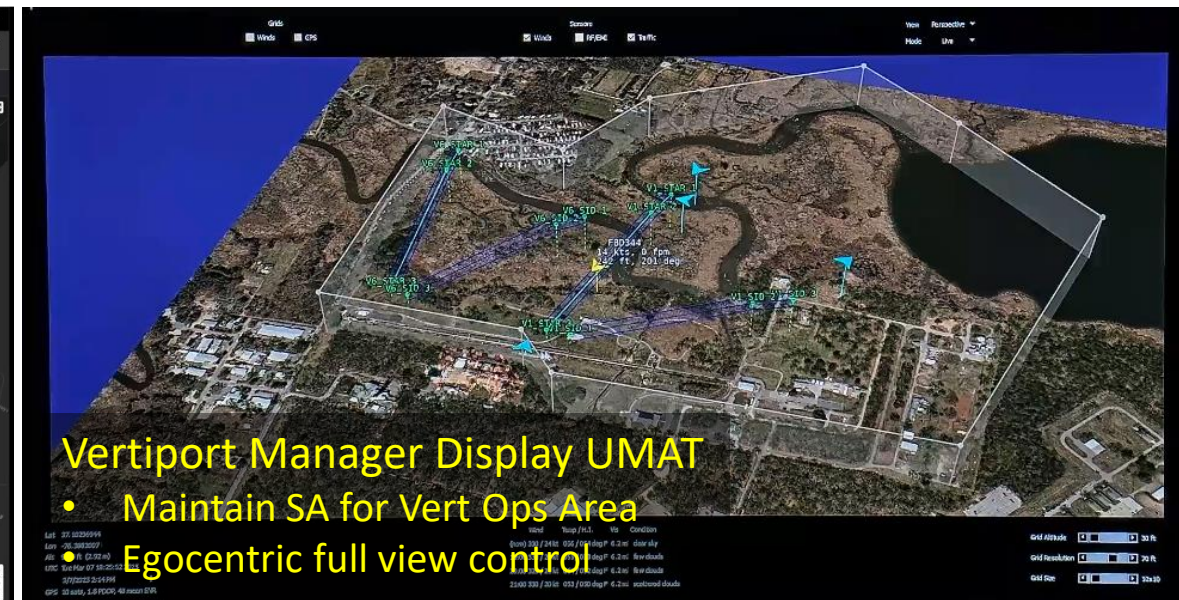
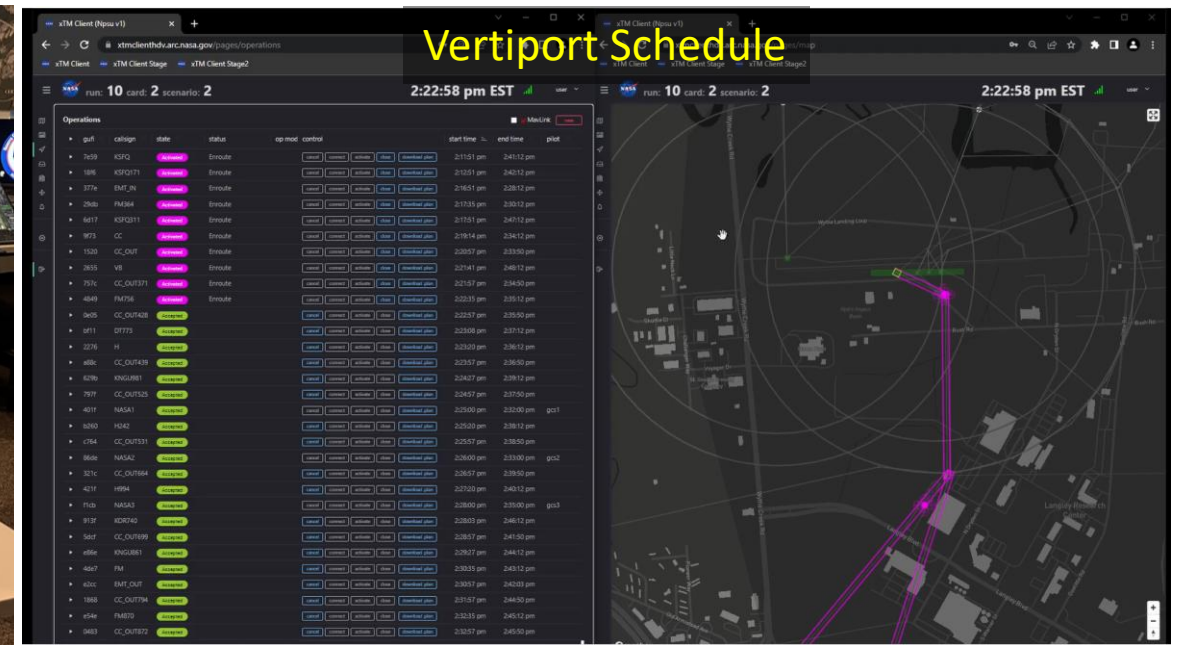
ROAM I/II Control Stations



- Also includes
- Range Safety Officer
 - Airspace Monitor



Vertiport Manager Displays and Controls (ROAM)





