National Aeronautics
and Space Administration

Advanced Air Mobility (AAM): Overview and Integration Considerations

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National Aeronautics and Space Administration

Presentation Outline:

I. Overview of AAM

II. Airspace Integration Considerations

III. Airport/Vertiport Integration Considerations

IV. Closing Thoughts

Disclaimer: any opinions expressed in this presentation are solely those of the presenter and do not necessarily reflect the views of the US Government or NASA

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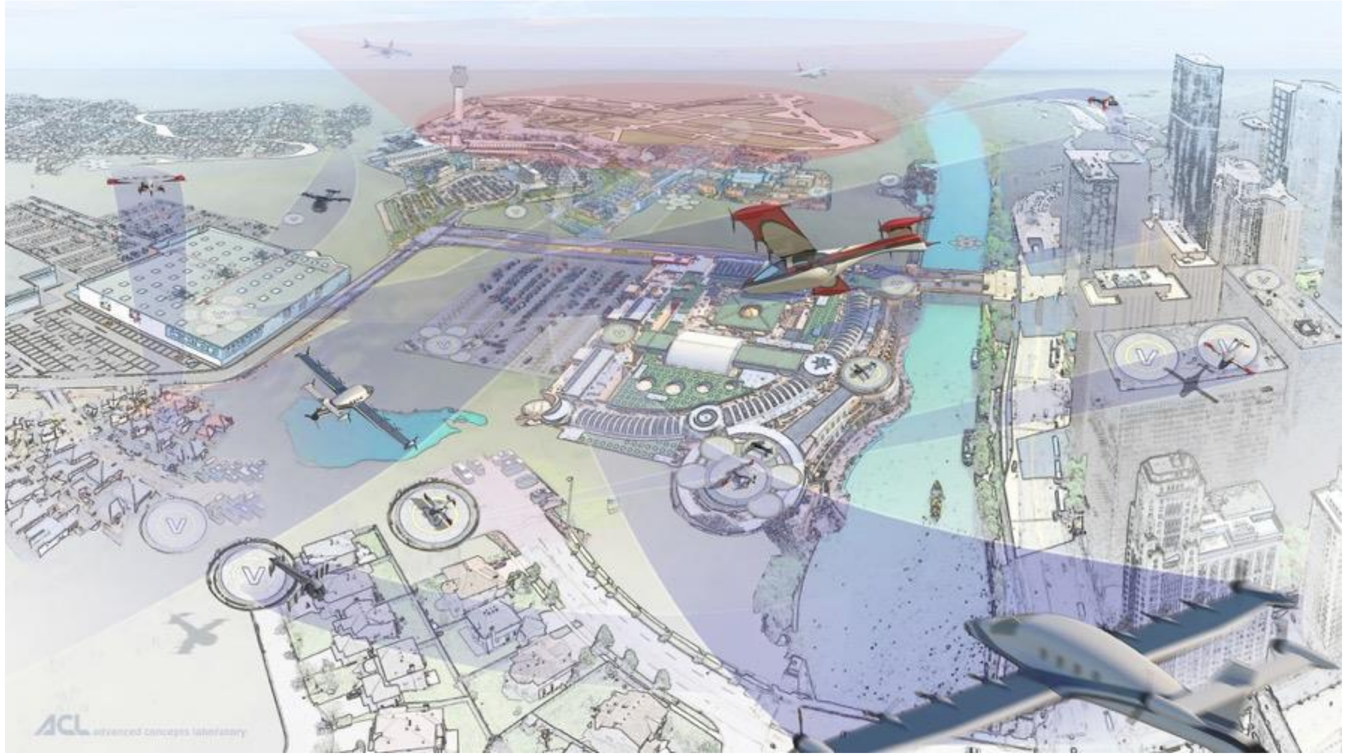
Overview of AAM

Advanced Air Mobility (AAM) Vision

Safe, sustainable, affordable, and accessible aviation for transformational local and intraregional missions

Advanced Air Mobility (AAM): Bringing Aviation into Daily Life

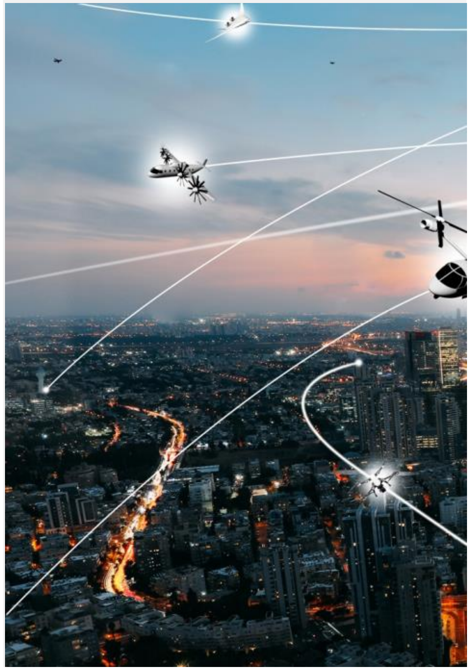
- Three primary applications:
  - Urban Air Mobility (UAM)
    - "Local" missions up to ~75 miles around metropolitan areas
    - Largely novel "vertiport" infrastructure
    - eVTOL, potentially eSTOL or eCTOL aircraft
    - Up to ~6 passengers or equivalent cargo
  - Small Unmanned Aircraft Systems (sUAS)
    - Local missions for aerial work or small cargo delivery (e.g., food, small packages)
    - Range of required takeoff/landing infrastructure from none to specialized
    - Typically VTOL-capable aircraft
  - Regional Air Mobility (RAM)
    - "Intraregional" missions up to ~500 miles
    - Primarily utilize existing (smaller) airports
    - eCTOL and eSTOL aircraft
    - Up to 19 passengers or equivalent cargo



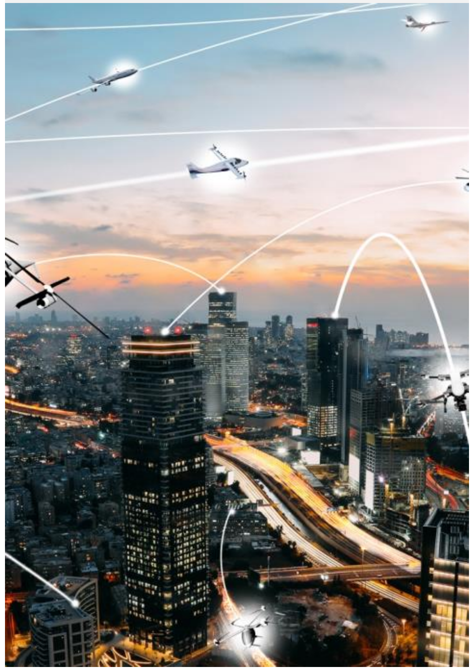
- AAM is generally enabled by electrification & automation
- Many potential uses, including
  - Passenger transport
  - Cargo/package delivery
  - Emergency services/public good (e.g., air ambulance, EMT transport, etc.)
  - Aerial work (e.g., infrastructure inspection, photography, etc.)

NASA Role to Address AAM Challenges

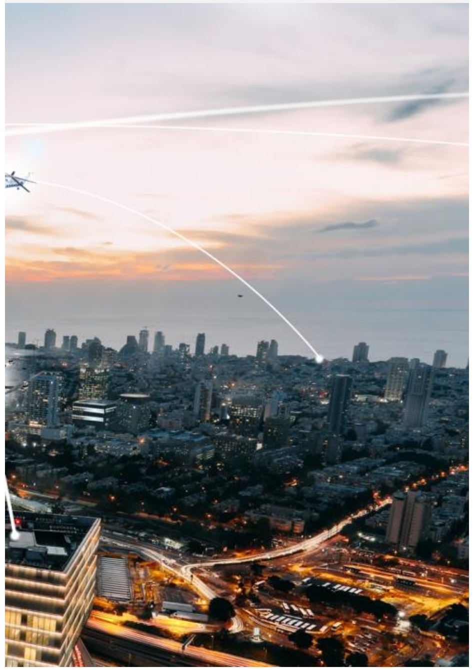
Vehicle Development and Operations



Airspace Design and Operations



Community Integration



NASA and key partners are collectively taking on the most difficult mission challenges to enable industry to flourish by 2030

- **Research and Development Portfolio**
- **Robust Ecosystem Partnerships**
- **AAM National Campaign Series**

NASA to deliver long term technical solutions and architecture requirements for industry, regulatory community

