Development of Candidate Airspace Procedures for Urban Air Mobility Operations in the Dallas Area

Rania W. Ghatas, Richard H. Mogford, Savita A. Verma,
Robert D. Wood, Gabriela M. Rosado-Torres, and Amir H. Farrahi

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Overview

- Background
- Approach to Refining and Developing Candidate Airspace Procedures
  - Airspace Structure
  - Guiding Principles and Assumptions
  - Tabletop Activities #1 and #2
  - Shakedown Human-in-the-Loop
- Key Takeaways
- Questions and Answers

Background

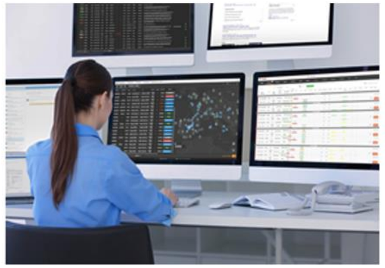
- Urban Air Mobility Overview
- Research Objectives
- Why does this research matter?
- Motivation for Research
- Previous NASA Research

Urban Air Mobility Overview

- A highly anticipated and revolutionary form of on-demand air travel, which “leverages the sky to better link people to cities and regions, giving them more possibilities to connect” [1]
- An air transportation system that moves people and cargo in “locations not previously served or underserved by aviation” [2]
- Hinges on the notion of using small electric vertical takeoff and landing (eVTOL) aircraft that are designed with cutting-edge technology and automation
- Anticipated to carry approximately four to six passengers
- Aircraft expected to operate in both controlled and uncontrolled airspace
    - Similar to current-day helicopters operating under Part 135 certification

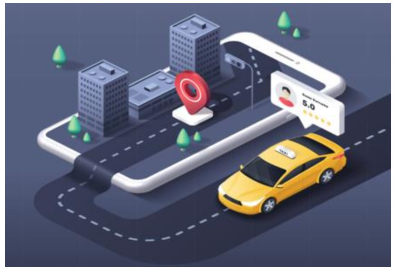
[1] Airbus, “Urban air mobility.” https://www.airbus.com/en/innovation/low-carbon-aviation/urban-airmobility
[2] Federal Aviation Administration, “Concept of operations. Urban air mobility (UAM).” Version 2.0, Washington, D.C., April 2023. https://www.faa.gov/sites/faa.gov/files/Urban%20Air%20Mobility%

Agents in UAM EcoSystem



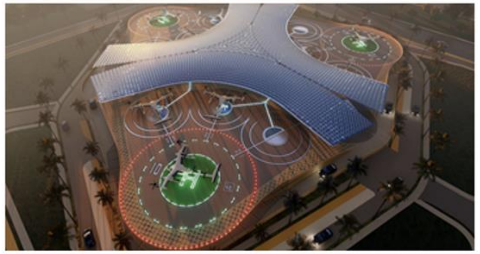
Flight Follower/ Dispatcher
Responsible for the efficient planning and following of company aircraft and passengers through an air mobility network

eVTOL Pilot (PIC)
Flies the flight portion of the multimodal trip, facilitates repositioning



Multimodal Rideshare Coordinator
Monitors metropolitan transportation across modalities

Automation



Vertiport Manager/ Fixed Base Operator
Vertiport: eVTOL land and takeoff. FBO: a commercial entity granted rights by airport authority to operate on that airport and provides aviation services, e.g., fuel, parking and hangar space

ATC
Coordinates the operations of aircraft departing from or arriving at the primary airport or flying at low altitudes in the vicinity that airport

Automation
- Information exchange
- Flight operations planning
- Demand-capacity balancing

