National Aeronautics and Space Administration

Advanced Air Mobility (AAM): An Overview and Sustainability & Integration Considerations

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National Aeronautics
and Space Administration

Presentation Outline:

I. Overview of AAM

II. AAM Sustainability Considerations

III. Airport/Vertiport Integration Considerations

IV. Closing Thoughts

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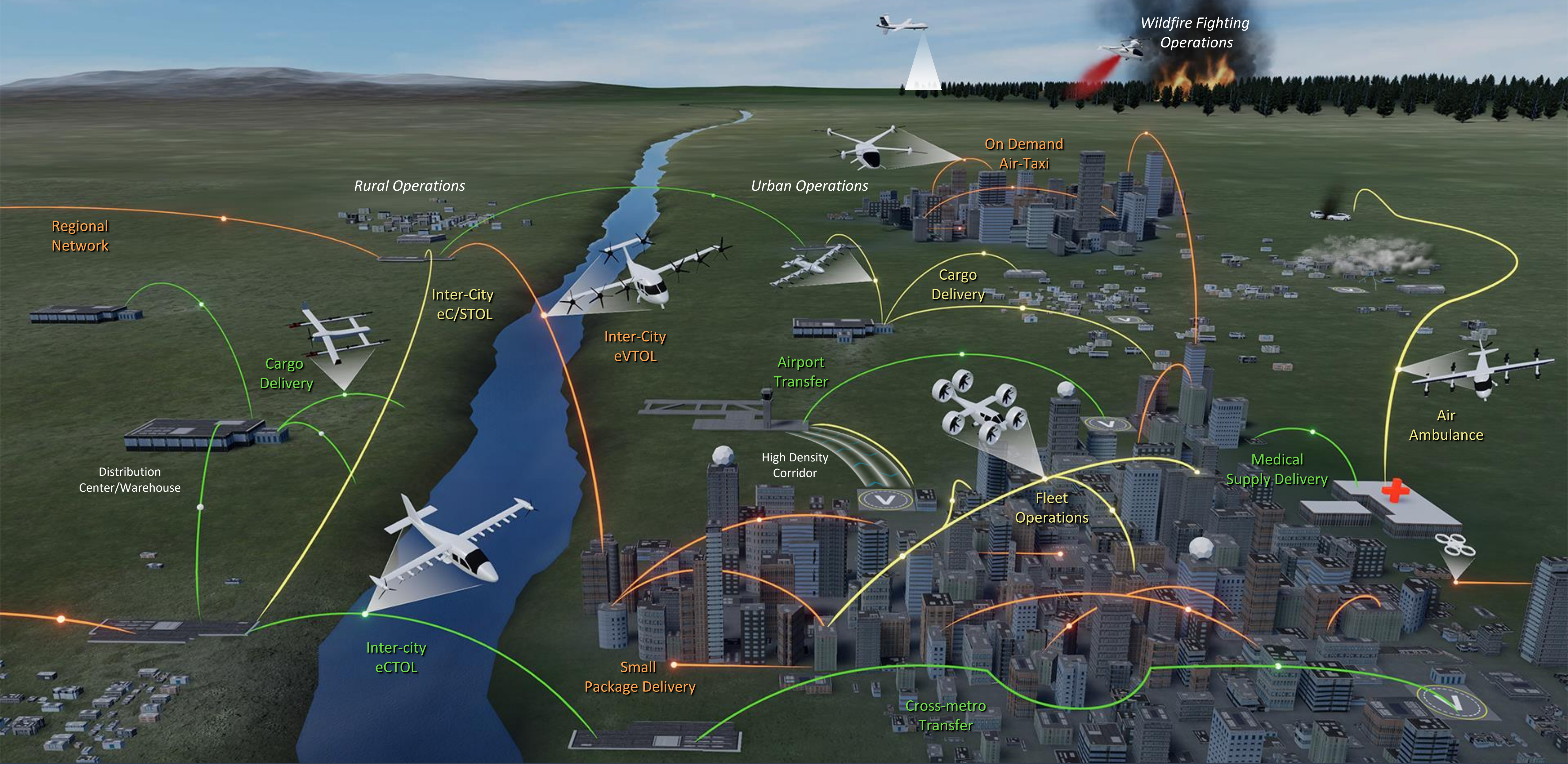
Overview of AAM

