inter•noise 2021

Community noise assessment of urban air mobility vehicle operations using the FAA Aviation Environmental Design Tool

Abstract ID 1482

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Motivation and Goal

- FAA Aviation Environmental Design Tool (AEDT) is the required tool to assess aircraft noise and other environmental impact due to federal actions at a civilian airport or vertiport, or in the U.S. airspace for commercial flight operations.

- Recent white paper† on urban air mobility (UAM) noise recommended that *"Research be conducted to more fully explore limitations in methods for assessing community noise impact of UAM vehicles in their operational environments, and to generate a software development plan that addresses the limitations of current models over time."*

- Goal is to investigate an approach for assessing UAM community noise using the standard distribution of AEDT, i.e., without modification.

† Rizzi et al., "Urban air mobility noise: Current practice, gaps, and recommendations," NASA TP-2020-5007433, 2020.

Concept Vehicles

<u>Quadrotor</u>†

- All-electric variant
- 3-bladed rotors
- 6469 lb. GTOW
- V_{max} 109 KTAS

<u>Lift Plus Cruise</u>†

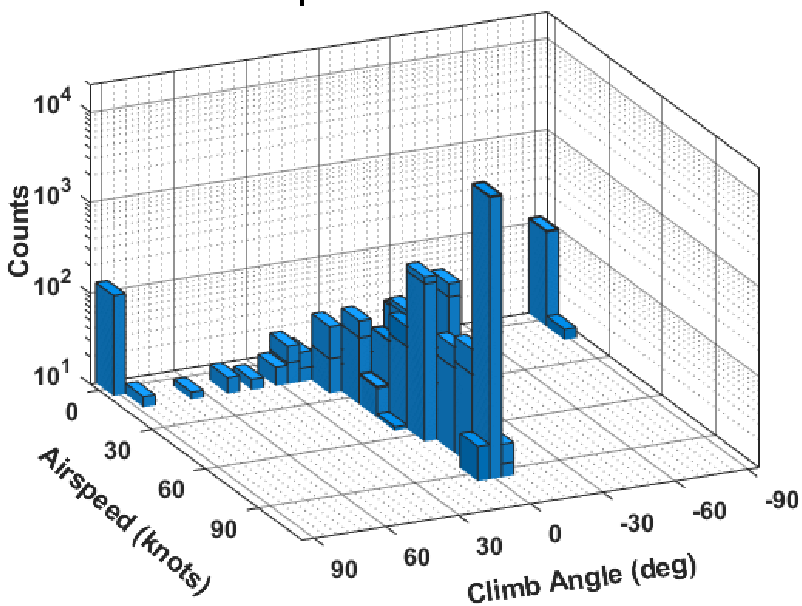
- Turboelectric variant
- (8) 2-bladed lifting rotors
- 3-bladed pusher propeller
- 5903 lb. GTOW
- V_{max} 123 KTAS

- Both vehicles sized for 1200 lb. payload (up to six passengers) executing a representative mission profile.‡

† Silva et al., "VTOL urban air mobility concept vehicles for technology development," AIAA Aviation Forum, AIAA-2018-3847, 2018.
‡ Patterson et al., “A proposed approach to studying urban air mobility missions including an initial exploration of mission requirements," *AHS International 74th Annual Forum,* 2018.

