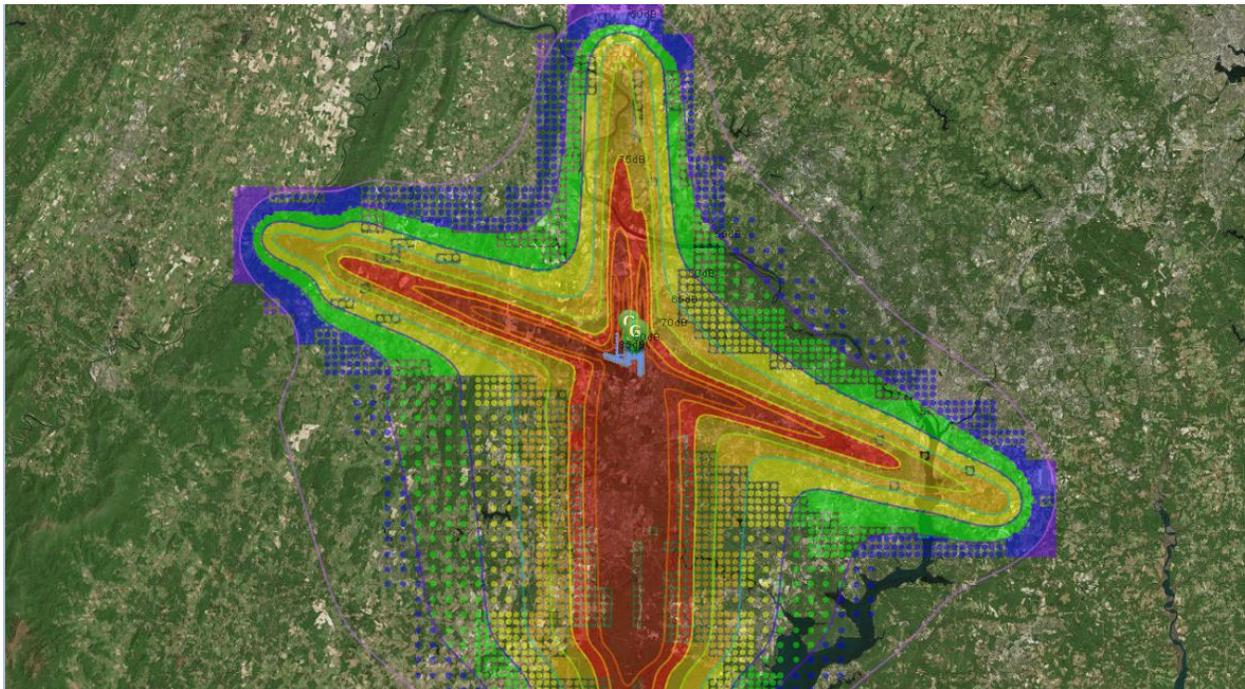


NoiseMap and AEDT Gap Analysis

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Federal Aviation Administration
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**Federal Aviation
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in ²	square inches	645.2	square millimeters	mm ²
ft ²	square feet	0.093	square meters	m ²
yd ²	square yard	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi ²	square miles	2.59	square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
oz	ounces	28.35	grams	g
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m ²	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in ²	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
mL	milliliters	0.034	fluid ounces	fl oz
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
g	grams	0.035	ounces	oz
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F



SI* (MODERN METRIC) CONVERSION FACTORS

ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m²	candela/m ²	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	Kilopascals	0.145	poundforce per square inch	lbf/in ²

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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List of Abbreviations

Abbreviation	Term
AAD	Average Annual Day
AAM	Advanced Acoustic Model
ACAM	Air Conformity Applicability Model
ACS	American Community Survey
AEDT	Aviation Environmental Design Tool
AFE	Airfield Elevation
AG	Air-to-Ground propagation
AICUZ	Air Installation Compatible Use Zones
AIR	Aerospace Information Report
AMS	American Meteorological Society
ANP	ICAO Aircraft Noise and Performance Database
APU	Auxiliary Power Unit
ASIF	AEDT Standard Input Format
ATAR	Air Traffic Activity Reports
ATC	Air Traffic Controllers
BADA	Eurocontrol Base of Aircraft Data
BFFM2	Boeing Fuel Flow Method 2
CAS	Calibrated Air Speed
CNEL	Community Noise Equivalent Level
CO	Carbon Monoxide
CO2	Carbon Dioxide
CPA	Closest Point of Approach
dB	Decibel
DEM	Digital Elevation Model
DNL	Day-Night Average Sound Level
DNWG	DoD Noise Working Group
DOD	Department of Defense
DOPAA	Description of Proposed Actions and Alternatives
ECAC	European Civil Aviation Conference
EDB	ICAO Engine Emissions Databank
EDM	Emissions Dispersion Module
EDMS	Emissions and Dispersion Modeling System
EPNL	Effective Perceived Noise Level
FOA	First Order Approximation
GG	Ground-to-Ground propagation
GIS	Geographic Information System
GSE	Ground Support Equipment
GUI	Graphical User Interface
H2O	Water



Abbreviation	Term
HAP	Hazardous Air Pollutants
HC	Total Hydrocarbons
HIGE	Hover-in-Ground Effect
HOGE	Hover-Out-of-Ground Effect
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
INM	Integrated Noise Model
ISA	International Standard Atmosphere
L _{Amax}	Maximum A-weighted Sound Level
L _{eq,24hr}	Equivalent Continuous Sound Level
MRNMap	Military Operations Area and Military Training Route NoiseMap Model
NA	Number of Events Above
NAAQS	National Ambient Air Quality Standards
NASMOD	Military Aviation Simulation Model
NDADS	Noise Data Analysis and Display System
NED	National Elevation Dataset
NEF	Noise Exposure Forecast
NEPA	National Environmental Protection Act
NMGF	Noise Model Grid Format
NMHC	Non-Methane Hydrocarbons
NMODD	Noise Modeling Operational Data Description
NO _x	Oxides of Nitrogen
NPD	Noise-Power-Distance
NvDC	Noise versus Distance Curves
OTO	One-Third Octave band spectrum
PA	Probability of Awakening
PM	Particulate Matter
PNL	Perceived Noise Level
PPM	Parts Per Million
RNM	Rotorcraft Noise Model
ROC	Rate of Climb
SAE	Society of Automotive Engineers
SEL	Sound Exposure Level
SFI	Senzig-Fleming-Iovinelli
SOG	Speciated Organic Gases
SO _x	Sulfur Oxides
TA	Time Above/Time Audible
TF	Transition Factor Curve
TOG	Total Organic Gases
VFR	Visual Flight Rules
VOC	Volatile Organic Compounds
WECPNL	Weighted Equivalent Continuous Perceived Noise Level



I. Introduction

NoiseMap and the Aviation Environmental Design Tool (AEDT) both use an integrated modeling approach to calculate aircraft noise in and around an airfield. Both models also employ the same general overall approach by using airfield operational data, standard reference noise databases, and flight trajectories as inputs to their computational models, which calculate the individual noise exposures from each flight trajectory and accumulates the total noise exposure within a grid of points. However, differences between the NoiseMap and AEDT models exist in the details within each of these general areas. Given the considerable overlap in capabilities between the Federal Aviation Administration's (FAA) AEDT and the Department of Defense (DOD) NoiseMap suite of programs and considering the US Government's investment and future plans for continued AEDT improvement, a gap analysis was conducted to evaluate technical overlaps and gaps that currently exist between the two toolsets. This report covers the following technical areas: Physical Modeling, Input Data/Graphic User Interface (GUI), and Output Capabilities.