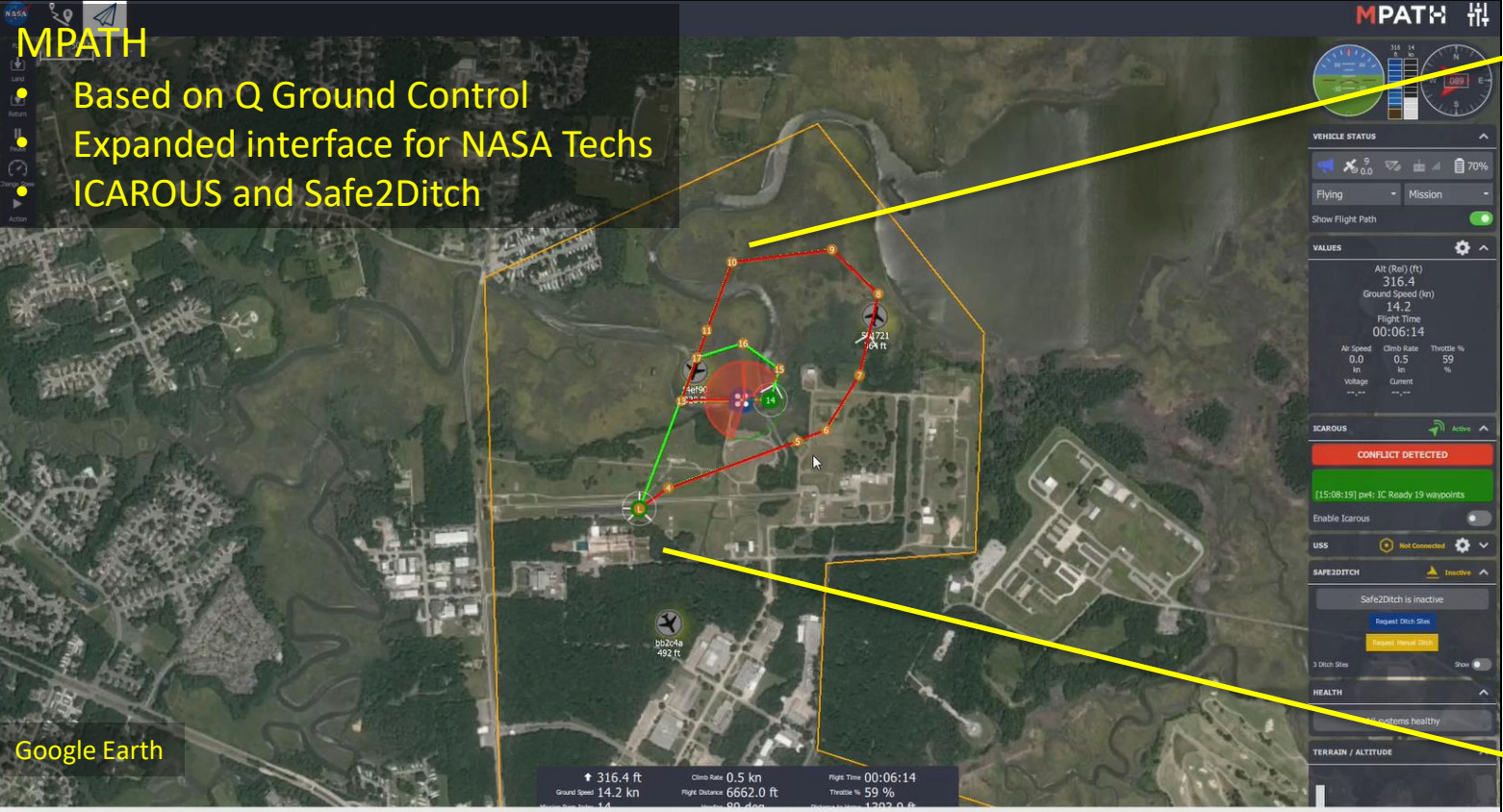
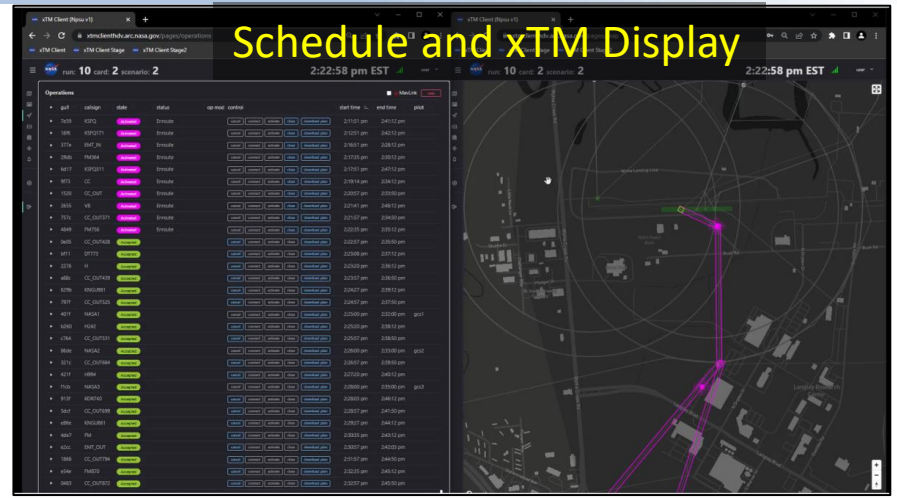
Vertiport Manager Traffic Monitoring Display



NASA bought terrain imagery



Ground Control Station Operator



Research/Test aircraft: Modified FreeFly Alta 8 Pro (5 aircraft)



- Configured to be representative UAM vehicles
- Includes: Autonomous DAA, V2V, Autonomous Safe Landing
- Operated in Extended Visual Line of Sight+ mode
- Pixhawk/PX-4
- Nvidia Xavier Mission Computer
- NASA Class-C software (MPATH, ICAROUS, S2D)



