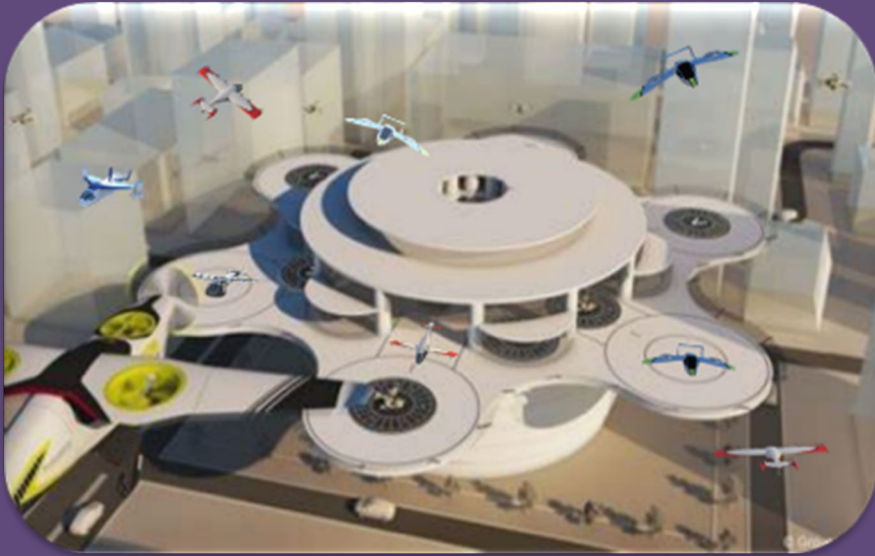




*NASA Advanced Air Mobility (AAM) Project
High Density Vertiplex Sub-Project
Scalable Autonomous Operations(SAO) Prototype Assessment HHITL Sim/Flight Test*



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.



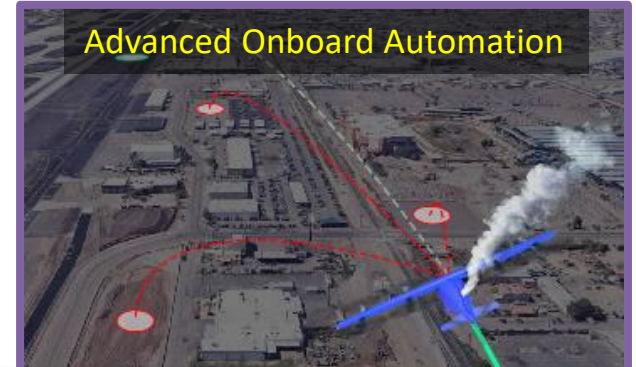
HDV Project Overview

- 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 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
 - Acquire essential results to inform future research investments
 - 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

Advanced Onboard Automation



FY 22 to 23

Scalable Autonomous Operations



FY 24 to 25

Vertiplex Operations





HDV UML-4 UAM 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

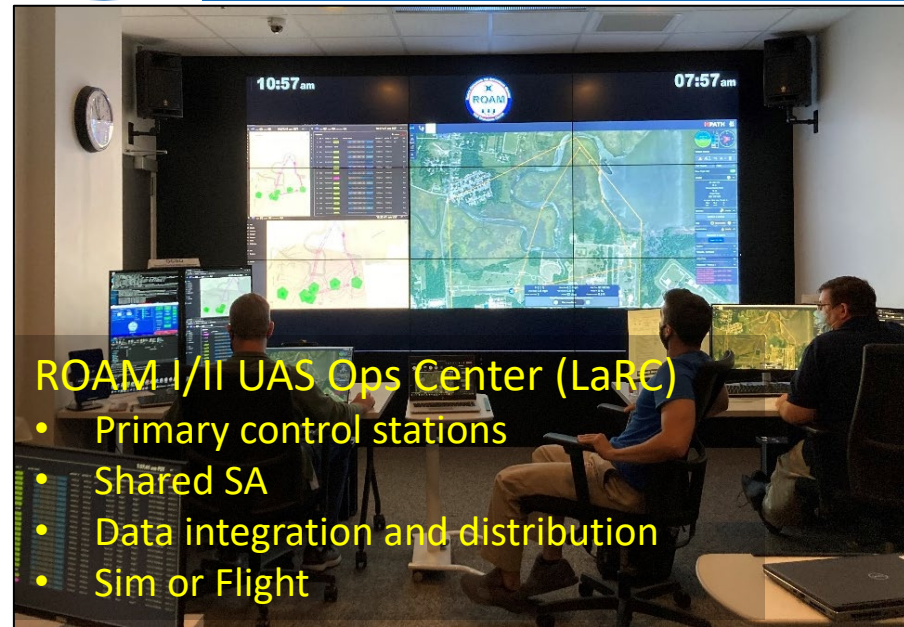
- GCSO system and interface
- **Ground Control System Operator**
- Fleet Manager system and interface
- **Fleet Manager**

