Software Scoping Document for Integration of Urban Air Mobility Vehicles into the Federal Aviation Administration's Aviation Environmental Design Tool

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13. ABSTRACT (Maximum 200 words)

USDOT Volpe, The National Transportation Systems Center, supported the National Aeronautics and Space Administration (NASA) through a technical exchange process to facilitate the development of NASA's AIRNOISEUAM and the Federal Aviation Administration (FAA) Aviation Environmental Design Tool (AEDT) for predictions and mitigations of Urban Air Mobility (UAM) fleet noise. Volpe assessed the functional requirements for UAM fleet noise modeling, evaluated the capabilities of AEDT and AIRNOISEUAM, and scoped software developments necessary to close the gaps between current tools and the functional requirements.

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1. Introduction

Studies conducted as a part of NASA's Advanced Air Mobility (AAM) mission estimate that by 2035 significant numbers of new air vehicles will be operating to support Urban Air Mobility (UAM). These vehicles will differ in size, speed, and configuration depending on the purpose, which may include final-mile delivery, new forms of public transportation, cargo delivery and air taxi services. Many of these vehicles use new eVTOL (electric Vertical TakeOff and Landing) technologies that are developed to be quieter than traditional aircraft and helicopters.

UAMs will operate in high density populated urban areas, and aviation noise remains a primary concern for these communities. UAMs will also primarily fly between vertiport to vertiport that will be located on top of buildings or parking garages. With the introduction of a new, unfamiliar, noise source it is important that the characteristics of the noise be quantified and understood. The Federal Aviation Administration (FAA) requires the use of the Aviation Environmental Design Tool (AEDT) for all noise, fuel burn and emissions modeling for FAA actions under the National Environmental Policy Act (NEPA) as well as other FAA approved studies, such as those under 14 CFR Part 150 and Part 161.

As an initial proof of concept, NASA has developed a model, AIRNOISEUAM, that is based on the same fundamental noise computations used by AEDT. This report describes the current capabilities for modeling noise produced by conceptual urban air mobility (UAM) vehicles, the limitations of the existing approaches, and possible model refinements. Recognizing that it is likely that quantifying the noise from UAM vehicles will likely be required in support of FAA actions, specific recommendations for improvements to AEDT that would facilitate modeling UAM in AEDT are included.

The Volpe Center was asked to support NASA researchers in the evaluation of AEDT and AIRNOISEUAM for their suitability for UAM fleet noise management. The work included identifying data inputs and outputs of AEDT required for UAM fleet noise predictions. A comparison of outputs from AIRNOISEUAM was used to identify data and software requirements for potential integration or data exchanges of these tools. For example, overlaying VTOL vehicles' noise contours computed by AEDT on UAM noise map created by the AIRNOISEUAM environment module for preliminary illustration of potential community noise impacts of VTOL aircraft during all flight phases.

This report serves as an initial assessment that may lead to the development of UAM flight trajectories with noise as a constraint based on the benchmark problems and serve as the initialization for the ongoing process of the development of standardized UAM operation procedures.

2. Functional Requirements for UAM Fleet Noise Analysis

This section describes the ideal end state UAM fleet noise analysis capability. As such, the statements may be interpreted as being "shall" statements for software requirements if the full capability is to be delivered. Review and prioritization are recommended to better determine those aspects necessary for an initial capability.

The functional requirements for UAM fleet noise modeling are largely the same as for other aircraft noise modeling. These requirements are described in noise modeling guidance documents such as SAE AIR 1845 and ECAC.CEAC Doc 29. The sections below will describe the inputs, outputs, and methodologies needed for UAM fleet noise modeling with a particular focus on areas that may differ from other aircraft.

2.1 Inputs

The inputs for UAM noise modeling can be organized into two overall groups: physical and operational. Physical inputs include anything that can be measured in physical units (e.g. speed in knots, altitude in feet, temperature in degrees). These include characterization of the vehicle and the environment. Operational inputs include the number and timing of operations.

Table 2-1 provides a high-level summary of the noise modeling inputs.

Table 2-1. Aircraft Noise Modeling Inputs Summary

Input Categories	Note
Vehicle Characteristics (Physical Input)	
Source spectrum	Spectrum shape
Source levels	Noise curves are linked to performance data via thrust or mode
Source directivity	
Aircraft performance information	Defined procedures that are interpreted dynamically by a performance model or direct definition of the aircraft profile
General vehicle characteristics	As needed for performance calculations (e.g. vehicle weight for climb performance) or acoustical calculations (e.g. rotor diameter for blade tip Mach number adjustment)
Environmental Characteristics (Physical Input)	
Airfield coordinates and elevation	
Atmospheric conditions (temperature, humidity, and wind)	Used for acoustic propagation and (optionally) vehicle performance
Flight ground tracks	Individual or representative average flight paths
Receptors	Grids for contours and noise sensitive locations
Terrain	Terrain elevation affects source-receiver distance and causes acoustical shielding
Man-made structures	High fidelity modeling in urban areas may benefit from incorporating the effects of building shielding
Operations Input	
Total operations	Typically for an average annual day
Fleet mix	Breakdown of aircraft types
Profile splits	Percentage distribution of profiles for each aircraft
Day-night splits	Time of day distribution
Runway utilization	Distribution across vertiports
Flight track utilization	Distribution across flight tracks

2.1.1 Physical Inputs: Vehicle Characteristics

The acoustical characterization of the source has three parts: the source spectrum shape, noise levels, and directivity. The source spectrum shape is necessary for calculation of atmospheric absorption and attenuation due to terrain. It is defined for different phases of flight such as arrival, departure, and level flight within which the spectrum is largely similar. Noise levels are needed for a range of thrust values or for each mode of flight (e.g. accelerating climb). In this manner the performance state of the aircraft is mapped to its acoustical output. The directivity of the vehicle should be characterized to the extent necessary for the computation of the aggregate noise exposure for each complete flight. For some vehicles general equations applied to all aircraft of the class may be sufficient to characterize the directivity (e.g. jet aircraft start of takeoff roll), while other vehicle classes and operations may require directivity patterns specific to each vehicle and mode combination (e.g. helicopter hover).

The purpose of vehicle performance data in an aircraft noise model is to place the noise source at a realistic and representative location, orientation, and speed in space and time for noise calculations. This may be accomplished by defining detailed aircraft performance parameters (thrust and flap coefficients) and dynamically computing the resulting thrust, altitude, and speed as a function of flight track ground distance for a specific set of flight procedures under a specific set of environmental conditions. The thrust altitude, and speed may also be directly defined without the aid of a performance model within the noise model. In either case, the correct noise levels can be referenced from the thrust (or mode) and propagated to the receiver (based on the distance computed between the source location and receiver), and adjusted for duration using the vehicle speed.

Other vehicle characteristics may be necessary to support the performance or noise calculations. If a performance model is used, data such as vehicle weight and number of engines will be needed to compute, for example, the climb rate on departure. If the profile is directly defined, these parameters may be included for descriptive purposes, but will not influence the results. Parameters that may more directly affect the acoustical calculations may be necessary for some vehicles. For example, the engine mounting location can be used to trigger different source directivity functions. Coefficients can be defined for adjustments to source levels based on flight conditions such as speed.

2.1.2 Physical Inputs: Environmental Characteristics

The environmental characteristics are used by the noise model to adjust aircraft performance and place the aircraft profile in space. The general airfield characteristics include the airfield location and elevation, the latter of which can influence aircraft performance via air density. The atmospheric conditions can influence aircraft performance (temperature and wind) and acoustical propagation (temperature and humidity).

Aircraft flight tracks provide the ground projection of the aircraft trajectory. When combined with the performance profile, a complete three-dimensional trajectory is formed. Aircraft flight paths generally originate or terminate at runways or helipads. UAM noise modeling will require the definition of vertiports and vertiport-to-vertiport flight tracks and profiles.

Noise may be computed at one or more individually defined receptors or at grids of receptors, typically for the production of noise contours. The locations and elevations of the receptors are necessary for the computation of source-receiver distance. The elevation of receptors can be specified individually or by the use of terrain data over the study area. Elevation data may also be used to account for the shielding effects of terrain. In cases where terrain shielding is not likely to be significant, these computations should be avoided due to impact on model run times. Likewise, the shielding effects of man-made structures could be incorporated to improve the fidelity of noise predictions in urban areas, but would drastically increase the necessary computation time.

2.1.3 Operational Inputs

The physical inputs provide sufficient information to compute the noise exposure at a receptor for each individual flight. The operational inputs allow the calculation of the noise exposure for a particular set of flights (e.g. an average annual day). If all individual flights are modeled then each flight has a particular aircraft, operation type, profile, time of day, vertiport, and flight track. Often, a noise modeling run represents an averaged condition such as an average annual day and the noise modeling inputs use representative averaged flight tracks. The total operations are distributed on these flight tracks using percentage distributions of each of the parameters, typically with sub-groupings such as aircraft class or operator sharing the same distributions.

2.2 Outputs

Once implemented, it is expected that noise from UAM can be represented using the same metrics, shown in Table 2-2, that are currently available for the "traditional" aircraft fleet. The results of these metrics will be reported at receptor locations, which can be fed into currently available contouring and population exposure methods. The support of the currently available metrics will provide initial compatibility with the regulatory use case described in the introduction as well as existing non-regulatory analysis and research activities.

FAA Order 1050.1F provides the FAA's policies and procedures to ensure agency compliance with the NEPA. This Order should be consulted to understand the metrics that are appropriate to use in connection with FAA actions.