Langley sUAS Category	I
sUAS Type	Multi-Rotor, 8 Motor(Brushless)
Diagonal Length	52 in (1.3 m) *Does not include Props
Maximum Weight	40 lbs (18.14 kg)
Empty Weight	22.0 lbs (6.2 kg) *As shown in image
Propulsion Battery	6-cell Li-Poly (Nominal 22.2V)
Speed	0 – 30 kts (0-15.4m/s)
Max/MinEndurance	34/8 mins
Operating Frequency	2.4 GHz RC TX C2 900 MHz C2 & Flight Data 700MHz/1700MHz C2 & Flight Data & Video
Command and Control	RC TX Laptop
Replacement Cost	Approx \$20k



SAO PAO Scenarios Simulation and Flight

Scenario	Primary Contingency maneuver	Narrative Description
1	None	Nominal flight demonstrating 60 ops/hr
2	Speed Change	30 second arrival shift - Departing aircraft took off late, (but not a closure) - Vertiport Manager adjusts STA slot->FM speed change cmd>GCSO change speed
3	Missed Approach	Temporary vertiport closure for emergency inbound traffic. - VM->close vertiport to make room for emergency vehicle->FM req new slot new route->GCSO executes - Vehicle must execute missed approach and give way to emergency traffic
4	Speed Change	Temporary vertiport FATO closure (minor delay, <60 seconds) Vertiport Manager Temporarily Closes FATO with minor delay <1 mins (at least 1 vehicle impacted)
5	Divert	Temporary vertiport FATO closure (moderate delay, ~3 minutes) - Vertiport Manager Temporarily Closes FATO with moderate delay ~3 mins (Many vehicles impacted) - FM Trial Plan to V6->Send to GCSO to execute
6	MA + Divert + Speed Change	Temporary vertiport FATO closure (major delay, >3 minutes) - Vertiport Manager Temporarily Closes FATO with significant delay >3 mins (Many vehicles impacted) - GCSO initiate MA->FM Trial Plan to V6->GCSO executes re-route

Off Nominal

Key capabilities

FM: operations submissions and operations modification
Trial planning: rerouting and missed approach recovery
VM: schedule updating
GCSO: missed approach procedures

Key services

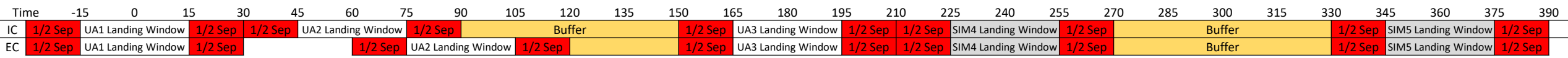
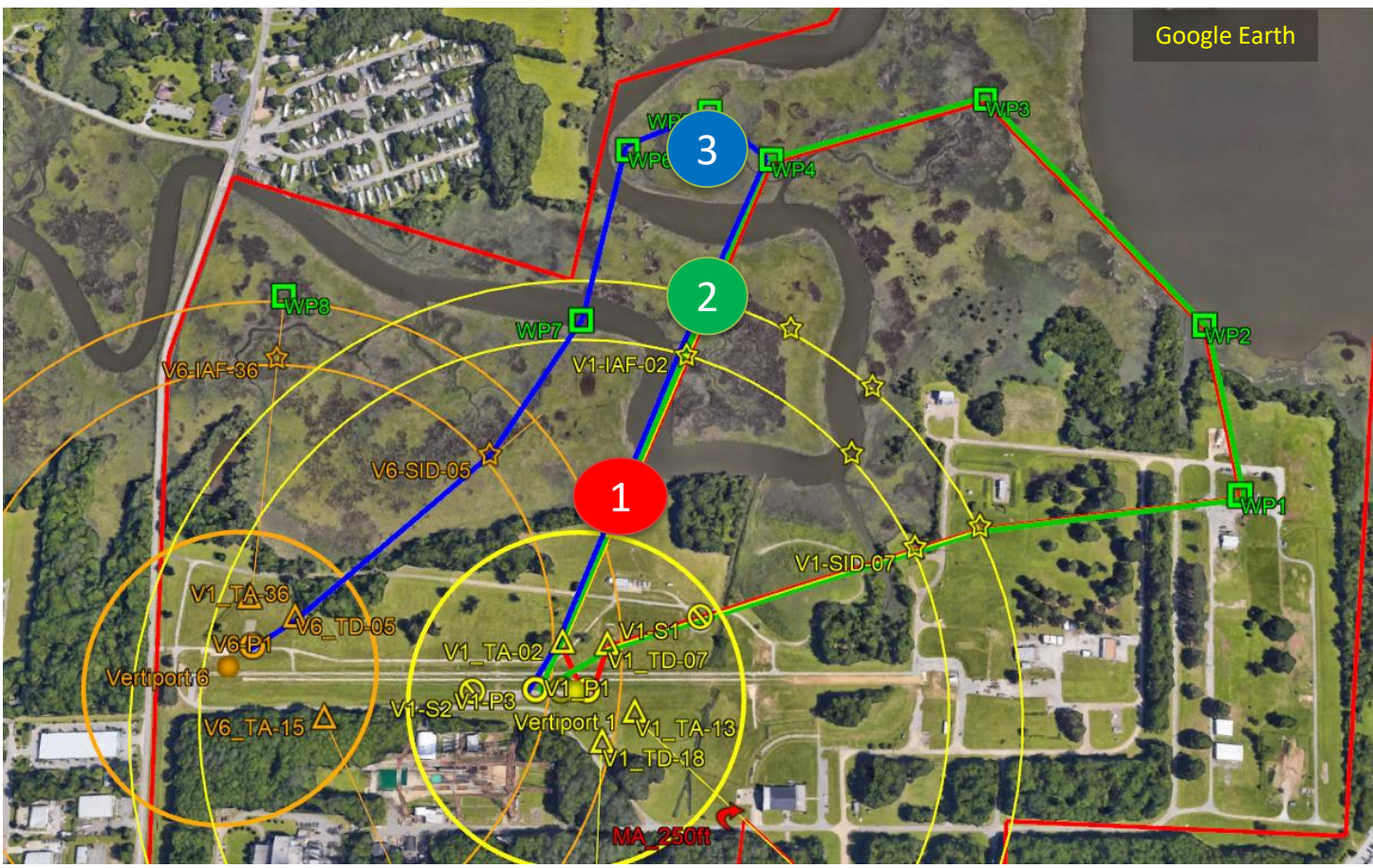
VAS: Scheduling
PSU: Operations planning and updates