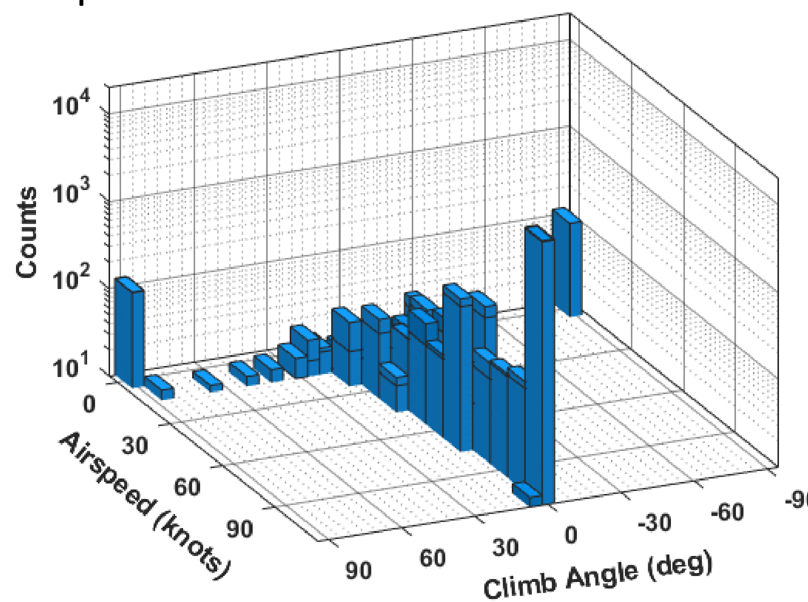
Trajectories and Operating States

- Trajectory data generated using mission planner† using route data from X2 engineering evaluation conducted by NASA ATM-X Project.
  - Route data represent 16 routes in Dallas-Ft. Worth area.
- 4D (x,y,z,t) trajectory data at 1 Hz sampling rate evaluated at operational states defined by pairs of airspeed (knots) and climb angle (deg).
  - Counts represent number of instances of operational state over all routes.



Quadrotor

- 42 unique states



Lift Plus Cruise

- 44 unique states

† Guerreiro et al., "Mission planner algorithm for urban air mobility – Initial performance characterization," AIAA AVIATION Forum, AIAA-2019-3626, 2019.

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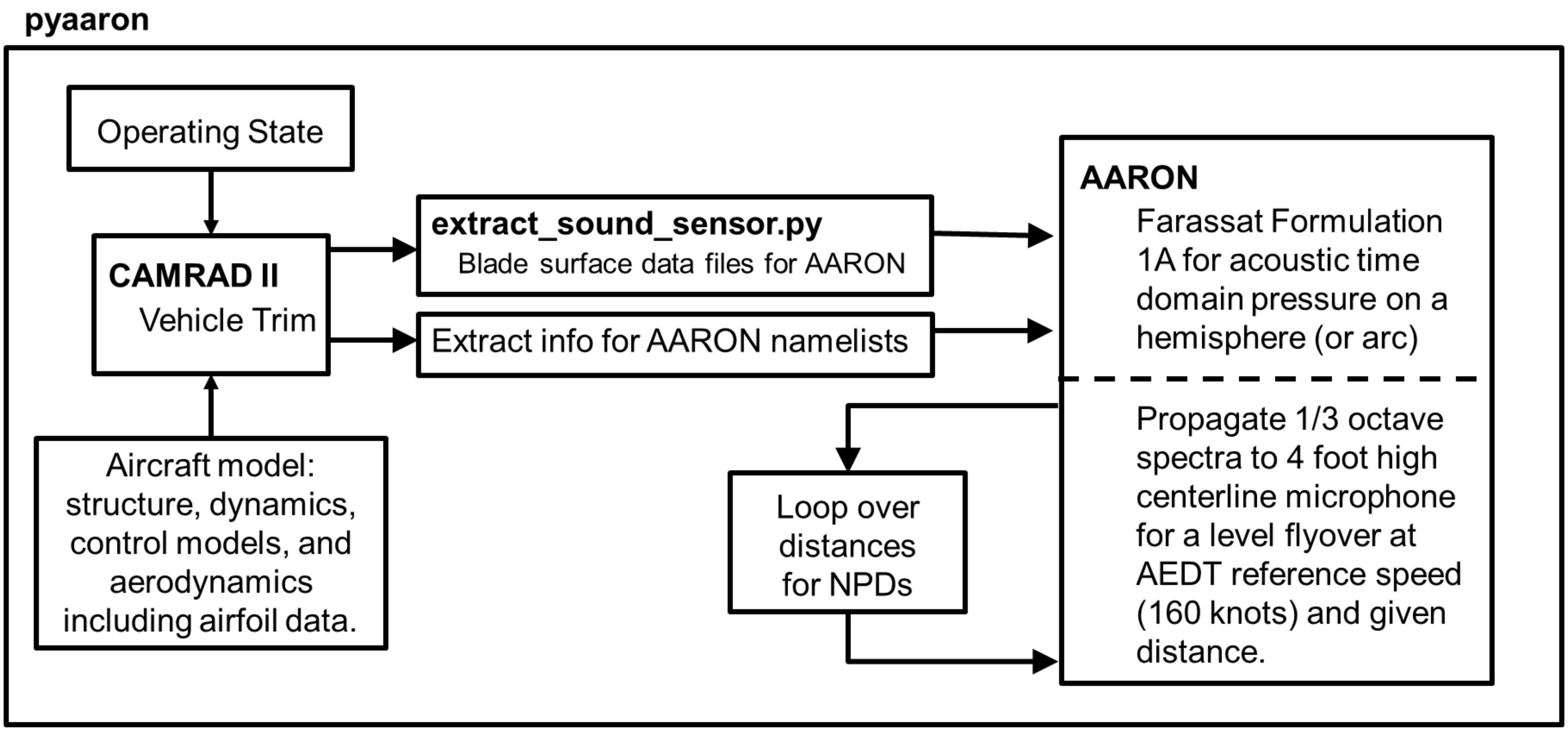
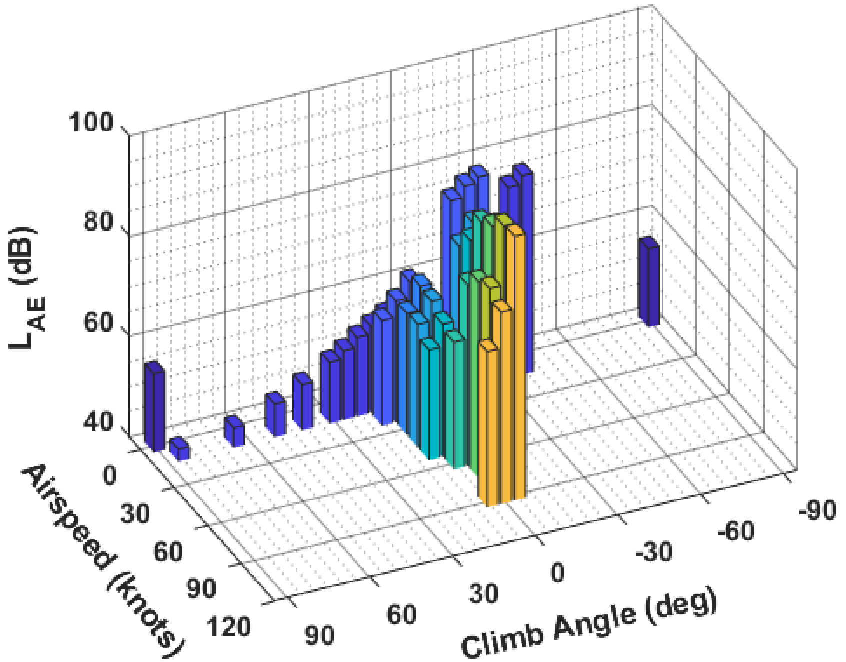
Noise-Power-Distance Data Generation