I.1 Background

AEDT is a software system that models aircraft performance in space and time to estimate noise, fuel consumption, emissions, and air quality consequences. AEDT is designed to process individual studies ranging in scope from a single flight at an airport to scenarios at the regional, national, and global levels. AEDT leverages geographic information system (GIS) and relational database technology to achieve this scalability and offers rich opportunities for exploring and presenting results. AEDT is actively used by the US government for domestic aviation system planning as well as domestic and international aviation environmental policy analysis.

In contrast to the individual air quality and noise analysis tools: Emissions and Dispersion Modeling System (EDMS) and Integrated Noise Model (INM), AEDT unifies noise, fuel consumption, and emissions calculation capabilities into a single application. AEDT includes a database of over 3,000 airframe-engine combinations and runway information for over 30,000 airports around the globe. These system databases allow users of AEDT to quickly build studies and estimate the interdependencies between noise, fuel consumption, and emissions consequences of aviation activity.

For DOD actions that involve NEPA analysis, DOD mandates the use of NoiseMap for airfield noise analysis. For joint use facilities, DOD preference is to have military aircraft modeled with NoiseMap and commercial aircraft modeled with AEDT. DOD utilizes the Air Installation Compatible Use Zone (AICUZ) program to work with communities to avoid land uses that encroach on an airbase's mission. These AICUZ noise studies are also conducted with NoiseMap.



1.2 Overview

For physical modeling of aircraft noise, both AEDT and NoiseMap employ an integrated calculation approach for estimating noise exposures from individual aircraft operations with differences in various aspects on the noise calculation. For reference noise, the two models share each other's databases, but they are not consistently updated between each model. Two major differences in noise propagation modeling between the two tools are the representation of the effects of terrain and ground cover and aircraft performance modeling. For terrain effects, AEDT is limited to line-of-sight blockage and simple slant range adjustment, whereas NoiseMap has a more complex method for the inclusion of terrain and ground effects. For elevation variation, NoiseMap utilizes three basic terrain cut types: flat, valley, and hill with specific user defined elevation to determine the ground attenuation between the source and receiver. The ground effects are modeled whether the line-of-sight is blocked or not. For ground cover effects, NoiseMap considers a mix of acoustically hard and soft ground covers in a binary manner along the propagation path, whereas AEDT corrects* for hard ground (water) only for propeller aircraft. For aircraft performance modeling, AEDT and NoiseMap are distinctly different. NoiseMap requires a user to be responsible for the accuracy of the modeled flight trajectories, which may result in inconsistent profiles among different users. Additionally, within NoiseMap, the flight profiles are not checked for physical correctness as no performance and flight kinematics modeling are performed. In contrast, AEDT includes a more robust methodology for determining flight profiles by providing realistic, standard commercial flight trajectories and a mechanism for creating profiles based on aircraft performance data. AEDT also contains algorithms to screen aircraft-specific flight profiles for realism. However, the nature of military operations does not readily lend itself to the use of standard operational profiles.

For input data and graphical user interface, NoiseMap requires a user to obtain most of the required operational input except for reference noise data. NoiseMap's GUI, BaseOps, provides a flexible and easy to use interface for developing and entering the required operational data. AEDT's GUI has a comparable functionality to BaseOps, and it also includes detailed databases on airports, weather, ground tracks, altitude surfaces, flight performance parameters and it additionally conducts an error check of all data entries. Flight operations for civilian airfields are well defined and often documented and recorded using various means, while operations at a military airfield are not. This lack of documentation requires in-person data collection interviews for each military noise study.

For the model output capabilities, both tools generate very similar range of primary and supplemental acoustical metrics. Both tools use the same Noise Model Grid Format (NMGF) Standard (version 2.5) to generative georeferenced grid of receiver locations. NoiseMap also includes specialized tools for noise analyses and outputs: FLT Optimizer and Advanced Acoustic Model (AAM). FLT Optimizer provides "best" flight profile/track to balance noise, emissions, and fuel burn for given flight operations. AAM is a simulation based noise model, which provides higher resolution of supplemental metrics, TA ambient and audibility analysis, and acoustic animations.

* In limited situations the soft ground correction calculations can be "turned off" to approximate acoustically hard ground (i.e. water), however AEDT does not represent acoustic impedance in a physics based manner.



For air emissions and air quality, AEDT includes an extensive toolset, whereas NoiseMap does not have a direct link to an air emission and air quality tool although individual practitioners have developed techniques for utilizing NoiseMap modeling inputs/outputs in external emission and air quality models. Overall, AEDT mostly overlaps NoiseMap capabilities on the technical aspects of airport noise modeling. However, noise studies for DOD require flexibility due to the variation in operations across services, locations, and squadron types. Thus, NoiseMap requires a knowledgeable user to develop the operational input data, whereas AEDT contains procedural requirements within the data input portion of a noise study. Implementing procedural requirements for DOD noise studies will require additional work by each branch and will require DOD harmonization before transition to AEDT is viable. Additionally, DOD is working toward establishing AAM as the primary noise calculation model within NoiseMap. This computational shift to a simulation model utilizing a three-dimensional spectral directivity noise database will result in a large gap between the two tools.



2. Task I: Physical Modeling

This section provides a summary of the physical modeling capabilities (i.e. noise modeling, aircraft performance modeling, and air emissions and air quality modeling) in the NoiseMap suite of programs and AEDT. Additionally, an overview of the gaps between the physical modeling capabilities of NoiseMap and AEDT are provided.

2.1 NoiseMap

A summary of the physical modeling capabilities in the NoiseMap suite of programs (primarily BaseOps, NoiseFile, Omega, NMap, and Optimizer routines) are discussed in this section.

2.1.1 Noise Modeling

NoiseMap modeling of the noise exposure of aircraft operations consist of the following steps:

- Reference Source Noise
- Noise versus Distance Curves (NVDC)
- Sub-segmentation of the Flight Profiles
- Ground/Terrain Effects
- Weather Effects

2.1.1.1 Reference Source Noise

The reference source noise data for NoiseMap is referred to as NoiseFile, which contains two separate datasets: flyover and ground run-up noise. For the flyover data (Flight01.dat), two to seven reference engine power conditions are included for each aircraft. For each reference condition, seven integrated metrics are included: Perceived Noise Level (PNL), tone-corrected PNL, Maximum A-weighted Sound Level (L_{Amax}), tone-corrected L_{Amax} , Effective Perceived Noise Level (EPNL), Sound Exposure Level (SEL), and tone-corrected SEL. Also for each reference condition, a one-third octave (OTO) band spectrum is included. This spectrum is the average spectrum that occurs at maximum PNL for a flyover. In addition to the noise data, the following associated operational data are included: the engine power settings, engine power extrapolation limits, airspeed, vehicle configuration, number of measurements, angle of maximum PNL and data of analysis. These reference data normally are directly measured during dedicated flight tests in which each engine condition is repeated two to six times. From these repeated measurements, the data are averaged and normalized to 1,000 ft and US Standard Atmospheric Conditions¹ of 59° and 70% relative humidity. One technical issue with the measured data is that the noise is collected at 5 ft (1.5m) so the receiver height is convolved in the reference data.