[Ref: SAO Flt Test Plan.pptx](#)



Scenario 2: 30 second arrival shift

- Three vehicles flying into V1
- Departing aircraft took off late
 - Requires delay of inbound aircraft
- Vertiport requires 30 second shift in UA2's arrival
- Vertiport Manager **adjusts STA slot**
 - Fleet Manager speed change cmd
 - GCSO change speed for UA2
- UA2 slows down
- UA3 unaffected
- Can this be applied to UTM operations?
- Multi vehicle deliveries to a single area?



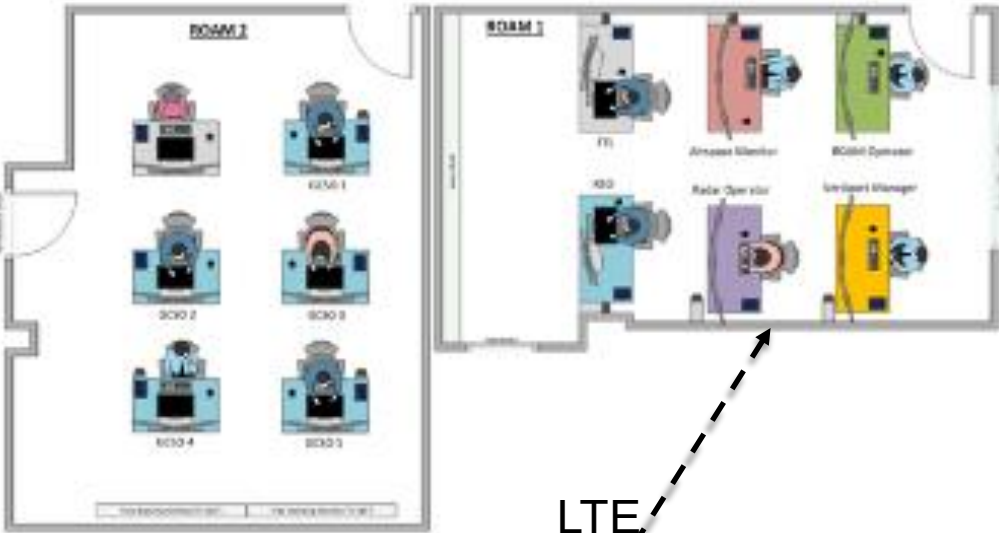
UA2 30 second slowdown

2.2 Overview of Command and Control Room



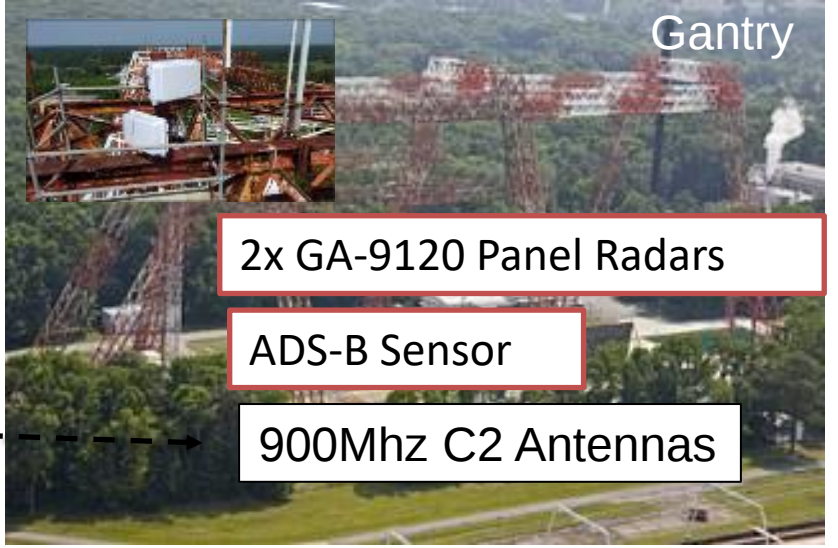
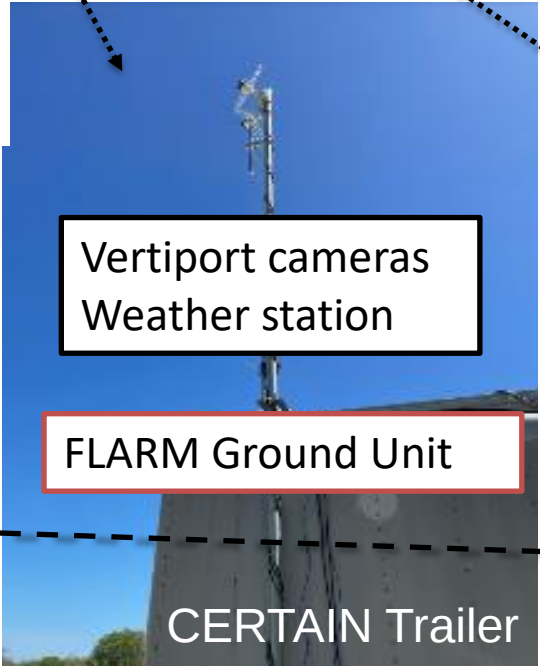
HDV Config 5.1 – Ground Systems