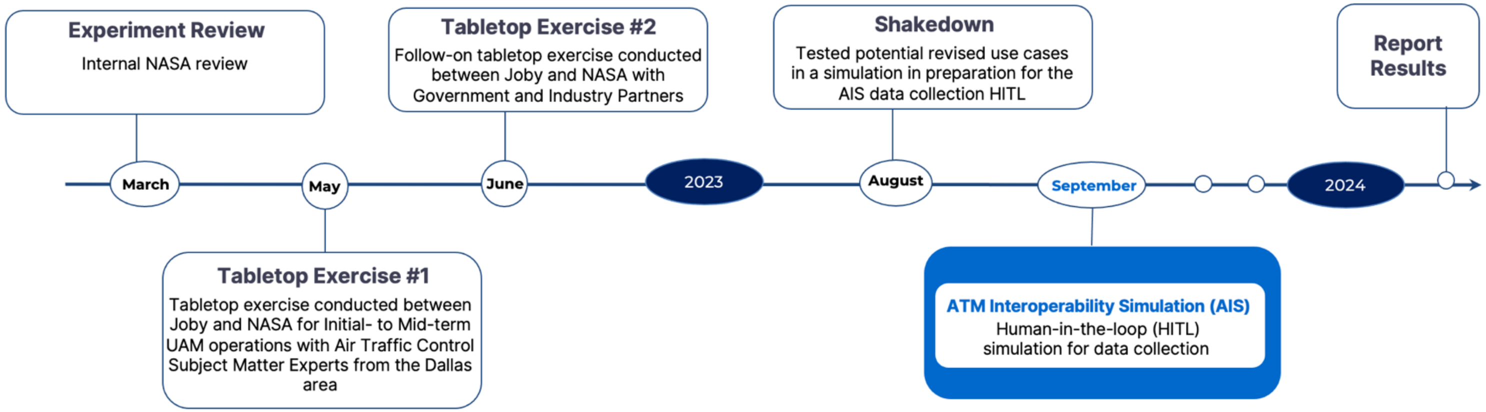
Image Credits:
Flight Follower/Dispatcher: https://www.rocketroute.com/blog/flightboard-dispatch-mode
eVTOL Pilot (PIC): https://mashable.com/article/drone-helicopter-hybrid-flight
Multimodal Rideshare Coordinator: https://www.netsolutions.com/insights/ride-sharing-app-essential-features/
Vertiport Manager / Fixed Base Operator: https://flightplan.forecastinternational.com/2020/04/20/vertiplaces-and-navigating-the-world-of-urban-air-mobility-infrastructure/
ATC: https://thepointsguy.com/2015/07/what-do-air-traffic-controllers-actually-do/

ATM Interoperability Simulation (AIS) Research Objectives

A joint NASA-Joby investigation to understand how to seamlessly integrate UAM operations with other users and managers of the airspace in current-day and mid-term environments

Research Objectives

- Develop and test notional bi-directional air traffic control (ATC)-pilot-in-command (PIC) communications and procedures (voice and digital) for initial and midterm Urban Air Mobility (UAM) operations in the Dallas Metropolitan area
- Assess the information requirements, workload, and scalability/feasibility of candidate air traffic procedures for UAM operations



Evolution of UAM Operations
(FAA ConOps, Version 2.0)

Initial

- Low operational tempo
- UAM operations are conducted by conventional helicopters or UAM aircraft
- Current rules and regulations and local agreements
- Existing air traffic services and routes, new routes as necessary
- No Cooperative Operating Practices (COPs), operational needs addressed in LOAs
- Onboard pilot

Midterm

- Higher operational tempo requiring changes in the existing regulatory framework and procedures
- UAM corridors are a performance-based cooperative environment with new or modified procedures, updated regulations and COPs
- Industry defines COPs that will be approved by the FAA
- Increased levels of automation
- Onboard pilot, few remote pilots (1 per ops)

Mature State

- Significant increase in tempo
- UAM corridors with increasing structural complexity
- Deconfliction may be allocated to UAM operator, pilot or operator's automation
- Additional UAM driven regulations and more complex COPs
- Automation improvements may lead to Human-Over-the-Loop (HOVTL) capabilities
- Remote pilot more widely available

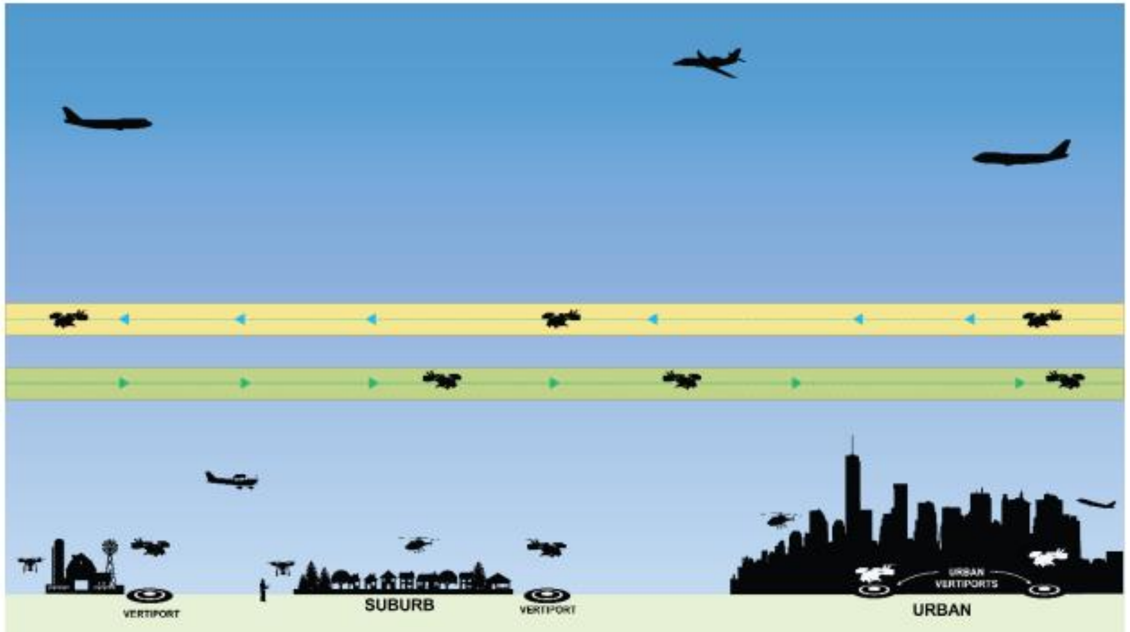
Why does this research matter?