For the ground run-up data (Static01.dat), two to seven engine power conditions are included for each aircraft. The noise data are provided as OTO band spectra from 10 to 10k Hz in 10° steps from 0° to 180°.



The reference distance for the ground run-up noise data is 250 ft as this distance is the standard distance used for the measurements. Ground run-up data are required for military aircraft since the data are used for the take-off roll for modeling departure flight operations.

If a military aircraft does not have measured noise data, then its reference noise data are estimated from measured surrogates based primarily on engine type and airframe configuration. These surrogates are noted in Flight01.dat and Static01.dat.

NoiseFile also includes civilian aircraft flyover data, which were translated from the Integrated Noise Model (INM). These civilian data include four integrated metrics: L_{Amax} , EPNL, SEL and tone-corrected SEL and a OTO band spectrum from a spectral class (50 to 10k Hz). The associated data includes engine power settings and interpolation type, extrapolation limits, airspeed, and configuration. They are also normalized to 1000 ft and US Standard Atmospheric Conditions 59° F and 70% RH.

2.1.1.2 Noise Versus Distance Curves

The development of the NvDC for flight noise involves the OMEGA10 module that generates two curves for the following metrics: SEL, EPNL, L_{Amax} , and tone-corrected PNL. One curve is for Air-to-Ground propagation (AG), and the other is for Ground-to-Ground propagation (GG). The AG curves include losses due to geometric spreading and atmospheric absorption. The GG curve adds in losses from ground attenuation. The atmospheric absorption is based on the Society of Automotive Engineers Aerospace Recommended Practice 866A, “Standard Values of Atmospheric Absorption as a Function of Temperature and Humidity”², which is now outdated. The selected atmospheric conditions are based on the sixth absorptive month out of twelve monthly average values of temperature and relative humidity. These values are applied to the OTO spectrum for the selected engine power condition. If the selected condition is not a reference condition, then the spectrum is a linear interpolation between the two reference engine power conditions. If it is outside the reference values, then it is an extrapolation from the nearest reference set as long as it is within the extrapolation limits. If it is outside the limits, then the engine power condition is changed to the extrapolation limit value. The NvDC do not include directivity as directivity is convolved in the integrated metrics in the measurement of the noise data.

For ground run-up operations, the NvDC are generated by the OMEGA11 module that generates a series of curves for the following metrics: L_{Amax} and tone-corrected PNL. The NvDCs include losses from geometric spreading, atmospheric absorption, and ground attenuation, and they are directional with NvDCs from 0° to 180° in 10° steps.

2.1.1.3 Sub-segmentation of Flight Profile: Noise Fraction

For flight operations, the flight profile consists of changes in engine power, airspeed, and altitude along a flight track that consist of straight and circular arc segments. Changes in engine power are assumed to occur at discrete points whereas changes in airspeed and altitude are modeled as linear variations between the given profile points. The flight profile is broken down into sub-segments where the flight parameters are given and the flight track segment is either straight or an arc. For example, Table 1 and 2 provide a departure ground track and flight profile, respectively. These result in the following modeled



flight trajectory, which is shown in Figure 1. The segmentation of this flight trajectory is highlighted by the orange vertical line along the trajectory. The segmentation can produce long and short segments.

Table 1. NoiseMap Ground Track Example

Segment Length or Turn Radius, ft	Heading Change, deg	Segment Distance, ft	Cumulative Distance, ft
6,076	0	6,076	6,076
6,076	72 R	7,635	13,711
300,000	0	300,000	313,711

Table 2. NoiseMap Flight Profile Example

Cumulative Track Distance, ft	Altitude, ft		V Airspeed, kts	Engine Power
0	22	MSL	0	96
2,000	22	MSL	135	96
8,000	1,022	MSL	250	96
13,975	1,500	MSL	300	95
24,608	2,750	MSL	300	90
39,250	4,000	MSL	300	84
80,297	4,000	MSL	300	95
110,000	17,000	MSL	300	84
300,000	17,000	MSL	300	84



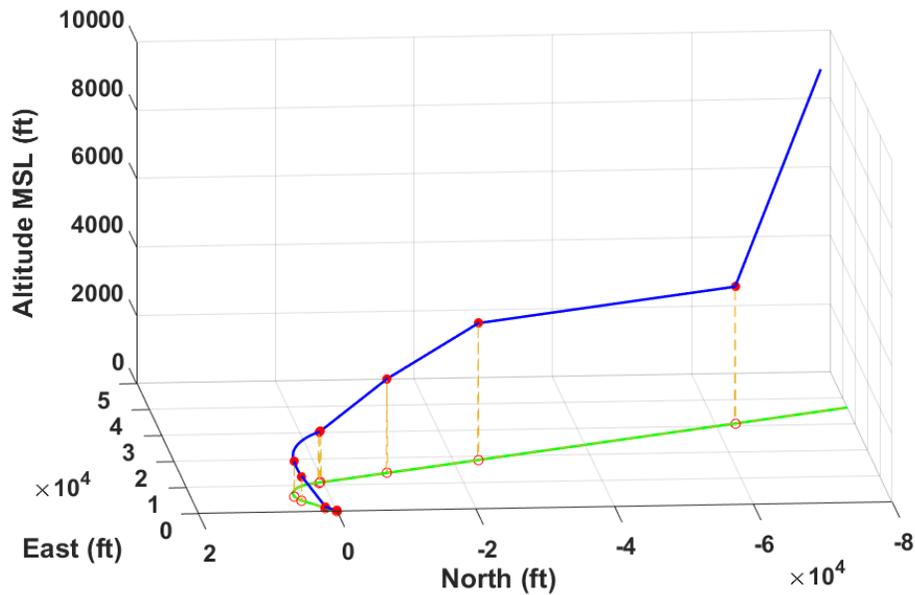


Figure 1. NoiseMap Flight Trajectory with Segmentation from Combination of Flight Track and Profile

After a flight profile is segmented, the noise fraction for each segment is collected at the grid points. For each segment, noise is calculated based on the segment end points and the Closest-Point-of-Approach (CPA) along a segment’s extended projection. The calculation varies if the CPA is between the segment’s end points or outside of the end points. NoiseMap uses a grid scanning scheme to stop the calculation once the levels reach and maintain values less than a threshold.