ROAM @B1268



All remote systems connect to ROAM via LarcNET

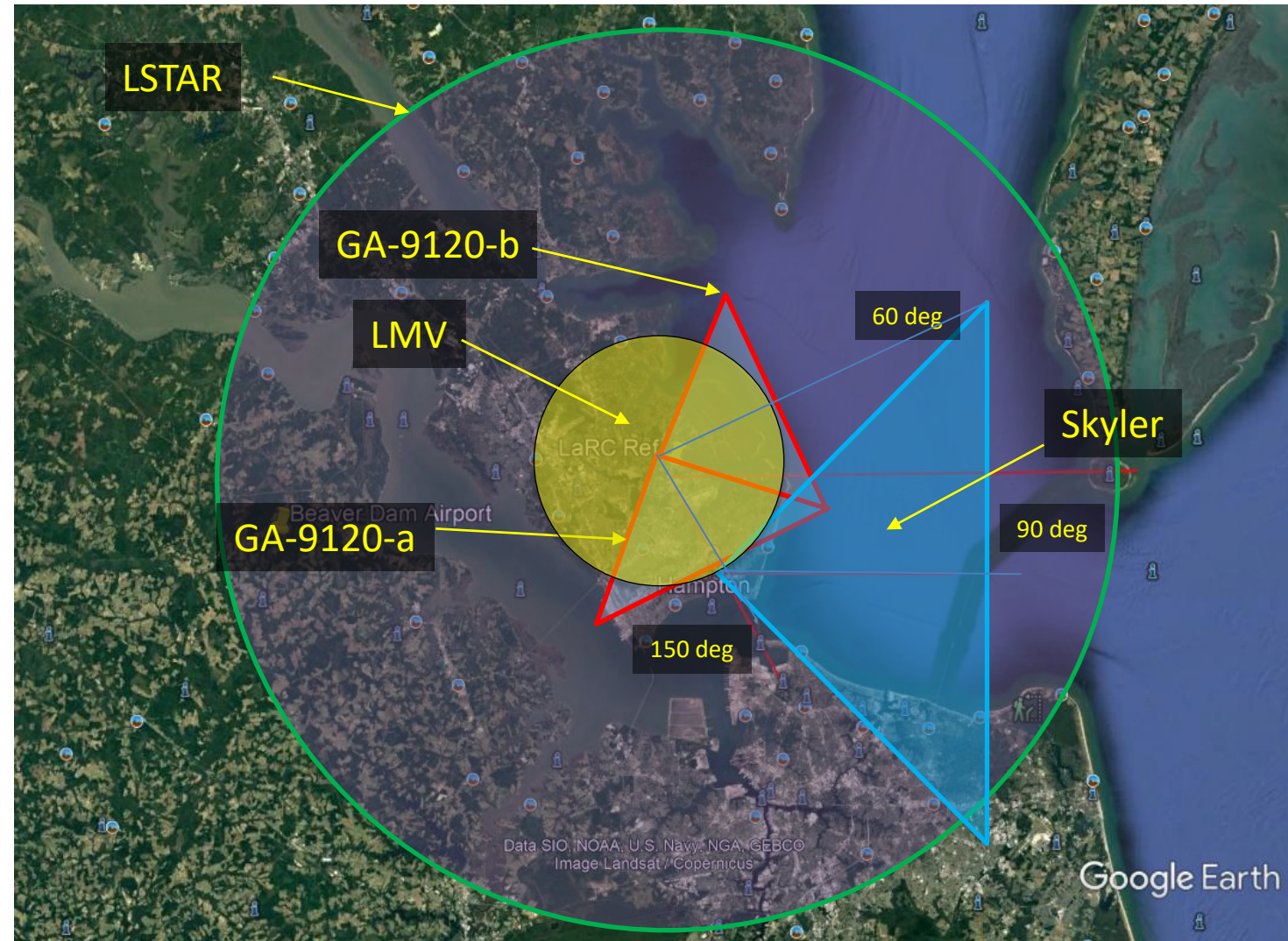
LTE





Approximate Integrated Radar Coverage

- LSTAR
 - 360 deg coverage
 - 1.2 to 1.3 GHz
 - 40 km (22 nm)
 - 360 Az, +30/0 El FOV
- GA-9120
 - 3 panels procured
 - 10 km range (5.4 nm)
 - 3.2 to 3.3 GHz
 - 120 deg Az, 12.5 El FOV
 - May procure additional panels
- Skyler 2
 - 1 panel available
 - 20 km range (11 nm)
 - 9 to 9.6 GHz
 - +/-60 deg Az, +/-20 deg El FOV
- Triple coverage in coastal Hampton area





Anra Common Operating Picture

- Traffic monitoring sources:
 - LSTAR radar system
 - Provides coverage out to ~20nm
 - Down to or below 1,000 ft AGL
 - GA-9120 radar system
 - Higher frequency
 - Coverage out to ~10nm
 - Raytheon Skyler radar
 - Longbow SAA
 - Located in downtown Hampton via HDV/NASA IoT
 - uAvionix Ping III ADS-B
 - Provides info about cooperative air traffic
 - Multi lateration
 - Flight Alarm in (FLARM)
 - sUAS V2V
 - Redundant position info
- Anra Smart Skies CTR system for traffic fusion/display
- Extensive system integration and testing completed over last ~12 months