Table 2-2. Minimum Required Noise Metrics

Metric	Description
DNL or L_{DN}	A-weighted day, night average sound level Primary noise metric used for FAA actions
CNEL	Community noise equivalent (California) May be used for FAA actions in California in lieu of DNL
CEXP	C-weighted Sound Exposure Level (multi-event) Provides a uniform way to make comparisons among noise events of various durations with an emphasis on lower frequencies
CDNL	C-weighted day, night average sound level Provides a means of evaluating lower frequency noise in a manner consistent with FAA's primary noise metric
EPNL	Effective Perceived Noise Level (multi-event)
LA_{eq}	Equivalent Sound Level for 24 hours Provides a measure of aggregate sound at a location with multiple events
LA_{eqD}	Equivalent Sound Level for a 15-hour day Provides a measure of aggregate sound at a location with multiple events
L_{maxA}	Maximum A-weighted Sound Level Documents the maximum measured sound level during an event
L_{maxC}	Maximum C-weighted Sound Level Documents the maximum measured sound level during an event with an emphasis on lower frequency noise
PNLTM	Maximum Perceived Noise Level (multi-event)
SEL	A-weighted Sound Exposure Level (multi-event) Provides a uniform way to make comparisons among noise events of various durations
TALA	Time Above an A-weighted Sound Level Threshold Often used when evaluating the introduction of sound in areas of natural quiet
TALASC	Time Above an A-weighted Sound Level using the overlapping events method (Statistical Compression)

Metric	Description
	Often used when evaluating the introduction of sound in areas of natural quiet
TALC	Time Above a C-weighted Sound Level Threshold Often used when evaluating the introduction of lower frequency sound in areas of natural quiet
TALCSC	Time Above a C-weighted Sound Level using the overlapping events method (Statistical Compression) Often used when evaluating the introduction of lower frequency sound in areas of natural quiet
TAPNL	Time Above a Perceived Noise Level Threshold Often used when evaluating the introduction of sound in areas of natural quiet
TAPNLSC	Time Above a Perceived Noise Level using the overlapping events method (Statistical Compression) Often used when evaluating the introduction of sound in areas of natural quiet
TAUD	Time Audible Often used when evaluating the introduction of sound in areas of natural quiet
TAUDSC	Time Audible using the overlapping events method (Statistical Compression) Often used when evaluating the introduction of sound in areas of natural quiet
TAUDP	Time Audible Percent Often used when evaluating the introduction of sound in areas of natural quiet
TAUDPSC	Time Audible Percent using the overlapping events method (Statistical Compression) Often used when evaluating the introduction of sound in areas of natural quiet

2.3 Methodologies

It is expected that existing, well established, methodologies currently in use to generate the outputs described in Section 2.2 for "traditional" fixed-wing and rotorcraft can be extended to support the estimation of noise from UAM. Specifically, the framework of applying the ICAO Doc 9911 methodology, where thrust and meteorological parameters as used to locate the relevant segment on a noise power distance (NPD) curve with measured noise data being defined as a series of spectra.

As further described in Section 4.1.3, the expansion of the ICAO Doc 9911 methodology would enable the computation of the noise metrics listed in the previous section. However, given that the nature of the operations of UAM are also anticipated to be fundamentally different than “traditional” aircraft, with many operations to and from unconventional landing zones, the ability to define tracks and vertical profiles along these new routes is needed. As concepts of operations come to be more clearly defined, additional refinement of the noise calculation methodology may be required to better account for this new operating environment.

3. Evaluation of Existing Models

3.1 AEDT

3.1.1 Existing Functionality

FAA’s AEDT models aircraft performance in space and time in order to estimate noise, emissions, emissions dispersion, and fuel consumption. By leveraging the same performance data to compute both noise and emissions, it supports the analysis of interdependencies between environmental consequences. AEDT is scalable from a single airport to global analyses and is used to support regulatory and research applications alike.

A typical AEDT single-airport annual noise contour study for a large commercial airport may contain several hundred representative model flight tracks to several hundred thousand individual radar flight tracks. The fleet of aircraft may include hundreds unique fixed-wing aircraft and helicopters operating across several runways and helipads. Though it can be larger for certain studies, it is most common for the study area to extend several nautical miles from the airport in order to capture, at a minimum, the extents of the 65 dB DNL contour. Depending on available computing resources, a study of this size may run in several hours to a day for a single scenario. For regional studies that include dozens of airports, the number of inputs and the necessary study areas can be much larger. In these studies, AEDT’s distributed computing capabilities prove especially useful in maintaining practical run-times.

AEDT provides the ability to model two vehicle types: helicopters and fixed-wing aircraft. The trajectory of both of these vehicle types are defined in terms of a ground track and a vertical profile. The ground track can be described either by a series a points (lat/lon) or as vectors (e.g. turn right 45° with a radius of 2 nmi, then fly straight for 5 nmi). The vertical profile of helicopters is essentially defined in terms of geometry, whereas for fixed wing aircraft the profile can either be expressed as a fully defined set of points (including thrust), or as a set of procedures.

Section 3.1.2 describes possible ways in which each of these types can be applied to estimate the noise from UAM.

3.1.1.1 Helicopters in AEDT

The AEDT 3d fleet database contains noise and performance data for 26 helicopters representing 77 unique real-world airframe-engine combinations. Excepting one helicopter, each helicopter has one arrival, one departure, and one taxi profile. Helicopters in AEDT have 16 modes of operation as described in Table 3-1. The use of these modes include some restrictions as follows: Altitude and speed can only be constant or increasing for departures or decreasing for arrivals. Overflights allow for combinations of altitude and speed changes, but not takeoff and landing.

Table 3-1. Helicopter Modes of Operation in AEDT

Step Type	Description	State	Parameters
A	***Approach at constant KTAS.*** This step is used to descend at constant speed to a given altitude over a given distance. Input the track distance covered by the step and the final altitude. The initial altitude and speed are defined by the previous step.	Move	Distance (feet) Altitude (feet AFE)
D	**Depart at constant KTAS.** This step is used to climb at constant speed to a given altitude over a given distance. Input the track distance covered by the step and the final altitude. The initial altitude and speed are defined by the previous step.	Move	Distance (feet) Altitude (feet AFE)
L	**Level flyover at constant KTAS.** This step is used to maintain altitude and speed for a given distance. Input the track distance covered by the step. Altitude and speed are defined by the previous step.	Move	Distance (feet)
G	**Ground idle.** This step is used to maintain ground idle for a given duration. Input the duration of the step. The altitude is zero, the horizontal position of the step is calculated from the previous step, and the horizontal speed is zero.	Static	Duration (seconds)
H	**Flight idle.** This step is used to maintain flight idle for a given duration. Input the duration of the step. The altitude is zero, the horizontal position of the step is calculated from the previous step, and the horizontal speed is zero.	Static	Duration (seconds)
I	**Hover in ground effect.** This step is used to maintain altitude and horizontal position for a given duration while in ground effect. Input the duration of the step. The altitude is defined by the previous step, the horizontal position of the step is calculated from the previous step, and the horizontal speed is zero.	Static	Duration (seconds)
J	**Hover out of ground effect.** This step is used to maintain altitude and horizontal position for a given duration while out of ground effect. Input the duration of the step. The altitude is defined by the previous step, the horizontal position of the step is calculated from the previous step, and the horizontal speed is zero.	Static	Duration (seconds)
V	**Vertical ascent in ground effect.** This step is used to maintain horizontal position while ascending to a final altitude over a given duration while in ground effect. Input the duration of the step and the final altitude. The horizontal position of the step is calculated from the previous step and the horizontal speed is zero.	Static	Duration (seconds) Altitude (feet AFE)
W	**Vertical ascent out of ground effect.** This step is used to maintain horizontal position while ascending to a final altitude over a given duration while out of ground effect. Input the duration of the step	Static	Duration (seconds)

Step Type	Description	State	Parameters
	and the final altitude. The horizontal position of the step is calculated from the previous step and the horizontal speed is zero.		Altitude (feet AFE)
Y	**Vertical descent in ground effect.** This step is used to maintain horizontal position while ascending to a final altitude over a given duration while in ground effect. Input the duration of the step and the final altitude. The horizontal position of the step is calculated from the previous step and the horizontal speed is zero.	Static	Duration (seconds) Altitude (feet AFE)
Z	**Vertical descent out of ground effect.** This step is used to maintain horizontal position while ascending to a final altitude over a given duration while out of ground effect. Input the duration of the step and the final altitude. The horizontal position of the step is calculated from the previous step and the horizontal speed is zero.	Static	Duration (seconds) Altitude (feet AFE)
B	**Approach with horizontal deceleration.** This step is used to decelerate to a final speed at constant altitude over a given distance. Input the track distance covered by the step and the final speed. The altitude and initial speed are defined by the previous step.	Move	Distance (feet) Airspeed (KTAS)
C	**Approach with descending deceleration.** This step is used to descend and decelerate to a final altitude and speed over a given distance. Input the track distance covered by the step, the final altitude, and the final speed. The initial altitude and speed are defined by the previous step.	Move	Distance (feet) Altitude (feet AFE) Airspeed (KTAS)
E	**Depart with horizontal acceleration.** This step is used to accelerate to a final speed over a given distance. Input the track distance covered by the step and the final speed. The altitude and initial speed are defined by the previous step.	Move	Distance (feet) Airspeed (KTAS)
F	**Depart with climbing acceleration.** This step is used to climb and accelerate to a final altitude and speed over a given distance. Input the track distance covered by the step, the final altitude, and the final speed. The initial altitude and speed are defined by the previous step.	Move	Distance (feet) Altitude (feet AFE) Airspeed (KTAS)

Step Type	Description	State	Parameters
X	**Taxi at constant speed.** This step is used to taxi at a given speed. Input the speed. The track distance is calculated based on the assigned taxi ground track, and the altitude is defined by the previous step. Helicopters defined as not having wheels must taxi at an altitude greater than zero.	Move	Airspeed (KTAS)
S	**Start altitude (feet AFE) at constant KTAS.** This step is used to start a profile at a given altitude and speed. Input the starting altitude and speed.	N/A	Altitude (feet AFE) Airspeed (KTAS)

The ground effect altitude in the steps above is defined as 1.5 times the main rotor diameter. If the procedure step stays below the ground effect altitude, the procedure step correlates with the corresponding In Ground Effect flight operational mode. If the step stays at or above the ground effect altitude the procedure correlates with the corresponding Out of Ground Effect flight operational mode. If a given Dep Vertical or App Vertical procedure step crosses the ground effect altitude, AEDT automatically divides the step into two at the ground effect altitude and assigns flight operational modes to the two steps as appropriate.

Helicopter procedure steps explicitly define a helicopter's flight path. There are no thrust calculations for helicopter flight paths as there are for fixed-wing aircraft. Rather, each procedure step correlates with a helicopter flight operational mode and each mode has its own set of NPD data.

Vertical profiles and the associated NPD curves in AEDT all reflect a steep climb to or descent from 1,000 feet AGL with a 15 nmi level segment. However profiles and NPD curves could be custom-defined to better reflect UAM operations with the appropriate data.