Ground Control Station /
Fleet Management

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



HDV SAO Simulation and Flight Testing (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



1



2



3



4



5



AOL (ARC)

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



SIVL Lab (LaRC)

- 6 DOF sim
- Autonomous system integration

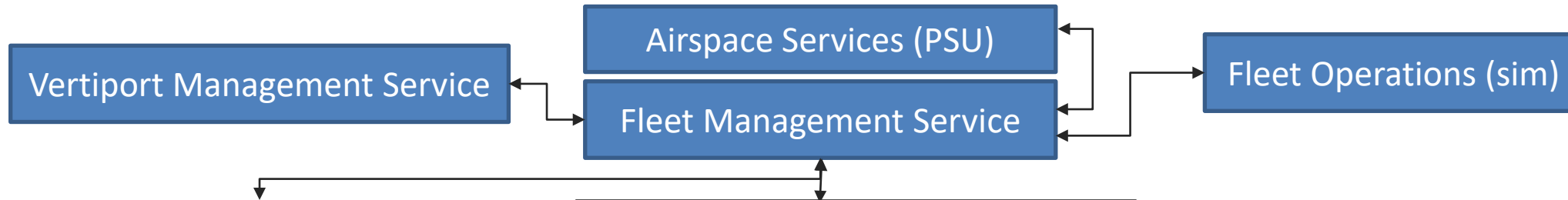


AVAL (ARC)

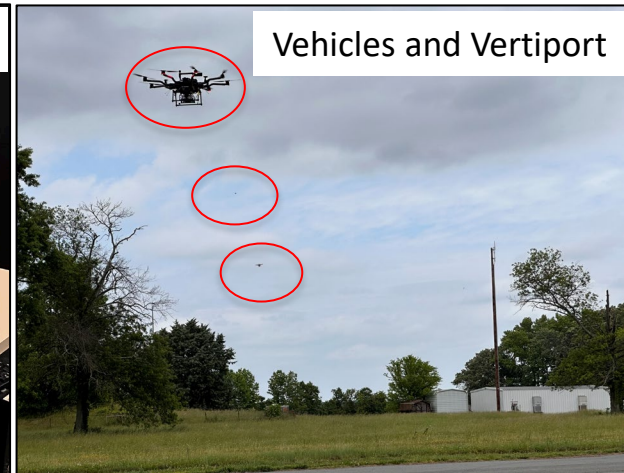
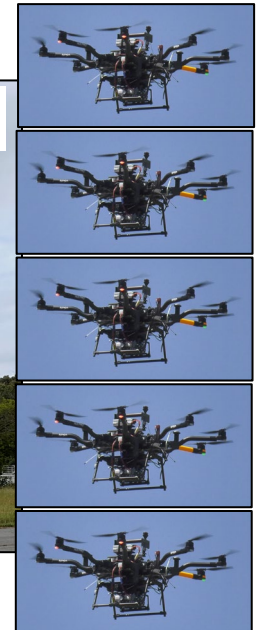
- Overall test quality monitoring
- Trial planning tool testing and development