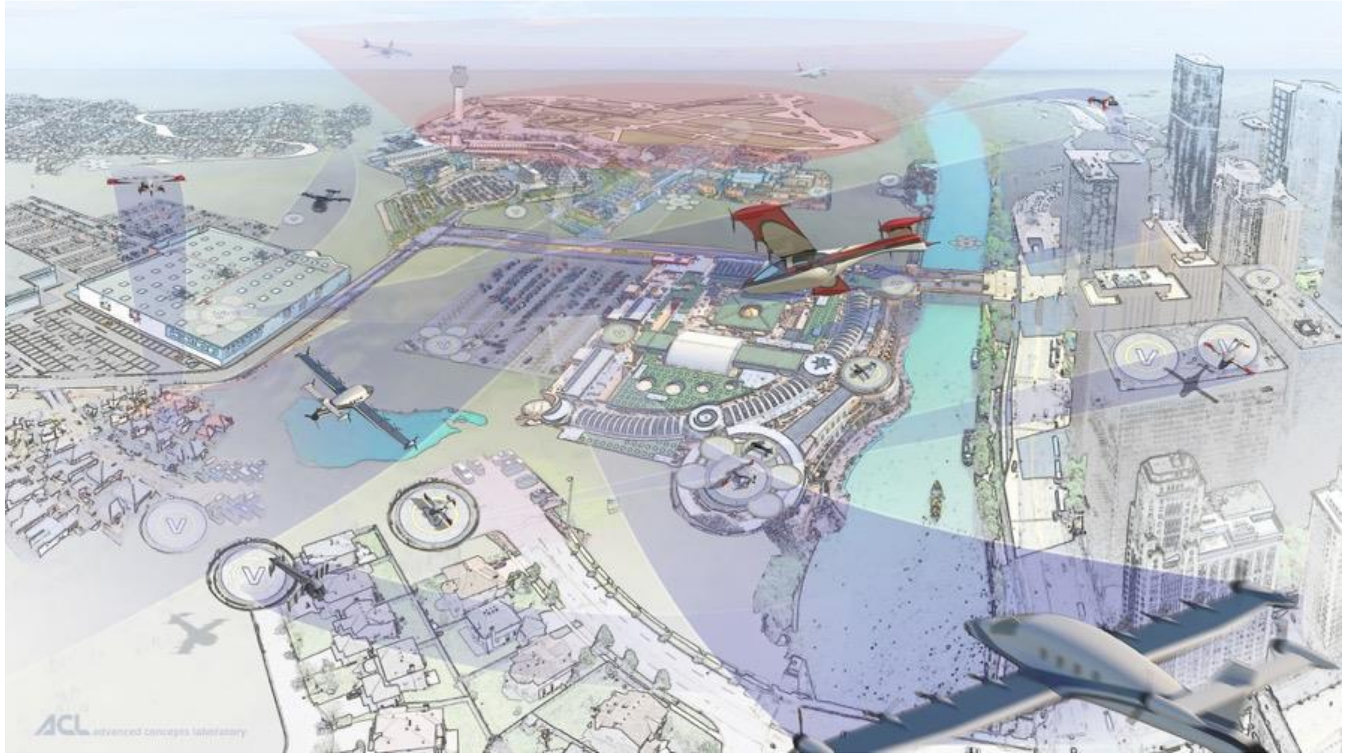
Advanced Air Mobility (AAM) Vision



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
  - Low Altitude Mobility (LAM)
    - 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 Small Unmanned Aircraft Systems (sUAS)
    - 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.)

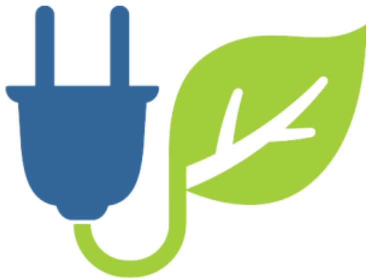
AAM is Convergence of the General Aviation and UAS Communities

AAM can be traced back to the early 2000s.
Interest has grown exponentially since the late 2010s.