AEDT accounts for acoustic directional effects by left-center-right NPD curves for the dynamic modes in the table above (those whose state is "move"). Full directivity is assumed for static modes. Spectral data are grouped into classes for arrivals, departures, and level flight. AEDT does not include noise data for rotor configurations not found on "traditional" helicopters (a single main rotor and a tail rotor).

3.1.1.2 Fixed-Wing Aircraft in AEDT

The AEDT 3d fleet database contains noise and performance data for 289 fixed-wing aircraft representing 3,502 unique real-world airframe-engine combinations. The database contains 5,165 profiles for arrivals, departures, touch and goes, and circuits for the 289 aircraft. Unlike helicopters, fixed-wing aircraft in AEDT have a more comprehensive performance model where thrust is either computed or directly specified and that thrust information is used to obtain noise data from NPD curves. For calculating thrust below 10,000 feet MSL, AEDT includes two performance models: the ICAO Doc 9911 model (often referred to as the ANP model) and Eurocontrol's Base of Aircraft Data (BADA) Family 4.

AEDT aircraft equipment are composed such that they always contain an ANP airplane (an ANP dataset based on a specific equipment combination) and optionally, contain a BADA 4 airplane (a BADA 4 dataset based on a specific equipment combination). The ANP and BADA 4 airplanes are based on respective equipment combinations that are similar to (but not generally the same as) each other, and to the equipment combination the AEDT airplane is meant to model. Even in cases where they are both based on the same exact equipment combination, the two datasets do not necessarily capture aerodynamics-modeling data for the same set of configurations. In general, there is not a one-to-one correspondence between configurations captured by the ANP airplane and the BADA 4 airplane.

AEDT allows for two types of procedural profiles, ANP and BADA 4, which are intended to be used with their corresponding flight performance models. However, it is possible to process ANP and BADA 4 profiles using the opposite flight performance model as described in the table below.

Table 3-2. Treatment of ANP and BADA 4 Profiles by AEDT Performance Model

Procedural Profile	Flight Performance Model	Description
ANP	ANP	An ANP profile is created and processed with the ANP performance model or An ANP profile attempts to process using the BADA 4 flight performance model, but lacks data so is processed with the ANP performance model
ANP	BADA 4	An ANP profile is created, AEDT determines the BADA 4 configuration (flaps/landing gear setting), and processes with the BADA 4 performance model For AEDT airplanes that have both ANP and BADA 4 airplanes assigned, AEDT is able to determine the corresponding BADA 4 configuration for an ANP flap configuration
BADA 4	ANP	A BADA 4 profile is created and processed using the ANP performance model based on the ANP configuration (flap ID) that was defined during the BADA 4 profile creation Or A BADA 4 profile attempts to process using the BADA 4 flight performance model, but lacks data; so is processed with the ANP performance model based on the ANP configuration (flap ID) that was defined during the BADA 4 profile creation
BADA 4	BADA 4	A BADA 4 profile is created and processed using the BADA 4 performance model

The primary difference between these two types of profiles is the degree of flexibility in specifying airplane configuration for a procedure step. When defining an ANP profile, only an ANP configuration (flap setting) can be specified for a procedure step. When defining a BADA 4 profile, an ANP configuration (flap setting) can be specified as well as a BADA 4 configuration (flaps/landing gear setting). This means that when an ANP profile is run using the BADA 4 performance model, AEDT determines the BADA 4 configuration (flaps/landing gear setting) based on the ANP configuration (flap setting); but when a BADA 4 profile is used with the BADA 4 performance model, the BADA 4 configuration is specified directly. In addition, if a BADA 4 profile is processed using the ANP performance model, the ANP configuration can also be specified directly through the BADA 4 profile.

Procedural profiles are composed of procedure steps, of which there are fourteen types. The procedure step types available in AEDT are listed and described in the table below. The Step Type in AEDT column represents the name of the step as shown in the AEDT interface for BADA 4 profile creation along with the full name and description.

Table 3-3. Procedure Step Types Available in AEDT

Step Type in AEDT (BADA 4)	Full Name	Description
Takeoff	Takeoff	On the ground, in configuration Z and thrust setting Y, accelerate to initial climb CAS.
Climb	Climb	In the air, in configuration Z and thrust setting Y, maintain CAS and climb to altitude X feet AFE.
N/A	Cruise-Climb	In the air, in configuration Z, maintain CAS and climb at angle Y to altitude X feet AFE.
Accelerate	Accelerate	In the air, in configuration Z and thrust setting Y, climb at climb rate X to higher CAS W.
Percent Accelerate	Accel-Percent	In the air, in configuration Z and thrust setting Y, climb at acceleration energy share X to higher CAS W.
Level	Level	In the air, in configuration Z, maintain CAS and altitude over distance Y.
Decelerating Thrust Level	Level-Decel	In the air, in configuration Z, maintain altitude over distance Y to reduced CAS X.
Idle Thrust Level	Level-Idle	In the air, in configuration Z and at (idle) thrust setting Y, maintain altitude over distance Y to CAS X.
Fit to Track Distance	Level-Stretch	In the air, in a circuit operation, maintain altitude, CAS, and thrust over the distance required to make the profile fill the track.
Descend	Descend	In the air, in configuration Z, maintain CAS and descend at angle Y to altitude X feet AFE.
Decelerating Thrust	Descend-Decel	In the air, in configuration Z, descend at angle Y to altitude X feet AFE and reduced CAS W.
Idle Thrust Descend	Descend-Idle	In the air, in configuration Z and at (idle) thrust setting Y, descend at angle X to altitude W feet AFE and CAS V.
Land	Land	On the ground, immediately following touch-down, roll over distance Z to CAS Y and thrust X.
Landing Decelerate	Decelerate	On the ground, roll over distance Z to CAS Y and thrust X.

Alternatively, users have the ability to fully define the state of the aircraft using fixed-point profiles. These profiles do not leverage the ANP or BADA 4 performance models and reflect the result of the atmospheric conditions under which they were developed. Fixed-point profiles can be defined using the elements provided in Table 3-4.

Table 3-4. Fixed-Point Profile Definition

Element	Description
Point Number	Fixed-point profile point number.
Operational Mode	Noise operational modes – Approach, Departure, or Afterburner.
Altitude AFE (ft)	Altitude above field elevation.
Track Distance (ft)	Horizontal distance value from a reference point (where the reference point is at track distance=0). Track distance can be positive or negative, and increases as the airplane flies the profile.
Speed TAS (kt)	True airspeed (KTAS).
Thrust Setting	For most civil airplanes, this parameter is corrected net thrust per engine in pounds; but some civil airplanes use percent of static thrust.

3.1.1.3 Comparison of Helicopter of Fixed-Wing Aircraft Modeling in AEDT

The methods used in AEDT to model noise for helicopters and fixed-wing aircraft are similar in their general methodology, but have important differences in regards to the selection of noise curves and vehicle directivity. Table 3-5 compares these two vehicle types.

Table 3-5. AEDT Helicopter and Airplane Noise Modeling Comparison

Category/Item	AEDT Airplane (3d Tech Manual)	AEDT Helicopter (3d Tech Manual)
Flight Profiles		
Fixed point profiles	Yes; ground distance, altitude, speed, thrust, operation type	No
Procedural profiles	Performance model based (3.6.2)	Mode based; no performance model; limited number of modes (3.6.3)
Performance model	Yes	No
Noise Data		
Spectra	One spectral class selection for arrival, departure, and afterburner from a set list	One spectral class selection for arrival, departure, and level from a set list
Source levels	NPD curves	NPD curves and directivity adjustments for static operations, Left, Right, Center NPD curves for dynamic operations
Static mode directivity	No	Adjustments specified by azimuth angle to NPD curves for a mode (4.5.3)
Dynamic mode directivity	No	Left 45 degrees, center, right 45 degrees of elevation angle via NPD curves for a mode (4.5.2)
Acoustic Propagation		
Blade tip Mach number adjustment	No	Level flight only for when speed or temperature differs from reference values (4.5.1)
Ground-based directivity adjustment	Used for behind start of take-off roll and run-ups (4.4.2)	No
Atmospheric absorption	SAE-ARP-866A, SAE AIR-1845, SAE ARP-5534 (4.3.1)	same as Airplane
Acoustic impedance adjustment	Yes (4.3.2)	same as Airplane

Category/Item	AEDT Airplane (3d Tech Manual)	AEDT Helicopter (3d Tech Manual)
ISA atmosphere	Yes; (3.3.1, 3.3.2)	same as Airplane
Duration adjustment for exposure-based metrics	Adjustment for speeds different than 160 kts (4.3.4)	Adjustment for speeds different than NPD reference speed (4.3.4)
Static mode duration adjustment	No	Yes (4.5.4)
Lateral attenuation adjustment for civil aircraft	Includes engine installation, ground effect, refraction-scattering (4.3.5.1)	Includes ground effect and refraction-scattering (4.3.5.1)
Noise fraction adjustment for flight path segments	Yes (4.3.3.1)	same as Airplane
Noise fraction adjustment for behind start of take-off roll	Yes (4.3.3.2)	No
Thrust reverser adjustment	Yes (4.4.1)	No
Ground type	All soft	same as Airplane
Terrain distance adjustment	Yes	same as Airplane
Terrain shielding	Yes (4.3.6)	same as Airplane
Aircraft bank angle calculation	Yes; used to change depression angle for lateral attenuation and for procedural profile performance calculations (3.6.5)	No; lateral attenuation and LCR directivity do not use bank angle

3.1.2 Options for UAM Noise Modeling Utilizing Existing Functionality

Table 3-6 lists five options for modeling UAM vehicles in AEDT with the advantages and disadvantages of each approach. The use of the airplane functionality with thrust used as a noise identifier offers the greatest trajectory and noise mode flexibility. The use of the helicopter functionality offers the best directivity. A hybrid approach would offer these advantages on different portions of the flight path at the cost of increased complexity (and the corresponding disadvantages on each portion of the flight path).