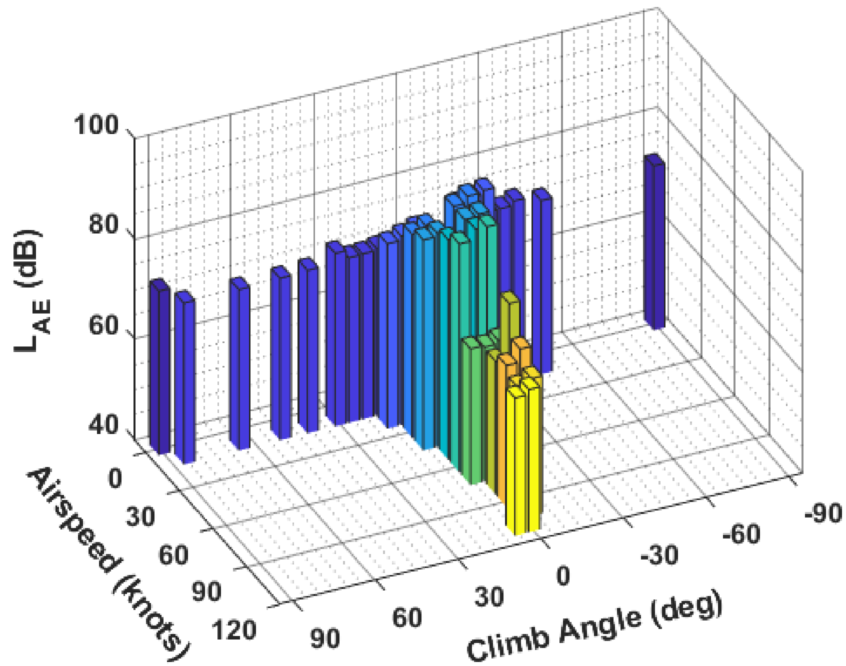


- Quadrotor was trimmed utilizing collective pitch control and constant RPM. The same trim mode was used for all speeds.
- Lift plus Cruise was trimmed utilizing collective pitch control with constant RPM. Three different trim modes used for low, moderate, and high speeds.