AAM Sustainability Considerations

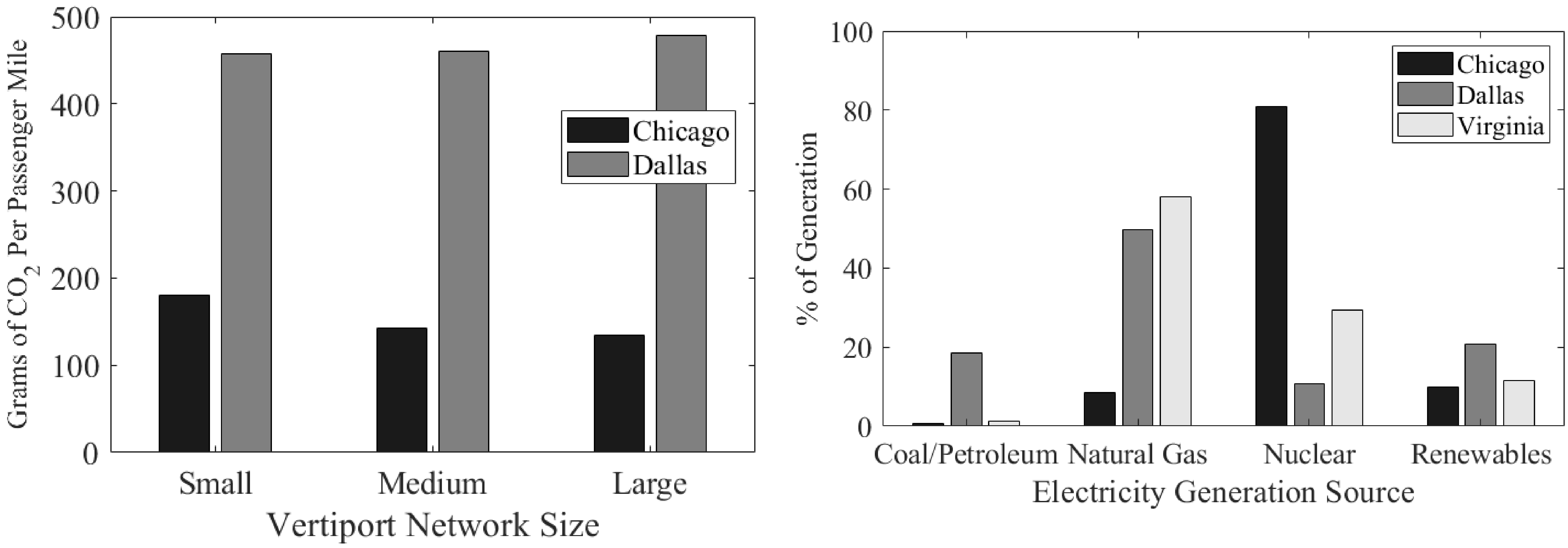
Sustainability and AAM

- Sustainability:
  - "Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future" [Brundtland Commission, United Nations General Assembly Document A/42/427]
- Often discussed with "Three Es": environment, economy, equity
- Sustainability is being considered by the AAM ecosystem
  - Full lifecycle is important: production, operations, retirement
  - Electric aircraft primarily being pursued
  - More efficient aircraft
  - Ride sharing
  - Low noise
  - Land use considerations
    - "Build a mile of road, and you can drive one mile. Build a mile of runway, and you can go anywhere." –Dan Wolf (Cape Air)
    - Roads remove carbon "sinks" (e.g., trees, grasses) and generate non-negligible emissions in construction and maintenance
    - Lower throughput via small AAM aircraft compared to roads



Electric Grid Composition is Likely to Drive Emissions from Electric AAM

- Recent work from Purdue has estimated potential demand for and operating CO_2 emissions from near-term UAM trips around the Chicago and Dallas-Ft Worth areas



References: AIAA 2020-2913, https://doi.org/10.1177/03611981211006439, AIAA 2021-3174, US Energy Information Administration