Table 3-6. UAM Modeling Options in AEDT 3d

Method	Advantages	Disadvantages
Airplane, fixed-point profiles	Simple profile specification	Lack of directivity specification Ground based directivity function Limited spectral classes or use of unmodified NPD curves Noise interpolation between thrust values All variations in noise level must be specified only by the selection of arrival or departure mode and the thrust level
Airplane, fixed-point profiles, thrust as noise identifier	Simple profile specification Unlimited noise modes	Lack of directivity specification Ground based directivity function Limited spectral classes or use of unmodified NPD curves
Airplane, procedural profiles	Able to model new or modified procedures using reference data Modification of aircraft performance based on field elevation and atmospheric conditions	Uses airplane performance model Must generate all reference coefficients Lack of directivity specification Ground based directivity function Limited spectral classes or use of unmodified NPD curves Noise interpolation between thrust values All variations in noise level must be specified only by the selection of arrival or departure mode and the thrust level
Helicopter	360 degree static directivity Left, center, right dynamic directivity	Trajectory segments must be converted to AEDT helicopter trajectory segment types Noise modes correspond one to one to a limited number of flight segment types Limited spectral classes or use of unmodified NPD curves
Hybrid: airplane (fixed-point profiles, thrust as noise identifier) / helicopter	Unlimited noise modes on some portions of flight (see airplane) Improved directivity on some portions of flight (see helicopter)	Increased complexity of inputs and runs Some trajectory segments must be converted to AEDT helicopter trajectory segment types Regions with unlimited noise modes will have limited directivity Regions with improved directivity will have limited noise modes Limited spectral classes or use of unmodified NPD curves

3.1.3 Planned Development

As of July 2021, development of AEDT version 3e is underway. This is expected to be the final release of AEDT within the 3 series. The initial release of AEDT 4 is anticipated in spring 2023 and will mark the transition toward more detailed noise modeling. The proposed enhancements identified in this section are subject to change based on current FAA priorities and are in addition to numerous emissions modeling enhancements that are outside the scope of this paper. The following updates planned for AEDT 4 may be relevant to UAM modeling.

3.1.3.1 Noise Propagation over Hard, Soft, and Mixed Ground Surfaces

AEDT models noise propagation over soft ground surfaces in the calculation of lateral attenuation based on SAE-AIR-5662, Method for Predicting Lateral Attenuation of Airplane Noise. Recognizing that aircraft do not only operate over soft ground, an updated method is needed to better account for noise propagation over a range of ground types. ACRP Project 02-52, Improving AEDT Noise Modeling of Hard, Soft, and Mixed Ground Surfaces, provided a number of recommendations that are planned to be implemented in AEDT.

3.1.3.2 Aircraft Noise Reflection and Diffraction from Terrain and Manmade Structures

AEDT's use of terrain data to support noise modeling is limited, in particular since it does not include a method to account for noise reflection from terrain or buildings. In addition, although AEDT does include a noise diffraction algorithm, it is not intended to accurately represent the diffraction associated with buildings. ACRP Project 02-79, Improving AEDT Modeling for Aircraft Noise Reflection and Diffraction from Terrain and Manmade Structures, provided recommendations to address these limitations that are planned to be implemented in AEDT.

3.1.3.3 Higher Fidelity Aircraft Noise Characterization

The use of noise power distance (NPD) curves to provide a link between thrust and noise data is well established. However, research has shown that aircraft configuration can have a significant effect on noise. An update to the NPD framework to include configuration information (NPD+C) is planned. Once in place, AEDT will be updated to leverage NPD+C data as they become available.

3.1.3.4 Helicopter Noise Modeling Improvements

AEDT, like its predecessor model, INM, implements the Heliport Noise Model to account for noise from helicopters. ACRP Project 02-44, Helicopter Noise Modeling Guidance, recommended a number of improvements to the existing integrated noise modeling methodology that are planned for implementation in AEDT.

3.1.4 Environmental Justice

AEDT includes an environmental justice (EJ) model which uses the U.S. Census, American Community Survey (ACS) to identify and analyze potential minority and/or low income populations and populations with limited English proficiency.

The AEDT EJ Model is implemented as a workflow that the analyst can exercise as part of any study modeling US airports and/or airspace. In AEDT, the analyst can explore select ACS data with or without other metric results (including noise, fuel burn, and emissions) over various maps. An internet connection is necessary to use the EJ model. The EJ analysis results can be exported to geospatial (shapefile) and spreadsheet (CSV) formats for use outside of AEDT.

There are two types of EJ analyses that can be performed, environmental justice and limited English proficiency. The two types of analyses use different data resolutions based on the US Census Bureau API endpoint data. For the EJ analysis, the data is available at block group level. For limited English proficiency analysis, the data is only available at the tract level.

- Environmental Justice Analysis – analysis of low income and minority populations at the census block group level.
- Limited English Proficiency Analysis – analysis of population that "speaks English less than very well" at the census tract level.

3.1.5 Development Gaps

3.1.5.1 Traditional Airspace and Landing Facility Constraint

Design for AEDT began in 2003 and its architecture reflects the airspace utilization of that time period. As such, aircraft that takeoff and land are expected to do so from airports or heliports. Similarly, noise calculations are calibrated to support quantifying sound either in the vicinity or airports/heliports or en-route in the form of overflights, such as for airspace analysis. AEDT does not currently provide an easy to use means to define operations that are from point to point where not all of the locations are a traditional landing facility. UAM noise modeling will require easy definition of vertiport locations and the modeling of vertiport to vertiport flights with standard and user-defined flight profiles. Though some airport to airport modeling capability exists in AEDT, the interface largely reflects a focus on individual arrival or departure operations at airports and heliports.

3.1.5.2 User-Defined Aircraft Limitations

Although AEDT allows users to define their own aircraft, they are limited to defining either a conventional fixed wing aircraft or a traditional helicopter with a single main rotor. AEDT does not include a performance model specific to a multi-rotor configuration that many of the proposed UAM vehicles include. For an initial capability, it may not be necessary to include detailed performance modeling if AEDT could allow for the result of a performance model to fully define the state of the vehicle using data from an external performance model, input as fixed-point profiles.

In order to more fully model the noise, AEDT could be updated to allow for different noise levels to be defined based on flight path angle, configuration, and speed.

3.2 AIRNOISEUAM

3.2.1 Existing Functionality

AIRNOISEUAM version 1.0 b implements the majority of AEDT's propeller airplane noise modeling capability using fixed-point profiles. The noise curves are used without adjustment similar to the SAE 1845 atmospheric absorption option in AEDT, therefore the model does not require spectral classes for the noise curves. AEDT's ground-based directivity adjustment is not appropriate for UAM vehicles and is not implemented in AIRNOISE UAM. Table 3-7 summarizes AIRNOISEUAM's noise modeling functionality.

Table 3-7. AIRNOISEUAM Functionality Summary

Functionality	Note
Point type tracks	Tracks are defined as a set of coordinates.
Fixed-point profile method	Altitude, speed, and ground track distance are directly specified along the trajectory. A noise identifier is used at each point to match directly to a single noise curve.
Spherical spreading and atmospheric absorption	Noise levels are specified as a function of distance for each noise identifier and interpolated or extrapolated for the actual source receiver distance
Terrain adjustment	Terrain is utilized to adjust source-receiver distance
Acoustic impedance adjustment	Same as described in AEDT TM 4.3.2
Duration adjustment for exposure-based metrics	Adjustment for speeds different than 160 kts (same as described in AEDT TM 4.3.4)
Lateral attenuation adjustment for civil aircraft	Includes ground effect and refraction-scattering (same as described in AEDT TM 4.3.5.1)
Noise fraction adjustment for flight path segments	Same as described in AEDT TM 4.3.3.1
Calculation of exposure-based metrics	Single or multiple operations runs can be created to compute SEL, DNL, or CNEL.
Input / output methods	Tool is designed to run from the command line. Grid output is processed into noise contour via a script.

3.2.2 Development Gaps

AIRNOISEUAM fulfills many of the requirements for UAM fleet noise analysis by computing cumulative noise levels via an automated process using accepted calculation methods. The primary development gaps in AIRNOISEUAM relate to improvements in the following acoustical calculations:

- Improved vehicle directivity
  - Addition of azimuthal directivity and duration parameter for static flight modes
  - Addition of lateral directivity for dynamic flight modes
- Improved propagation calculations
  - Addition of spectrum for each noise identifier

- Addition of atmospheric absorption calculation to allow the use of reference data over a range of atmospheric conditions
- Addition of effects of various ground types
- Addition of shielding from terrain and structures
- Addition of reflections from structures

- Improved noise metrics
  - Addition of EPNL would allow additional analysis of perception of noisiness

4. Software Scoping

4.1 AEDT UAM Vehicle Integration

The existing helicopter noise modeling capability provides the best starting point for the development of a UAM noise modeling capability in AEDT. The proposed approach involves the replication of the helicopter specific database tables with minor modifications, the addition of UAM specific vehicle data, and the replication of the helicopter noise modeling algorithms with minor modifications. The database and algorithm modifications relative to the existing helicopter functionality are primarily related to additional flexibility for flight trajectories and the specification of noise emissions in various flight modes.

4.1.1 Database Requirements

Table 4-1 presents the recommended new database tables. The UAM vehicle tables are based on copies of the helicopter tables for directivity, noise curves, noise identifiers, and vehicles. UAM vehicles retain the helicopter's basic noise functionality with left, right, center noise curves for dynamic flight modes and a single noise curve plus a directivity specification for static flight modes. Like helicopters, these curves are specific to categorical flight modes and not numerical power settings. Helicopters are limited to one spectral class each for arrival, departure, and level flight, but the UAM vehicles may specify a different spectral class for each flight mode. Unlike helicopter flight modes, the UAM flight modes are not limited in number.

The UAM profile tables are based on the tables for airplane fixed-point profiles. The profile is specified with the altitude, speed, and mode as a function of flight track distance. The thrust is not needed and a duration field is added for use with static flight modes.

Table 4-1. AEDT UAM Noise Modeling Required New Tables

Table	Modeled On	Note
FLT_ANP_UAM_DIRECTIVITY	FLT_ANP_HELICOPTER_DIRECTIVITY	No changes
FLT_ANP_UAM_NOISE_GROUPS	FLT_ANP_HELICOPTER_NOISE_GROUPS	Change structure to allow a spectral class for each mode
FLT_ANP_UAM_NPD_CURVES	FLT_ANP_HELICOPTER_NPD_CURVES	Change structure to allow more modes
FLT_ANP_UAM_PROFILE_POINTS	FLT_ANP_AIRPLANE_PROFILE_POINTS	Change structure to remove thrust, allow more modes, and add duration (for static operations)
FLT_ANP_UAM_PROFILES	FLT_ANP_AIRPLANE_PROFILES	No changes
FLT_ANP_UAM	FLT_ANP_HELICOPTERS	Change structure to remove rotor diameter, rotor rpm, wheels flag, blade tip Mach number coefficients, and NPD operation mode adjustment

Table 4-2 lists the required modification to existing AEDT tables for the integration of UAM vehicle noise modeling. The changes to the runway end, track, and equipment tables facilitate the addition of vertiports, UAM flight tracks, and UAM vehicles.

