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

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**ABSTRACT**

**In contrast to most commercial air traffic today, vehicles serving the urban air mobility (UAM) market are anticipated to operate in communities close to the public at large. The approved model for assessing environmental impact of air traffic actions in the United States, the Federal Aviation Administration's Aviation Environmental Design Tool (AEDT), does not support analysis of such operations due to a combined lack of a UAM aircraft performance model and aircraft noise data. This paper discusses the initial development of a method to assess the acoustic impact of UAM fleet operations on the community using AEDT and demonstrates its use for representative UAM operations. In particular, methods were developed using fixed-point flight profiles and user-supplied noise data in a manner that avoids unwanted behavior in AEDT. A set of 32 routes in the Dallas-Ft. Worth area were assessed for single and multiple (fleet) operations for two concept vehicles.**

## 1. INTRODUCTION

In the U.S., the FAA Aviation Environmental Design Tool (AEDT) [1] is the required tool to assess aircraft noise and other environmental impacts due to federal actions at a civilian airport or vertiport, or in U.S. airspace for commercial flight operations. AEDT and prediction tools with the same or similar modeling technologies are used in other countries as well [2]. For fixed-wing aircraft, AEDT calculates various noise metrics using Noise-Power-Distance (NPD) data specific to each aircraft. In its customary mode of operation, the AEDT performance model determines the power required to execute the specified flight operation. The noise data are interpolated for power and distance, along with various adjustments, to estimate the sound exposure at a set of receptors on the ground. For rotary-wing aircraft (helicopters), AEDT calculates sound exposure using Noise-Operating Condition-Distance (still termed NPD) data specific to each vehicle, with the operating condition, e.g., hover, directly specified through a procedure step. For urban air mobility (UAM) vehicles, there exists neither a measured NPD database, nor a generic

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performance model. Thus, the modeling of UAM vehicles within AEDT cannot be accomplished by simply creating NPDs for new fixed-wing or rotary-wing vehicles.

A recent white paper [3] established a set of high-level goals to address key issues associated with UAM noise. One of these goals is to examine UAM fleet noise impacts through prediction and measurement, along with a recommendation 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*." To that end, this paper describes an approach for assessing UAM community noise using the standard distribution of AEDT, i.e., without modification. Specifically, a set of simulated trajectories are examined for two concept vehicles to determine operating states for which NPD data are generated through analysis. With the aid of small observational studies, a modeling methodology using fixed-point flight profiles is established. The methodology is demonstrated by assessing UAM community noise associated with a set of representative operations in the Dallas-Ft. Worth area.

## 2. CONCEPT VEHICLES, TRAJECTORIES, AND OPERATING STATES

### 2.1. Vehicle Descriptions

Two reference vehicles developed under the NASA Revolutionary Vertical Lift Technology (RVLT) Project were included in this investigation, namely, the quadrotor and "lift plus cruise" (L+C) vehicles, see Figure 1. Both vehicles were sized for a 1200 lb. payload (up to six passengers) executing a representative mission profile [4]. The quadrotor was an all-electric variant, with three-bladed rotors, gross weight of 6469 lb., and maximum airspeed $V_{max}$ of 109 knots true airspeed (KTAS). The L+C was a turboelectic variant, with eight two-bladed lifting rotors, a three-bladed pusher propeller, gross weight of 5903 lb., and $V_{max}$ of 123 KTAS. Additional details on these configurations can be found in Ref. [5].

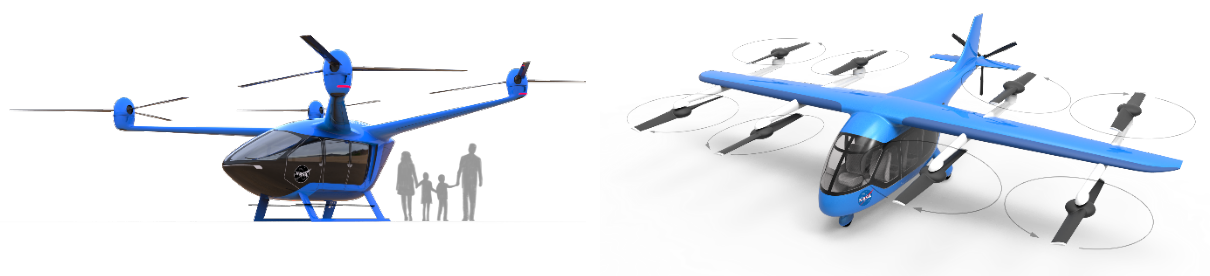


Figure 1: NASA RVLT reference vehicle configurations considered in this study: quadrotor (left) and lift plus cruise (right).

### 2.2. Trajectory Data

Trajectory data were generated using a mission planner algorithm developed by NASA for UAM operations research [6]. The route data are the same as those used in the X2 engineering evaluation conducted by the NASA Air Traffic Management – Exploration (ATM-X) Project, UAM subproject. The X2 evaluation consisted of sixteen routes around the Dallas-Ft. Worth, TX, area. For each aircraft, the output of each simulated route consisted of the 4D trajectory (time, latitude, longitude, and altitude), heading, ground speed, and rate of climb, at a 1 Hz sampling rate. For the purposes of this study, the altitude of each vertiport was fixed at 600 ft. (flat earth) relative to mean sea level (MSL), for compatibility with an early version of the AIRNOISEUAM tool described in the companion paper [7]. In addition, the maximum airspeed was limited to 85% of $V_{max}$.