AAM Ecosystem Working Groups

Align on a common vision for AAM

Learn about NASA's research and planned transition paths

Adopt a strategy for engaging the public on AAM

Collectively identify and investigate key hurdles and associated needs

Develop AAM system and architecture requirements

Support regulatory and standards development

Form a connected stakeholder community

Join the conversation! See https://nari.arc.nasa.gov/aam-portal/ for more information

Accelerate the development of safe and scalable AAM flight operations by bringing together the broad and diverse ecosystem

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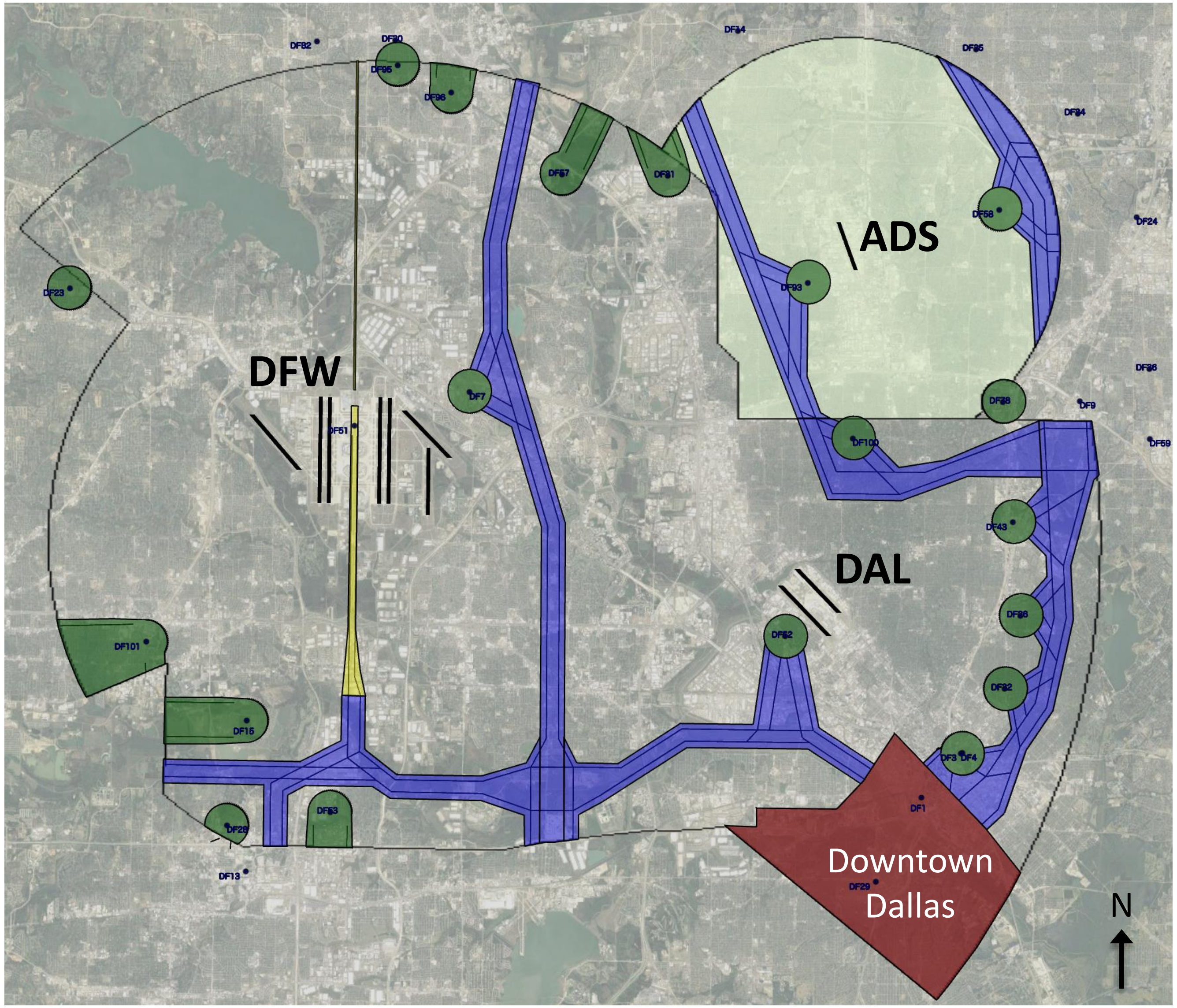
Airspace Integration Considerations

AAM Airspace Integration Overview

- Small Unmanned Aircraft Systems
  - UAS Traffic Management (UTM): a service-oriented paradigm for ATM
  - < 400 ft AGL altitude
  - Flight intent sharing and UAS Service Suppliers (USSs)
- Urban Air Mobility
  - Early operations (~2024) under existing rules with novel aircraft
  - Further-future operations (~2028) move toward service-oriented paradigm for ATM
    - Operational intent sharing and Providers of Services for UAM (PSUs)
  - UAM Corridors
    - Airspace structure of defined geometry analogous to SFRAs and helicopter routes
    - Operations follow UAM-specific rules/procedures within Corridors
- Regional Air Mobility
  - Generally leverages existing rules
  - Increases in aircraft automation to require modified rules/procedures (e.g., digital communications, fixed routes, etc.)



Notional UAM Corridor design in the Dallas-Ft Worth area, including boundaries of Class B and Class D airspace boundaries

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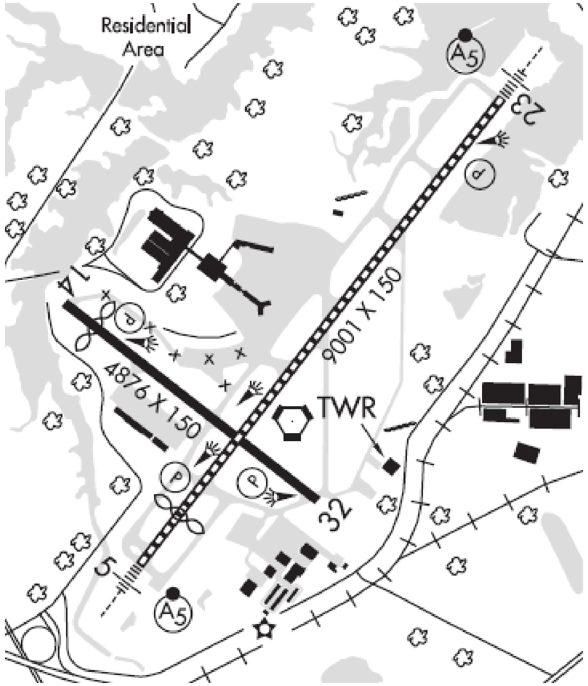
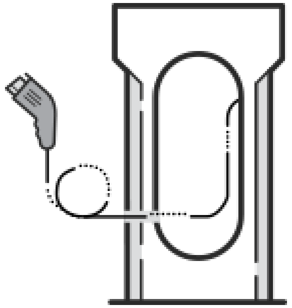
Airport/Vertiport Integration Considerations

Airport Considerations: Electrification

- Installation of chargers
  - Accessible locations for all operations
  - Consider use also for ground vehicles
  - Ongoing charging standardization discussions
  - How to monetize charging?
- Connectivity to electrical grid
  - Potentially large additional power requirements (multi-MW)
  - Long lead times
- Microgrids/renewables
  - Potentially large available land area
  - Sustainable energy supply for aviation and/or to improve local electricity grid



Roanoke Airport diagram from FAA's Chart Supplement



Solar arrays outside of runway object free area at Chattanooga Airport (CHA)

Imagery from NationalMap.gov

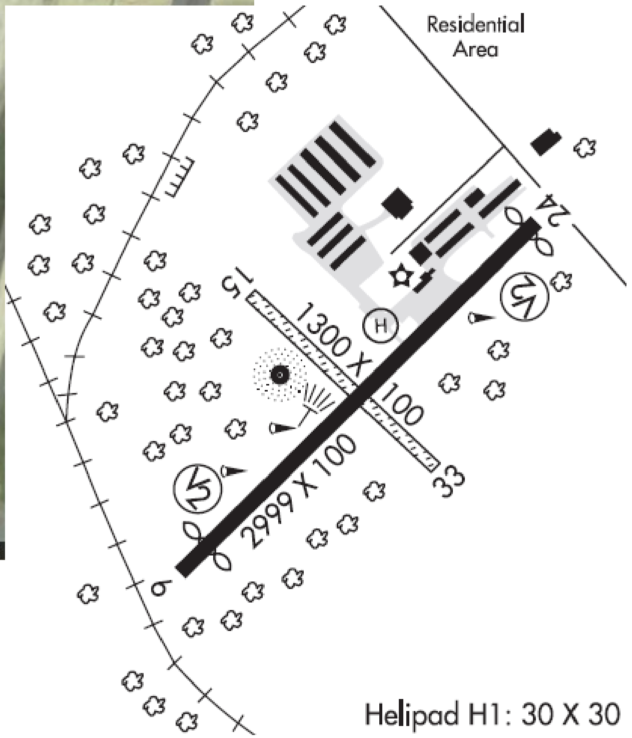
Note: ongoing NASA-funded research by Georgia Tech assessing potential energy demand for RAM and potential for on-airport renewables to generate needed electricity