Noise Metrics

- AEDT noise metrics calculated at distances of 200, 400, 630, 1k, 2k, 4k, 6.5k, 10, 16k, and 25k ft. at reference speed of 160 knots.
- An operational state index used as the “Power” in NPD data.





Quadrotor

- Louder in cruise

Lift Plus Cruise

- Louder on takeoff and landing

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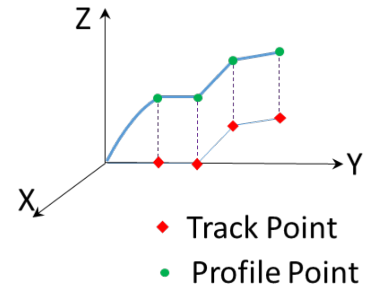
AEDT Modeling Approach

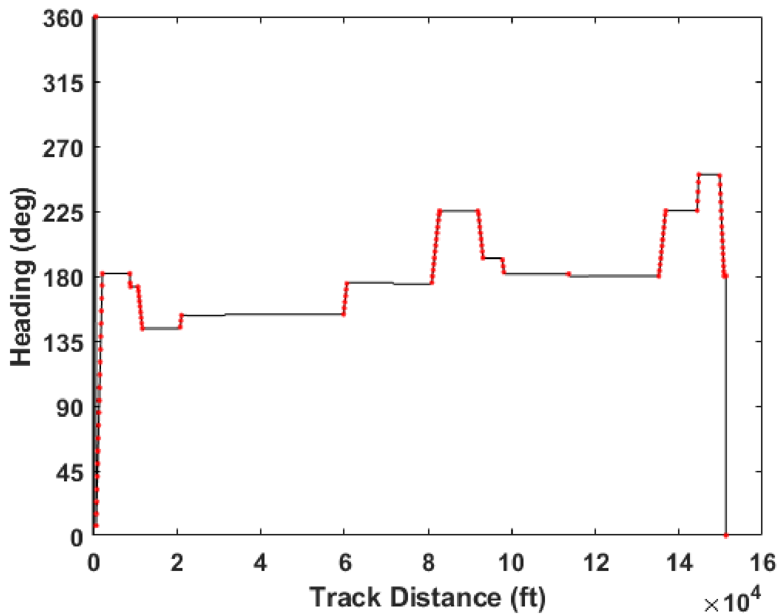
- Selection of aircraft type (fixed-wing vs. rotary-wing) made based on:
  - Using a common methodology independent of aircraft configuration,
  - Understanding an approach for mitigating unwanted behaviors, and
  - Representing as many operating states as may be needed.
- Fixed-wing mode
  - Pro: Use of a fixed-point flight profile (aircraft state specified directly by a set of profile points) gets around lack of AEDT performance model.
  - Con: Interpolation of noise between adjacent profile points with substantially different operating states.
- Rotary-wing mode
  - Pro: Better representation of source directivity and no interpolation of NPD data between operational modes.
  - Con: Limited number of operation modes (16). No rationale for downselecting from set of 40+ NPDs.

Fixed-wing aircraft type using fixed-point flight profiles deemed to offer most flexibility.