### 2.3. Determination of Operating States

The trajectory data were reduced to determine a fewer number of aircraft operational states for which noise estimates are needed, see Section 3. In this paper, the aircraft operating states are defined by pairs of airspeed (knots) and climb angle (deg.). Given that each simulated flight had a duration of about 20 minutes, it was considered impractical to generate noise estimates for the approximately 1200 unique operational states for each of sixteen routes for two vehicles.

Without an a priori understanding of the sensitivity of the noise to operating state, a simple scheme was devised to sort the 1 Hz operating state data across evenly distributed bins in climb angle (from -90° in descent, to 90° in ascent) and airspeed (from 0 to $0.85V_{max}$), in equal increments of 5° and 10 knots, respectively. If there were less than 10 occurrences in any bin (across all routes for each vehicle), then the noise associated with the operating state corresponding to that bin was not calculated. This condensation process resulted in 42 and 44 unique operating states for the quadrotor and L+C vehicles, respectively, see Figure 2. Each is dominated by the high speed cruise condition, and the general shape is a reflection of the flight envelope of each vehicle. Low occurrence conditions are associated with low speed ascent and descent conditions, typically in proximity to the vertiports. For each vehicle, a unique numerical identifier, e.g., 101, 102, etc., was used to identify the particular operating state.

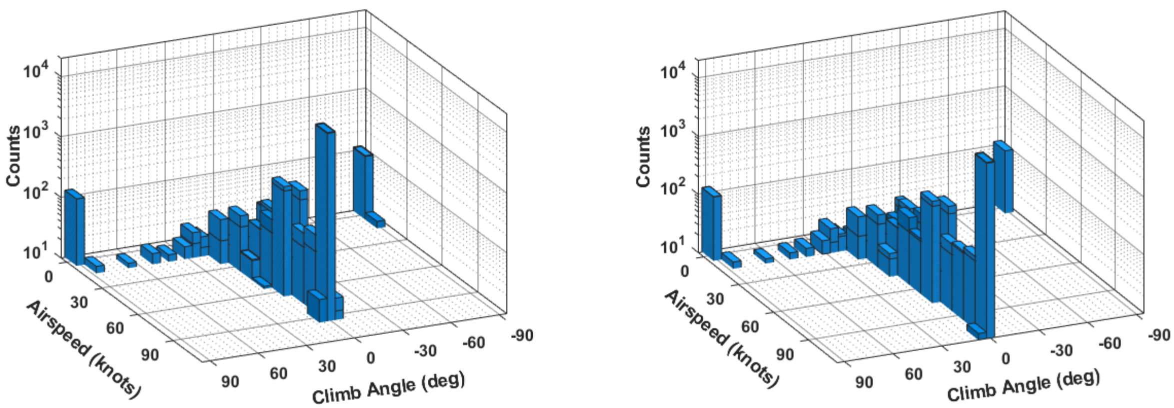



Figure 2: Operating states for the quadrotor (left) and L+C (right) vehicles.

## 3. NOISE-POWER-DISTANCE DATA GENERATION

One of the impediments to using AEDT for assessment of community noise from UAM vehicle operations is the lack of noise-power-distance (alternatively noise-operational mode-distance for helicopters) or NPD data for UAM vehicles in the Aircraft Noise and Performance (ANP) database [8]. This section describes the process for generating user-defined NPD data through analysis. The process involves multiple steps including determining the trimmed conditions for each vehicle, performing an acoustic analysis to generate the source noise definition, and generating noise metrics at a ground receiver at a set of prescribed distances. A summary of each analysis step follows. The overall process is depicted in Figure 3, in which the script "pyaaron" executes all steps for each operating state.

### 3.1. Vehicle Trim

For a given vehicle configuration (quadrotor and L+C) and prescribed operating state, the vehicle is "trimmed" in an iterative fashion using a comprehensive analysis code. In the trimmed condition, the control surface configuration of the vehicle corresponds to the desired operating state (airspeed and climb angle). For this work, the Comprehensive Analytical Model of Rotorcraft Aerodynamics and Dynamics (CAMRAD II) [9] was used to trim the vehicles.