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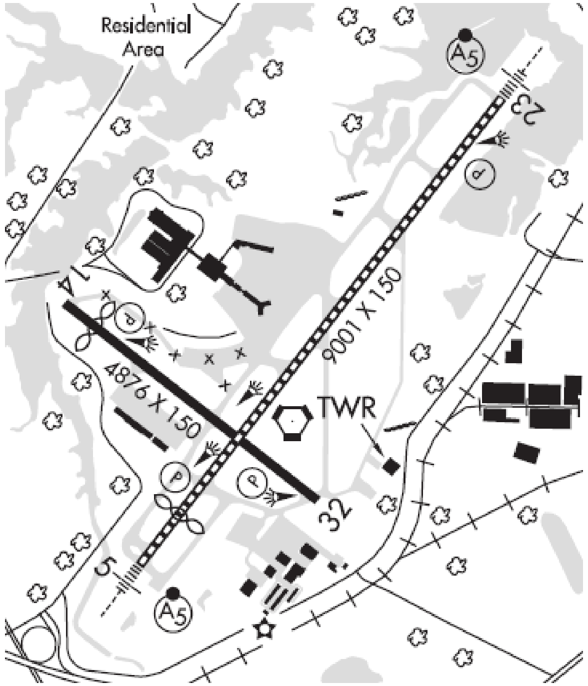
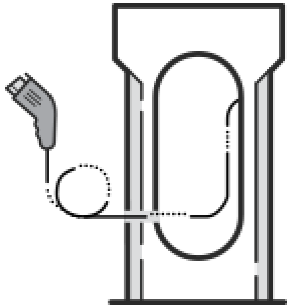
Airport/Vertiport Integration Considerations

Airport Integration 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

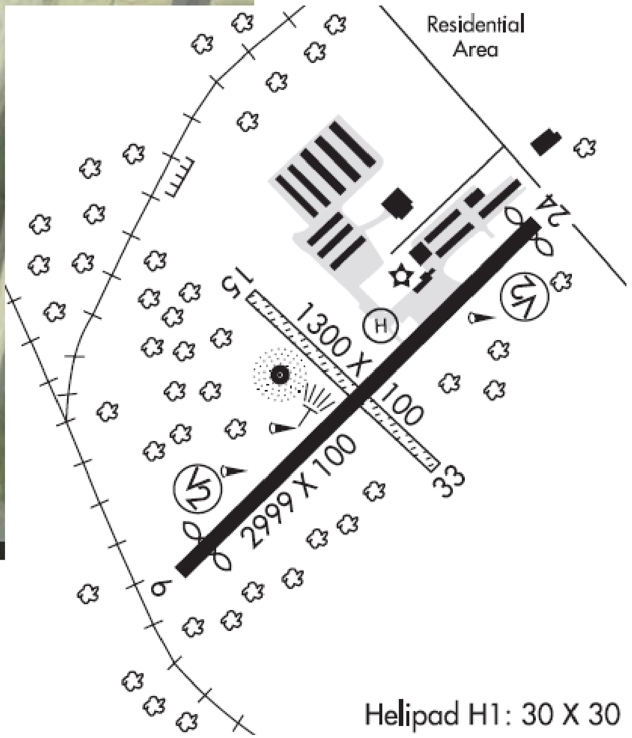
Note: ongoing NASA-funded research by Georgia Tech assessing potential energy demand for RAM and potential for on-airport renewables to generate needed electricity

Other Airport Integration 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

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, low altitude mobility (sUAS)
  - Common themes: electrification and increased automation
- The AAM ecosystem is considering sustainability in development
- 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