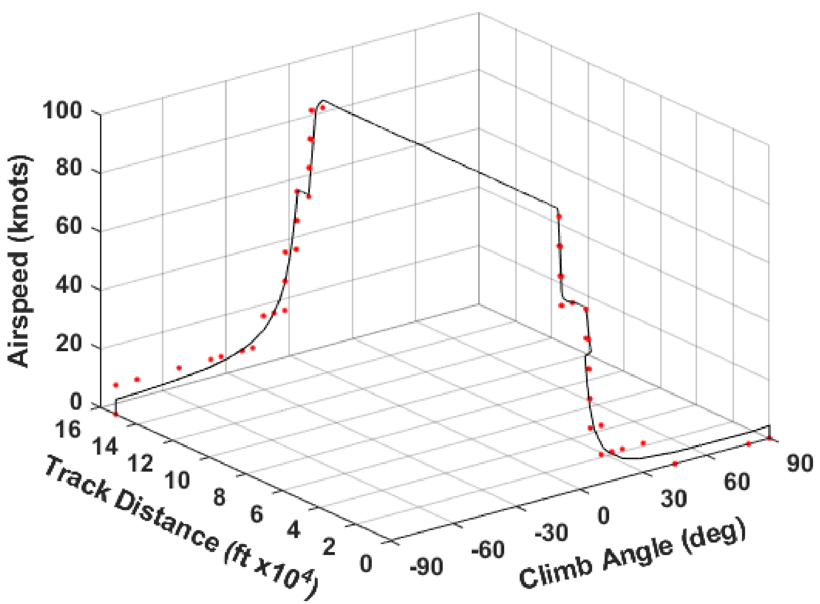
AEDT Modeling Approach

- AEDT study data consist of:
  - latitude, longitude, and elevations of vertiports
  - NPD data for each vehicle
  - a set of track points defining the 2D (x-y) routes along ground
  - set of profile points defining the aircraft operational state as a function of altitude and cumulative distance along the track





Track points based on
2° heading changes



Operational states
defining profile points

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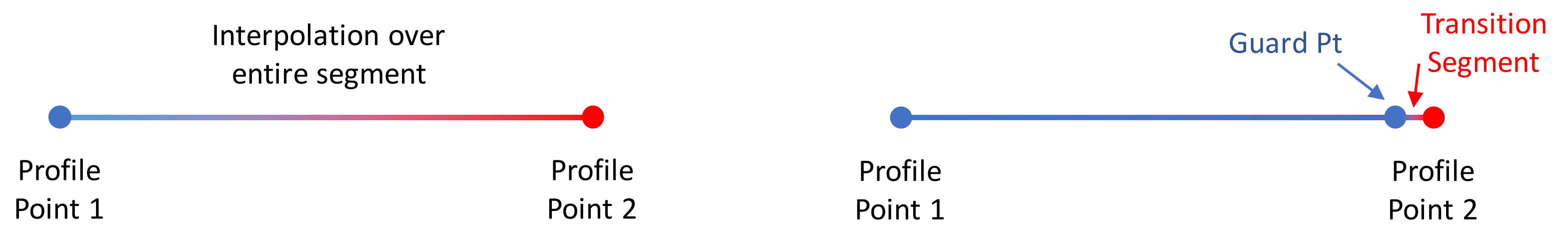
AEDT Modeling Approach

- Two focused studies conducted to inform procedure for constructing profile points.

- Guard Points and Transition Segments
  - Guard points were inserted to maintain constant operating states over majority of segment.
  - Interpolation occurs over very short transition segments.