Other Airport Considerations

- Improved multi-modal connectivity for FBOs
  - AAM operations *not* likely to use existing Part 121 passenger terminals
  - Mode change times need to be kept small
  - RAM and some UAM ops likely to utilize existing airport runways
  - FBOs may partner with indirect/direct air carriers
- Consider inclusion of new vertipads at airports
  - Ideally direct passenger access to existing passenger terminals (at larger airports)
  - Enable deconflicted approach/departure paths with existing air traffic

Notional vertipad locations on a parking garage at RIC

Imagery from Google Maps ©2021 Commonwealth of Virginia, Maxar Technologies, USDA Farm Service Agency



Airport diagram showing existing helipad at EZF (Shannon Airport, Fredericksburg) from the FAA's Chart Supplement

Vertiports

- Many potential locations
  - Greenfield sites
  - Rooftops
  - Parking garages
  - Barges
  - New overpasses / cloverleafs?
  - Etc.
- Many siting considerations
  - Multi-modal connectivity
  - Noise
  - Utilities (electric grid)
  - Proximity of other vertiports/pads
  - Equity
  - Etc.
- Vertiport design guidelines under development

Notional city waterfront vertiport

Notional cloverleaf vertiport

Closing Thoughts

Summary & Closing Thoughts

- AAM is *safe, sustainable, affordable, and accessible aviation for transformational local and intraregional missions*
- Many potential missions under the AAM umbrella
  - Three primary applications: urban air mobility, regional air mobility, small unmanned aircraft systems
  - Common themes: electrification and increased automation
- AAM is a burgeoning field
  - Many details still TBD
    - Still no type certified AAM aircraft!
    - Watch for regulatory guidance and how aircraft/operations evolve
  - Your involvement can shape the future!
    - Get engaged in the AAM Ecosystem Working Groups: https://nari.arc.nasa.gov/aam-portal/
    - Start developing plans and beginning pilot programs
- Many potential opportunities for existing airports
  - Potential for vastly increased passenger/cargo throughput
  - Multi-modal integration is key; airports could be new multi-modal transportation hubs
  - Don’t forget about sUAS operations (inspections, small cargo logistics, etc.)
  - Solar (or other renewable energy generation) hubs for electric aircraft and surrounding communities

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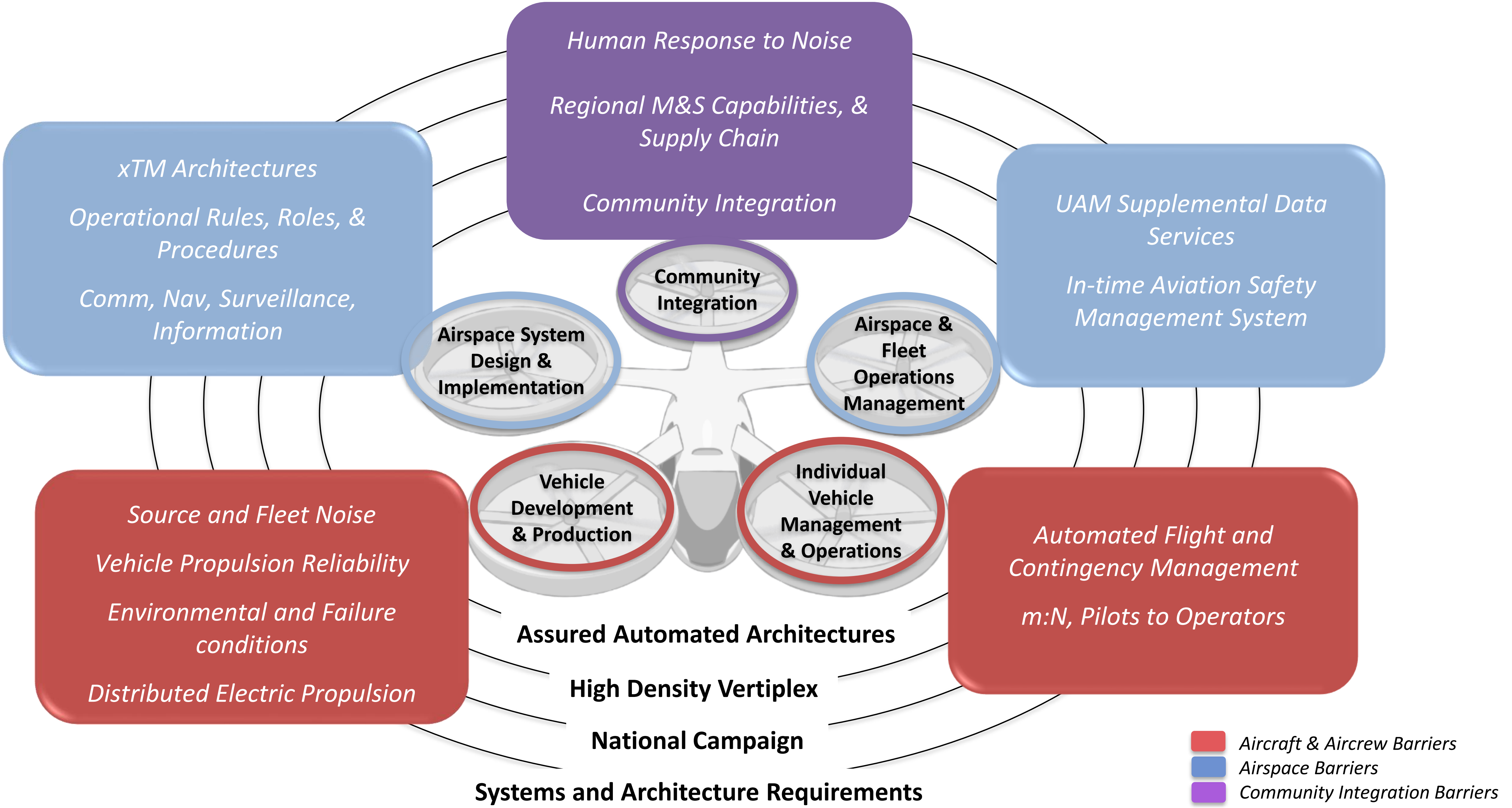
Questions / Discussion

BACKUP

Useful References

- FAA UTM ConOps v2.0: https://www.faa.gov/uas/research_development/traffic_management/media/UTM_ConOps_v2.pdf
- Regional Air Mobility White Paper: https://ntrs.nasa.gov/citations/20210014033
- UAM Market Studies
  - BAH (written report, detailed presentation, overview presentation):
    - https://ntrs.nasa.gov/citations/20190001472
    - https://ntrs.nasa.gov/citations/20190000519
    - https://ntrs.nasa.gov/citations/20190000517
  - Crown Consulting (overview presentation, detailed presentation):
    - https://ntrs.nasa.gov/citations/20190002046
    - https://ntrs.nasa.gov/citations/20190026762
- Electrical Infrastructure Study for UAM Aircraft
  - https://www.bv.com/sites/default/files/2019-11/NASA_eVTOL_Electric_Infrastructure_Study.pdf
  - https://na-admin.eventscloud.com/eselectv3/v3/events/474828/submission/files/download?fileID=93045cb05549cc78f1bb2869a767b429-MjAyMC0wOCM1ZjI0NDAyYjk1YmE4
- FAA UAM ConOps v1.0: https://nari.arc.nasa.gov/sites/default/files/attachments/UAM_ConOps_v1.0.pdf
- UML-4 Vision ConOps v1.0: https://ntrs.nasa.gov/citations/20205011091

NASA AAM Mission Priorities



NASA ARMD AAM Org Structure

Office of Associate Administrator (OAA) for Aeronautics
Bob Pearce, Associate Administrator (AA)
Steve Clarke, Deputy AA
Jon Montgomery, Deputy AA For Policy
Ed Waggoner, Deputy AA For Programs

AAM Mission Integration Office (AMIO)
Davis Hackenberg, Mission Integration Manager
Nancy Mendonca, Deputy Mission Integration Manger
Jim Murphy, System Architect and MBSE
Yuri Gawdiak, Risk Manager
Michael Patterson, ConOps and Studies
Kapil Sheth (NARI), Regional M&S Lead