Table 4-2. AEDT UAM Noise Modeling Existing Tables Requirements Summary

Table	Note
APT_RWY_END	Modify field IS_HELIPAD to TYPE to allow for runway, helipad, and vertiport flags
APT_TRACK	Modify AIRCRAFT_TYPE field to allow flags for airplane, helicopter, and UAM
FLT_EQUIPMENT	Modify structure to add UAM identifier field; add airframe, engine, engine modification, UAM identifier combination data

4.1.2 User Interface Requirements

Most of the functionality required for UAM noise modeling is already present in the AEDT user interface. Minor modifications to the new aircraft operations wizard and the equipment table will allow the definition of UAM flight operations and the display of UAM vehicles. A new button in the airport designer is required for the creation of vertiports in a similar manner to the existing helipad button. The airport designer currently has buttons to create point tracks and vector flight tracks. The same buttons are used for helicopters and airplanes. The functionality of these buttons should be modified to allow creation of UAM arrival and departure flight tracks. Given the likelihood of vertiport-to-vertiport flights within a relatively small study area, the interface should include buttons for creation of point and vector vertiport-to-vertiport flight tracks.

Table 4-3. AEDT UAM Noise Modeling User Interface Requirements Summary

Table	Note
Operations // Aircraft	Wizard includes UAM vehicles in equipment list, allows selection of UAM profiles, and provides list of helicopter//UAM tracks
Equipment // Aircraft	Display UAM vehicles
Airports // Designer	Add button for the creation of vertiports and vertiport to vertiport flight tracks and functionality to existing arrival and departure track creation buttons for creation of UAM point and vector tracks

4.1.3 Algorithm and Data Requirements

The proposed UAM noise calculations are based primarily on the existing AEDT helicopter noise calculations. The data requirements shown in Table 4-4 are largely the same as for helicopters. Section 11.2.2.3 of the AEDT 3d Technical Manual provides forms for the submission of helicopters for inclusion in the AEDT Fleet database. With the exceptions of the point profiles and the modifications to the database fields described in section 4.1.1, the necessary data would be the same for UAM vehicles.

In addition to the data that may be directly loaded into the database, new spectral classes may be added to the table FLT_ANP_CAT_SPECTRAL_CLASS, but only through ASIF import. Section 11.2.2 of the AEDT 3d Technical Manual provides an overview of the spectral class development process.

This proposed approach relies on external measurements and modeling of vehicle noise and performance to feed data into AEDT with limited algorithms to adjust for changes in noise and performance due to environmental conditions or modifications to profiles. This is an appropriate near-term approach until the general characteristics of these new and diverse vehicles can be distilled into modeling algorithms. For example, until these relationships are established, modeling differences in community exposure due to changes in descent angle will require the input of externally measured or modeled source noise levels for each desired descent angle. In the long term, once reliable algorithms are developed from the measurement of a large number of vehicles within a particular class over a wide range of conditions, a limited set of measurement data could be extended to cover a range of flight conditions by algorithms within AEDT.

Table 4-4. AEDT UAM Noise Modeling Data Requirements

Table/Data	New Table	Note
FLT_AIRFRAMES		Add airframes data for UAM vehicles
FLT_ANP_UAM_DIRECTIVITY	X	Add directivity data for UAM vehicle static modes
FLT_ANP_UAM_NOISE_GROUPS	X	Add noise and spectral class identifiers for UAM vehicles modes
FLT_ANP_UAM_NPD_CURVES	X	Add left, center, right noise-mode-distance curves for UAM vehicles
FLT_ANP_UAM_PROFILE_POINTS	X	Add profile data for UAM vehicles
FLT_ANP_UAM_PROFILES	X	Add identifiers and weights for UAM vehicle profiles
FLT_ANP_UAM	X	Add descriptive information for UAM vehicles
FLT_ENGINES		Add UAM engines data; emissions factors likely zero for electric vehicles
FLT_ENGINE_MODS		Add UAM engine modification data; descriptive only, could be nominal
Land cover data		User supplies land cover data such as from the National Land Cover Database
Structures data		User supplies structure footprints and heights

Table 4-5 lists the required algorithms for UAM noise modeling in AEDT with the AEDT 3d Technical Manual section for each algorithm noted where appropriate. The profile method is the existing airplane fixed-point method with the addition of a duration field for static modes like the existing helicopter method. The handling of the spectra is different than airplanes and helicopters because it uses a spectrum for each flight mode. All other listed algorithms are the same as for helicopters, though the data requirements allow unlimited noise modes. The helicopter blade tip Mach number adjustment is not listed, as it may not be appropriate for UAM vehicles.

As UAM vehicles are created, the noise source characteristics of UAM vehicles may lend themselves additional algorithms, such as functions relating source noise levels and flight profile parameters. For example, vehicle specific coefficients for a function relating the rate of climb/descent and vehicle speed could be used to reduce the number of noise modes while still covering the full range of source sound emissions.

Currently, AEDT does not utilize bank angle calculations for helicopters. The elevation angle from the receiver is the only angle used to inform the selection and interpolation of the NPD curves. If analysis shows that bank angle is an important parameter for UAM vehicle source directivity, an algorithm would be necessary to compute bank angle based on the combination of flight path geometry and profile parameters. The formula used in AEDT for airplane bank angle (see AEDT 3d Technical Manual Section 3.6.5), may not be appropriate for other vehicle types. Alternatively, direct specification of the bank angle along a flight path would be possible, but would require that the full trajectory were specified for each flight rather than using AEDT's track/profile combination methodology.

Table 4-5. AEDT UAM Noise Modeling Algorithm Requirements

Algorithm	Note
Fixed-point profile method	Altitude, speed, mode, and ground track distance are directly specified along the trajectory with no modification due to environmental conditions. Duration is for points with static flight modes.
Source spectra	Spectra are defined for each flight mode
Spherical spreading and reference conditions atmospheric absorption	Noise levels under reference conditions are specified as a function of distance for each flight mode and interpolated or extrapolated for the actual source receiver distance (AEDT TM 4.2.2.4)
Atmospheric absorption adjustment	SAE-ARP-866A, SAE AIR-1845, SAE ARP-5534 (AEDT TM 4.3.1)
Acoustic impedance adjustment	Yes (AEDT TM 4.3.2)
Duration adjustment for exposure-based metrics	Adjustment for speeds different than NPD reference speed (AEDT TM 4.3.4)
Static mode duration adjustment	Yes (AEDT TM 4.5.4)
Lateral attenuation adjustment for civil aircraft	Includes ground effect and refraction-scattering (AEDT TM 4.3.5.1)
Noise fraction adjustment for flight path segments	Yes (AEDT TM 4.3.3.1)
Static mode directivity	Adjustments specified by azimuth angle to NPD curves for a mode (AEDT TM 4.5.3)
Dynamic mode directivity	Left 45 degrees, center, right 45 degrees of elevation angle via NPD curves for a mode (AEDT TM 4.5.2)
Terrain attenuation	Improved terrain shielding
Ground effect	Calculation of ground effect of full range of flow resistivities as mapped from land cover data
Structures attenuation and reflections	Calculation of shielding and reflections from man-made structures

One aspect of the UAM fixed-point profile method would be a vertiport-to-vertiport operation type. This could be handled in a similar manner to the fixed-point circuit profiles for airplanes. The profile would be specified from the ground up to level flight. A duplicate point in level flight would indicate the stretch segment to AEDT. Following the duplicate point, the descent portion of the profile would be specified. This would allow the same profile to be used for multiple vertiport-to-vertiport tracks if the track is not shorter than the profile.

4.1.4 A Phased Approach to AEDT UAM Vehicle Integration

The sections above discuss the integration of UAM vehicles into AEDT as a distinct category of vehicle with separate database tables, algorithms, and selections in the GUI. The most important aspects of the recommended requirements (improved directivity, more noise modes) could be achieved with minor modifications to the existing AEDT helicopter functionality without the creation of a new vehicle category. Table 4-6 presents a phased approach to introduction of improved UAM noise modeling functionality into AEDT. None of the actions listed for any of the phases will modify the calculations for existing helicopters in AEDT.

Table 4-6. A Phased Approach to AEDT UAM Vehicle Integration

Phase	Note
Current Status (AEDT 3d)	Airplane fixed-point profile modeling with no atmospheric absorption adjustment allows the modeling of many modes, but with no directivity or static operations; helicopter modeling has directivity for static and dynamic modes, but modes are limited in number and must match uniquely to a profile segment type
Phase 1 (option 1) – helicopter directivity with unlimited modes	Modify AEDT to allow the optional direct specification of the OP_MODE in addition to the STEP_TYPE in FLT_ANP_HELICOPTER_PROCEDURES. Allow unlimited arbitrary OP_MODE NPD curves. Continue to generate NPD curves for desired atmospheric conditions. Use the SAE 1845 atmosphere run setting so that AEDT will not use the assigned spectral classes for arrival, departure, and level.
Phase 1 (option 2) - helicopter directivity with unlimited modes	Modify AEDT to allow fixed-point profiles with arbitrary modes for helicopters (adds FLT_ANP_HELICOPTER_PROFILE_POINTS table database). Continue to generate NPD curves for desired atmospheric conditions. Use SAE 1845 atmosphere run setting so that AEDT will not use the assigned spectral classes for arrival, departure, and level.
Phase 2 – add spectral classes by mode	Modify the structure of FLT_ANP_HELICOPTER_NOISE_GROUPS to NOISE_ID, OP_MODE, SPECT, and SPEED. By allowing (but not requiring) the association of a different spectral class with each OP_MODE, it will be possible to input reference conditions NPD curves and utilize AEDT's various atmospheric absorption settings and its line-of-sight blockage algorithm.
Phase 3	Implement fully distinct UAM vehicle type with separate tables, GUI selections, and algorithms

4.2 AIRNOISEUAM

The AIRNOISEUAM development gaps in Section 3.2.2 are in the areas of improved vehicle directivity and improved acoustical propagation. Most of the development gaps can be addressed by adding AEDT's helicopter noise modeling capabilities and improved atmospheric, ground, terrain, and structures attenuation.