SAO Integrated Architecture Elements



5 total

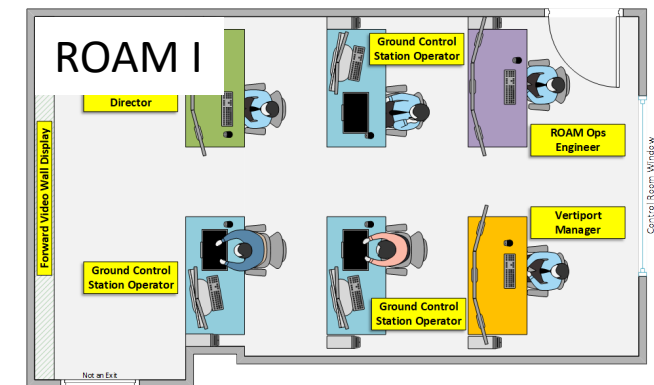
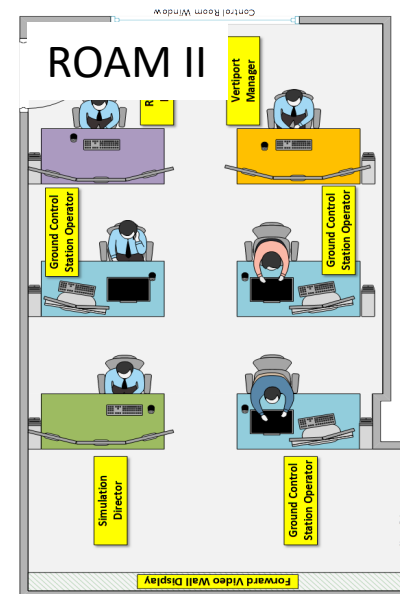


ARC

LaRC



ROAM I/II Control Stations



Also includes

- Range Safety Officer
- Airspace Monitor



Airspace Operations Laboratory (AOL)