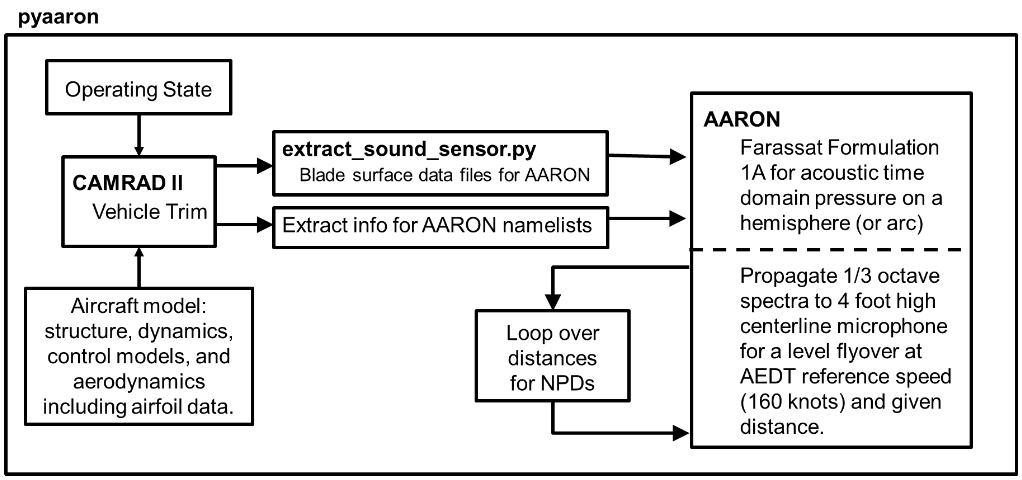



Figure 3: NASA process for generating NPD data.

Quadrotor Vehicle Trim

The rotors on the quadrotor vehicle operate at a constant RPM with a 20 Hz blade passage frequency (BPF) and utilize collective pitch control. The trim targets are the six degrees-of-freedom ($F_x$, $F_y$, $F_z$, $M_x$, $M_y$, and $M_z$), and trim variables include four collective control combinations of rotor pairs, plus vehicle pitch and roll. The same trim mode was used at all speeds.

L+C Vehicle Trim

The lifting rotors and pusher propeller on the L+C vehicle also operate at a constant RPM (35 Hz BPF for lifting rotors, 127 Hz BPF for propeller) and utilize collective pitch control. However, different trim modes are used depending on the speed. At low speeds, the pusher propeller was not used. The trim targets are three degrees-of-freedom for longitudinal trim ($F_x$, $F_z$, and $M_y$), and trim variables include two collective control combinations of the lifting rotors, plus vehicle pitch. At moderate speeds, all lifting rotors and the pusher propeller operate. The trim targets are the same as those used at low speed, and trim variables include two collective control combinations of the lifting rotors, plus the pusher collective. At high speed (cruise) conditions, the lifting rotors are turned off and the wing produces lift. The trim targets are two degrees-of-freedom for longitudinal trim ($F_x$ and $F_z$), and trim variables include the pusher collective and vehicle pitch. The dividing line between trim modes is determined by a number of factors related to the operating state.

### 3.2. Source Noise Definition

The resulting blade loadings and motion from the trim operation serve as input to a system noise prediction. In this work, the ANOPP2 Aeroacoustic ROtor Noise (AARON) tool, a part of NASA's 2$^{nd}$ generation Aircraft Noise Prediction Program (ANOPP2) [10], was used for the system noise prediction. The acoustics solver uses Farassat's Formulation F1A [11] to compute the periodic loading and thickness noise components under a quasistatic operating condition. These two components constitute the so-called first generation (Gen 1) NPD database. The database (Gen 1.2) used in this work includes improvements in wake modeling over the original Gen 1 database developed in 2020. Subsequent generations will include additional noise components, e.g., broadband self noise and electric motor noise.

### 3.3. Noise Metrics

For the reasons later discussed in Section 4.1, AEDT noise exposure estimates are performed using the fixed-wing aircraft type. For fixed-wing aircraft, the above source noise definition is subsequently "flown", through simulation, at the 160 knot AEDT reference speed and at the AEDT distances (the "Distance" in NPD) of 200, 400, 630, 1k, 2k, 4k, 6.3k, 10k, 16k, and 25k ft. above an observer under the flight path. This is analogous to adjusting measured data from the as-flown velocity to the AEDT reference speed. The requisite noise metrics (the "Noise" in NPD) are calculated using ANOPP2's Acoustic Analysis Utility and include the maximum A-weighted sound pressure level $L_{Amx}$, the A-weighted sound exposure level $L_{AE}$, the maximum tone-corrected perceived noise level $L_{PNTSmx}$, and the effective tone-corrected perceived noise level $L_{EPN}$. As in the rotary-wing vehicle type in AEDT, the operational state identifier is used here to refer to the operational state (airspeed and climb angle), not the thrust (the "Power" in NPD).

Resulting $L_{AE}$ data are shown in Figure 4 for the range of operational states. It can been seen for cruise conditions (> 60 knots) that the L+C is quieter than the quadrotor as the L+C lifting rotors are turned off and lift is generated by the wings. However, the L+C noise is significantly higher than the quadrotor on liftoff (low speed and high positive climb angles), but comparable on landing. Figure 4 also shows that any alternative scheme for discretizing the data in airspeed and climb angle, e.g., to avoid interpolation between operational states with large differences in noise, would need to be configuration dependent. At the same time, the distribution of noise with operating state suggests that reduction in the number of operating states may be possible.