Integrated Aviation Systems Program (IASP)
Lee Noble, Director

Advanced Air Mobility (AAM) Project
Mike Guminsky, Manager

General – Ken Goodrich
National Campaign – Starr Ginn, Shivanjli Sharma
Automated Flight and Contingency Management – Trish Glaab
High Density Vertiplex – Marcus Johnson

Flight Demonstrations and Capabilities (FDC)
Tom Horn, Manager

Capabilities – Karla Shy
X-57 – Nick Borer, Sean Clarke

Airspace Operations and Safety Program (AOSP)
Akbar Sultan, Director

Air Traffic Management – Exploratory (ATM-X) Project
William Chan, Manager

UAM Airspace Management System and Services – Kevin Witzberger, Arwa Aweiss
NC Simulation – Spencer Monheim
CNSI – Casey Bakula
Pathfinding for Airspace with Autonomous Vehicles – Kurt Swieringa, Rob Fong

System Wide Safety (SWS) Project
Misty Davies, Manager

IASMS, Safety, Hazards, Assurance – Kyle Ellis

Advanced Air Vehicles Program (AAVP)
Jimmy Kenyon, Director

Revolutionary Vertical Lift Technology (RVLT) Project
Susan Gorton, Manager

General – Carl Russell
Crash Safety – Justin Littell
Noise and Acoustics – Kyle Pascioni, Noah Schiller

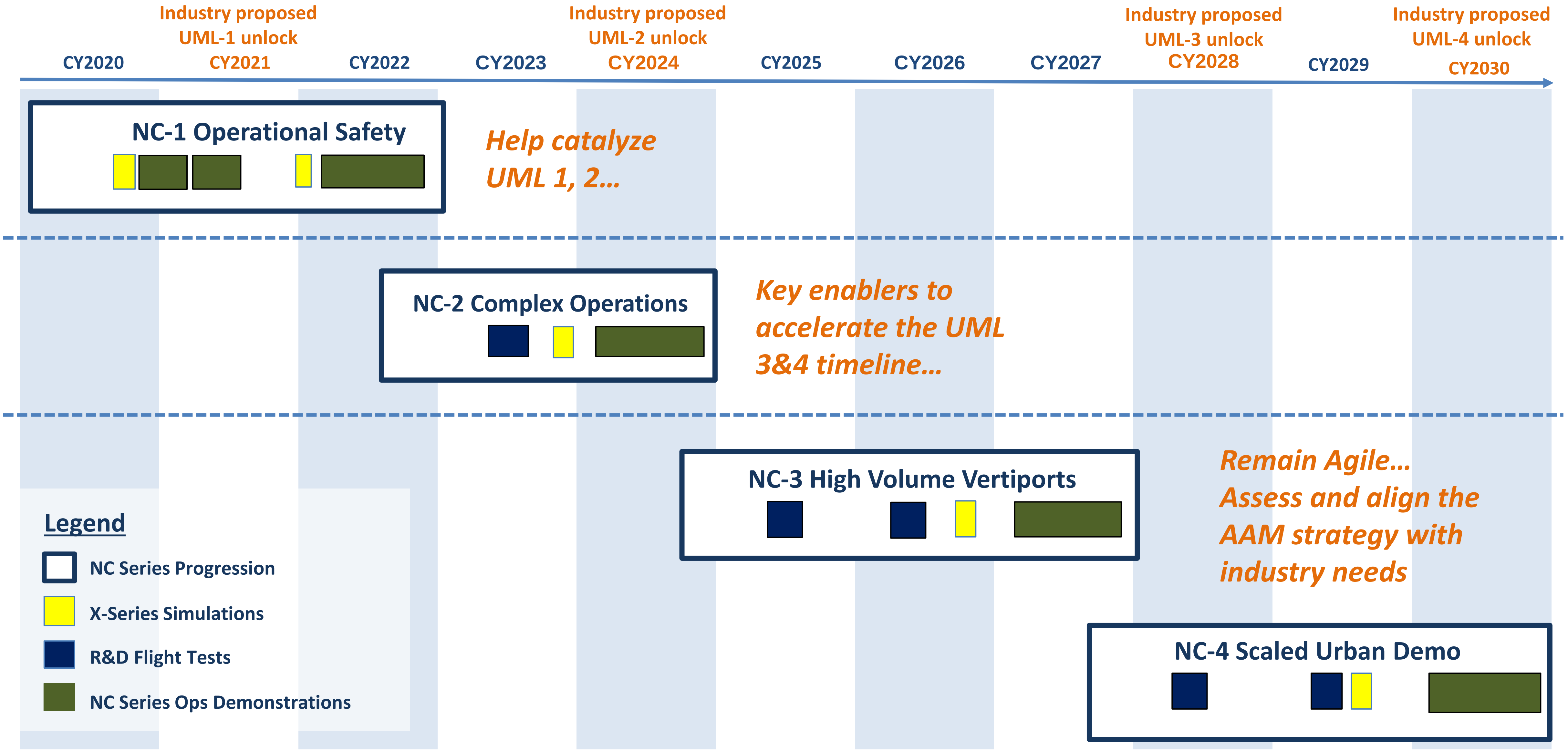
Transformative Aeronautics Concepts Program (TACP)
John Cavolowsky, Director

Transformative Tools and Technologies (TTT) Project
Mike Rogers, Manager

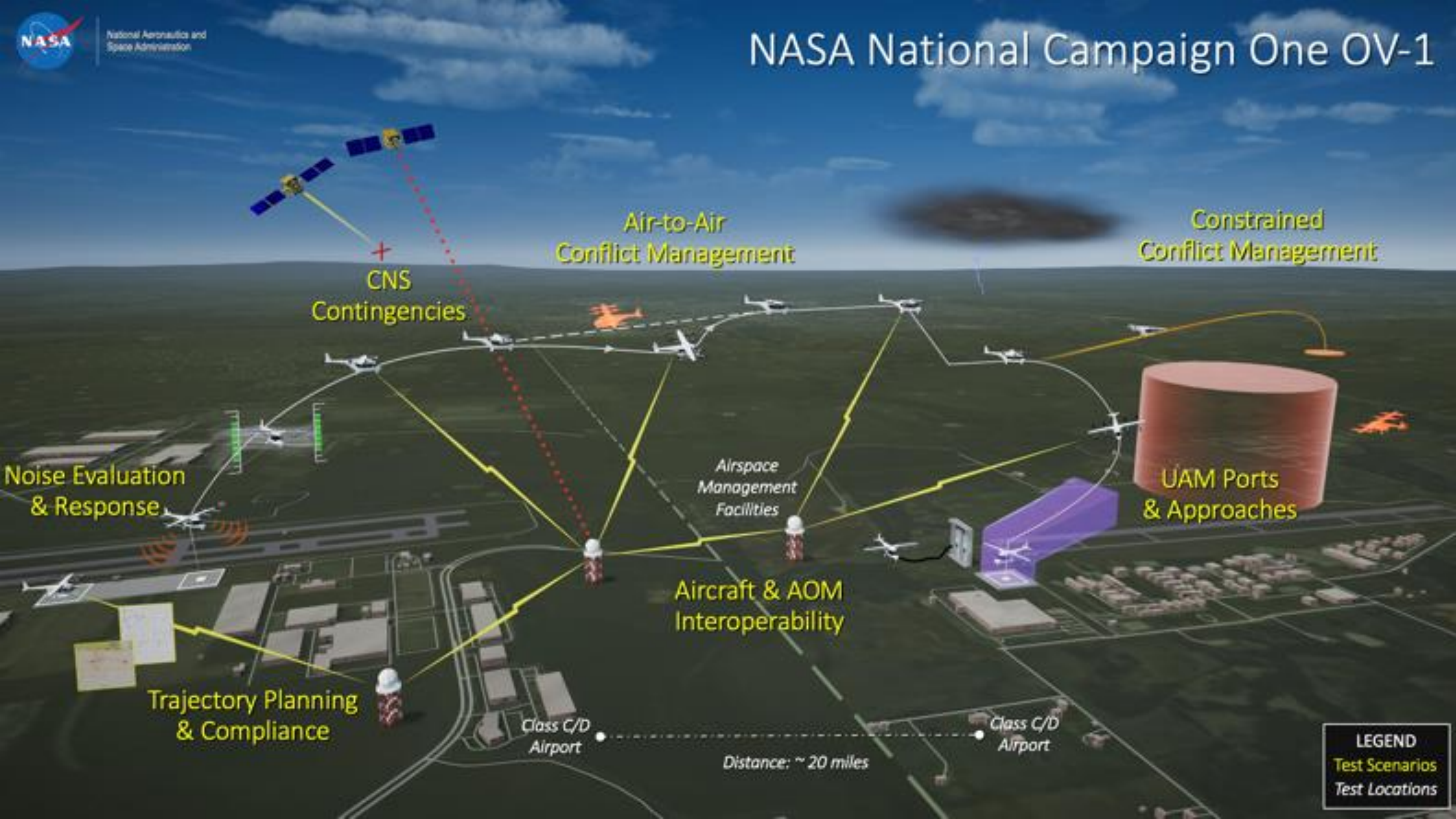
Autonomous Systems – Vanessa Aubuchon
m:N – Jay Shively
Perception – Kelley Hashemi