Fleet Operations



Conference Room

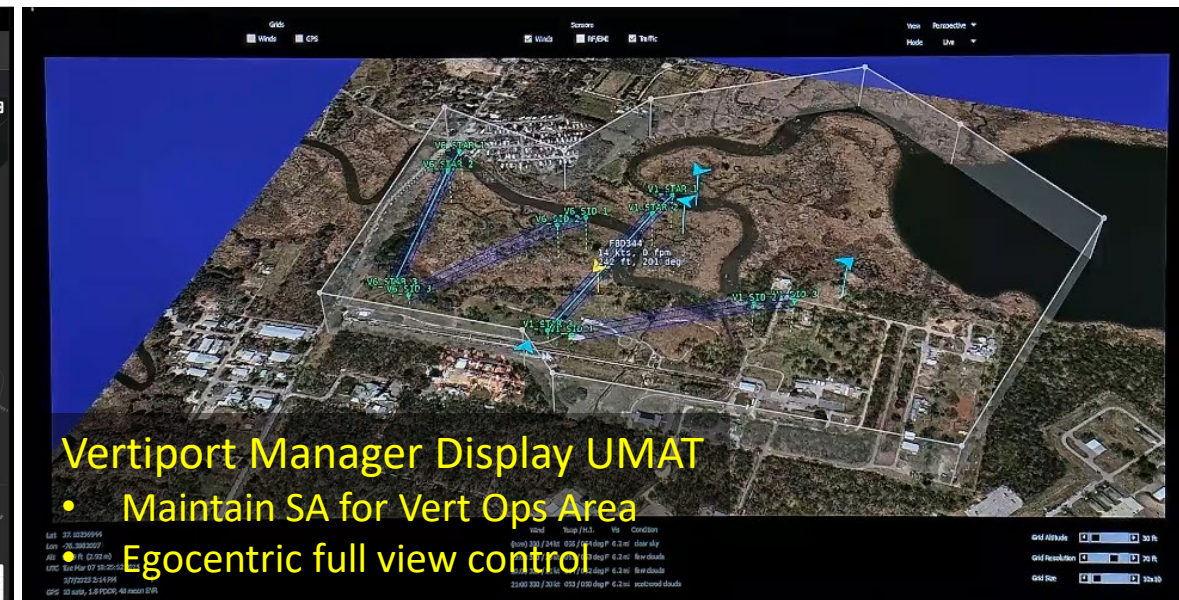
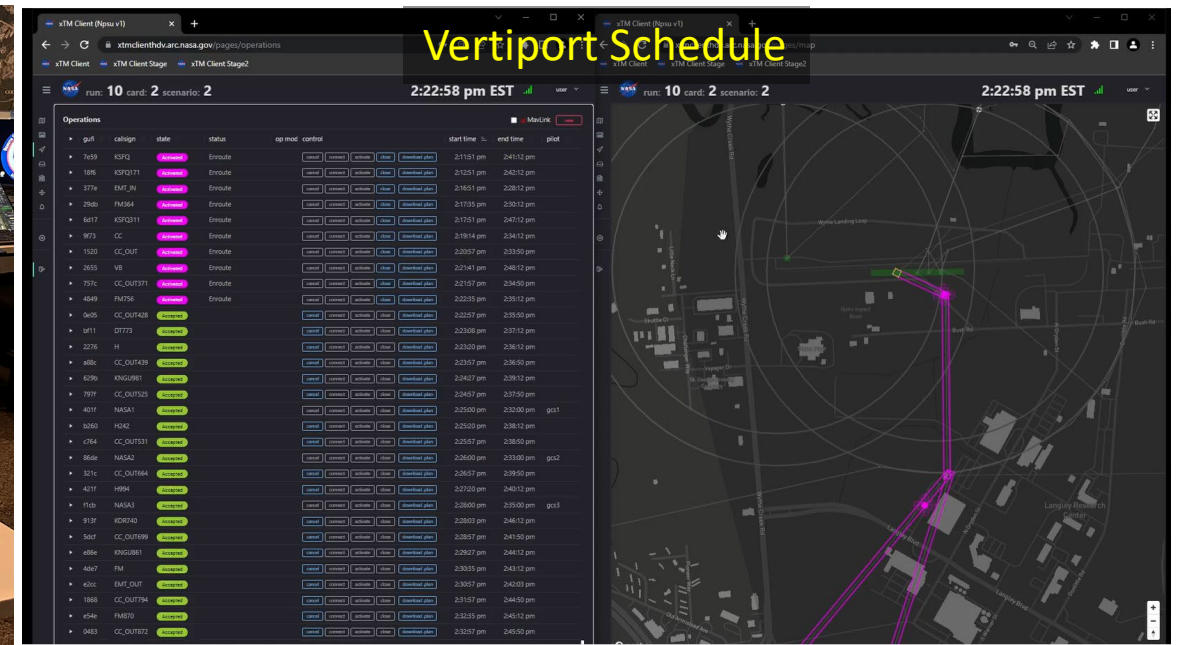


- Management of fleet operations
 - Fleet Manager participant position
 - Simulation controls of fleet traffic
- Multiple configurable displays of airspace and traffic management information
- Researcher observation and questionnaire administration
- Data management