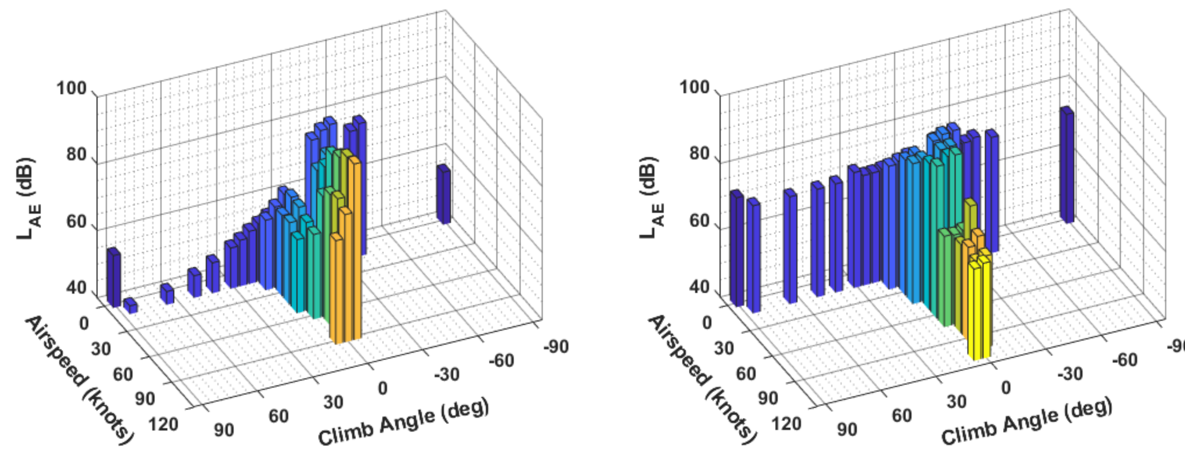



Figure 4: $L_{AE}$ data for the quadrotor (left) and L+C (right) vehicles at a distance of 200 ft.

## 4. AEDT MODELING APPROACH

### 4.1. Aircraft Type Selection

There are two aircraft types supported within AEDT: fixed-wing and rotary-wing (helicopters). The analysis of UAM vehicles in AEDT must therefore be performed as either fixed-wing, rotary-wing, or as a hybrid using a combination of the two types. As the intent of this effort was to develop a methodology for using AEDT as-is, i.e., without changes to the program itself, the selection of which aircraft type(s) to use was made in consideration of several factors. Those factors included i) the desire to have a common methodology independent of UAM aircraft configuration, ii) having an understanding and approach for mitigating unwanted behaviors, and iii) representing as many operating states as may be needed.

Fixed-Wing Type

Within AEDT, the flight profile contains information about the aircraft state, including altitude above field elevation (AFE), speed, and thrust (power), as a function of distance along the ground track. A performance model (using data in the ANP database) determines the aircraft state associated with the specified flight operation. When the flight operation is comprised of a set of procedural steps, e.g., a descent, AEDT calculates a set of profile points describing the flight profile. The lack of a general performance model for UAM vehicles is another limitation to using AEDT for assessment of UAM community noise. One way around this is to use fixed-point flight profiles, in which the aircraft state is specified directly by a set of profile points. In this usage, the operational state identifier is used as a surrogate for the thrust. This approach allows any and all of the 40+ generated NPDs to be included in the analysis. A compromise associated with using the fixed-wing type applied to UAM is AEDT's interpolation on noise between adjacent profile points with differing operating states (because the identifier is being used in place of the thrust).

Rotary-Wing Type

The rotary-wing type avoids the need for a performance model to determine the aircraft state by specifying a set of procedure steps that define the flight profile. Each procedure step represents an operational mode, and each operational mode has a single NPD curve (noise vs. distance). In that sense, procedure steps are akin to the fixed-point flight profiles in the fixed-wing type. Advantages of the rotary-wing type over the fixed-wing type include i) a better representation of the source directivity, and ii) no interpolation of NPD data between operational modes. However, the main compromise of using the rotary-wing type is the limited number of operational modes supported; up to 12 for dynamic operational modes and up to 4 for static operational modes [1]. Using the rotary-wing type would necessitate downselecting from the set of 40+ generated NPDs without some rationale for doing so.

It was decided to use the fixed-wing aircraft type with a fixed-point flight profile for this first generation (Gen 1) assessment, as it offered the most flexibility and ability to include as many operating states as deemed necessary. It also does not apply procedure-induced adjustments on takeoff and landing. Further, within the fixed-wing aircraft type, specification of the UAM vehicles as propeller-driven aircraft disables application of fixed-wing adjustments for engine installation effects (as part of the lateral attenuation calculation).

### 4.2. Focused Studies

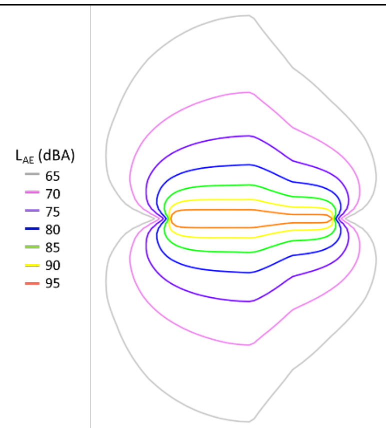
Two focused studies were conducted to help inform the procedure for constructing the profile points that are used in the AEDT assessment. Specifically, the studies related to the use of guard points and transition segments, and segment velocity.