Convergent Aeronautics Solutions (CAS) Project
Keith Wichman, Manager

National Campaign Series Support of the Industry Timeline



UML ”unlocks” based on a range of publicly available industry projections and conversations with partners; not a consensus view


NASA
National Aeronautics and Space Administration
NASA National Campaign One OV-1
Air-to-Air
Conflict Management
Constrained
Conflict Management
CNS
Contingencies
Noise Evaluation
& Response
Airspace
Management
Facilities
UAM Ports
& Approaches
Aircraft & AOM
Interoperability
Trajectory Planning
& Compliance
Class C/D
Airport
Class C/D
Airport
Distance: ~ 20 miles
LEGEND
Test Scenarios
Test Locations

HDV Research Flow to National Campaign

CY2021	CY2022	CY2023	CY2024	CY2025	CY2026

AOA → SAO → VO → IAS-2 → NC-3

Technology Transfer

Automated Aircraft

Small UAS

X3

Automated Landing

Small UAS

X5

Merging and Spacing

Small UAS

X7

Contingency Decision Making

Representative eVTOL

UAS Automation Reference Architecture → **ASTM F38, FAA, AFCM, SWS**

Operations

Simulation and Multi-Aircraft VLOS Flight Test

Simulation and Limited BVLOS

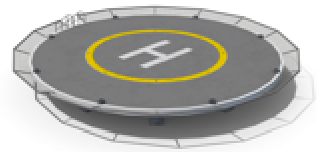
Simulation and Expanded Operations (BVLOS & m:N aircraft control)

Operational Environment (e.g. Test Range for NC)

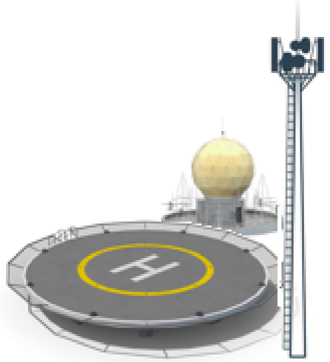
BVLOS Safety Case

Scenarios and Use Cases → **JARUS, UAST, FAA, NC**

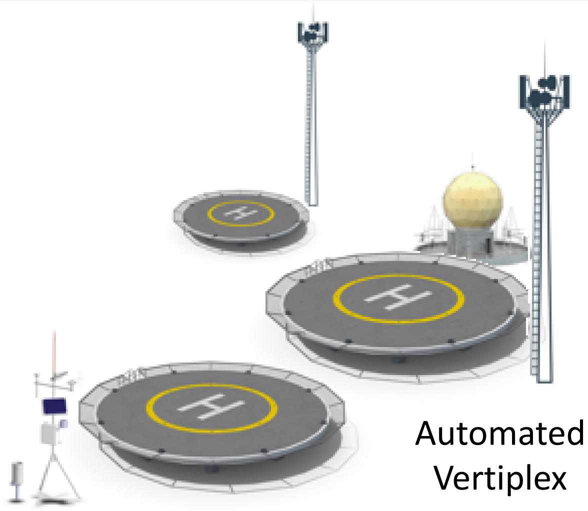
Infrastructure



Vertiport Terminal Procedures Design



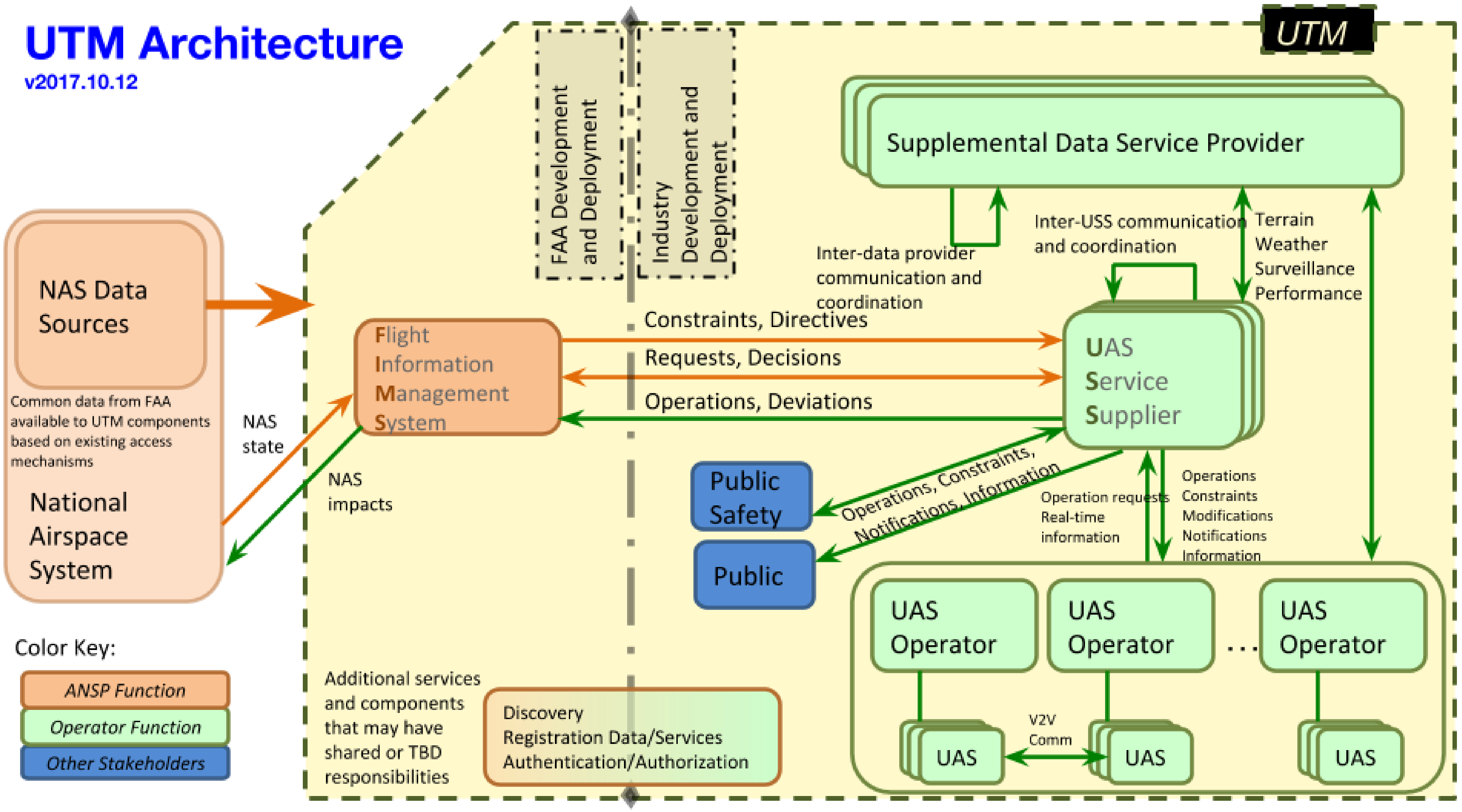
Instrumented Vertiport



Automated Vertiplex

Vertiport Automation Reference Architecture → **FAA, ASTM F38, AFCM, NC**

UAS Traffic Management Architecture



FAA NextGen's v1.0 UAM Research ConOps: A Quick Overview

- Released June 26, 2020
- Initial state operations (UML-2)
  - Earliest operations occur within existing system/rules/procedures
  - Document focuses on concept for next step of evolution
- Concept ***not*** coordinated across FAA
- UAM flight contained within corridors
  - Builds off of existing concept of helicopter routes and special flight rules areas
- Community-Based Rules (CBRs) to govern "cooperative traffic management" within corridors
- Providers of Services for UAM (PSUs) enable sharing of information (e.g., intent)