Questions / Discussion

Vertiports

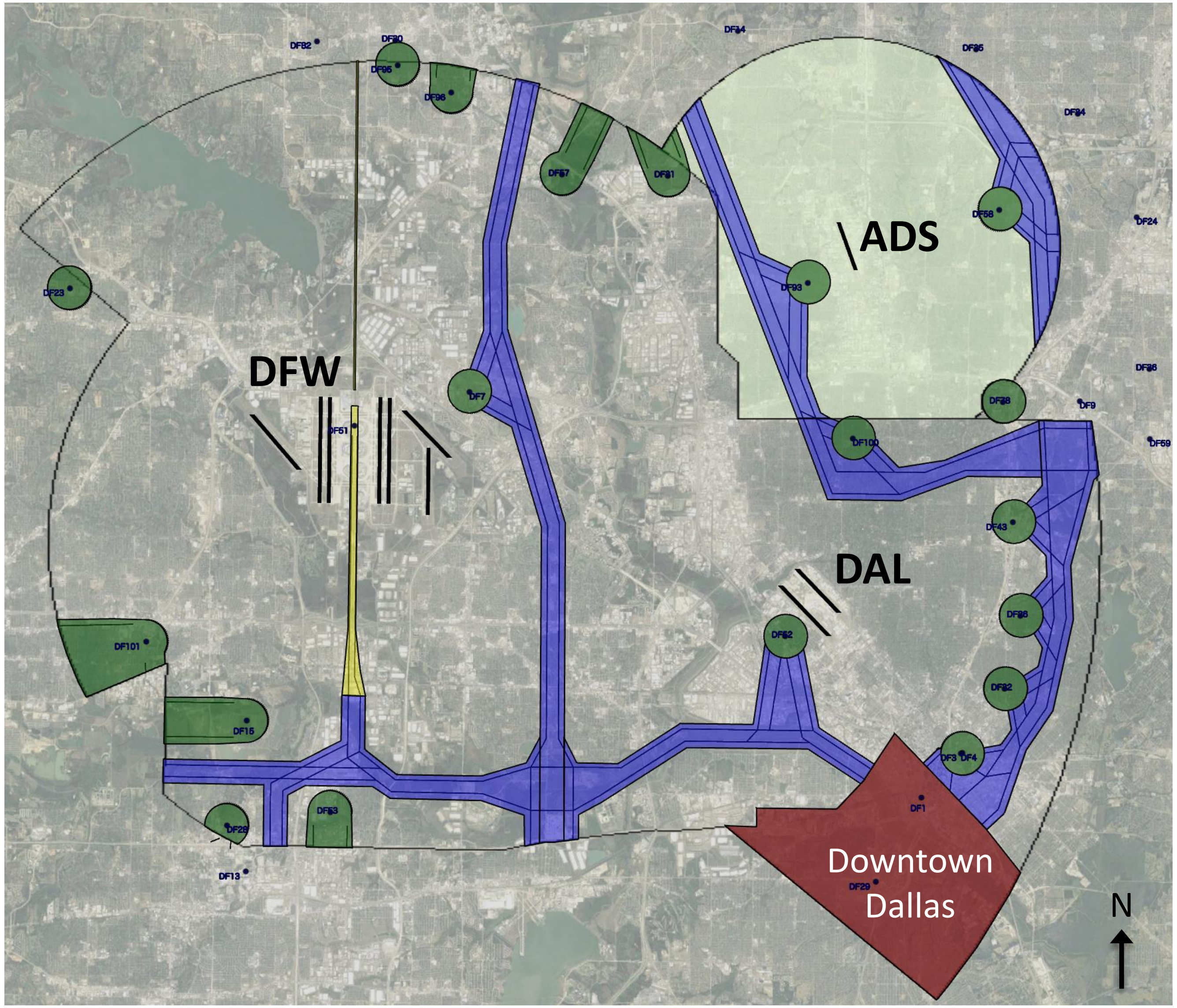
- Many potential locations
  - Greenfield sites
  - Rooftops
  - Parking garages
  - Barges
  - New overpasses / cloverleafs?
  - Etc.
- Many siting considerations
  - Multi-modal connectivity
  - Noise
  - Utilities (electric grid)
  - Proximity of other vertiports
  - Equity
  - Etc.
- Vertiport design guidelines under development
  - Initial draft engineering brief released in Feb 2022: https://www.faa.gov/airports/engineering/engineering_briefs/drafts/media/eb-105-vertiport-design-industry-draft.pdf


Notional city waterfront vertiport


Notional cloverleaf vertiport

AAM Airspace Integration Overview

- Low Altitude Mobility
  - 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.)