Guard Points and Transition Segments

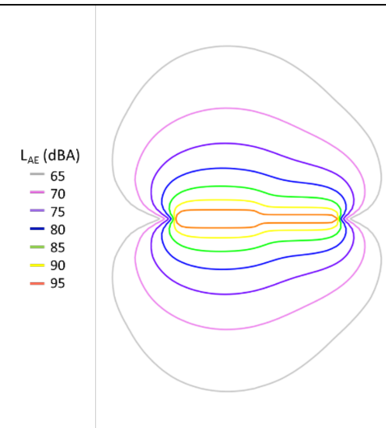
As previously noted, AEDT will interpolate NPD data between profile points when analyzing fixed-wing operations. While the interpolation of noise based on distance is appropriate, the interpolation of noise based on operating state is not because there is no established relationship between the noise at different operating states, as there is between the noise at different thrust (power) levels in the conventional usage.

Figure 5 demonstrates the behavior for a change in operating states midway between two profile points for a vehicle traveling from right to left. In the left-hand figure, AEDT interpolates the noise between operational states 1 and 2 on the segment between profile points 1 and 2. Because of the 90° dipole model for sound radiation, the noise fraction adjustment produces an unsmooth transition. The behavior is accentuated for receptors at increasing lateral distances from the ground track and for greater changes in noise between operational states (not shown). Interpolation (on distance) still occurs between profile points 2-3, but since the operating state is the same, the noise fraction along the segment is as expected. In the right-hand figure, the introduction of 'guard' profile point 2 (shortly before the intended transition) keeps the operational state (and noise) constant, as intended, along the majority of the segment. Interpolation still occurs between operational states 1 and 2 in the short transition segment between profile points 2-3, but because the noise fraction is small, it does not appreciably distort the contour. The choice of a

12 ft. transition segment was made to avoid AEDT removing points closer than 10 ft. if speed and thrust (operational state) data between two points are the same [1], while still keeping it short and its noise fraction low. Note that AEDT will remove the second of two overlapped profile points, e.g., AEDT would remove profile point 3 if guard profile point 2 were also set at that location.




| Profile Point | Dist. (ft.) | Alt. (ft. MSL) | Speed (knots) | Op. State |
|---|---|---|---|---|
| 1 | 0 | 50 | 60 | 1 |
| 2 | 2000 | 50 | 60 | 2 |
| 3 | 4000 | 50 | 60 | 2 |




| Profile Point | Dist. (ft.) | Alt. (ft. MSL) | Speed (knots) | Op. State |
|---|---|---|---|---|
| 1 | 0 | 50 | 60 | 1 |
| 2 | 1988 | 50 | 60 | 1 |
| 3 | 2000 | 50 | 60 | 2 |
| 4 | 2000 | 50 | 60 | 2 |

Figure 5: $L_{AE}$ contours between 65-95 dBA without (left) and with guard profile points (right).

Segment Velocity

For fixed-point flight profiles, the distance along the ground track is specified as part of the profile data. Consideration of the segment velocity only affects the AEDT duration adjustment, given by:

$$DUR_{ADJ} = 10\log_{10}\left[ V_{ref} / V_{seg} \right], \quad (1)$$

in which $V_{ref}$ is the reference airspeed of 160 knots for fixed-wing aircraft, and $V_{seg}$ is the airspeed at the closest point of approach to a receptor for the segment.‡ It is clear from Equation (1) that operating states for which $V_{seg}$ = 0 knots are problematic. Such data are present in the generated NPD data at speeds below 5 knots as a consequence of discretizing operating states. This would also be the case for hover conditions, though there are no hover events in the present trajectories. To avoid that numerical condition, $V_{seg}$ was chosen as the average airspeed along the segment, $V_{avg}$. Treatment of the hover condition, for which $V_{avg}$ = 0, remains an outstanding issue. The difference in the duration adjustment between the airspeed of a particular operational state at which the NPD data were calculated, $V_{NPD}$, and $V_{avg}$ is then

$$\Delta DUR_{ADJ} = 10\log_{10}\left[ V_{ref} / V_{NPD} \right] - 10\log_{10}\left[ V_{ref} / V_{avg} \right] = 10\log_{10}\left[ V_{avg} / V_{NPD} \right]. \quad (2)$$

This quantity is never actually calculated, so $V_{NPD}$ = 0 does not present a computational problem. However, it does show that the difference can be large at low speed, e.g., $V_{avg}$ = 5.01 knots and

‡ Recall that all computed sources were "flown" at 160 knots in order to generate noise data for the NPDs. If $V_{seg}$ equals $V_{NPD}$ (the airspeed of a particular operational state for which a NPD has been calculated), then the duration correction will result in the correct noise level.

$V_{NPD}$ = 10 knots results in a 3 dB difference, or if there is no $V_{NPD}$ close to $V_{avg}$. The latter only occurs if an operating state was not computed due to few occurrences. According to Equation (2), differences at higher speeds will generally be small. Finally, by selecting $V_{seg} = V_{avg}$, the cumulative duration within AEDT correctly matches to the duration of the flight.