2.1.1.4 Ground/Terrain Effects

NoiseMap has two modes for the inclusion of ground effects. The original version is a flat earth model that uses an empirical ground attenuation curve. The “newer” version, NoiseMap7, includes topography effects in the calculation of losses for propagation over the surface.

2.1.1.4.1 Flat Earth:

The original flat earth model has the following features: straight line distance, empirical ground attenuation curve, and a transition factor curve. The empirical ground attenuation curve is based on military aircraft noise measurements conducted by the Air Force Research Laboratory in the 1980’s. The transition factor curve (TF) weights the received sound between the AG and GG NvDC based in the propagation angle to the receiver point as shown in Figure 2. The noise exposure at a receiver distance, d , and a propagation angle, β , is calculated by the following series of equations:³

$$\text{Noise exposure } (d, \beta) |_{MIL} = TF \times 10^{(GG(d)/10)} + (1 - TF) \times 10^{(AG(d)/10)}, \text{ where}$$

$$TF = 1 \text{ for } 0 \leq \beta < 2^\circ$$



$$= \left(\frac{2.093}{\beta} \right) - 0.04651 \text{ for } 2^\circ \leq \beta < 45^\circ$$

$$= 0 \text{ for } 45^\circ \leq \beta \leq 90^\circ$$

Noise exposure $(d, \beta) | (d, \beta) |_{CIV} = 10^{\left(\frac{AG(d) - \Delta}{10}\right)}$, where
 Δ = the SAE lateral attenuation values for civil aircraft

Figure 3 plots the relationship between β and TF.

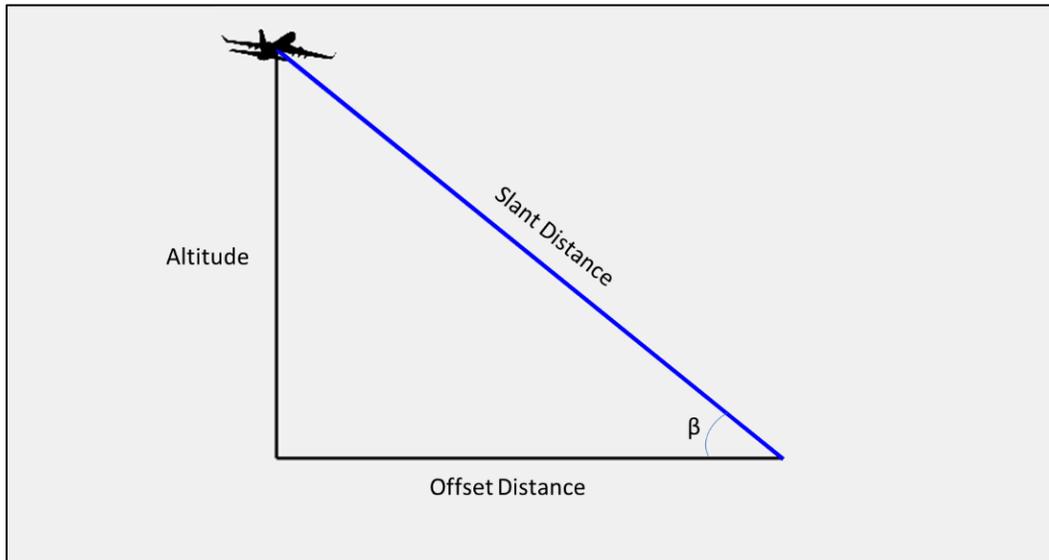


Figure 2. Basic Flight Geometry

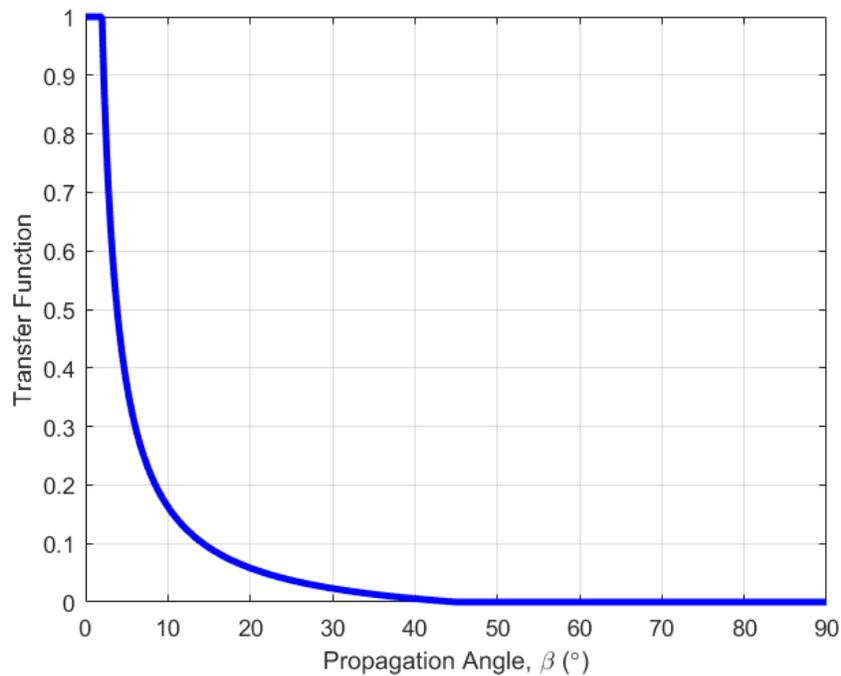


Figure 3. Transfer Function versus Propagation Angle



Topography Effects: The topography model includes ground cover and elevation changes. Ground cover variations are handled with a hard/soft binary characterization of the ground surface. Generally, ground is modeled as soft, which has additional absorption, and water surfaces are modeled as hard with no additional absorption. The effect of this variation allows sound to propagate further over water surfaces compared to ground surfaces. In addition to the effect of ground cover, the model also includes the effect of variations in ground elevation along the path from the source to the receiver. The model classifies these variation as terrain cuts into the following groups: flat, valley, and hill. These representative terrain cuts are show in Figure 4. The attenuation for each terrain cut type is based on semi-empirical A-weighted curves developed with comparison to full spectral calculations.⁴

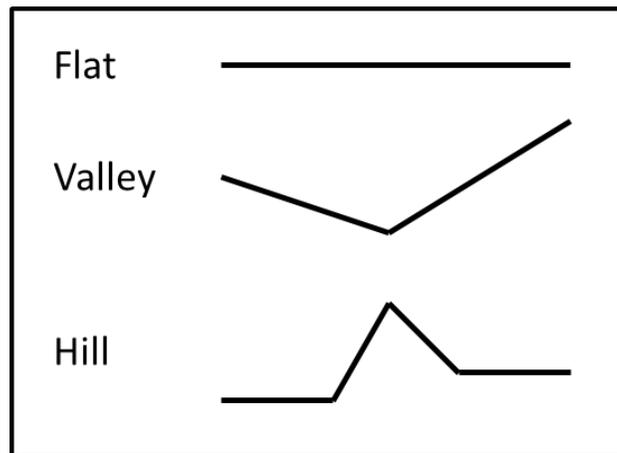


Figure 4. NoiseMap Terrain Cut Models for Topography Attenuation Calculation

2.1.1.5 Duration Adjustments

The effect of duration on noise exposure (SEL and EPNL) from an aircraft overflight is modeled with two adjustments. One for airspeed, and another for distance³. The airspeed adjustment is the following equation:

$$\text{Speed Adjustment} = -10 \log\left(\frac{V_x}{V_{ref}}\right),$$

where

$$\begin{aligned} V_x &= \text{desired airspeed} \\ V_{ref} &= \text{reference airspeed.} \end{aligned}$$