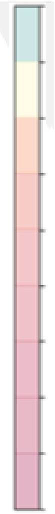
Notional UAM Corridor design in the Dallas-Ft Worth area, including boundaries of Class B and Class D airspace boundaries

Purdue Analysis Background Information

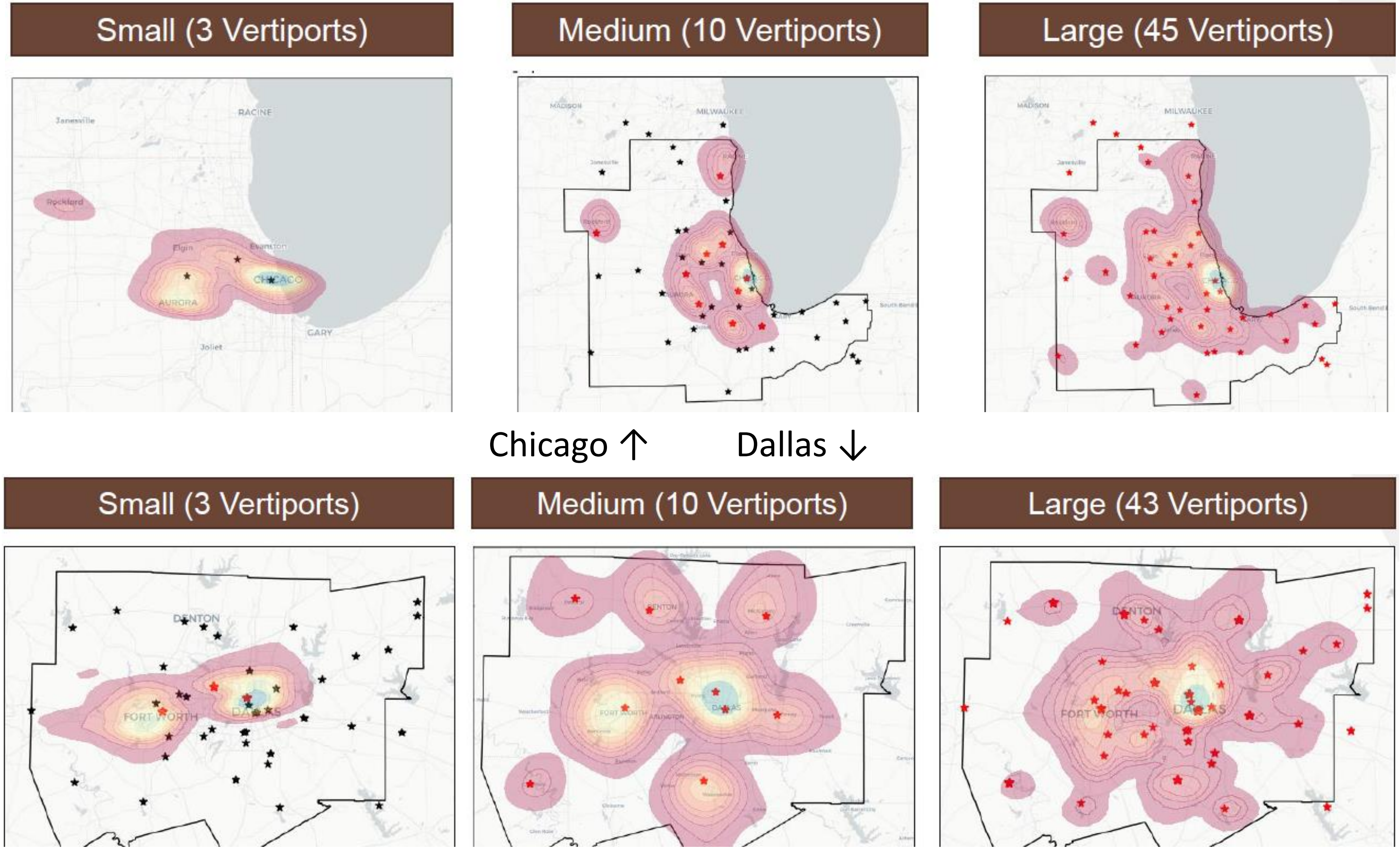
- Some key assumptions of the analysis include (but are not limited to):
  - 1 passenger per vehicle (ground or air)
  - Simple mode choice model based on the "effective cost" of the trip as determined by the cost for operating the vehicle (ground or air) and a cost based on the traveler's value of time (as estimated from income data in the US Census)
  - Air distance flown of 1.25 times the haversine distance between vertiports
  - Utilizing existing infrastructure (i.e., airports, heliports) as vertiport locations, but assume that this infrastructure can handle all operations that desire to utilize this infrastructure (i.e., no throughput limitations)
  - 100% load factor (i.e., no deadhead trips)
  - Results presented on slide 8 assume internal combustion engine cars are utilized for first-mile and last-mile legs to/from vertiports
  - Many other assumptions are documented in AIAA 2020-2913, https://doi.org/10.1177/03611981211006439, and AIAA 2021-3174