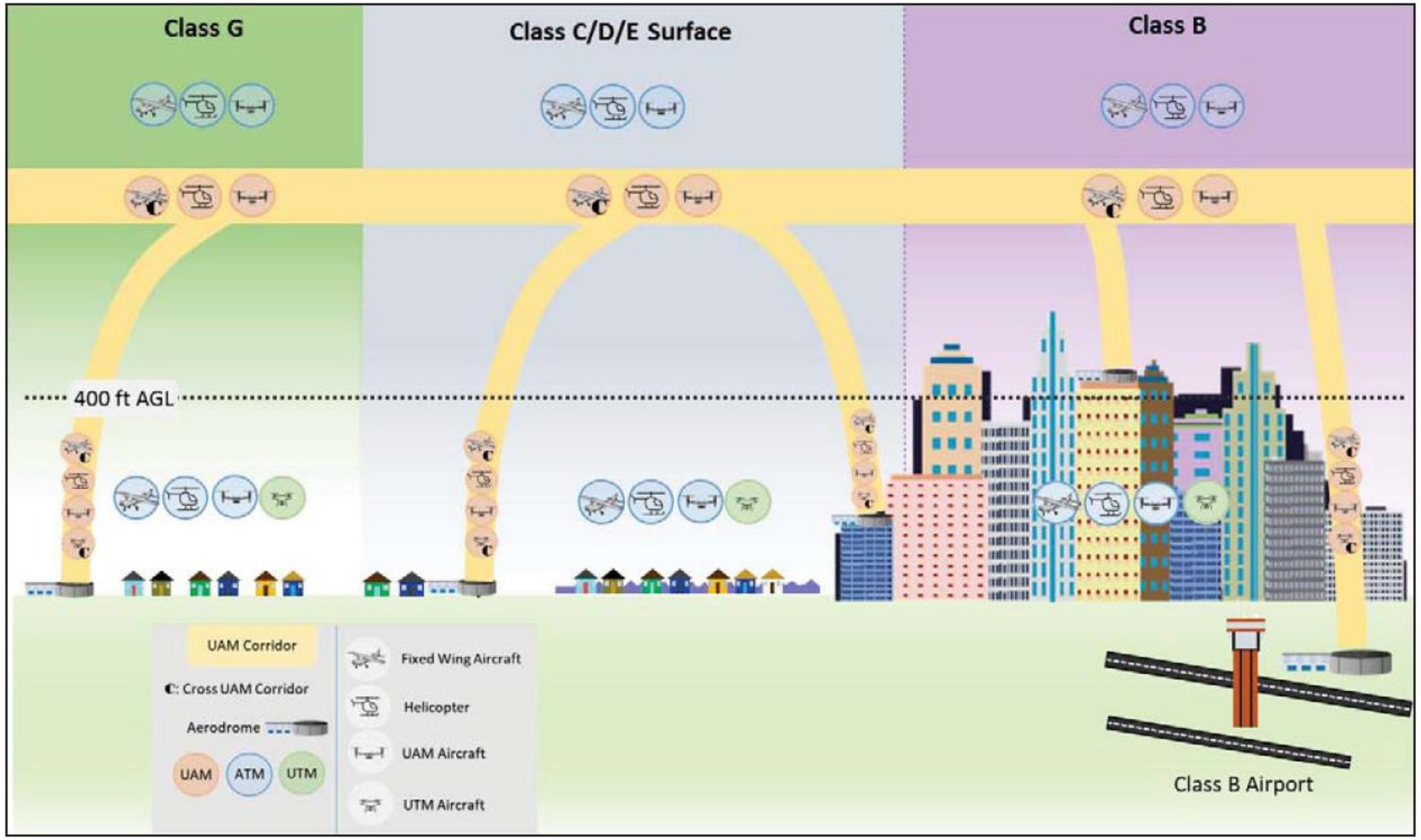


Figure 1-2: UAM, UTM, and ATM Operating Environments

Figure from FAA NextGen's v1.0 UAM ConOps document: https://nari.arc.nasa.gov/sites/default/files/attachments/UAM_ConOps_v1.0.pdf