4.2.1 Requirements to Close Existing UAM Noise Modeling Gaps with AEDT

The majority of the acoustical algorithms in AEDT for airplanes and helicopters are the same. The AEDT helicopter functionality could be added to AIRNOISE UAM with relatively few changes as shown in Table 4-7. Note that exact replication of AEDT's helicopter noise modeling functionality would require restriction of the noise identifiers to a finite number and uniquely tying these to particular types of trajectory segments (e.g. level acceleration). This restriction is functionally detrimental is only recommended if exact replication is necessary.

AEDT's blade tip Mach number adjustment is not recommended for UAM noise modeling and is not included in the listed requirements.

Table 4-7. Requirements to Close AIRNOISEUAM UAM Noise Modeling Gaps with AEDT

Functionality	Note
Fixed-point profile method	AEDT's helicopter procedure profile method is functionally equivalent to a fixed-point profile. The addition of a duration field for static operations would provide the full AEDT helicopter functionality.
Source spectrum	Defined for each noise identifier; necessary for atmospheric absorption adjustment
Atmospheric absorption adjustment	SAE-ARP-866A, SAE AIR-1845, SAE ARP-5534 (AEDT TM 4.3.1)
Duration adjustment for exposure-based metrics	The helicopter duration adjustment allows the NPD curves to be at any reference speed and not just at 160 kts as for airplanes. (same as described in AEDT TM 4.3.4)
Static mode noise curves and directivity	Static modes (e.g. hover) have a single NPD curve and directivity in 15 degree increments as a function of azimuth angle (AEDT TM 4.5.3)
Dynamic mode directivity (via NPD curves)	Dynamic flight modes have left 45 degrees, center, right 45 degrees (elevation angle) NPD curves for each mode. Calculations for elevation angles between 45 and 90 degrees interpolate between the left or right and center curves (AEDT TM 4.5.2)

4.2.2 Requirements for Improved UAM Noise Modeling

In addition to the existing AEDT functionality, additional acoustical attenuation algorithms would improve the noise modeling of UAM vehicles. UAM vehicles will be operating in environments with large amounts of hard ground, obstacles to sound propagation, and reflective surfaces. AEDT has a basic line of sight terrain blockage functionality, but otherwise both AIRNOISEUAM and AEDT lack capabilities to account for the unique propagation effects of this type of environment. Table 4-8 lists the remaining AIRNOISEUAM requirements not covered in Table 4-7.

Table 4-8. Requirements for Improved AIRNOISEUAM Noise Modeling

Functionality	Note
Terrain	Allow import of terrain and account for shielding provided by terrain
Ground type	Allow import of land cover data, map land cover to flow resistivities, and account for effect of ground type
Structures	Account import of structures and account for shielding and reflections from man made structures

4.3 AEDT and AIRNOISEUAM Data Exchange

The efficient interchange of data between AIRNOISEUAM and AEDT requires the automation of the entry of inputs, running of scenarios, and the export of results.

4.3.1 AEDT Requirements to Facilitate Data Exchange with AIRNOISEUAM

Inputs may be entered into AEDT currently though the GUI, via ASIF, and directly into the database via SQL. Entry via ASIF can be partially automated via scripts to create the ASIF, however, use of the GUI is required to complete the actual import. With the exception of spectral class data, the input of all data can be automated via SQL. Thus, apart from this exception, further automation of AEDT inputs is not required. See Appendix A for examples of data entry SQL scripts.

Appendix H of the AEDT 3d User's Manual describes the syntax for using the Run Study command line tool. It allows a used to run an individual metric result directly from the command line. Further automation of running noise results is not required.

Noise results in AEDT are serialized and stored in the study database. No capability currently exists for users to directly export results from the database. The addition of a command line tool to extract the noise results to a text file would facilitate the full automation of analyses.

Table 4-9. AEDT Requirements to Facilitate Data Exchange with AIRNOISEUAM

Functionality	Note
Spectral class import	Allow direct import of spectral class data via SQL
Automated noise results export	Allow extraction of noise results tables from the database and production of noise contours via a command line tool

4.3.2 AIRNOISEUAM Requirements to Facilitate Data Exchange with AEDT

Table 4-10 lists the requirements to update AIRNOISEUAM for improved data exchange with AEDT. Apart from integrating a future AEDT noise results export command line tool, all items can be done currently.

Each item in the table could be partially automated by creating scripts or batch files that could be run manually or fully automated by integrating the creation and running of the scripts directly into AIRNOISEUAM. For example, direct import of AIRNOISEUAM inputs into AEDT can be accomplished in a semi-automated fashion by manually running a SQL script that bulk inserts the various AIRNOISEUAM input text files into temporary tables, reformats the data to match the AEDT table definitions, populates the necessary keys and indices, and inserts records into each AEDT table. Full automation would be accomplished by integrating this process into AIRNOISEUAM itself.

Table 4-10. AIRNOISEUAM Requirements to Facilitate Data Exchange with AEDT

Functionality	Currently Possible	Note
Inject AIRNOISEUAM inputs to AEDT study database	X	Vehicle Runways/helipads Flight tracks Profiles Operations Runs (metric, operation IDs)
Pull AEDT inputs from AEDT study database into AIRNOISEUAM	X	Vehicle Runways/helipads Flight tracks Profiles Operations Runs (metric, operation IDs)
Run AEDT	X	Create batch files for Run Study command line tool
Export AEDT results		Create batch files to export AEDT noise results (via future AEDT command line tool)
Import of AEDT noise results	X	Allow import of AEDT's exported noise grid results and comparison to AIRNOISEUAM results

5. Abbreviations, Initialisms, and Acronyms

Abbreviation	Description
AAM	Advanced Air Mobility
ACRP	Airport cooperative research program
AIRNOISEUAM	NASA Developed tool for urban air mobility noise prediction
AEDT	Aviation environmental design tool
AFE	Above field elevation
ANP	Aircraft noise and performance
ASIF	AEDT standard input file
BADA	Base of aircraft data (Eurocontrol model and dataset)
eVTOL	Electric Vertical Take-off and Landing
Ft	Feet
INM	Integrated noise model
MSL	Mean sea level
NEPA	National environmental policy act
NPD	Noise power distance
SQL	Structured query language
UAM	Urban air mobility

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Appendix A – Example AEDT SQL Data Import Scripts

```
-- Bulk Import of AEDT Tracks
-- All operation (A,D,V,T), aircraft (fixed wing = 0, helicopter = 1 ), and track
(Point, Vector) types
-- ***********************
--   CSV Input File Specs:
--  one line per track point/segment
--  the descriptive info is redundant on lots of lines, but it keeps the input to
a single file
--Field                       Format         Note
--SORT                        int            sort order of track segments
--AIRPORT_LAYOUT_ID           int            see table AIRPORT_LAYOUT
--RWY_END_ID                  int            see table APT_RWY_END
--OP_TYPE                     nchar(1)       arrival (A), departure (D), touch and
go / circuit (T), overflight (V)
--TRACK_NAME                  nvarchar(255)  name must be unique for this study
within a combination of runway end and operation type
--TRACK_TYPE                  nchar(1)       point (P), vector (V)
--RUNWAY_END_DELTA_DISTANCE   int            Delta distance from nominal start-roll
or touch-down point (ft)
--AIRCRAFT_TYPE               int            fixed-wing (0), helicopter (1)
--VECTOR_COURSE_AT_HELIPAD    float          direction (angle from North) for
helicopter operations of vector type (deg); NULL in all other cases
--SUBTRACK_NUM                smallint       0 for backbone only
--PCT_DISPERSION              real           100 for backbone only
--SEGMENT_NUM                 smallint       segment point number (1,2,...n for
each subtrack)
--SEGMENT_TYPE                nchar(1)       point (P); for vector tracks: straight
(S), left turn (L), right turn (R)
--PARAM_1                     float          for point-type track, latitude
coordinate (deg); For vector-type track, distance/radius (ft)
--PARAM_2                     float          for point-type track, longitude
coordinate (deg); For vector-type track, the angle (deg)
--ALTITUDE                    float          altitude (ft MSL)
--ALTITUDE_CONTROL            int            at or below (1), match (2), at or
above (3)-- ******************************

-- VNTSC BLN 7/16/21


-- ***** Update Parameters Section  *****
USE STUDY_INM
DECLARE @path nvarchar(255) = 'C:\Temp\trkSegs.csv'
-- ****** END of Parameters *****

-- Create temp table for track segments
IF OBJECT_ID('tempdb..#trkSegs') IS NOT NULL DROP TABLE #trkSegs
CREATE TABLE #trkSegs (
       SORT int,
       AIRPORT_LAYOUT_ID int,
       RWY_END_ID int,
       OP_TYPE nchar(1),
       TRACK_NAME nvarchar(255),
       TRACK_TYPE nchar(1),
       RUNWAY_END_DELTA_DISTANCE int,
    AIRCRAFT_TYPE int,
```

```
    VECTOR_COURSE_AT_HELIPAD float,
      SUBTRACK_NUM smallint,
      PCT_DISPERSION real,
      SEGMENT_NUM smallint,
      SEGMENT_TYPE nchar(1),
      PARAM_1 float,
      PARAM_2 float,
      ALTITUDE float,
      ALTITUDE_CONTROL int
)

-- Insert csvfile into temporary track segments table
DECLARE @sql nvarchar(255) = 'BULK INSERT #trkSegs FROM ''' + @path + ''' WITH (
FORMAT=''CSV'');'
EXEC(@sql)

--SELECT * FROM #trkSegs


-- **********  POPULATE APT_TRACK **********
DECLARE @BASE INT
SET @BASE = (SELECT IsNull(MAX(TRACK_ID),0) FROM APT_TRACK)

IF OBJECT_ID('tempdb..#trks') IS NOT NULL DROP TABLE #trks
SELECT
       MIN(SORT) as SORT
        ,[AIRPORT_LAYOUT_ID]
      ,[RWY_END_ID]
      ,[TRACK_NAME]
      ,[TRACK_TYPE]
      ,[OP_TYPE]
      ,[RUNWAY_END_DELTA_DISTANCE]
      ,[AIRCRAFT_TYPE]
      ,[VECTOR_COURSE_AT_HELIPAD]
INTO #trks
FROM #trkSegs
GROUP BY
         [AIRPORT_LAYOUT_ID]
        ,[RWY_END_ID]
      ,[TRACK_NAME]
      ,[TRACK_TYPE]
      ,[OP_TYPE]
      ,[RUNWAY_END_DELTA_DISTANCE]
      ,[AIRCRAFT_TYPE]
      ,[VECTOR_COURSE_AT_HELIPAD]

INSERT INTO APT_TRACK
SELECT
      @BASE + ROW_NUMBER() OVER (ORDER BY SORT) as TRACK_ID,
      '1900-01-01 00:00:00' as [EFF_DATE]
      ,'2079-06-06 23:59:00' as [EXP_DATE]
      ,[RWY_END_ID]
      ,[TRACK_NAME]
      ,[TRACK_TYPE]
      ,[OP_TYPE]
      ,[RUNWAY_END_DELTA_DISTANCE]
      ,[AIRCRAFT_TYPE]
      ,[VECTOR_COURSE_AT_HELIPAD]
      ,NULL as [GATE_ID]
```

```
      ,NULL as [ANCHOR_POINT_LATITUDE]
      ,NULL as [ANCHOR_POINT_LONGITUDE]
FROM #trks

--SELECT * FROM APT_TRACK

-- **********  POPULATE APT_SUBTRACK **********
IF OBJECT_ID('tempdb..#subTrks') IS NOT NULL DROP TABLE #subTrks

SELECT DISTINCT
      RWY_END_ID
        ,OP_TYPE
        ,TRACK_NAME
        ,SUBTRACK_NUM
        ,PCT_DISPERSION
INTO #subTrks
FROM #trkSegs

INSERT INTO APT_SUBTRACK
SELECT
      at.[TRACK_ID]
      ,st.[SUBTRACK_NUM]
      ,st.[PCT_DISPERSION]
FROM APT_TRACK at
JOIN #subTrks st on st.RWY_END_ID = at.RWY_END_ID AND st.OP_TYPE = at.OP_TYPE AND
st.TRACK_NAME = at.TRACK_NAME
WHERE at.TRACK_ID > @BASE
ORDER BY at.[TRACK_ID]

--SELECT * FROM APT_SUBTRACK

-- **********  POPULATE APT_SEGMENT **********
INSERT INTO APT_SEGMENT
SELECT
       ast.[SUBTRACK_ID]
      ,ts.[SEGMENT_NUM]
      ,ts.[SEGMENT_TYPE]
      ,ts.[PARAM_1]
      ,ts.[PARAM_2]
      ,ts.[ALTITUDE]
      ,NULL as [SPEED]
      ,ts.[ALTITUDE_CONTROL]
      ,NULL as [SPEED_CONTROL]
      ,NULL as [SEGMENT_NAME]
      ,NULL as [MESSAGE_TIME]
      ,NULL as [HALF_WIDTH]
      ,NULL as [ELEVATION]
FROM #trkSegs ts
JOIN APT_TRACK at on ts.RWY_END_ID = at.RWY_END_ID AND ts.OP_TYPE = at.OP_TYPE AND
ts.TRACK_NAME = at.TRACK_NAME
JOIN APT_SUBTRACK ast on ast.TRACK_ID = at.TRACK_ID AND ast.SUBTRACK_NUM =
ts.SUBTRACK_NUM
WHERE at.TRACK_ID > @BASE
ORDER BY ast.SUBTRACK_ID, ts.SORT

--SELECT * FROM APT_SEGMENT

-- **********  POPULATE TRACK_LAYOUT_ASSOCIATION **********
INSERT INTO TRACK_LAYOUT_ASSOCIATION
```

```sql
SELECT DISTINCT
          at.[TRACK_ID]
      ,t.[AIRPORT_LAYOUT_ID]
FROM APT_TRACK at
JOIN #trks t on t.RWY_END_ID = at.RWY_END_ID AND t.OP_TYPE = at.OP_TYPE AND
t.TRACK_NAME = at.TRACK_NAME
WHERE at.TRACK_ID > @BASE
ORDER BY at.[TRACK_ID]
```