HDV Real No-VO BVLOS Flight Path

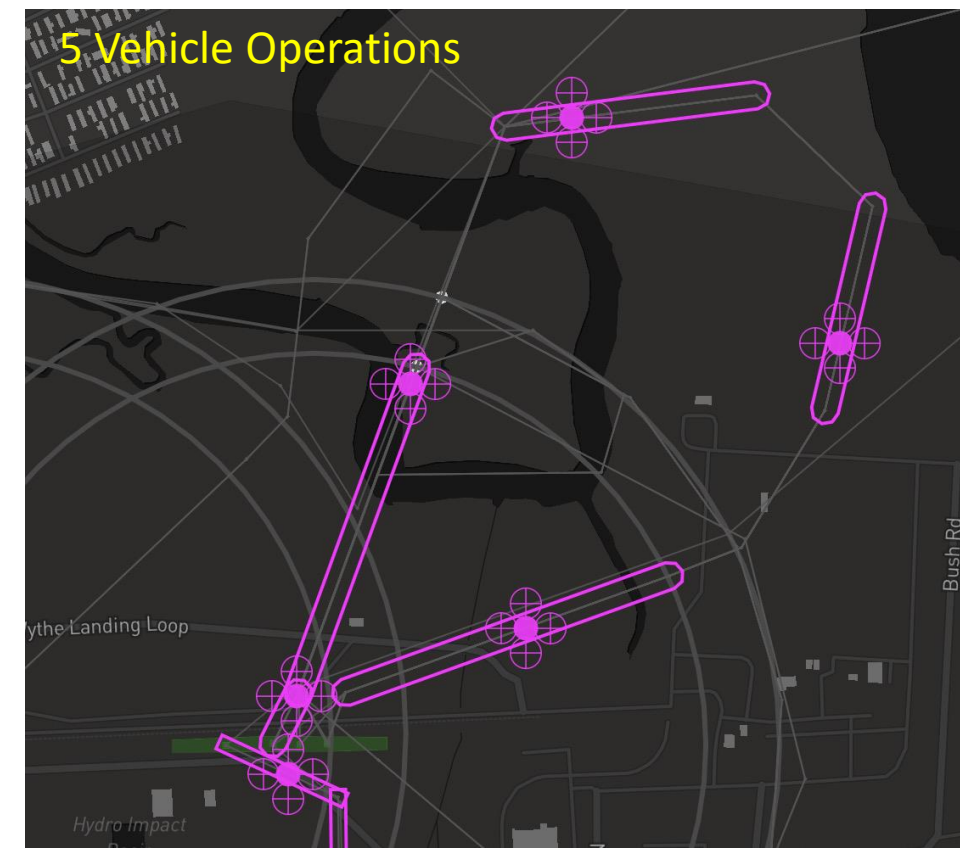
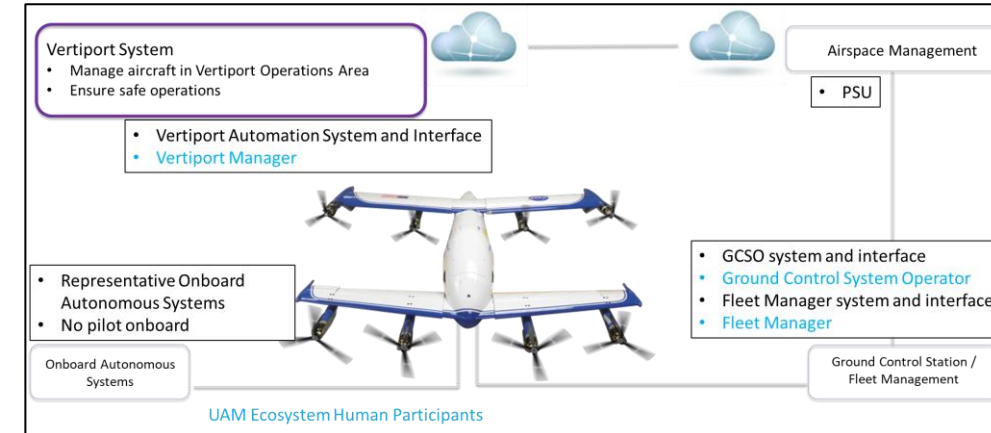
- Primary limits
 - Below 300 ft in 30 seconds
 - On the ground in 2 mins
 - 30 kts RTL cruise
 - 4 kts descent
- Expansion requires additional landing zones
 - Camera coverage
 - Manned
 - Or Safe2Ditch
- Camera locations
 - Vertiport 2
 - Vertiport 1
 - Vertiport 6