- 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



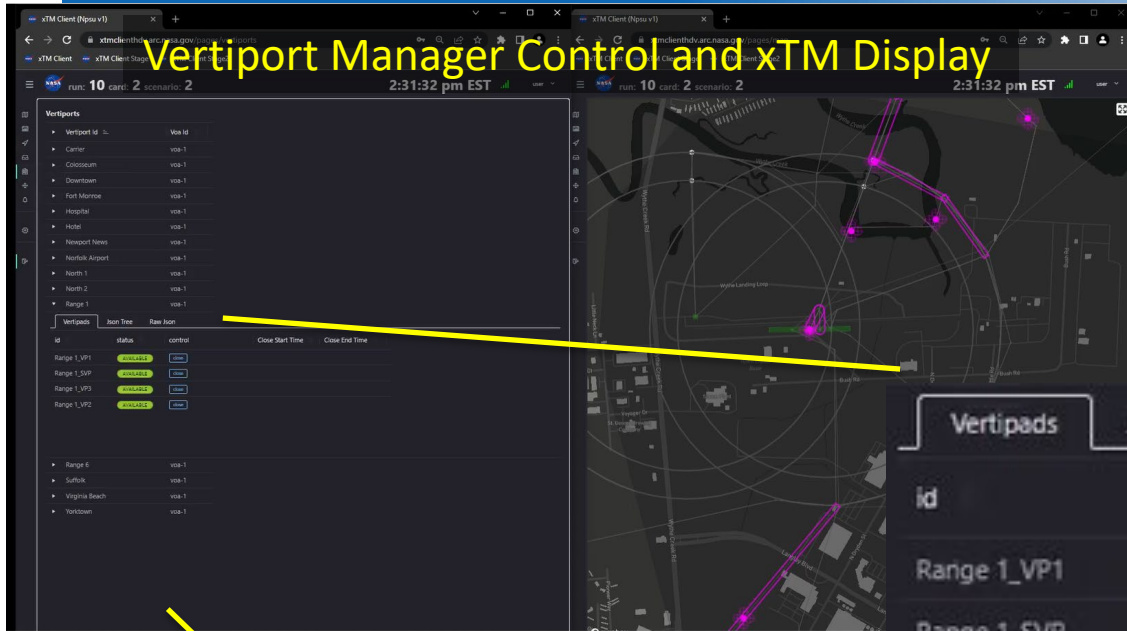
Vertiport Manager Displays and Controls (ROAM)





Vertiport Manager Controls

Vertiport Manager Control and xTM Display



Expanded View of VM Control Interface

- Open/close vertipads
- Select expected reopening time

Expanded View of VM Control Interface

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	voa-1
▶ Suffolk	voa-1
▶ Virginia Beach	voa-1
▶ Yorktown	voa-1



Fleet Manager Station (AOL)