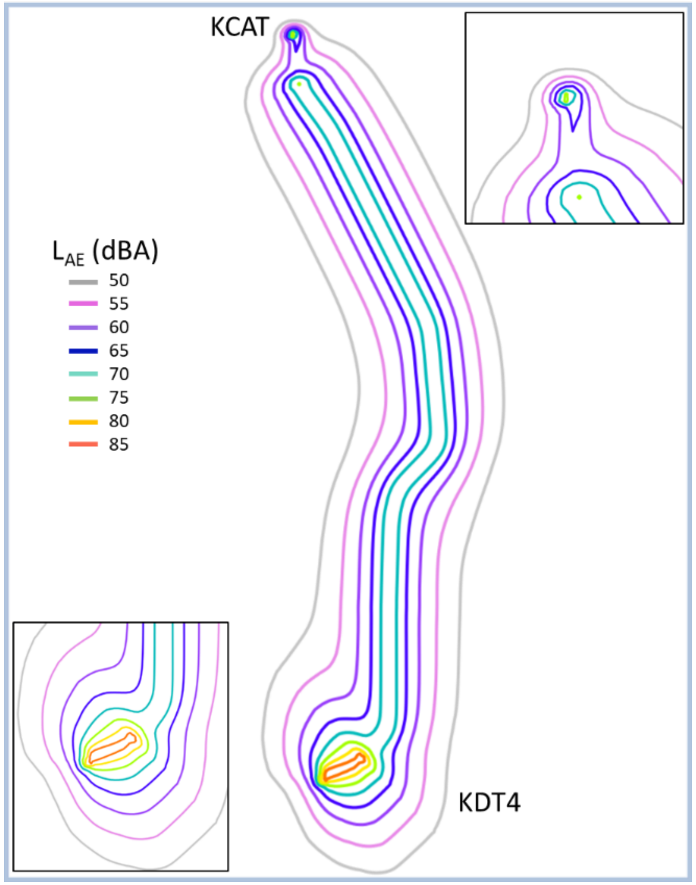


- Segment Velocity
  - The segment velocity was chosen as the average velocity to avoid zero speed cases in which the AEDT duration adjustment blows up.

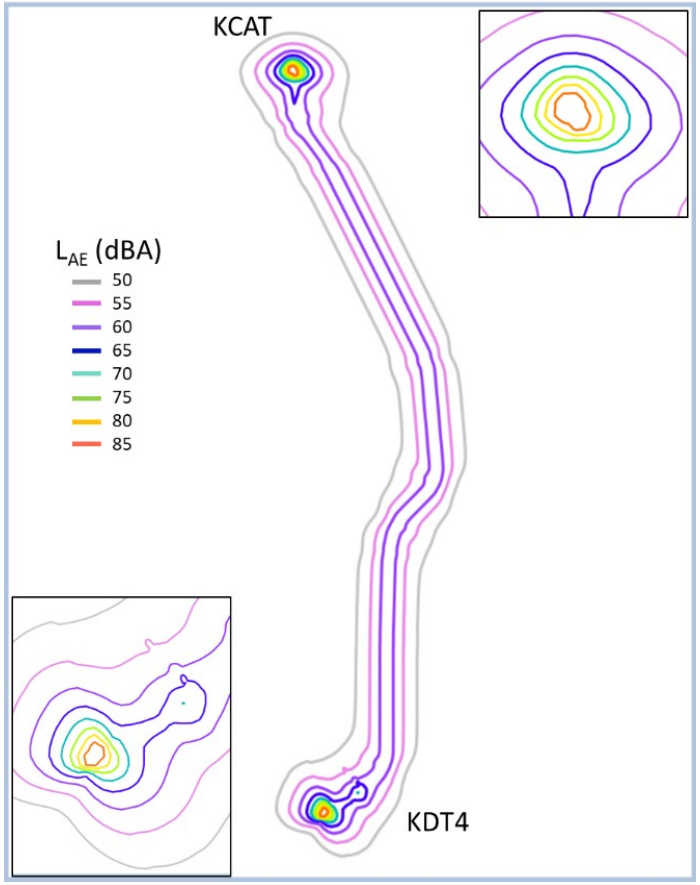
$$DUR_{ADJ} = 10\log_{10}\left[V_{ref} / V_{seg} \right]$$

Single Operation Results

Sound exposure level contours for a sample route (KCAT-KDT4)