The adjustment for distance is based on field measurements [ref] and is the following:

$$\text{Distance Adjustment} = 6 \log\left(\frac{D_x}{D_{ref}}\right),$$

where

$$\begin{aligned} D_x &= \text{desired distance} \\ D_{ref} &= \text{reference distance (usually 1,000 ft).} \end{aligned}$$



The factor of 6 for the distance adjustment⁵ is smaller than 7.5 recommended by the Society of Automotive Engineers (SAE)⁶. For a omni-directional sound source, the factor is 10. However, to account for aircraft directivity, these smaller factors are used. NoiseMap's factor will reduce the values of SEL and EPNL faster with increasing propagation distance compared to AEDT.

2.1.1.6 Weather Effects

In terms of weather analysis capabilities, NoiseMap only includes the effect of atmospheric absorption on the calculated levels. Absorption calculations are based on the normalized OTO band spectra for maximum PNL of an overflight. For the structure of the integrated modeling, the inclusion of atmospheric refraction would have to be integrated with the NvDC generated by the OMEGA programs. The effect of atmospheric wind profiles would require directional NvDC outputs and additional determination of the selected NvDC outputs to use the various propagation directions. Additionally, this direct wind effect would have to be balanced with its indirect effect of runway utilization since some wind directions would be incompatible with the use of a particular runway.

2.1.2 Aircraft Performance Modeling

NoiseMap has no internal performance modeling embedded within BaseOps. A user is required to ensure the input flight profiles are realistic and match local course rules. Additionally, NoiseMap does not provide any feedback on the physical correctness of the flight profiles. With the addition of topography effects, a simple check of flight altitude above ground was turned off, so a flight profile can easily be defined to be underneath the ground.

The Flight Profile Optimizer,⁷ which is based on NoiseMap calculations, does provide some performance in terms of user provided trade-offs in engine power and climb/descent rates. Currently, the parameters for these trade-offs are limited to F/A-18C/D and F/A-18E/F aircraft. In addition, simple checks are provided with this tool to ensure candidate flight profiles remain within defined airspace limits provided by the user.

2.1.3 Air Emissions and Air Quality Modeling

NoiseMap does not have any air emission or air quality data or calculation tools. In practice, the input file to the computational module (*.opx) can be used to calculate Time-In-Mode for prescribed calculations in the Air Force's Air Conformity Applicability Model (ACAM). However, no direct link or import function exists from NoiseMap to ACAM.

The Flight Profile Optimizer does contain emissions and fuel burn data and calculations. The air emissions data is for Time-In-Mode for flight operations, and the fuel burn is for the flight time within the aerodome. The data for these factors are obtained from DoD databases, which are not necessarily complete for all current aircraft.



2.2 The Aviation Environmental Design Tool

AEDT is a software system that models aircraft performance in space and time to estimate noise, fuel consumption, emissions, and air quality consequences. AEDT is designed to process individual studies ranging in scope from a single flight at an airport to scenarios at the regional, national, and global levels. AEDT leverages geographic information system (GIS) and relational database technology to achieve this scalability and offer rich opportunities for exploring and presenting results. AEDT is actively used by the US government for civil aviation regulatory studies, research, and aviation system planning, as well as domestic and international aviation environmental policy analysis.

AEDT unifies noise, fuel consumption, and emissions calculation capabilities into a single application. AEDT includes a database of over 3,000 airframe-engine combinations and runway information for over 30,000 airports around the globe. These system databases allow users of AEDT to quickly build studies and estimate the interdependencies between noise, fuel consumption, and emissions consequences of aviation activity.

A summary of the physical modeling capabilities in the AEDT suite of programs are discussed in this section.

2.2.1 Noise Modeling

AEDT modeling of the noise exposure of aircraft operations consist of the following steps:

- Reference Source Noise
- Noise versus Distance Curves
- Sub-segmentation of the Flight Profiles
- Ground/Terrain Effects
- Weather Effects

2.2.1.1 Reference Fleet Database

The AEDT Fleet database contains 152 tables that store aircraft and non-aircraft equipment related information for use by the AEDT system. The AEDT Fleet database tables are relationally linked and each can be categorized into three tiers of aircraft data – physical, modeling, and type. The Fleet database contains approximately 4,600 aircraft (airframe/engine combinations) and approximately 400 non-aircraft emissions sources (ground support equipment, stationary power and fuel equipment, and auxiliary power units).

The modeling in AEDT utilizes aircraft parameters in three aircraft representations to evaluate the environmental impacts of interest in AEDT. These three models include:

- International Civil Aviation Organization (ICAO) Aircraft Noise and Performance Database⁸ (ANP)



- Eurocontrol Base of Aircraft Data⁹ (BADA)
- ICAO Engine Emissions Databank¹⁰ (EDB)

2.2.1.2 Noise-Power-Distance (NPD) Data Sets

The AEDT Fleet database contains noise vs. power vs. distance acoustic data (or noise vs. operational mode vs. distance data for helicopters), augmented by a database of spectral characteristics (known as spectral classes) and additional aircraft-specific data to support several noise adjustments available in AEDT.

The noise vs. power vs. distance acoustic data (or noise vs. operational mode vs. distance data for helicopters) in AEDT, also referred to as NPD data, represent the aircraft source noise level for a given operational mode and power setting at a range of slant distances from the aircraft to account for acoustic propagation through a standard atmosphere. Two types of NPDs are included in AEDT: fixed wing aircraft NPDs (for all commercial and military fixed wing aircraft) and helicopter NPDs. The NPD data for fixed-wing aircraft consist of a set of decibel (dB) levels for various combinations of aircraft operational modes, engine power settings, slant distances from aircraft to receptor, and base noise metrics that are associated with a specific aircraft engine. The NPD data for helicopters consist of a set of decibel levels for various combinations of aircraft operational modes, slant distances from aircraft to receptor, and base noise metrics that are associated with a specific helicopter engine. These data are usually obtained from the AEDT Fleet database, but they can also be user-defined. These commercial fixed-wing aircraft NPD data are also consistent with the Eurocontrol ANP database[†].

NPDs represent the source noise for a specific aircraft. A decibel level on an NPD includes the noise generated by the airframe and all engines[‡]. For helicopters, NPDs also includes rotor noise. For fixed wing aircraft, each NPD is associated with an engine power setting, also known as thrust setting. NPDs at different power settings represent the different types of noise generated by those power settings.