- On-demand air mobility is now driving the future of flight the airspace to enable on-demand urban air travel as a safe and cost-effective alternative to other transportation
- There is a need to identify and understand gaps, challenges, and human factors issues to support the influx of these new air vehicles over highly dense, urban communities
- Maintaining safety is a priority for those in the air and on the ground

Motivation for Research

FAA Concept of Operations on UAM Operations, Version 2.0

- Air traffic management vision for initial UAM operations
- FAA-defined UAM corridors with specific performance requirements for midterm operations
- Vehicles planned for UAM likely to be electric vertical takeoff and landing (eVTOL)
- Aircraft operator connection to a “Provider of Services for UAM” (PSU)
- Separation within corridors assigned to pilots, operators, and PSUs - not Air Traffic Control (ATC)
- UAM operations will start with today’s rules and procedures and evolve to incorporate Cooperative Operating Practices (COPs)



Source: FAA UAM ConOps, version 2.0

Previous NASA Research

Thipphavong, et al.

- Attempted to analyze existing airspace as a starting point for emerging UAM operations
- Eight metropolitan areas with FAA published helicopter route charts were investigated, including the Dallas area
  - Helicopter routes are designed in a manner that mitigate societal concerns, such as increased noise, by overlaying highways and freeways on the ground, which also provides visual reference for pilots while in the air
- Existing corridor structures were also analyzed, such as the Los Angeles Special Flight Rules Area (SFRA), which consists of two routes
  - Flights flying northwest within the Los Angeles SFRA operate at 4,500 ft mean sea level (MSL), while those flying southeast operate at 3,500 ft MSL
- Research focused on enabling early UAM entrants into the U.S. National Airspace System and explored "possibilities for the services, procedures, and tools necessary to support high-tempo, high-density mature operations."