SAO PAO Status and Summary

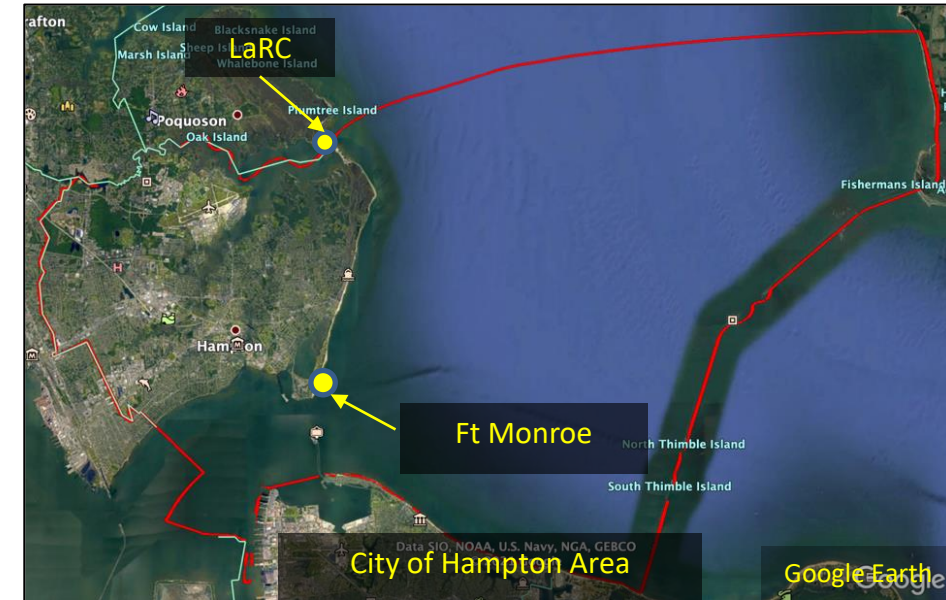
- Prototype UAM Ecosystem established
 - Onboard autonomous systems
 - Ground Control/Fleet management
 - Airspace management systems
 - Vertiport Automation System (VAS)
- SAO simulation completed in March
 - 3 Fleet Managers (FMs)
 - 3 Vertiport Managers (VMs)
 - 9 Ground Control Station Managers (GCSOs)
- SAO Flight Test completed
 - 3 FMs, 3 VMs, 9 GCSOs completed
 - Mix of 2, 3, and 4 vehicle operations
 - 5 vehicle ops performed 6/7
 - Several reports going to SciTech in Jan
 - HDV VIP event on 7/14
- SAO BVLOS flights planned for September
 - GCSO PICs completed training (5)
 - 91.113 waiver approved 6/12
 - No-VO BVLOS COA received effective 8/22/2023
 - NASA Flight Safety Release received 9/14 (fingers crossed)
- Planned Vertiplex Operations cut from program
 - Establish SmartVAS
 - Real-time sensors with integration to UAM Ecosystem





Proposed Maritime Surveillance Reference Mission

- Use-Cases and Market Review
 - Drones as First Responders
 - Coastal Search and Rescue
 - Emergency Response Operations
- Perform NASA/**Industry** Tech Transfer/Demonstration
 - **UAS Traffic Management (UTM) system (3PSP)**
 - Safe2Ditch autonomous safe landing
 - ICAROUS autonomous sense and avoid
 - Ground Risk Assessment Service Provider (GRASP)
 - SWS health monitors
- Leverage progress achieved in HDV BVLOS
 - Surveillance systems, BVLOS Safety Case, ROAM, C2 links (uAvionix C-Band)
- System integration, testing and safety risk assessment (SRA) for actual use cases is missing for tech transfer
 - Key for FAA RTT progress and ARC report
- Comprehensive testing and SRA are provided by the Maritime Surveillance Reference Mission
- SAA with Longbow, Raytheon, City of Hampton, Hampton U



Supervolo is rain-tolerant, long endurance

ICAROUS: Integrated Configurable Architecture for Reliable Operations of Unmanned Systems



Pivot Transition to UTM BVLOS

- Look to understand DroneUp operations and challenges
 - WalMart National Ops
 - Key Site activity (24, 25, 26, etc)
- Explore leveraging existing results going forward
 - Existing HDV SAO work
- Potential tests and evaluations to expand DroneUp ops
 - Weather system integration
 - Off nominal UTM BVLOS operations
 - GCSO PIC training
 - m:n>1 operations test and eval
 - Integrated Detect and Avoid (GBSS, ADS-B, V2V, Acoustic, Optical)
 - F3442 eval/revision/update
 - Integration of DroneUp vehicles into NASA Ops
 - Ground Risk Assessment Program integration
 - Autonomous Safe Landing (Safe2Ditch)
 - Wide Area Hazard Locator for Drone Overflight (WAHLDO)