Example Flight Track CSV file:

```
1,1,3000000,D,01LD01,V,0,0,,0,100,1,S,10000,,,
2,1,3000000,D,01LD01,V,0,0,,0,100,2,R,2000,45,,
3,1,3000000,D,01LD01,V,0,0,,0,100,3,S,100000,,,
4,1,3000000,A,01LA01,V,0,0,,0,100,4,S,100000,,,
5,1,3000000,A,01LA01,V,0,0,,0,100,5,L,2000,45,,
6,1,3000000,A,01LA01,V,0,0,,0,100,6,S,30000,,,
```

```sql
-- Create operations for a list of equipment, profile, and track combinations (fixed-wing
airplanes only)
-- VNTSCEX BLN 7/16/21

-- ***************************************************************
-- ******************* Update Parameters Section  *******************
-- ***************************************************************

-- Typical use of this script will involve edits to study name, test equipment list, and
@user_id_tag
-- These items are    <<<<<<<<<<<<<MARKED>>>>>>>>>>>>>>>>

USE STUDY_INM                                        --<<<<<<<<<<<<<<<<UPDATE STUDY
NAME>>>>>>>>>>>>>>>>>>

IF OBJECT_ID('tempdb..#NEW_OPS') IS NOT NULL DROP TABLE #NEW_OPS
CREATE TABLE #NEW_OPS
(EQUIP_ID              int,           -- See table FLT_EQUIPMENT
PROFILE_ID             int,           -- See table FLT_ANP_AIRPLANE_PROFILES
TRACK_ID               int,           -- See table APT_TRACK
OP_COUNT             float,          -- Number of flights
OPERATION_TIME       datetime,       -- Time for flight(s)
[USER_ID]            nvarchar(255)) -- Useful as an description in the GUI or as a key to
match to external data

INSERT INTO  #NEW_OPS (EQUIP_ID, PROFILE_ID, TRACK_ID, OP_COUNT, OPERATION_TIME,
[USER_ID])
VALUES                                                                          --
<<<<<<<<<<<<<<<UPDATE NEW OPS>>>>>>>>>>>>>>>>>>>
(1261,1021,3,1.0,'2000-01-01 00:00:00.000','C172 Arrival A4'),
(1261,1022,5,0.5,'2000-01-01 00:00:00.000','C172 Departure D4'),
(3178,1539,3,1.0,'2000-01-01 00:00:00.000','PA28 Arrival A4'),
(3178,1540,5,0.5,'2000-01-01 00:00:00.000','PA28 Departure D4')

-- ***************************************************************
-- *******************   End Parameters Section   *******************
-- ***************************************************************


-- Make OP_TYPE key
IF OBJECT_ID('tempdb..#OP_KEY') IS NOT NULL DROP TABLE #OP_KEY;
CREATE TABLE #OP_KEY
(      OP_TYPE_NUM int,
       OP_TYPE_CHAR nchar(1),
       TRACK_TYPE_CHAR nchar(1),)
INSERT INTO #OP_KEY VALUES
(0,'A','A'),
(1,'D','D'),
(2,'T','T'),
(3,'F','T'),
(4,'V','V')


-- ADD AIRCRAFT (IF NECESSARY) TO AIR_OPERATION_AIRCRAFT - tag them with
Airframe:ANP:BADA:Engine
INSERT INTO AIR_OPERATION_AIRCRAFT
```

```
SELECT
       fa.MODEL + ':' + feq.ANP_AIRPLANE_ID + ':'  + feq.BADA_ID + ':' +
CAST(fen.ENGINE_ID as nvarchar(255)) + ' (' + fen.ENGINE_CODE + ')' as [NAME]
       ,feq.EQUIP_ID as [EQUIPMENT_ID]
       ,case when feq.EQUIP_ID >= 100000 THEN 1 ELSE 0 END as [AIRCRAFT_SOURCE]
       ,NULL as [AIR_OPERATION_AIRCRAFT_DETAIL_ID]
       ,NULL as [DESCRIPTION]
FROM (SELECT DISTINCT EQUIP_ID FROM #NEW_OPS) noe
JOIN FLT_EQUIPMENT feq on feq.EQUIP_ID = noe.EQUIP_ID
JOIN FLT_ENGINES fen on fen.ENGINE_ID = feq.ENGINE_ID
JOIN FLT_AIRFRAMES fa on fa.AIRFRAME_ID = feq.AIRFRAME_ID
LEFT JOIN AIR_OPERATION_AIRCRAFT aoa on aoa.EQUIPMENT_ID = feq.EQUIP_ID
WHERE aoa.EQUIPMENT_ID IS NULL

-- ADD ROWS TO AIR_OPERATION
-- Query will not add rows if there is a disagreement between the EQUIP_ID and the
PROFILE_ID (different ANP_AIRPLANE)
-- Query will not add rows if there is a disagreement between the TRACK_ID and the
PROFILE_ID (different OP_TYPE)
INSERT INTO AIR_OPERATION
SELECT
       aoa.AIRCRAFT_ID              as AIRCRAFT_ID,
       no.[USER_ID]                 as [USER_ID],
       ok.OP_TYPE_NUM               as OPERATION_TYPE,
       no.OP_COUNT                  as OP_COUNT,
       no.OPERATION_TIME            as OPERATION_TIME,
       CASE WHEN ok.OP_TYPE_CHAR in ('D','F') THEN tla.AIRPORT_LAYOUT_ID ELSE NULL END as
DEPARTURE_AIRPORT_LAYOUT_ID,
       CASE WHEN ok.OP_TYPE_CHAR in ('D','F') THEN trk.RWY_END_ID ELSE NULL END        as
DEPARTURE_RUNWAY_END_ID,
       CASE WHEN ok.OP_TYPE_CHAR in ('A','T') THEN tla.AIRPORT_LAYOUT_ID ELSE NULL END as
ARRIVAL_AIRPORT_LAYOUT_ID,
       CASE WHEN ok.OP_TYPE_CHAR in ('A','T') THEN trk.RWY_END_ID ELSE NULL END        as
ARRIVAL_RUNWAY_END_ID,
       no.PROFILE_ID                as PROFILE_ID,
       no.TRACK_ID                  as TRACK_ID,
       faap.PROF_ID2                as STAGE_LENGTH,
       NULL                         as AIRPORT_PAIR,
       NULL                         as SENSOR_PATH_ID,
       NULL                         as TAXI_OUT_TIME,
       NULL                         as TAXI_IN_TIME,
       NULL                         as AIR_OPERATION_DETAIL_ID,
       NULL                         as CRUISE_ALTITUDE,
       NULL                         as ARRIVAL_GATE_ID,
       NULL                         as DEPARTURE_GATE_ID,
       NULL                         as ACTIVITY_PROFILE_ID,
       NULL                         as BADA4_PROFILE_ID
FROM #NEW_OPS no
JOIN FLT_EQUIPMENT feq on feq.EQUIP_ID = no.EQUIP_ID
JOIN AIR_OPERATION_AIRCRAFT aoa on aoa.EQUIPMENT_ID = feq.EQUIP_ID
JOIN FLT_ANP_AIRPLANE_PROFILES faap on faap.ACFT_ID = feq.ANP_AIRPLANE_ID and
faap.PROFILE_ID = no.PROFILE_ID
JOIN #OP_KEY ok on ok.OP_TYPE_CHAR = faap.OP_TYPE
JOIN APT_TRACK trk on trk.TRACK_ID = no.TRACK_ID and trk.OP_TYPE = faap.OP_TYPE
JOIN TRACK_LAYOUT_ASSOCIATION tla on tla.TRACK_ID = no.TRACK_ID
```