### 4.3. Procedure for Constructing Study Data

Four pieces of user-supplied data are required to construct an AEDT study of UAM operations. These include i) latitude, longitude, and elevations of vertiports (if not in the AEDT airport database), ii) NPD data for each vehicle, iii) a set of track points defining the 2D (x-y) routes, and iv) a set of profile points defining the aircraft operational state as a function of altitude and cumulative distance along the track (from start to finish for each route for each vehicle). The vertiport data are known, and are provided as part of the simulation data in the present study. NPD data are calculated according to the process described in Section 3, and the track point and profile point data are determined from the 4D simulation data, as next described.

AEDT supports five types of flight operations for fixed-wing aircraft including approach, departure, overflight, circuit flight, and touch-and-go. They cannot be combined into a single point-to-point operation; circuit flight and touch-and-go types are at the same airport, overflights start and end in the airspace, and approach and departure account for only one of two points (destination or origin). In this study, departure type flight operations were used, with track points originating at one vertiport and ending at another. The cumulative distance of the last profile point is made to be at the intended destination. In other words, each flight operation begins as a departure from one vertiport and simply ends at the location of another vertiport.

<u>Track Points</u>

Within AEDT, the number of flight segments is determined by combining track points with profile points. There is an incentive to keep the number of flight segments low because AEDT noise calculations are performed segment by segment, and the computational time increases accordingly. The minimum number of track points is that which resolves the ground track; each straight line segment requires just two track points. Additional track points are inserted to represent heading changes. A change in heading increment is used to keep small changes in heading in the 4D trajectory data from generating excess track points; a 2° heading change increment was used in this work. Consequently, otherwise smooth turns are represented by a sequence of faceted straight line segments.

Each of sixteen routes were evaluated for each vehicle in an automated fashion. For each, an ordered list of all track points was assembled consisting of the takeoff point, all points from sequential heading changes, and the landing point. The track and vertiport data were written to AEDT standard input file (ASIF) [12] ‘study’ files as the means of inserting these data for analysis. Example quadrotor track data for one of the routes (vertiport KCAT to vertiport KDT4) are shown in Figure 6.

<u>Profile Points</u>

Determination of profile points was made on the basis of changes in operational state. The 4D trajectory data were analyzed to determine airspeed and climb angle, and each was sequentially assigned a bin according to the discretization described in Section 2.3. Aside from the first and last trajectory points, additional profile points were selected upon either a change in the binned airspeed or climb angle. Each profile point had an operational state identifier (and hence NPD data) associated with it, except for a few operating states that were not analyzed for noise due to their rare occurrence. For those conditions, the nearest calculated operating state was used, and that selection was first made on the basis of the nearest climb angle and then on the basis of the nearest airspeed, due to the higher sensitivity of noise to climb angle than airspeed in the range of missing data.

Next, additional profile points were added as guard points to force all but short transition segments to have a constant operating state. Based on the focused study, transition segments of 12 ft. were created through the addition of guard points having the same operating state as the preceding profile point. A guard point was not added if the associated segment length was less than twice the transition segment length. The addition of guard points nearly doubled the number of profile points selected on the basis of operational state changes alone.

Each route was analyzed in an automated fashion. A sequential set of profile data for each route, consisting of the segment number, cumulative distance along the ground track, altitude (ft. AFE), average airspeed, operational state identifier, and operation mode (always departure) was written along with the NPD data to an 'ANP' ASIF file for insertion into AEDT. Example quadrotor profile data for the route KCAT-KDT4 are shown in Figure 7.

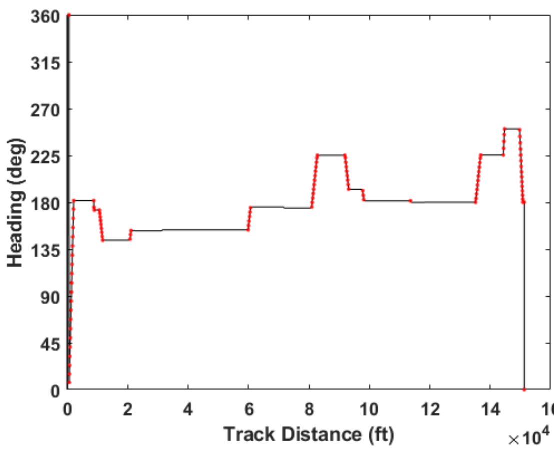


Figure 6: Track points (red) of quadrotor vehicle on route KCAT-KDT4 (black).