FAA NextGen’s v1.0 UAM Research ConOps

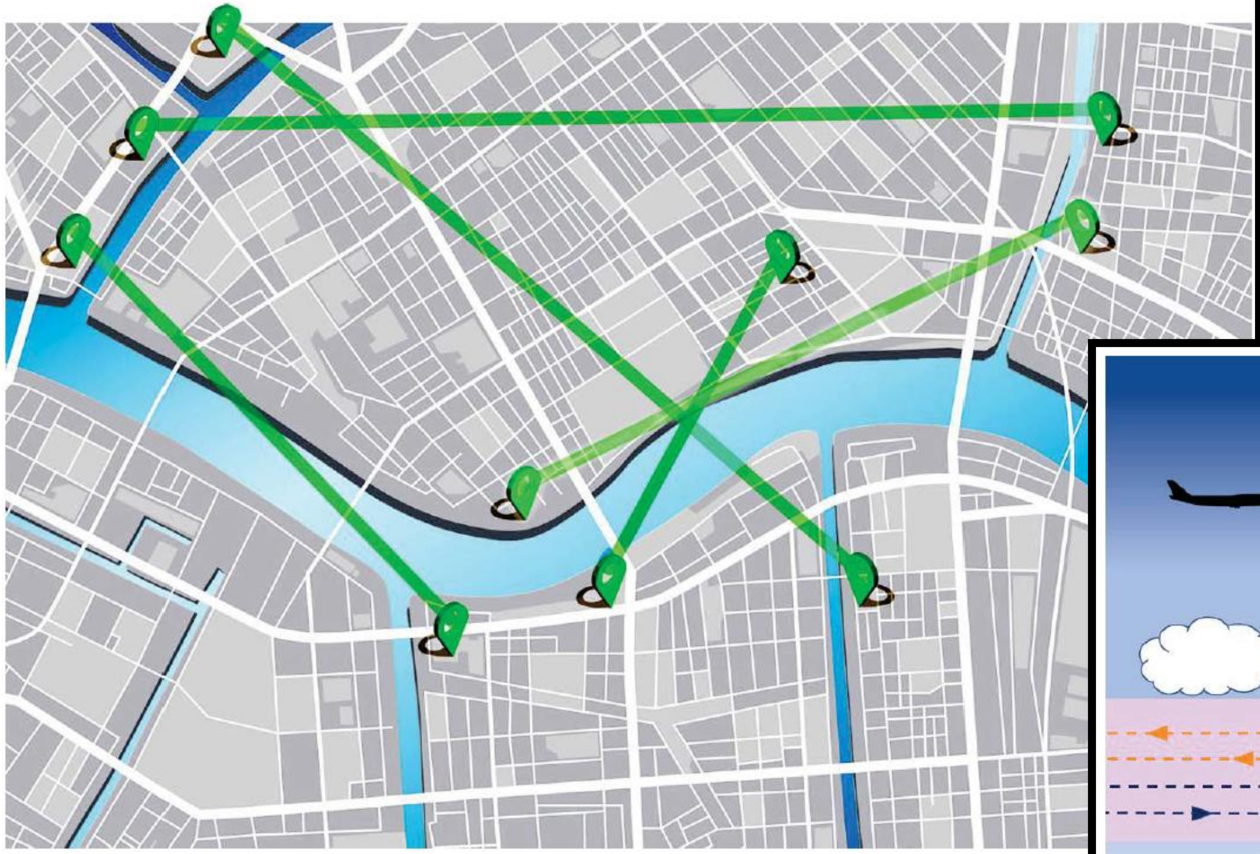


Figure 4-1: Multiple UAM Corridors

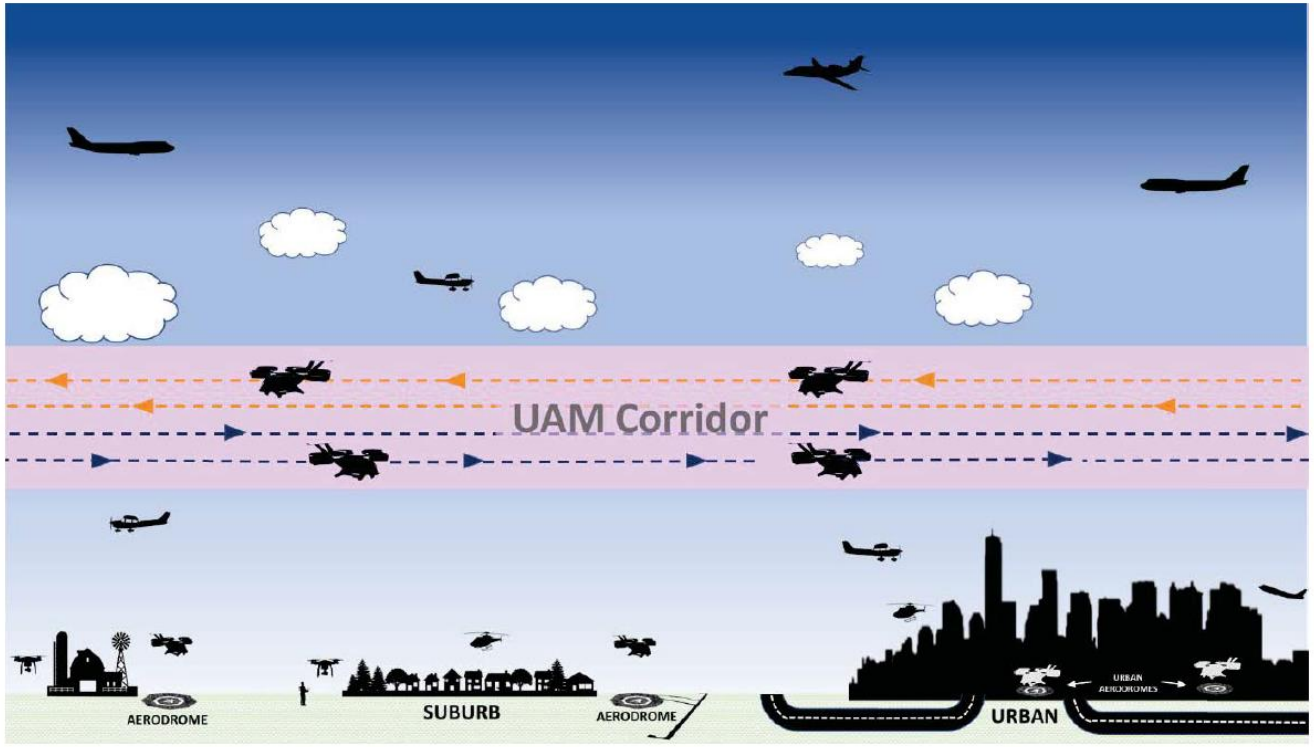


Figure 4-2: UAM Corridor with “Tracks”

Figures from FAA NextGen’s v1.0 UAM ConOps document: https://nari.arc.nasa.gov/sites/default/files/attachments/UAM_ConOps_v1.0.pdf

FAA NextGen's v1.0 UAM Research ConOps

- Slides presented in Airspace AEWG meeting by Steve Bradford (FAA NextGen Chief Scientist):

UAM Concept *Overview*

- UAM leverages a common shared environment for UAS Traffic Management (UTM)
- A community-based traffic management system in which the operators are responsible for coordination, execution, and management of their operations
  - Community rules approved by the FAA
- Operations between known locations in volumes of airspace (UAM Corridor) with specified performance requirements
- Cooperative Separation Environment when within UAM Corridor
  - Operators will be responsible for maintaining proper separation when transiting a UAM Route and staying within the bounds of the UAM Corridor
  - Operations must meet the airspace & performance requirements when not operating within UAM Corridor

UAM Concept *Overview* (continued)

- Leveraging the current model of UTMs UAS Service supplier (USS) a similar model will be needed to provide services for UAM operations.
- A Provider of Services for UAM (PSU) assists UAM Operators with meeting UAM operational requirements that enable safe and efficient use of airspace and UAM Routes
  - Shared network environment
    - Same federated UAM/UTM environment
  - Provide operator with information along the route
    - Based on shared intent data
  - Share operator intent with others via a shared network environment

- Recording of Aircraft AEWG meeting discussing slides: https://youtu.be/ohZEt-f0Wqo
- Slides from: https://nari.arc.nasa.gov/sites/default/files/attachments/AAMWG-Airspace%20August4-2020_IL.pdf