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

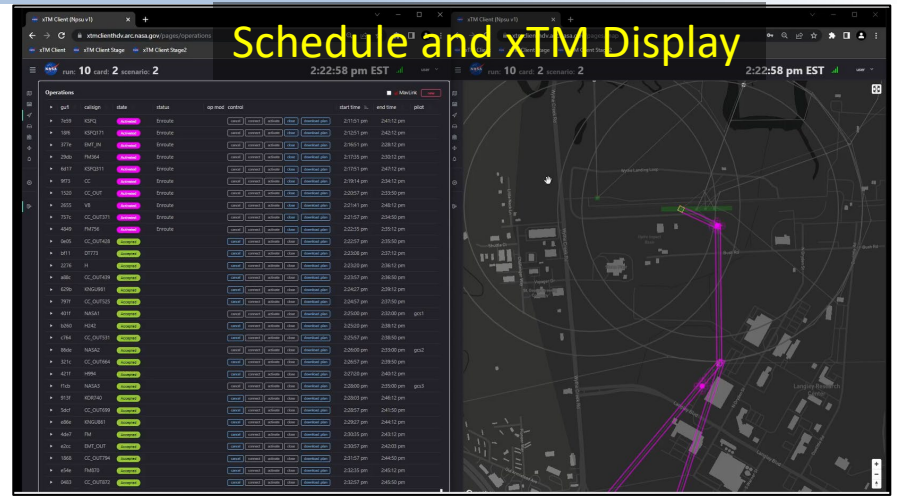




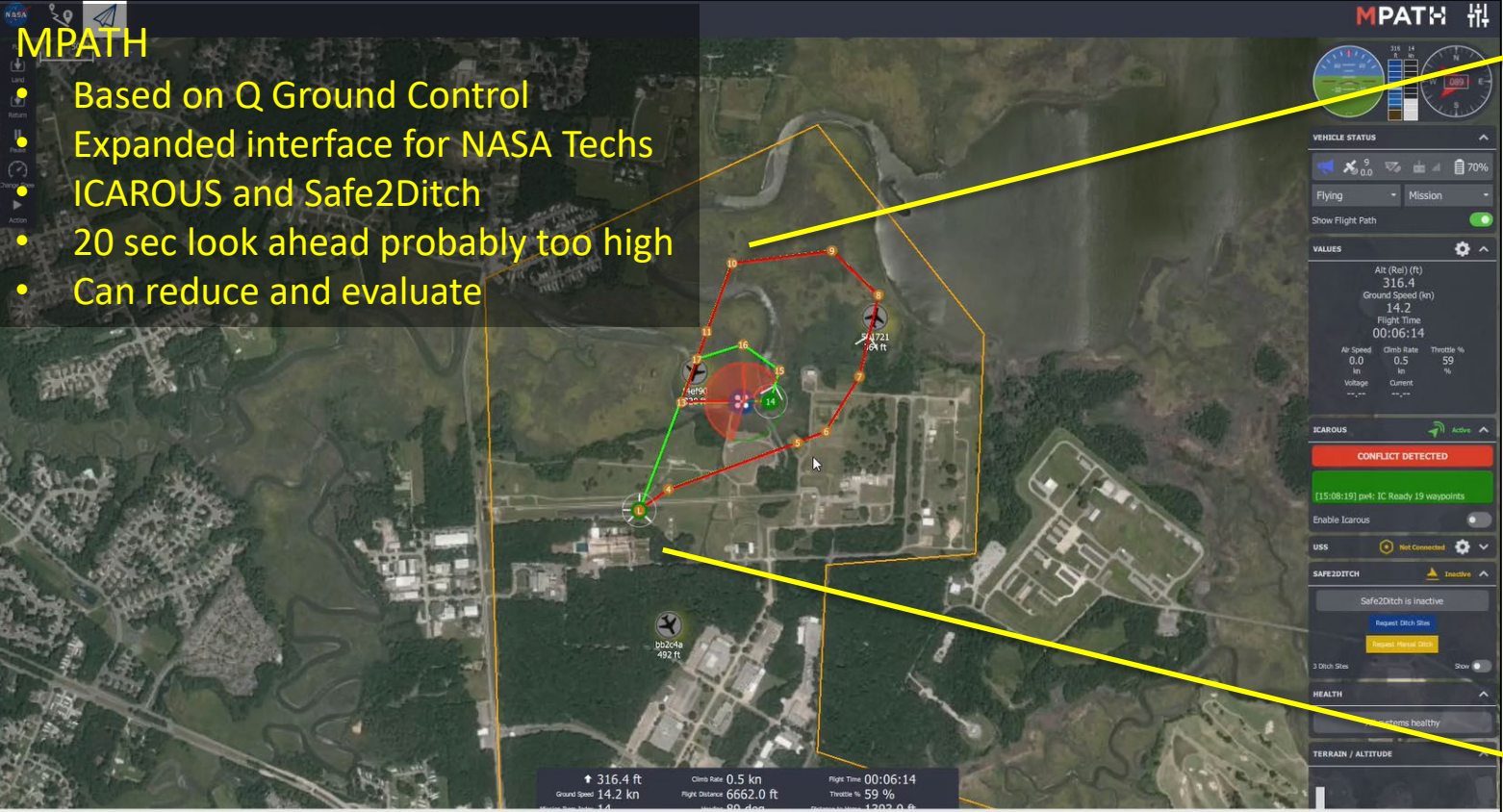
Ground Control Station Operator



Ground Control Station

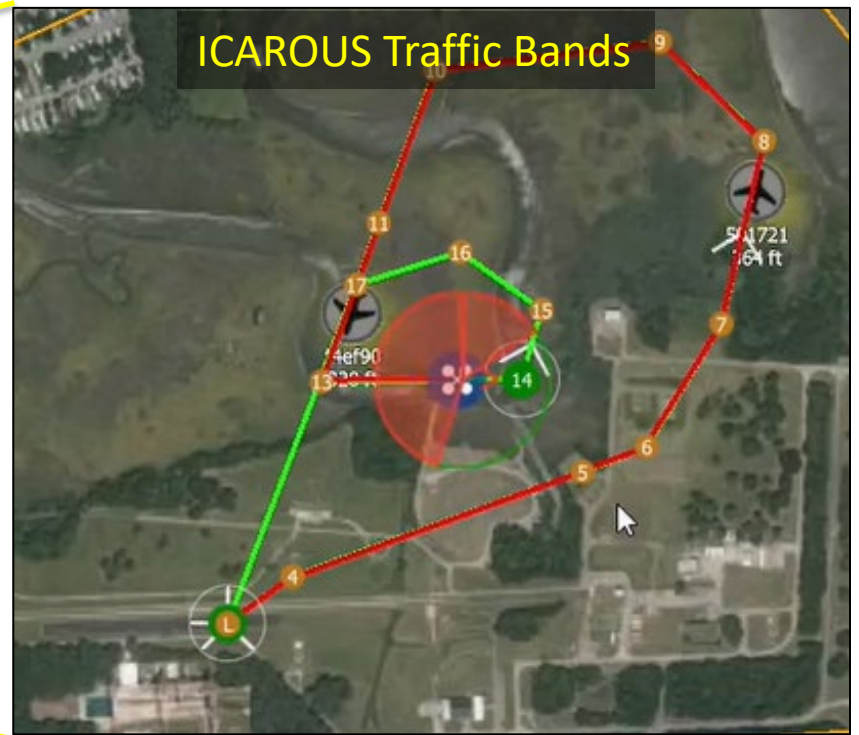


Schedule and xTM Display



MPATH

- Based on Q Ground Control
- Expanded interface for NASA Techs
- ICAROUS and Safe2Ditch
- 20 sec look ahead probably too high
- Can reduce and evaluate



ICAROUS Traffic Bands

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



- Configured to be representative UAM vehicles
- Includes: Autonomous DAA, V2V, and Autonomous Safe Landing
- Operated in Extended Visual Line of Sight+ mode