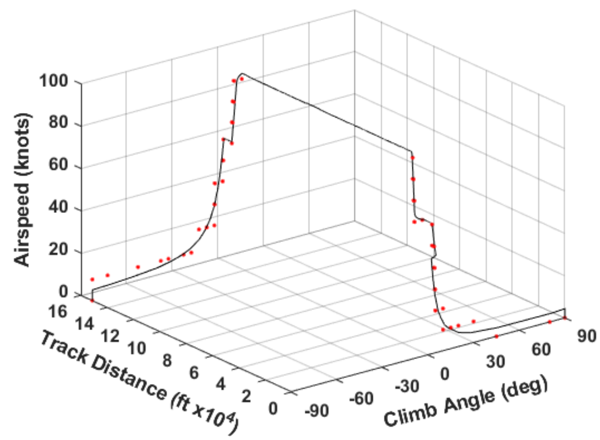


Figure 7: Operating states (red) from profile of quadrotor on route KCAT-KDT4 (black).

## 5. SAMPLE RESULTS

Sample results for single and multiple operations are next presented to both demonstrate the methodology and examine differences in community noise between the two concept vehicles. Collectively, these analyses are referred to as the Gen 1 assessment. In the following, AEDT lateral attenuation is enabled, atmospheric absorption is unadjusted from that used in generating the NPD data [13], and bank angle treatment is not considered applicable.

### 5.1. Single Operation

Typical sound exposure levels are presented in Figure 8 for route KCAT-KDT4. This route is common to the companion papers [7, 14]. Reflecting the NPD data shown in Figure 4, the L+C levels are lower than the quadrotor along the cruise segment, while the L+C takeoff levels at the KCAT vertiport exceed those of the quadrotor. Maximum levels are comparable at the KDT4 destination vertiport, although the quadrotor contour areas are greater. Contour areas along the entire route are provided in Table 1 and indicate that total exposure area for the quadrotor exceeded that of the L+C at all contour levels.

### 5.2. Multiple Operations (Fleet)

Analysis of multiple operations for a fleet of vehicles was performed for a hypothetical level of service requiring 100 takeoff and landing operations per hour over a 12-hour daytime period (i.e., no 10 dB nighttime penalty). This resulted in 600 departures per route, or one every 72 s.

Day-night average sound levels are shown in Figure 9 for both vehicles on 16 routes in the Dallas-Ft. Worth area. The routes and operations are such that enroute noise slightly exceeds 65 $L_{dn}$ in limited areas for quadrotor operations, but rarely exceeds 50 $L_{dn}$ for L+C operations. As in the $L_{AE}$ example, exposure areas for the quadrotor exceed those of the L+C at all levels except the highest, where the area is minimal, see Table 2.

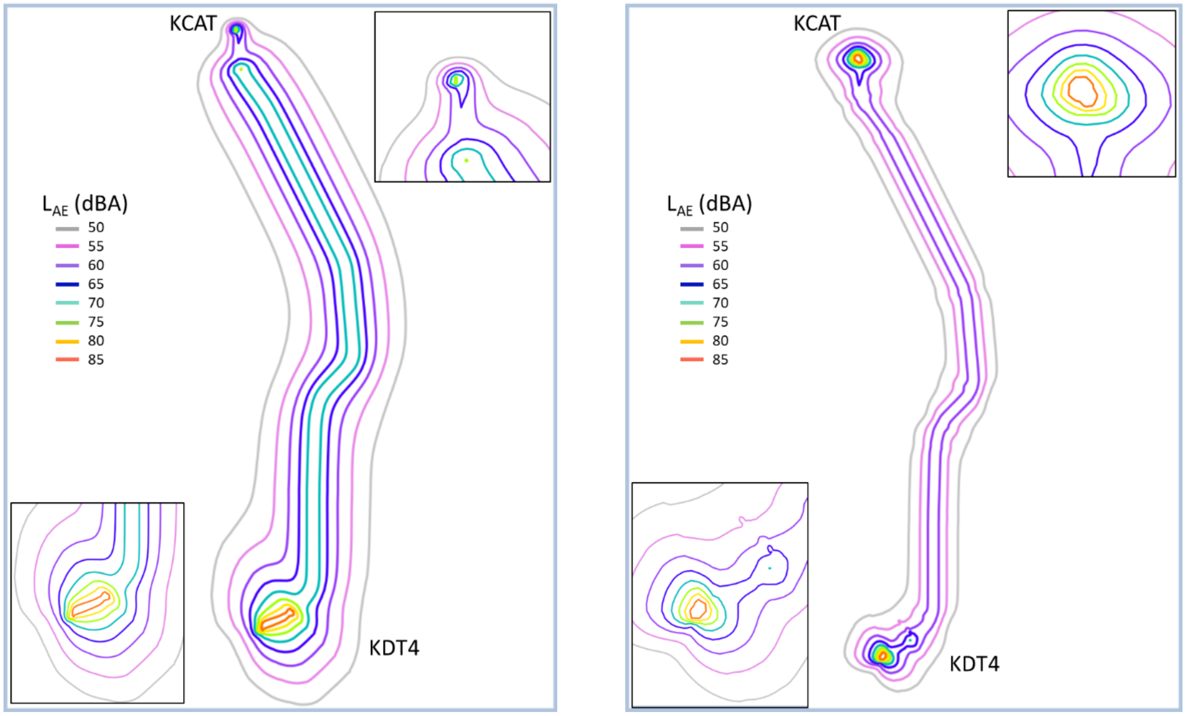



Figure 8: $L_{AE}$ contours for quadrotor (left) and L+C (right) vehicles on route KCAT-KDT4.