BACKUP



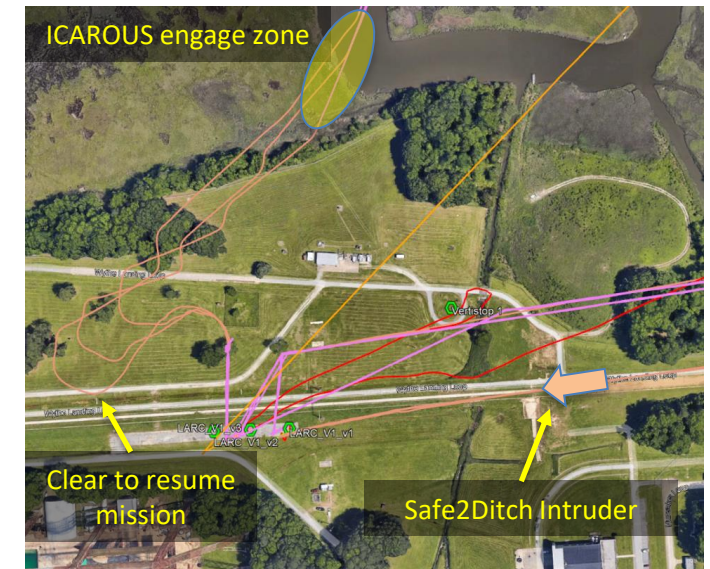
Onboard Autonomous Systems Overview

- Onboard Autonomous Systems
 - Integrated Core Flight Systems (CFS) architecture
 - Resides on Xavier computer
 - Interfaces with autopilot
- Safe2Ditch
 - Selects best/closest location based on size and risk database classification
 - Verifies location is safe to land through machine vision
 - Re-routes to next ditch site if motion detected in primary
 - Provides autonomous safe landing
 - Essential to support aborts within required time
 - 30 seconds below Gantry alt
 - 2 minutes to the ground
- ICAROUS
 - Provides deconfliction for detected traffic aircraft
 - Used to provide collision avoidance during link loss with the sUAS
 - Trigger aborts for unseen/surprise traffic encounters
 - Provides the route to take for traffic avoidance and S2D re-routing
 - Includes Class-C Geofence capability
 - Conforms to DAA DO-365 MOPs
 - **Updated to integrate multiple traffic sources including ground-based radar inputs**

Safe2Ditch



ICAROUS (AOA Flt Test)





WAHLDO

- Uses Machine Vision to monitor a Vertiport (or other area)
- Can be used to ensure safe autonomous landings





Airspace Operations Laboratory (AOL)

Fleet Operations



Conference Room



- Management of fleet operations
 - Fleet Manager participant position
 - Simulation controls of fleet traffic
- Multiple configurable displays of airspace and traffic management information
- Researcher observation and questionnaire administration
- Data management

- Conference area for Research Coordinator observation and communication with LaRC
- Multiple configurable engineering displays for assessment of test performance and data capture
- Dedicated workstations for recording of data and archive management

Five Vehicle Operations





SAO Integrated Architecture Elements



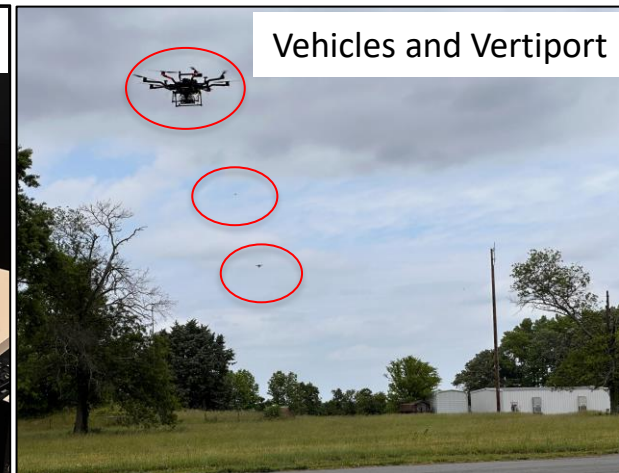
5 total



Vehicles and Onboard Automation

ARC

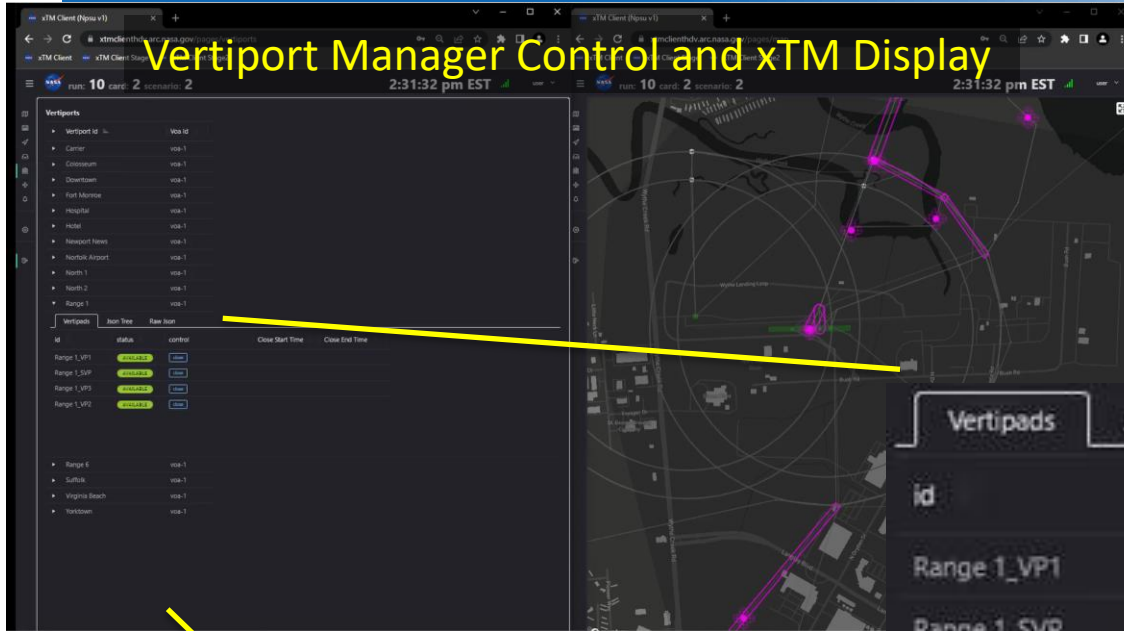
LaRC





Vertiport Manager Controls

Vertiport Manager Control and xTM Display



Expanded View of VM Control Interface

- Open/close vertipads
- Select expected reopening time

id	status	control	Close Start Time	Close End Time
Range 1_VP1	AVAILABLE	close		
Range 1_SVP	AVAILABLE	close		
Range 1_VP3	AVAILABLE	close		
Range 1_VP2	AVAILABLE	close		
Range 6				
Suffolk				
Virginia Beach				
Yorktown				