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

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

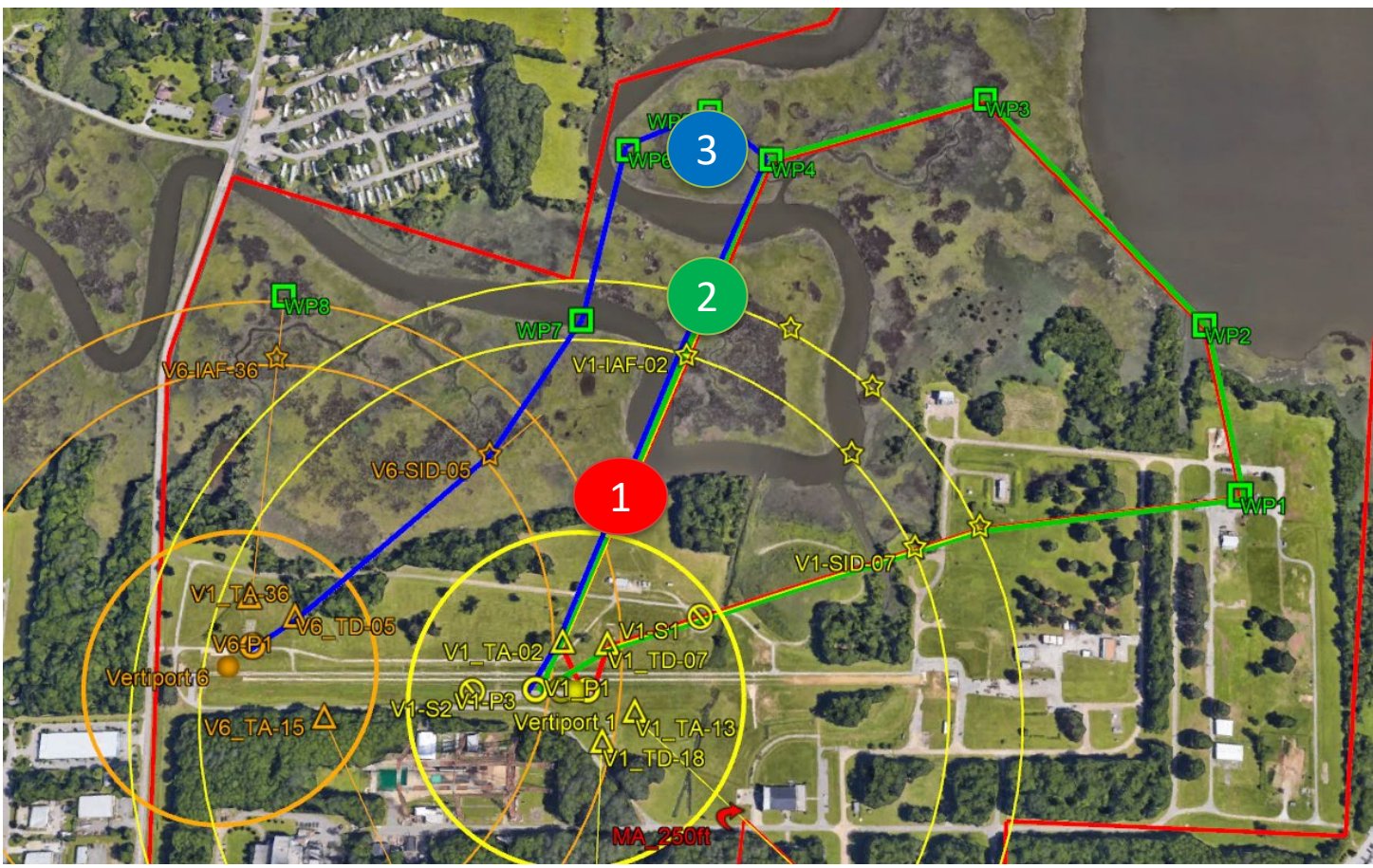
PSU: Operations planning and updates

[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



Time	-15	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375	390
IC	1/2 Sep	UA1 Landing Window	1/2 Sep	1/2 Sep	UA2 Landing Window	1/2 Sep	Buffer					1/2 Sep	UA3 Landing Window	1/2 Sep	1/2 Sep	SIM4 Landing Window	1/2 Sep	Buffer					1/2 Sep	SIM5 Landing Window	1/2 Sep			
EC	1/2 Sep	UA1 Landing Window	1/2 Sep		1/2 Sep	UA2 Landing Window	1/2 Sep		1/2 Sep	UA3 Landing Window	1/2 Sep	1/2 Sep	SIM4 Landing Window	1/2 Sep		Buffer		1/2 Sep	SIM5 Landing Window	1/2 Sep								

UA2 30 second slowdown



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 (FM)s
 - 3 Vertiport Managers (VM)s
 - 9 Ground Control Station Managers (GCSOs)
- SAO Flight Test underway
 - 2 FM)s, 2 VM)s, 6 GCSOs completed
 - Mix of 2, 3, and 4 vehicle operations
 - 5 vehicle ops planned for 6/7
 - Several reports going to SciTech in Jan
- SAO BVLOS flights planned for August
 - Transition GCSOs to be GCSOs PICs
 - Engage airspace surveillance system
 - LSTAR/ADS-B/FLARM->Anra SS CTR
 - Remove visual observer
- Vertiplex Operations FY24/25
 - Establish SmartVAS
 - Real-time sensors with integration to UAM Ecosystem