Table 1: Comparison of $L_{AE}$ contour areas on route KCAT-KDT4.

| $L_{AE}$ Contour Level (dBA) | Contour Area (sq nm) | |
|---|---|---|
| | Quadrotor | L+C |
| 50 – 55 | 36.09 | 22.94 |
| 55 – 60 | 26.50 | 16.10 |
| 60 – 65 | 19.60 | 10.80 |
| 65 – 70 | 14.28 | 1.06 |
| 70 – 75 | 11.17 | 0.36 |
| 75 – 80 | 0.74 | 0.20 |
| 80 – 85 | 0.53 | 0.13 |

## 6. CONCLUDING REMARKS

Within the existing capabilities of AEDT, an initial methodology for conducting community noise assessments of UAM vehicles was established. It is one in which user-supplied NPD data are assigned to constant operating state segments through the use of fixed-point flight profiles, and has shown to be effective in discriminating community noise between different UAM concept vehicles. While this approach is very flexible in terms of its ability to handle different types of vehicles, it has some limitations including i) lack of source directivity definition and built-in support for hover due to its use of the fixed-wing aircraft type, and ii) reliance on an extensive NPD database.

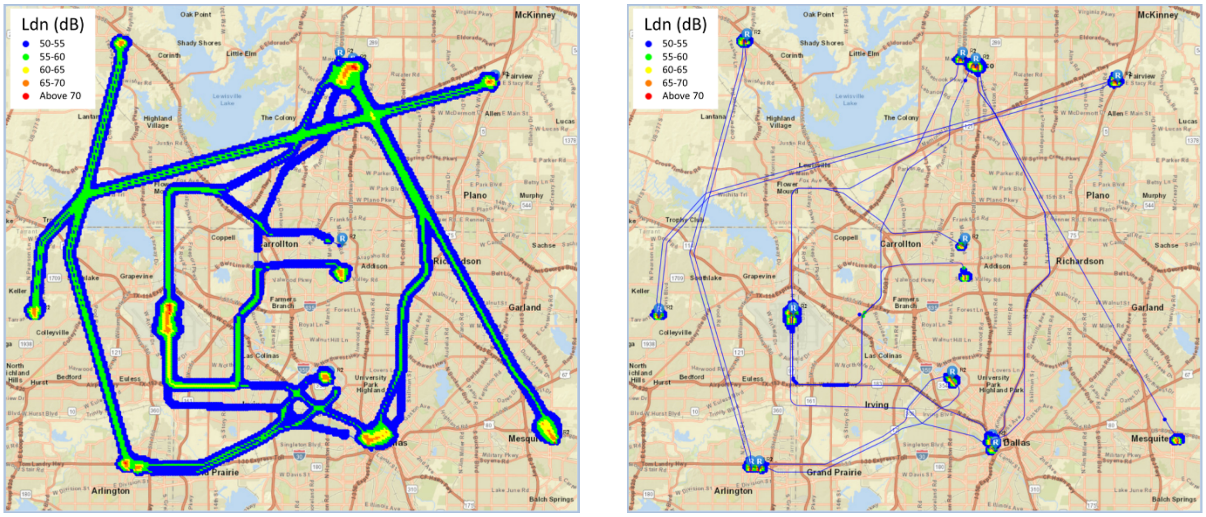



Figure 9: $L_{dn}$ levels for quadrotor (left) and L+C (right) vehicles.

Table 2: Comparison of exposure areas on basis of $L_{dn}$ for 16 routes in Dallas-Ft. Worth area.

| $L_{dn}$ Exposure Level (dB) | Exposure Area (sq nm) | |
|---|---|---|
| | Quadrotor | L+C |
| 50 – 55 | 90.93 | 3.56 |
| 55 – 60 | 28.06 | 1.98 |
| 60 – 65 | 4.20 | 1.16 |
| 65 – 70 | 1.71 | 0.69 |
| Above 70 | - | 0.10 |

Without making modifications to AEDT, it would appear that a hybrid approach using the fixed-wing type (for portions of the flight requiring many NPDs) and the rotary-wing type (when a better representation of the source directivity or hover is required) would be beneficial. However, such an approach detracts from the desire to apply one methodology irrespective of the characteristics of the UAM vehicle. Native support of fixed-point flight profiles for the rotary-wing aircraft type would be a worthwhile consideration, as it has the potential to address some of these limitations. When combined with a surrogate NPD model and/or a reduction in the number of operating states, the resulting assessment capability would be more accessible outside of the research community. An appropriate reduction strategy may become more evident as generated NPD data become more inclusive of other noise sources. Other practical considerations, including the need to model many thousands of projected operations per day, will also influence further development of the methodology.

Finally, it is important to note that the analyses presented herein are not expected to represent the anticipated community noise in the Dallas-Ft. Worth area, for reasons including use of trajectories that are not representative of expected operations (especially in the terminal area), absence of a real demand model (including nighttime operations), incomplete source noise definition in the NPDs, and use of a fixed-wing source directivity model.

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