Appendix B – Terrain and Man-made Structures in AEDT

AEDT3d

Currently, AEDT allows a user to model the acoustical effect of terrain at two levels. The "Use terrain data" checkbox enables calculations that account for changes in source-receiver distance caused by terrain data. The "Apply line of sight blockage" checkbox enables calculations that account for the attenuation of the terrain between the source and receiver[1]. AEDT's current calculation of lateral attenuation includes, a soft ground attenuation component, and air-to-ground component, and directivity due to engine installation location[2]. The lateral attenuation term is applied when "Use terrain data" is not checked or when the computed terrain attenuation is less than the computed lateral attenuation. AEDT does not currently account for the acoustical attenuation provided by man-made structures.

Users must place GeoTIFF, National Elevation Dataset (NED) GridFloat, 3CD, or Digital Elevation Model (DEM) terrain data files covering the extents of the intended receptor grid (and the flight trajectories, if using line of sight blockage) in the designated terrain directory. AEDT computes the line-of-sight blockage by creating a terrain slice with a spacing equal to the smaller of the terrain grid X and Y spacings. For each point in the slice, the increase in sound path length due to that terrain point relative to the direct path is computed. The largest of these increases is retained for computation of the Fresnel Number and barrier effect for each one-third octave band. After accounting for atmospheric absorption, the A-weighted spectrum for the appropriate spectral class is then adjusted for the barrier attenuation. Each one-third octave-band is limited to a maximum attenuation of 18 dB. The net effect on the total A-weighted sound level is utilized by AEDT as the line-of-sight blockage. AEDT applies the greater of the barrier attenuation or the lateral attenuation to the computed sound level.

AEDT uses the empirically based SAE-AIR-5662 lateral attenuation algorithms which accounts for:

- Ground reflection effects
- Refraction effects
- Airplane shielding and engine installation effects

The ground effect component of the lateral attenuation adjustment assumes propagation over soft ground, which is considered acoustically absorptive. The equation for this effect is a function of sideline distance and ranges from a value of 0 dB at 0 ft to 10.86 dB at 3,000 ft or greater. The lateral

---

[1] See AEDT 3d Technical Manual Section 4.3.6.

[2] AEDT 3d has the option to "Use hard ground attenuation for helicopters & propeller aircraft". This option turns off the lateral attenuation calculation for these aircraft. The engine installation adjustment is always equal to zero for helicopters and propeller aircraft.

attenuation adjustment for helicopter and propeller aircraft can be turned off in AEDT to approximate modelling propagation over hard ground types.

Planned Development

The planned AEDT implementation of improved terrain and ground attenuation and attenuation due to man-made structures follows from the Airport Cooperative Research Program (ACRP) project 02-52 "Improving AEDT Noise Modeling of Hard, Soft, and Mixed Ground Surfaces"[3] and ACRP Project 02-79 "Improving AEDT Modeling for Aircraft Noise Reflection and Diffraction from Terrain and Man-made Structures"[4].

The recommendations from ACRP 02-52 include:

- Allow computation of ground attenuation for all soft, all hard, or mixed ground
- Implement the new calculations in AEDT by
    - computing the ground effect for the desired ground
    - computing the ground effect for soft ground
    - applying the difference in these computations as an offset to the AEDT lateral attenuation (which includes a ground effect for soft ground)
- Utilize a single-parameter model of ground impedance based upon flow resistivity estimates of categories ground types based on the National Land Cover Database (NLCD) for the mixed ground calculations
- Compute the ground effect using an average of the flow resistivities along the major axis of a Fresnel ellipse between the source and receiver

The recommendations from ACRP 02-79 include:

- Compute the effects of terrain using the algorithms of the Advanced Acoustic Model (AAM)[5] [6]
- Model the effects of terrain throughout the study area
- Compute the effect of man-made structures using the algorithms of the Traffic Noise Model (TNM)[7] by calculating the difference between the sound level with terrain and structures and the sound level with terrain only

---

[3] Hobbs, Christopher M., Yuriy A. Gurovich, Eric Boeker, Aaron Hastings, Amanda Rapoza, and Juliet Page. Improving AEDT Noise Modeling of Mixed Ground Surfaces, ACRP Web-Only Document 32, March 2017.

[4] Downing, J. Micah, Juliet A. Page, and Judith L. Rochat. Improving AEDT Modeling for Aircraft Noise Reflection and Diffraction from Terrain and Manmade Structures, ACRP Web-Only Document 43, August 2019.

[5] Page, Juliet A., Amanda Rapoza, Alexander Oberg, Aaron Hastings, Gary Baker, Meghan Shumway. Advanced Acoustic Model (AAM) Technical Reference and User's Guide, DOT-VNTSC-20-05, December 2020.

[6] Much of the terrain code in AAM is based on Rasmussen, Karsten B., The Effect of Terrain Profile on Sound Propagation Outdoors, Danish Acoustical Institute Report J. No. 16-3265.E-885, January 1984.

[7] Hastings, Aaron L. Technical Manual: Traffic Noise Model 3.0. FHWA-HEP-20-012, December 2019.

- Model the effects of man-made structures only near the runways: 8,600 ft along the extended centerline from the arrival threshold and 7,218 ft laterally with a 1,000 ft transition region.

Appendix C – Noise Abatement Procedures

This appendix provides a general discussion of aircraft noise abatement than may provide useful background for UAM noise abatement. Although it is now nearly 20 years old, FAA Advisory Circular 150/5020-1[8] provides a useful distillation of noise abatement techniques. Due to subsequent regulation, some of the measures discussed in the AC are no longer pursued for airport noise abatement. However, the discussion of each measure provides insight on the philosophy of noise abatement.

CONSIDER THESE ACTIONS ▼		IF YOU HAVE THIS PROBLEM ►	NOISE FROM: TAXIING	DEPARTURE	APPROACH	LANDING ROLL	TRAINING FLIGHTS	MAINTENANCE	GROUND EQUIPMENT
AIRPORT PLAN	Changes in Runway Location, Length or Strength	1	●	●	●	●	●		
	Displaced Thresholds	2			●		●		
	High–Speed Exit Taxiways	3	●			●			
	Relocated Terminals	4	●					●	●
	Isolating Maintenance Runups or Use of Test Stand Noise Suppressors and Barriers	5	●					●	●
AIRPORT AND AIRSPACE USE	Preferential or Rotational Runway Use *	6	●	●	●	●	●		
	Preferential Flight Track Use or Modification to Approach and Departure Procedures *	7		●	●		●		
	Restrictions on Ground Movement of Aircraft *	8	●						
	Restrictions on Engine Runups or Use of Ground Equipment	9						●	●
	Limitations on Number or Types of Operations or Types of Aircraft	10	●	●	●	●	●	●	●
	Use Restrictions Rescheduling Move Flights to Another Airport	11	●	●	●	●	●	●	●
	Raise Glide Slope Angle or Intercept *	12			●		●		
AIRCRAFT OPERATION	Power and Flap Management *	13		●	●		●		
	Limited Use of Reverse Thrust *	14				●			
LAND USE	Land or Easement Acquisition	15	●	●	●	●	●	●	●
	Joint Development of Airport Property	16	●	●	●	●	●	●	●
	Compatible Use Zoning	17	●	●	●	●	●	●	●
	Building Code Provisions and Sound Insulation of Buildings	18	●	●	●	●	●	●	●
	Real Property Noise Notices	19		●	●	●	●	●	●
	Purchase Assurance	20		●	●	●	●	●	●
NOISE PROGRAM MANAGEMENT	Noise–Related Landing Fees	21	●	●	●	●	●		
	Noise Monitoring	22		●	●		●	●	
	Establish Citizen Complaint Mechanism Establish Community Participation Program	23	●	●	●	●	●	●	●

Figure 1 Matrix of Noise Control Actions (reproduced from AC 150/5020-1)

[8] https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_150_5020-1.pdf

AC 150/5020-1 contains a matrix of noise control actions and discussion of each action. The actions include both abatement (reducing noise) and mitigation (reducing the effects of noise) such as limited use of reverse thrust and sound insulation, respectively.

For the purposes of UAM noise compatibility planning, the following conclusions can be drawn from the concepts in Chapter 3 of AC:

- The goal is to reduce incompatibilities between aircraft noise and nearby communities
    - This requires information on local land use patterns and the values of the community in regards to social, economic, and environmental needs.
- Extensive coordination with local jurisdictions is required to form and implement solutions
- Noise abatement measures include
    - Manage flight profile parameters
        - Altitudes
        - Power settings
        - Speed
        - Flight path angle
        - Banking
    - Use alternative flight paths to overfly compatible land use
    - Maximize use of vertiports or pads within vertiports that have the lowest noise exposure
    - Manage time of operations (day vs. night)
    - Reduce engine idle time
    - Reduce hover and circling
    - Barriers (for ground noise only)
- Successful noise compatibility planning will likely require a combination of measures
    - Individual measures can be screened with single event noise contours (LAMAX, SEL)
        - By contour area
        - With statistics on population withing a single event noise contour
    - Promising measures can be assessed for their effect on cumulative exposure (Annual average day DNL)
        - Via comparison of a baseline case without the individual measure vs. an alternative case with the measure implemented
        - In a combination of measures to assess the cumulative change relative to a baseline case
    - Measures should be assessed for safety, economic, and environmental considerations