NPDs are delineated by operational modes (subcategories of phases of flight) as itemized in Table 3 and Table 4. Engine power setting is expressed on a per engine basis in a variety of units, as listed in Table 5. For helicopters, NPDs are not associated with an engine power setting and are instead associated with a helicopter operational mode.

Table 3. Operational Mode for Each Fixed-Wing Aircraft NPD Data Set

Operational Mode	Description
A	Approach
D	Departure
L	Level flight

[†] The ANP NPD database does not include military or helicopter data.

[‡] It is important to note that although engine power setting for a NPD is expressed on a per engine basis, the corresponding noise level on the NPD represents all engines on the aircraft.



Table 4. Operational Mode Procedure Steps for Each Helicopter NPD Data Set

Operational Mode	Description	State
A	Approach at constant speed	Dynamic
D	Departure at constant speed	Dynamic
L	Level flyover at constant speed	Dynamic
G	Ground idle	Static
H	Flight idle	Static
I	Hover in ground effect	Static
J	Hover out of ground effect	Static
V	Vertical ascent in ground effect	Static
W	Vertical ascent out of ground effect	Static
Y	Vertical descent in ground effect	Static
Z	Vertical descent out of ground effect	Static
B	Approach with horizontal deceleration	Dynamic
C	Approach with descending deceleration	Dynamic
E	Depart with horizontal acceleration	Dynamic
F	Depart with climbing acceleration	Dynamic
T	Taxi at constant speed	Dynamic

Table 5. Engine Power Setting Units

Engine Power (Thrust) Setting	Description	Units
Pounds	Corrected net thrust per engine	Pounds Force
TurbineInletTemperatureDegC	Turbine inlet temperature	Degrees Celsius
EnginePressureRatio	Engine pressure ratio	Dimensionless
EquivalentShaftPower	Equivalent shaft power	Horsepower
ManifoldPressureInHg	Manifold pressure	Inches of Mercury
PoundsPerHourFuelFlow	Fuel mass flow rate	Pounds per hour
Percent	Percent of ISA sea-level static thrust	Percent (dimensionless)
PercentFanSpeed	Percent of fan design speed	Percent (dimensionless)
PercentLowPressureCompressorSpeed	Percent of low pressure compressor design speed	Percent (dimensionless)
PowerLeverAngle	Power level angle	Degrees (in decimals)
PercentPropellerOrCompressorRPM	Percent of propeller or compressor design speed	Percent (dimensionless)
PropellerOrCompressorRPM	Propeller or compressor speed	Rotations per minute

Each NPD includes aircraft noise levels at the following ten distances: 200; 400; 630; 1,000; 2,000; 4,000; 6,300; 10,000; 16,000; and 25,000 ft. The propagation of aircraft noise under standard conditions is represented by NPDs in AEDT. The noise levels in the NPD data (for all aircraft types) have been adjusted for time-varying aircraft speed (exposure-based noise levels only), atmospheric absorption, distance-duration effects (if the simplified adjustment process is used for exposure-based noise levels), and spherical divergence to each of the ten distances in accordance with the methodology presented in SAE-AIR-1845¹¹ and summarized in Bishop *et al.*¹²



In the development of NPDs, a specific adjustment is used to account for distance-duration effects computed with the simplified adjustment process. For military aircraft, NPD data were developed using the simplified data adjustment procedure, and distance duration effects were computed using an empirically-derived $6.0 \log_{10}[d/d_{ref}]$ relationship consistent with NoiseMap. In contrast, NPD data for civilian aircraft that were corrected using the simplified procedure were adjusted using an empirically-derived $7.5 \log_{10}[d/d_{ref}]$ relationship. It was decided that the 6-log relationship would be maintained for the military aircraft in AEDT 2c, since it represents a best-fit empirical relationship for those aircraft.

Each set of NPDs in the database includes separate NPDs for four different base noise metrics:

L_{AE}	A-weighted sound exposure level (SEL);
L_{ASmx}	Maximum A-weighted sound level with slow-scale exponential time weighting (LAMAX);
L_{EPN}	Effective tone-corrected perceived noise level (EPNL); and
L_{PNTSmx}	Maximum tone-corrected perceived noise level with slow-scale exponential time weighting (PNLTM).

All metrics in AEDT, including C-weighted and time-based metrics, are computed using these four base noise level metrics. For fixed-wing aircraft, noise levels that lie between thrust values or between distance values are obtained by linear interpolation on thrust and logarithmic interpolation on distance. Extrapolation is used to obtain levels outside of the bounding thrust or distances values. For helicopters, no interpolation is performed between multiple operational modes.

While the underlying databases for fixed-wing aircraft, helicopters, and military aircraft are based on the same data format (NPDs in conjunction with spectral data), several key differences exist in the AEDT Fleet database between helicopter and fixed-wing NPDs that warrant a more detailed description. The helicopter NPDs main differences are that:

- They are delineated according to operational mode instead of thrust/power setting;
- No interpolation is performed between multiple operational modes;
- For the dynamic operational modes, they come in sets of three curves to represent helicopter noise lateral directivity; and
- For static operational modes, each single NPD curve is paired with a helicopter-specific directivity adjustment to represent helicopter noise directivity.

For dynamic operational modes, three sets of noise levels are provided for each combinations of helicopter operational modes (instead of thrust levels) at the ten standard distances. This set of three NPD curves is used to account for the asymmetrical directivity associated with helicopter noise; the three curves correspond to noise levels at locations directly below the helicopter (center) and at approximately 45 degrees to either side (left/right) of the centerline. For static operational modes, there is a single set of noise levels for various combinations of helicopter operational modes and slant distances from the helicopter to receptor. This single set of NPD curves is used in conjunction with a helicopter-specific directivity adjustment to account for static operational mode directivity.



2.2.1.3 Spectral Data Sets

The spectral data in AEDT consist of a set of sound pressure level vs. one-third octave-band frequency values measured at the time of $L_{AS_{mx}}$ or $L_{PNTS_{mx}}$ and corrected to a reference distance of 1,000 ft (305 m) using the SAE-AIR-184559 atmospheric absorption coefficients. The current AEDT database has been populated from 50Hz to 10kHz, however the database has been set up for future expansion to include one-third octave-band data from 10Hz to 10 kHz. These spectral data are used in AEDT to compute the following:

- Atmospheric absorption adjustment based on local temperature and relative humidity;
- Line-of-sight blockage adjustment due to terrain; and
- C-weighted noise metrics.