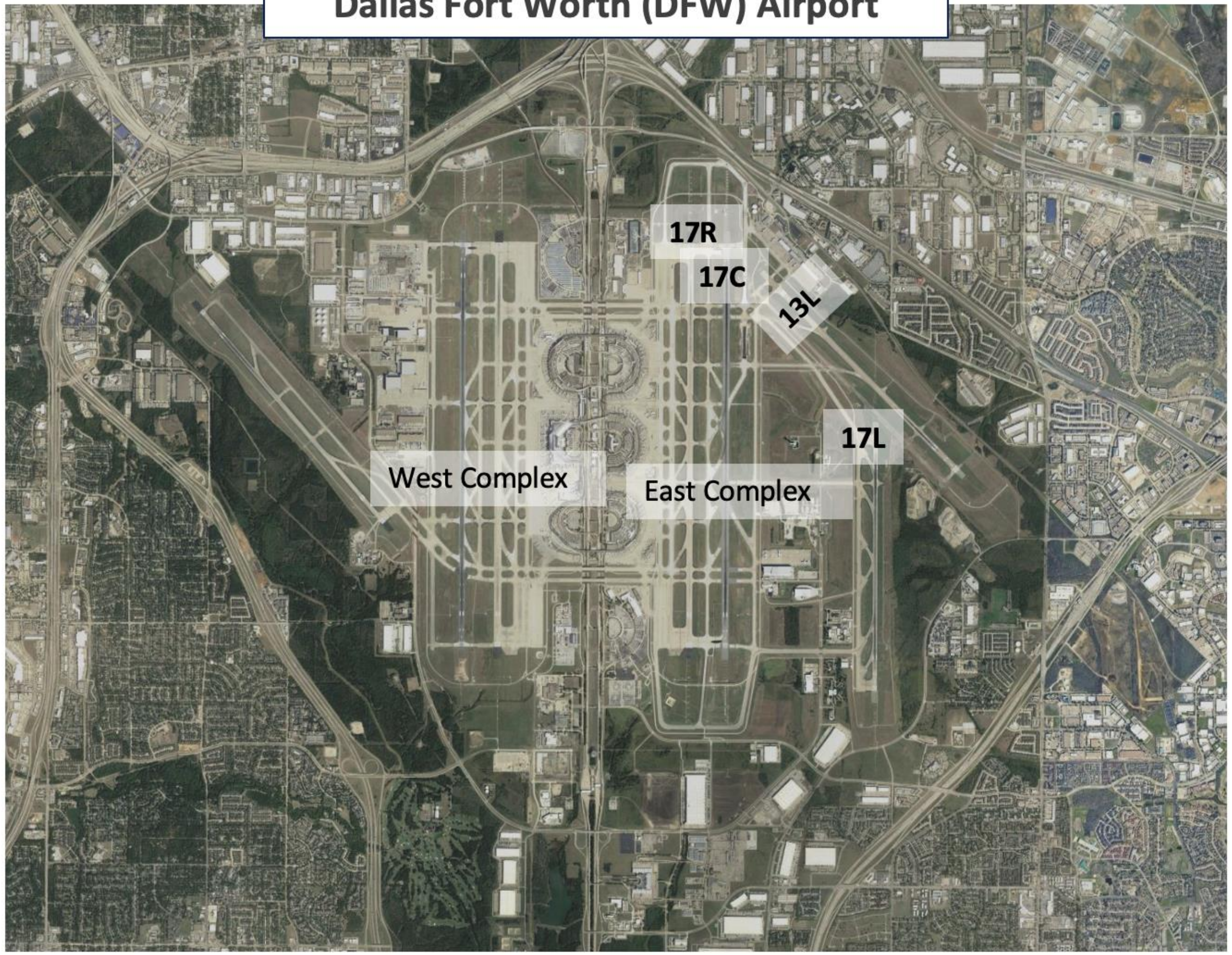
[5] D. Thipphavong, D. Apaza, B. Barmore, V. Battiste, C. Belcastro, B. Burian, Q. Dao, M. Feary, S. Go, K. Goodrich, J. Homola, H. Idris, P. Kopardekar, J. Lachter, N. Neogi, H. Ng, R. Oseguera-Lohr, M. Patterson, and S. Verma, "Urban air mobility airspace integration concepts and considerations." Paper 2018-3676, 18th AIAA Aviation Technology, Integration, and Operations Conference, June 2018.

Approach to
Developing and Refining Candidate Airspace Procedures for Urban Air Mobility Operations

- Dallas Area Airspace Structure
- Initial Guiding Principles and Assumptions
- Tabletop Activities #1 and #2
- Shakedown Human-in-the-Loop Simulation