Purdue Analysis Vertiport Network Information

- Colors indicate “density” of origin or destinations:



  - Color scales vary between figures

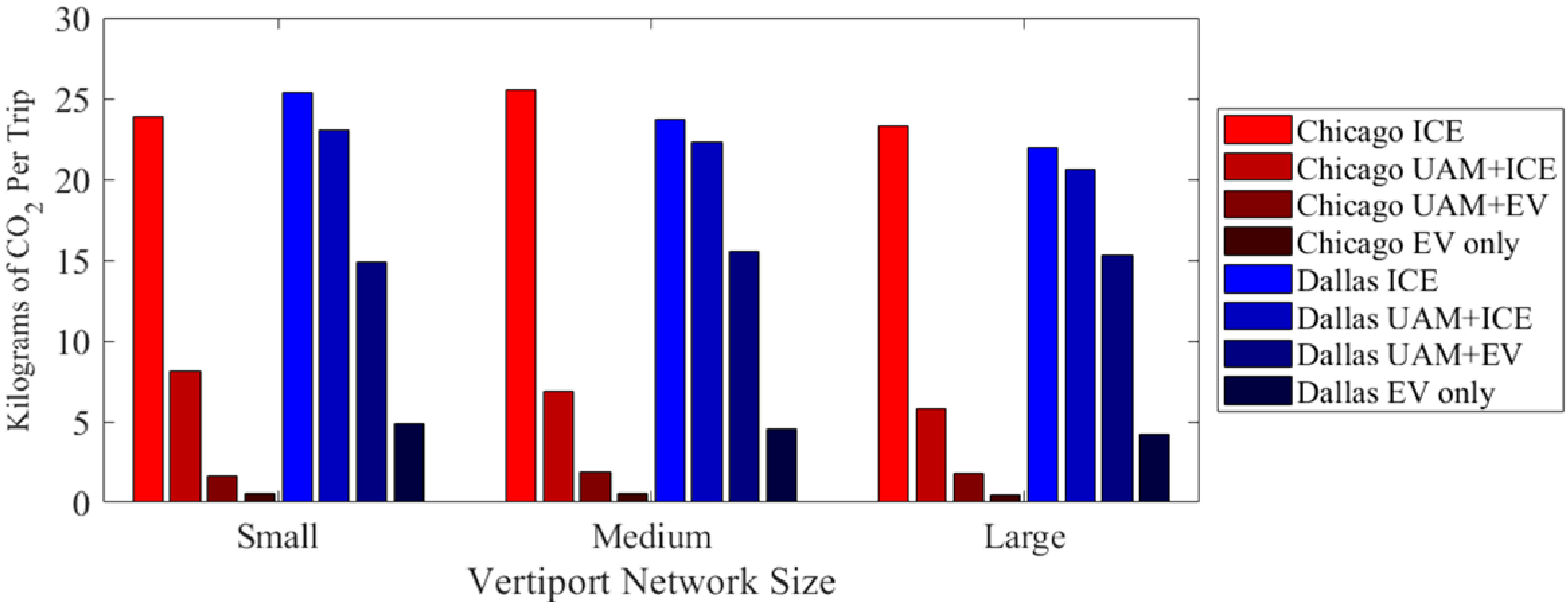


Background map data for all figures © OpenStreetMap contributors

Purdue Analysis Additional Information

- Total Number of Miles Traveled:

	Small Network	Medium Network	Large Network
Chicago Ground Only	19,280	195,794	319,673
Chicago UAM	17,866	182,776	296,292
Dallas Ground Only	47,619	122,271	331,911
Dallas UAM	42,953	112,872	298,585

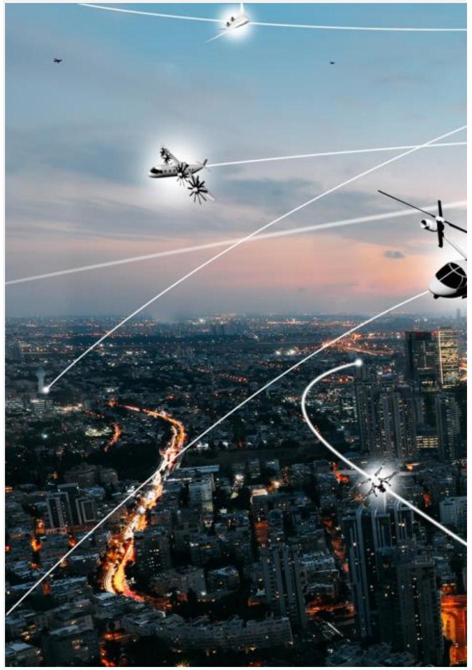


Useful References

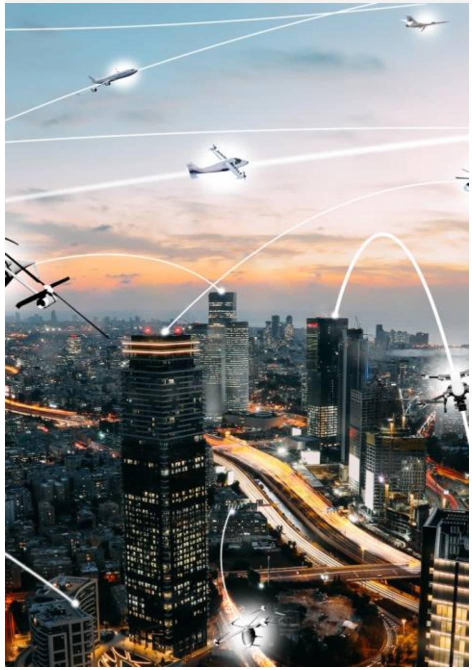
- FAA UTM ConOps v2.0: https://www.faa.gov/uas/research_development/traffic_management/media/UTM_ConOps_v2.pdf
- Regional Air Mobility White Paper: https://ntrs.nasa.gov/citations/20210014033
- UAM Market Studies
  - BAH (written report, detailed presentation, overview presentation):
    - https://ntrs.nasa.gov/citations/20190001472
    - 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 Role to Address AAM Challenges

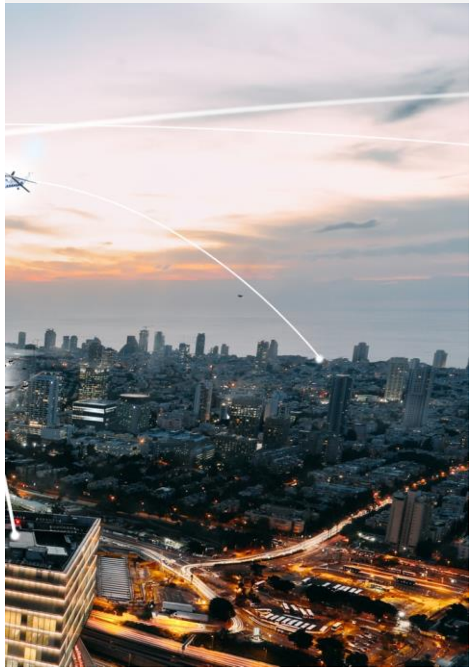
Vehicle Development and Operations



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

Form a connected stakeholder community

Collectively identify and investigate key hurdles and associated needs

Develop AAM system and architecture requirements

Support regulatory and standards development

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

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