FAA NextGen's v1.0 UAM Research ConOps

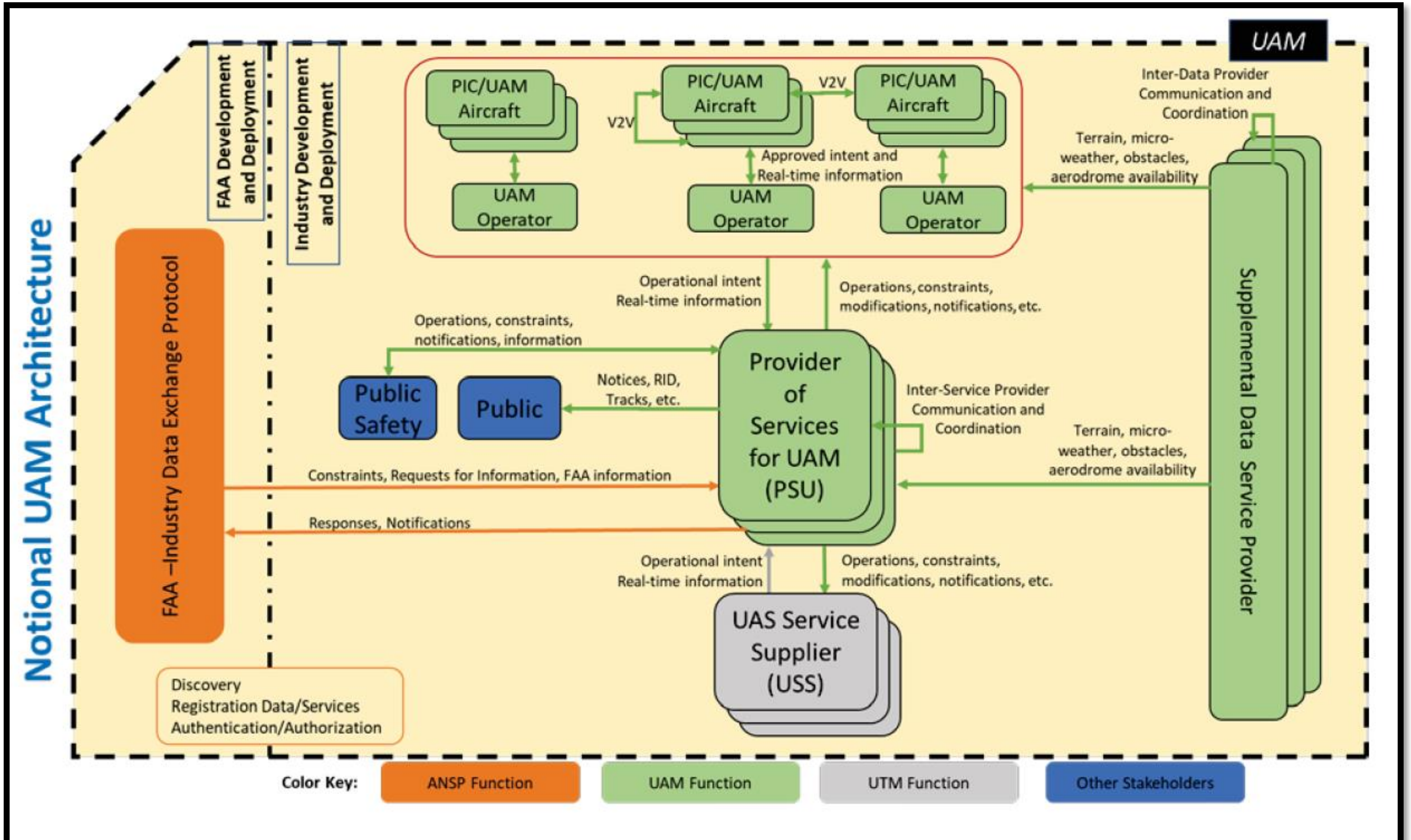


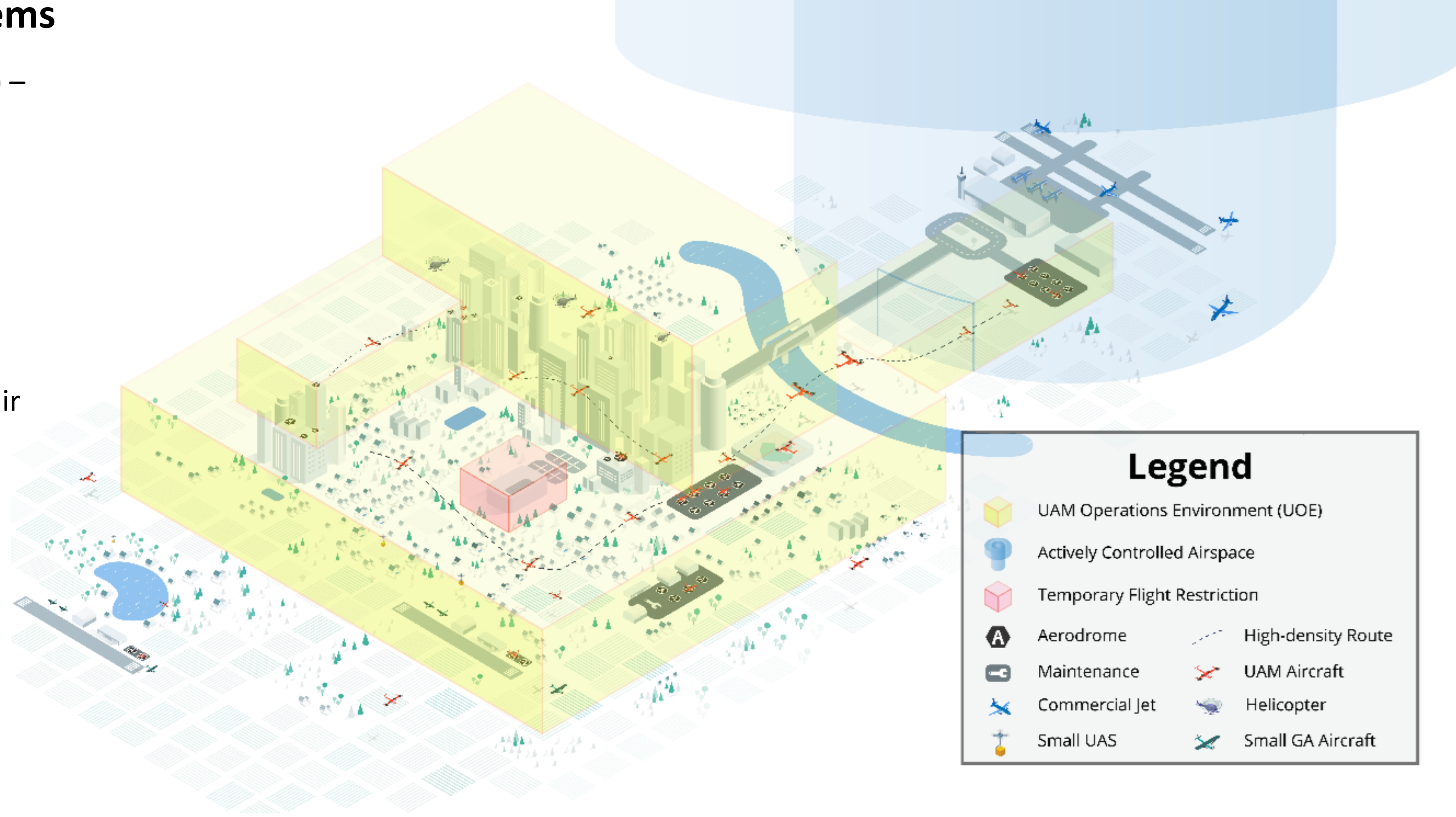
Figure 5-1: Notional UAM Architecture

Figure from FAA NextGen's v1.0 UAM ConOps document: https://nari.arc.nasa.gov/sites/default/files/attachments/UAM_ConOps_v1.0.pdf

Deloitte/NASA UML-4 Vision ConOps

UAM Maturity Level (UML) 4: Medium Density and Complexity Operations with Collaborative and Responsible Automated Systems

- UAM Operations Environment (UOE) – Flexible airspace volumes with high UAM activity
- Provider of Services to UAM (PSU) – Federated, 3rd party suppliers of services, including air traffic management services
- Advanced automation (aircraft and air traffic management) largely human-over-the-loop
- Aircraft capable of detect and avoid and performance based separation
- UML-4 is characterized by medium density operations between closely-spaced, high throughput UAM aerodromes



Note: Initial (v1.0) UML-4 ConOps document still under review

Intraregional Mission Example: Trip from Hampton Roads to DC

- NASA Langley (Hampton, VA) to DOT HQ

	Drive		AAM	
	Low	High	Low	High
Drive/TNC	2h 40m	4h 20m	18m	40m
Parking	5m	10m	-	-
Mode Switch	-	-	5m	15m
Flight	-	-	45m	55m
Mode Switch	-	-	5m	10m
TNC/Taxi	-	-	22m	65m
Total	2h 45m	4h 30m	1h 35m	3h 5m
Nominal Total	**~3hr**		**~1h 50m**	

Intraregional AAM travel saves ~1h 10m (~39%) for this one-way trip

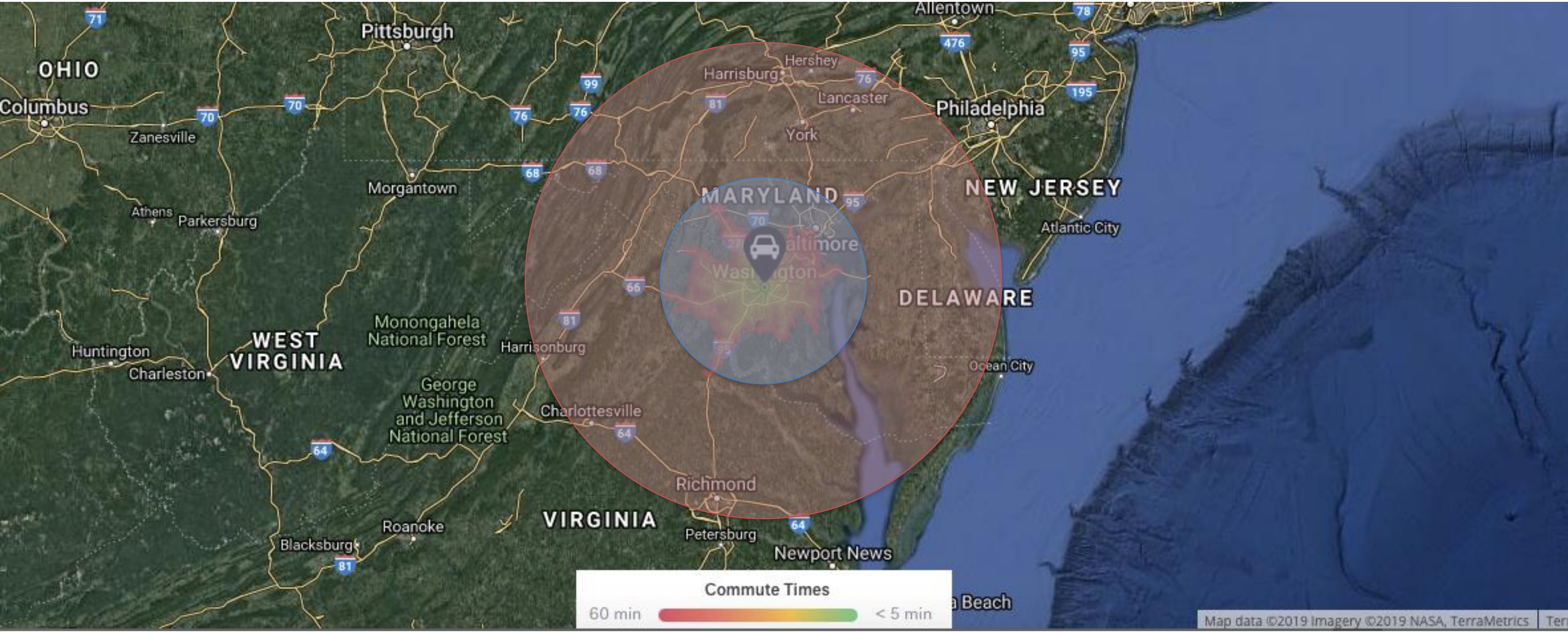
Combined AAM Mission Example: Trip from Hampton Roads to DC

- NASA Langley (Hampton, VA) to DOT HQ

	Drive		**AAM**	
	Low	High	Low	High
Drive/TNC	2h 40m	4h 20m	18m	40m
Parking	5m	10m	-	-
Mode Switch	-	-	5m	15m
CTOL Flight	-	-	45m	55m
Mode Switch	-	-	5m	10m
VTOL Flight	-	-	7m	12m
Mode Switch	-	-	2m	7m
Walk	-	-	6m	8m
Total	2h 45m	4h 30m	1h 28m	2h 27m
Nominal Total	**~3h**		**~1h 35m**	

AAM travel saves ~1h 25m (~47%) for this one-way trip

Urban Air Mobility Example: Aerial Reach from DC



24 hr weighted average
60 minute driving commute

Any time of day
~30 minute total commute
(~40 mi radius)

Any time of day
~60 minute total commute
(~100 mi radius)