Dallas Area Airspace Structure

Dallas Fort Worth (DFW) Airport



Source: Google Earth (n.d.). Retrieved 2023, from https://earth.google.com

Dallas Love (DAL) Airport

Source: Google Earth (n.d.). Retrieved 2023, from https://earth.google.com

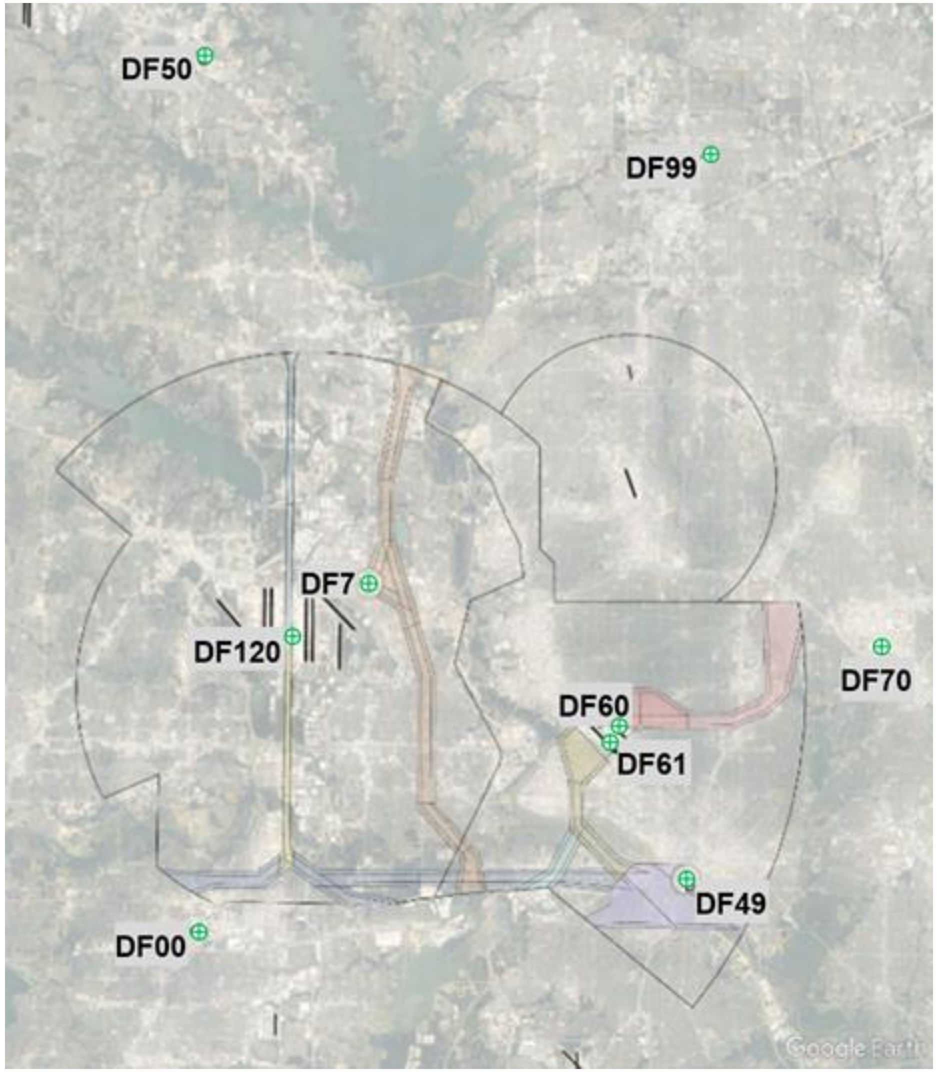
Vertiport Design and Locations

Inside Class B

- **DF120**: DFW Terminal E Parking Garage
- **DF7**: Periphery of DFW
- **DF60**: Business Ramp at DAL (existing)
- **DF61**: DAL Terminal E Parking Garage
- **DF49**: Dallas Downtown T49 (existing)

Outside Class B

- **DF99**: Frisco Superdome (existing)
- **DF50**: Denton (existing)
- **DF00**: AT&T Stadium (existing)
- **DF70**: Garland (existing)



Source: Google Earth (n.d.). Retrieved 2023, from https://earth.google.com

Initial Guiding Principles and Assumptions

- Federal Aviation Administration (FAA) to be the regulatory agency
- Cooperative Traffic Management
- Optimization of operations
- On-demand access to information
- Flexible and Scalable Architecture
- Data exchange between UAM and traffic management service providers
- Intent sharing and conformance to intent
- Demand-capacity management
- Performance Requirements

Tabletop Activities #1 and #2

Objective:

- Explore notional (candidate) airspace procedures and information exchange requirements between ATC and the UAM on-board pilot-in-command with stakeholders such as FAA and industry and get their feedback.

Benefit:

- Tabletop activities discussed several use cases in the Dallas Fort-Worth (DFW) area that allowed the research team to jointly explore ATC interaction with initial and midterm airspace constructs and technologies in the UAM context.

Discussion Topics Included (for initial and midterm operations):

- Automation
- Candidate airspace procedures
- Communications between ATC and the UAM on-board pilot-in-command
- Letters of Agreements
- Operational tempo
- Route and Corridor designs
- Vertiport design and locations

Participants:

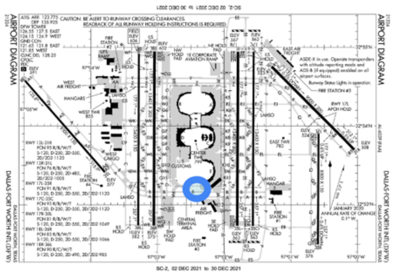
- Tabletop #1: Four retired air traffic controllers from DFW and DAL
- Tabletop #2: Government and industry partners + Participants from Tabletop #1

Research Assumptions and Conditions

Assumptions for all conditions

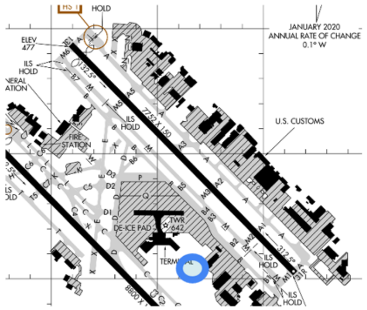
- On-board pilot-in-command (PIC)
- ATC provides separation for legacy aircraft
- Visual Flight Rules
- Visual Meteorological Conditions
- DFW South Flow