AEDT does not support a separate spectrum for each aircraft and operational mode. Instead, the spectral data in AEDT are in the form of spectral classes, which represent the spectral shape at time of maximum sound level for a group of aircraft deemed to have similar spectral characteristics for each different operation mode (approach, departure, level flight/afterburner). Sensitivity and validation tests were conducted on aircraft to identify appropriate spectral class groupings.¹³

Similar spectral data for military aircraft from the NoiseFile Database are included in AEDT. The military data also exist in the form of one-third octave-band spectra measured at the time of $L_{PNTS_{mx}}$. These data were corrected to a distance of 1,000 feet (305 meters) using the SAE-AIR-184559 atmospheric absorption coefficients to maintain similarity with the referenced report.¹²

Once the spectra were grouped together, a representative spectrum was determined for the group. The spectrum was calculated from a departure-weighted arithmetic average of the individual aircraft spectra in the group for commercial aircraft. For military aircraft, aircraft inventory data were collected and each spectral class was represented by the single military aircraft, which had the highest number in physical fleet inventory. Some single- and twin-engine turboprops and turbojets (i.e., business jets) have commercial, military, and private usages. For these aircraft, the representative spectrum was calculated using an equally weighted arithmetic average of all of the individual aircraft spectra.

2.2.1.4 Helicopter Static Directivity Data Sets

The AEDT Fleet database includes directivity data for modeling noise from helicopter static operations (ground idle, flight idle, hover-in-ground-effect (HIGE), and hover-out-of-ground-effect (HOGE)). The static directivity data account for changes to the sound level as a function of the helicopter azimuth angle, which is measured clockwise from the nose of the helicopter. These data are based on empirical measurements, and account for relative differences in sound level at 15-degree increments around the helicopter at a nominal radial distance of approximately 200 ft. Many helicopters in the AEDT Fleet database have both acoustically hard and soft ground directivity data.



2.2.1.5 Helicopter Operational Mode Adjustment

Although the AEDT database has the capability to include NPDs representing 16 different operational mode procedure steps, many helicopters in the database do not have a complete set of NPDs representing all of these procedure steps. In cases where NPDs do not exist in the AEDT database to model a procedure step for a particular helicopter, existing NPDs may be modified with a helicopter operational mode adjustment specific for that helicopter. For each helicopter in the AEDT database, there are six helicopter operational mode adjustments: vertical ascent (Vert Asc), vertical descent (Vert Dec), depart with horizontal acceleration (Accel Hor), approach with horizontal deceleration (Decel Hor), depart with climbing acceleration (Accel Clm), and approach with descending deceleration (Decel Dsc). These adjustments are in decibels, and they are applied as straight additions to the existing NPD levels. These offsets are applied to A-weighted, C-weighted and P-weighted NPDs at all distances. Additional details on the substitution process for helicopters may be found in the AEDT Technical Manual.¹⁴

2.2.1.6 Sub-segmentation of Flight

An underlying assumption is that NPD data represent an aircraft proceeding along a straight flight path of infinite length and parallel to the ground through a standard atmosphere. Differences from this assumption, such as flight segments, curved flight tracks and climbing/descending flight profiles, are accounted for by adjustments to the NPDs.

2.2.1.7 Ground/Terrain Effects

Varying terrain can greatly affect noise propagation. The terrain feature in AEDT allows for terrain elevation data of the modeling area to be included internally for noise computations. When terrain data are not included, AEDT assumes flat ground at a user-specified receptor elevation. Terrain elevation data are accepted in the following formats: National Elevation Dataset (NED) GridFloat, and Digital Elevation Model (DEM) for noise considerations. AEDT processes terrain data with the GlobalMapper software⁵ using a nearest neighbor interpolation to evaluate elevations at any given point covered by a given dataset.

2.2.1.8 Ambient Background Noise Data for Noise Analyses

Time-based noise metrics in AEDT require either an ambient threshold or ambient sound files depending on the noise metrics selected. All of these files include geospatial ambient sound data corresponding to a specific study area (and may also reflect specific study or operational conditions). Time Audible and Time Above metrics (TALA, TAPNL, TALC) require an ambient spectral map file, which correlates unique spectra to each ambient sound level specified in the ambient grid file.

⁵ For more details on GlobalMapper, see <http://www.bluemarblegeo.com/products/global-mapper.php>.



2.2.1.9 Weather Effects

The variation of atmospheric conditions and wind over a given domain in space and time constitutes a weather field. Although the SAE-AIR-1845/Doc 29 performance model specifies the ISA for its weather model, AEDT uses a model that allows for customization of weather conditions based on high fidelity or airport-specific average weather data. AEDT assigns an order of precedence to the types of weather data it supports, so that when a weather value is required at a given location and time, the data are taken from the highest-ranked sources that encompass the coordinate.

2.2.1.10 High-Fidelity Weather Model

High fidelity weather is used in AEDT to compute aircraft performance, emissions and air quality, but it is not utilized for sound propagation. The high-fidelity model of weather allows variation of all atmospheric properties (temperature, pressure, wind magnitude and direction, density, dew point, and relative humidity) along three spatial dimensions, and time. This weather modelling is done by reading and interpolating weather data defined on 4-D grids. These grids are supplied by the user. The data are defined on grids that are regularly spaced in time and along geographic coordinate systems, but may be irregularly spaced along the vertical direction.

In AEDT, all atmospheric data given for any specific time are interpolated linearly in space to define 3-D weather for that time. The atmosphere is assumed to remain static until the next time available in the data set. Whenever headwind is required, the wind vector field is interpolated to the desired location, and then the component of the interpolated vector that is opposite to the aircraft's direction of travel (i.e. headwind) is used.

2.2.2 Aircraft Performance Modeling

AEDT calculates aircraft performance information (such as flight path, thrust levels and fuel burn) for terminal-area and runway-to-runway operations. These calculations employ performance models to approximate the state of an aircraft through each full air operation. The calculated performance serves as the primary input to noise and emissions calculations. AEDT calculates a complete four-dimensional representation (x, y, z, time) of each segment of the flight path as well as thrust, fuel burn, and emissions mode values. Since the variation of an aircraft's position is included, this progression of aircraft states is called a trajectory. The performance calculation methods are described below.

AEDT provides standardized aircraft departure and arrival profiles for the entire fleet. These data are primarily defined as procedural profiles, which allow tailoring of the aircraft state based on environmental conditions (altitude, meteorological data etc.). Some vintage aircraft (for which updated performance coefficients are not available) have fixed point-to-point profiles. A description of the aircraft profile database is described below.



2.2.2.1 Aircraft Performance Calculation Methods

Performance in AEDT can be driven by a target flight profile or a target trajectory. Both methods require ground track specification, but the target states provided by profiles are not associated with any specific distances along the track, whereas target trajectories associate desired altitudes and speeds with the surface coordinates along the track.

The performance model in AEDT is primarily based on recommendations from two aircraft flight performance specifications. The first is presented in European Civil Aviation Conference (ECAC) Doc 29 (Doc 29)¹⁵, and since it is largely based on SAE Aerospace Information Report (AIR) No. 1845¹¹ (SAE-AIR-1845). This specification is intended for use only within the terminal area. Note that AEDT also uses the Senzig-Fleming-Iovinelli (SFI) fuel burn model^{16,17} in the terminal-area when the proper coefficients are available. The second specification used for performance calculations is presented in EUROCONTROL's User Manual for BADA¹⁰. BADA flight dynamics equations and modeling coefficients are defined for all phases of flight, but within AEDT, they are primarily used for modeling the en-route phase. Note that BADA includes a fuel burn model, which is used for terminal area modeling when coefficients for the SFI fuel burn model are not available, and for en-route modeling regardless of coefficient availability.