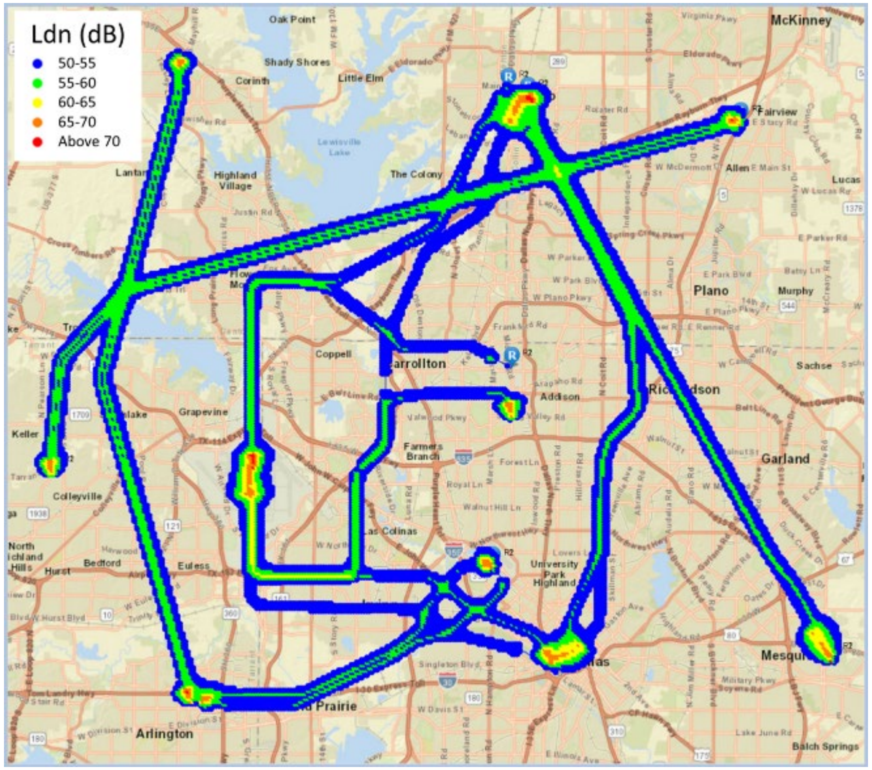
Quadrotor



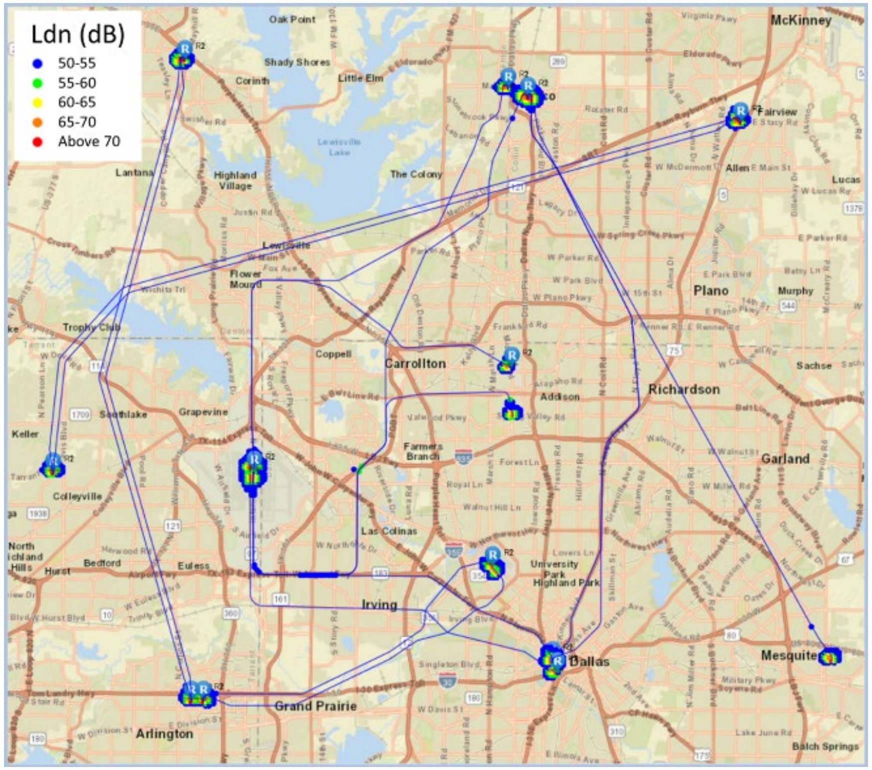
Lift Plus Cruise

Multiple Operation (Fleet) Results

- Day-night average sound levels for 16 routes in DFW area
  - Each vehicle has 600 departures per route over 12-hour daytime period



Quadrotor



Lift Plus Cruise

Concluding Remarks

- A methodology for conducting community noise assessments of UAM vehicles within existing capabilities of AEDT has been examined.
- User-supplied NPD data are assigned to constant operating state segments using fixed-point flight profiles.
- Limitations include lack of source directivity definition and built-in support for hover, and reliance on extensive NPD database.
    - Native support of fixed-point flight profiles for rotary-wing aircraft types would be a worthwhile consideration.
    - A surrogate NPD model and/or a reduction in the number of operating states would make this capability more accessible outside of the research community.

This work was supported by the NASA Aeronautics Research Mission Directorate, Revolutionary Vertical Lift Technology Project.