	UAM Operations	
	Initial Operations	Mid-Term Operations
Separation	ATC/Pilot	Operator/Pilot
Radar Acquisition	Pre-Assigned Beacon Code as per the Letter of Agreement	Pre-Programmed Automatic Dependent Surveillance – Broadcast (ADS-B)
Airspace Structure	Current-Day	New Airspace Structure (e.g., Corridors)
Automation	Current-Day	Automation Functions Assumed (Strategic and Tactical)
Procedures	LOA Defined Procedures	Implicit Clearance into Corridor Based on Airspace Authorization



DFW

AIS

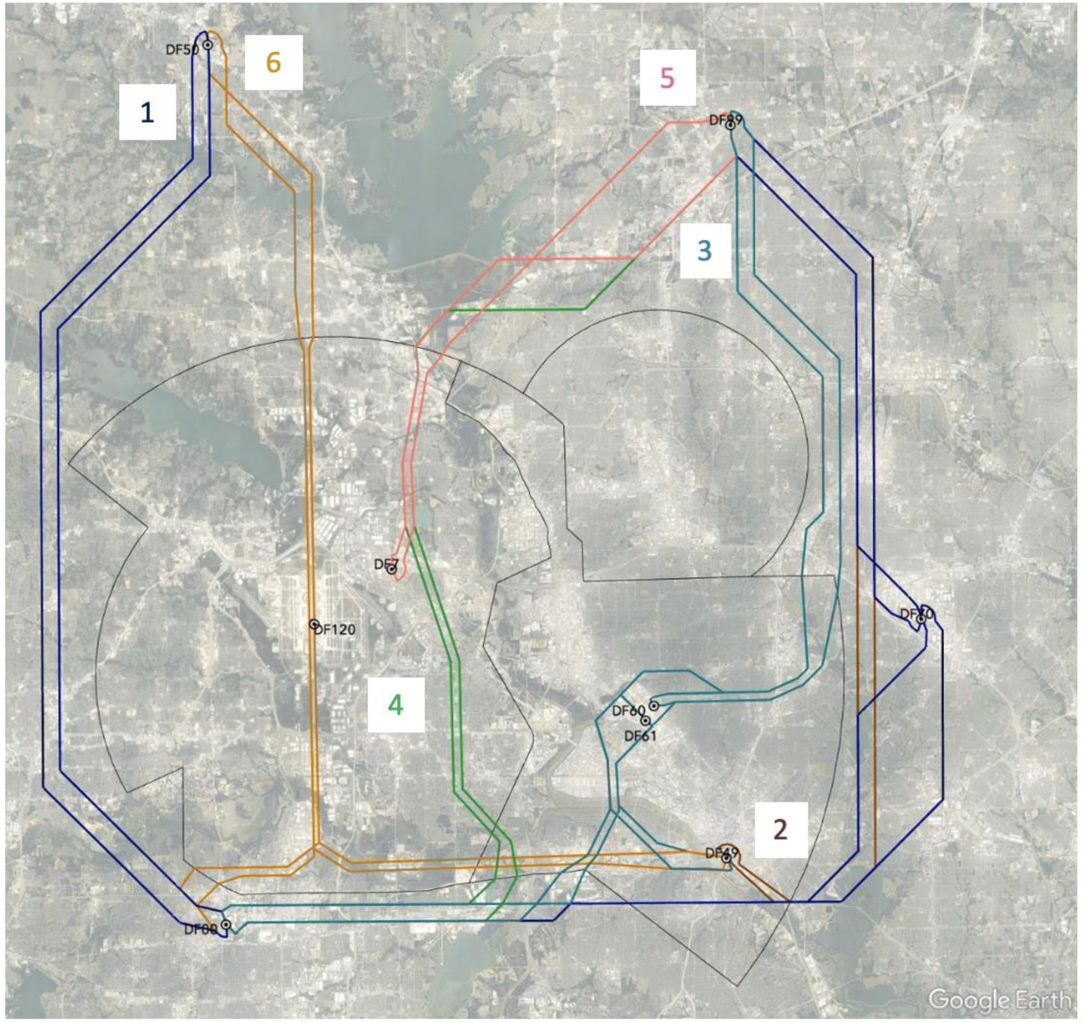


DAL

Tabletop Activities
Initial UAM Operations - Use Cases Explored

Initial UAM Operations - Use Cases:

- 1. UAM flights primarily in Class G/E
- 2. UAM flying in Class Bravo (entry & exit)
- 3. Airport transfers
- 4. Inside Class B
- 5. Airport periphery
- 6. UAM parallel to arrival/departures

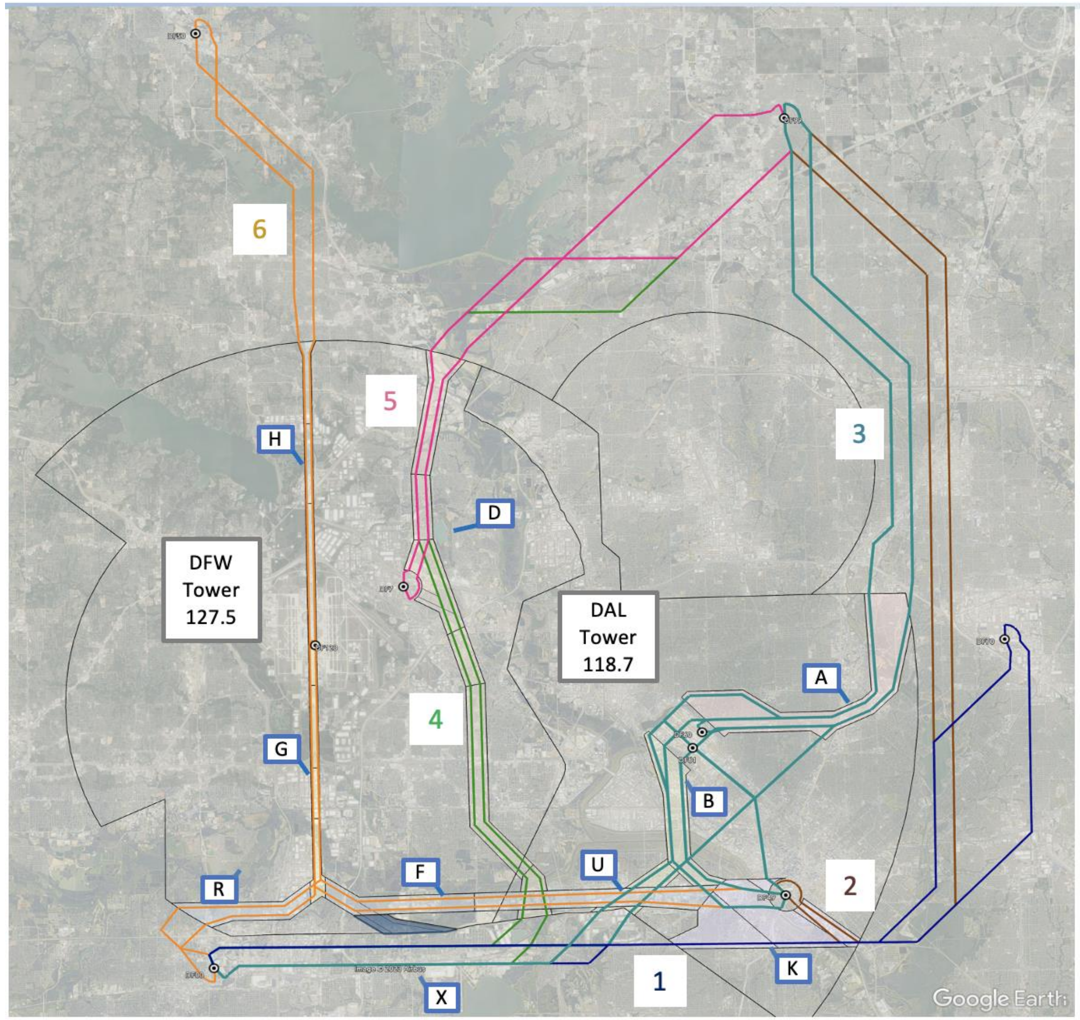


Source: Google Earth (n.d.). Retrieved 2023, from https://earth.google.com

Tabletop Activities
Midterm UAM Operations - Use Cases Explored

Midterm UAM Operations - Use Cases and Corridors:

- 1. UAM flights primarily in Class G/E to Class B
- 2. UAM flying in Class Bravo (entry & exit)
- 3. Airport transfers
- 4. Inside Class B
- 5. Airport periphery
- 6. UAM parallel to arrival/departures



Source: Google Earth (n.d.). Retrieved 2023, from https://earth.google.com

Midterm UAM Operations Assumptions

Airspace Operations

- Corridors designed in Class B/C/D to separate electric vertical takeoff and landing (eVTOL) from legacy traffic
- A waiver exists to the Class B separation criteria between VFR to VFR/Instrument Flight Rules (IFR) aircraft that weigh greater than 19000 lb and turbojet (1.5 mi lateral and 500 ft vertical) (FAR 7110.65 Chapter 7-9-4(b))
- Other aircraft are permitted to cross corridors
- Pilot-in-command is onboard, will use see and avoid for separation, and will monitor ATC frequency inside corridors

ATC Advisories

- The UAM on-board pilot-in-command will not receive explicit ATC clearances to enter a UAM corridor in controlled airspace provided they meet performance and operating requirements
- ATC does not provide separation services, traffic advisories, or safety alerts to UAM aircraft in corridors

Midterm UAM Operations Assumptions, cont.

Automation

- Every UAM aircraft is equipped with ADS-B In and Out, VHF voice radios, and other equipage required in the air traffic management environment
- Automation can assist with demand capacity balancing, strategic conflict management, spacing and sequencing

Communications

- Two-way voice communication with ATC is not expected during nominal operations inside corridors
- Specific beacon code displayed inside on STARS displays in the corridor for UAM aircraft. UAM aircraft's ADS-B pre-programmed with call sign will be available to the controller to access, if required

AIS Shakedown Human-in-the-Loop

Objective:

- Test revised use cases and LOAs in a simulation environment, explore appropriate aircraft volume for Initial and Mid-term UAM operations, and debug any simulation issues prior to data collection.

Benefit:

- Apply feedback from the Tabletop Activities in a simulation environment
- Test out the simulation environment in preparation for data collection
- Determine level of traffic for low and high conditions

Participants:

- Same four retired air traffic controllers from DFW and DAL who participated in Tabletop Activities #1 and #2

3D Model Rendering of the Future Flight Central at NASA Ames Research Center in Moffett Field, California, USA

Image Credit: NASA (https://www.nasa.gov/simlabs/ffc/) – Reference [11]

*AIS: Air Traffic Management (ATM) Interoperability Simulation

AIS Shakedown Human-in-the-Loop, cont.

Simulation Scenario Runs:

- A total of four scenario runs for each condition was examined, which resulted in a total of 16 counterbalanced runs
- Each run was 45-minutes in duration
- The initial use cases were conducted first followed by the midterm use cases

2 x 2 Experiment Matrix (Shakedown and AIS HITL)		
	Initial Use Cases	***Midterm Use Cases***
Low UAM Traffic Density	Condition A	Condition C
High UAM Traffic Density	Condition B	Condition D

AIS HITL Simulation at the Future Flight Central at NASA Ames Research Center in Moffett Field, California, USA

Image Credit: NASA (https://www.nasa.gov/simlabs/ffc/) – Reference [11]

*AIS: Air Traffic Management (ATM) Interoperability Simulation

Key Takeaways

Key Takeaways from Tabletop Activities & AIS Shakedown HITL

Tabletop 1 (May 2023) & Tabletop 2 (June 2023)

- **Objective:** Explore notional airspace procedures and information exchange requirements between ATC and the UAM on-board pilot-in-command (PIC) with stakeholders such as FAA and industry and get their feedback.

- **Outcomes:**
  - Simulation display suggestions to mimic real world operations
  - New proposed routes for traffic crossing runways
  - Identification of potential use cases for exploratory runs
  - Determination of feasibility for:
    - Pre-assigned beacon codes via the Letter of Agreement (if they are attached to the airframe)
    - Spine Road (including use in initial operations)
    - Proposed hypothetical Letter of Agreements for Initial and Midterm operations with minor adjustments
  - Determination of preference for:
    - Two-way communication (ATC-Pilot) when 1) entering Class Bravo Airspace in Mid-term operations and 2) departing vertiports inside the Class Bravo Airspace

Shakedown (August 2023)

- **Objective:** Test revised use cases and LOAs in a simulation environment, explore appropriate aircraft volume for Initial and Mid-term UAM operations, and debug any simulation issues prior to data collection.

- **Outcomes:**
  - Finalized airspace procedures for Initial and Mid-term use cases, survey questions, and training material
  - Determined level of traffic for low (50 aircraft with 1-mile in-trail) and high (100 aircraft with 0.5-mile in-trail) conditions
  - Iterated and implemented suggestions for data blocks characteristics and information presented on displays
  - Established simulation fixes for any issues concerning traffic scenarios

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[1] Airbus, "Urban air mobility." https://www.airbus.com/en/innovation/low-carbon-aviation/urban-airmobility

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Thank You!

For any questions or follow-ups, please contact:

Rania W. Ghatas
NASA Langley Research Center
rania.w.ghatas@nasa.gov

Website: https://csaob.larc.nasa.gov