2.2.2.2 Standard Aircraft Profile Database

Within AEDT users may use pre-defined procedural profiles or create their own custom profiles by stringing together sequence of segments consisting of the following types:

- Fixed point (defines the aircraft's state at a point);
- Takeoff Ground Roll (aircraft acceleration on the ground before becoming airborne);
- Constant Calibrated Air Speed (CAS) Climb (models climb at CAS to a target altitude);
- Accelerating Climb Step by Climb rate (acceleration to a target CAS at specified rate of climb (ROC));
- Accelerating climb step by energy share (acceleration to a target CAS with ROC specified indirectly as a percentage of available acceleration);
- Cruise-Climb Step (models climb at a specific angle to a target altitude and CAS);
- Descent Step (descent at a specific angle to a target altitude and CAS neglecting deceleration effects);
- Deceleration Sensitive Descent Step (descent at a specific angle to a target altitude and CAS adjusting the targets to preserve deceleration that would have been observed in an International Standard Atmosphere (ISA));
- Idle Descent Step (descent at a specific angle and idle thrust setting to a target altitude and CAS adjusting targets to preserve deceleration that would have been observed in an ISA);
- Level Step (level flight over specified distance at target CAS);
- Deceleration Sensitive Level Step (decelerating flight over specific distance to target CAS accounting for deceleration that would have been observed in an ISA);
- Level Idle Step (level flight at idle thrust over specific distance to a target CAS adjusting target speed to preserve deceleration that would have been observed in an ISA);



- Landing Ground Roll Step (models ground roll from touch down over specific distance to target CAS and thrust setting).

2.2.2.3 Trajectory Driven Flight Performance

Trajectory based flight performance is a subsection of aircraft performance in AEDT that allows for deviation from standard AEDT profiles and allows for much more freedom in choosing how an aircraft should fly. It is particularly useful for modeling situations where standard profiles do not accurately represent actual routes taken by aircraft. By defining points along the trajectory that the aircraft must pass through, operations can be modeled to fly more meaningful routes. Two types of trajectory-based inputs can drive flight performance in AEDT: altitude controls and sensor paths.

Altitude controls are one type of trajectory-based input that can drive AEDT flight performance. They allow specification of precise 3-dimensional locations to be reached along the flight path. An altitude control defines rules for what an aircraft’s altitude should and should not be as it passes over a particular track point. Specifically, it establishes a target altitude that an aircraft should try to reach as it passes over the track point, as well as restricted altitude ranges that the aircraft is not allowed to occupy as it passes over the track point. When altitude controls are present, first the flight path is calculated from the procedure as though there are no controls, as described in Section 3.6. This “standard” flight path is then modified to match the control targets as closely as possible, with flight dynamics first modeled according to SAE-AIR-1845/Doc 29 up to 10,000 ft, and then according to BADA thereafter.

AEDT supports trajectory specification for full flight runway-to-runway operations in the form of sensor path data. Each data sample specifies a location and groundspeed. The calculated performance result will tend to conform to these inputs, subject to the constraints of the performance model. The performance calculations for runway-to-runway operations proceed as follows:

- The input flight path is smoothed and filtered.
- The terminal-area departure portion of the operation is calculated.
- The en-route portion of the operation is calculated.
- The terminal-area approach portion of the operation is calculated.

2.2.3 Emissions Modeling

AEDT is able to leverage the same aircraft fleet and performance data used to support the noise calculations to also compute emissions and fuel consumption from aircraft. Emissions from both the aircraft main engines and the auxiliary power unit (APU) are modeled. In addition, the analyst is also able to model emissions from other sources commonly found at airports, including ground support equipment (GSE), on-road vehicles, and stationary sources, such as power generation facilities, boilers, fuel storage tanks, and training fires. The following emissions are modeled within AEDT:

- Carbon Monoxide (CO),
- Total Hydrocarbons (HC),
- Non-Methane Hydrocarbons (NMHC),



- Volatile Organic Compounds (VOC),
- Total Organic Gases (TOG),
- Oxides of Nitrogen (NOx),
- Sulfur Oxides (SOx),
- Particulate Matter (PM),
- Carbon Dioxide (CO₂),
- Water (H₂O), and
- Speciated Organic Gases (SOG), including hazardous air pollutants (HAPs).

2.2.3.1 Airborne Emissions

AEDT has two broad flight regimes in AEDT: terminal area and en-route. The term “terminal area” refers to portions of an aircraft’s flight trajectory below 10,000 ft airfield elevation (AFE), while the term “en-route” refers to portions of flight above 10,000 ft AFE. A runway-to-runway flight path covers both terminal area and en-route regimes. AEDT assigns the trajectory mode on each segment of the flight trajectory across both flight regimes. The terminal area trajectory modes in AEDT include takeoff ground roll, takeoff airborne, terminal climb, approach, landing ground roll, and landing ground roll with reverse thrust. En-route trajectory modes include en-route climb, cruise, and en-route descent.

The four methods used to compute airborne aircraft emissions in AEDT are described below:

- The Boeing Fuel Flow Method 2 (BFFM2)¹⁸ is used to compute NOx, HC, and CO;
- A First Order Approximation (FOA) 3.0 is used to compute particulate matter below the mixing height;
- Fuel composition-based factors are used to compute SOx, CO₂, and H₂O in addition to particulate matter above the mixing height; and
- Derivative factors are used to compute NMHC, VOC, TOG, and speciated organic gases.

These methods are publicly available and internationally recognized as adequate for aircraft emissions modeling. For emissions inventory, users can change the default value of 3,000 ft AFE for mixing height in AEDT. For emissions dispersion, 3,000 feet AFE is assumed for mixing height at all times.

2.2.3.2 Taxi Emissions

While on the ground, aircraft fuel consumption and emissions are modeled based on the time spent in the taxi mode. This time can be set as a static value or dynamically calculated through the use of the delay and sequencing model.

2.2.3.3 Startup Emissions

If the operation is a departure, then AEDT models the engine startup emissions, which consist only of the THC, NMHC, VOC and TOG pollutants and consume no fuel.



2.2.3.4 Auxiliary Power Units Emissions

In addition to the fuel consumption and emissions associated with the aircraft main engines, AEDT models the effects of running the APU, as well. Emission factors for CO, THC, NO_x, SO_x, and PM (both PM₁₀ and PM₂₅) are available for APUs. For NMHC, VOC, and TOG, the conversion factors of the turbine aircraft engines are used. APU emissions data comes from FAA and EPA documentation¹⁰ and industry correspondence.¹¹

2.2.4 Emissions Dispersion

The preceding section describe how total emissions from airport sources are calculated by AEDT. This section explains how those emissions are dispersed by the model in order to estimate concentrations at given receptor locations. Concentrations can take the form of mass per volume (e.g. mg/m³) or a unitless concentration (e.g. parts per million, PPM). The Emissions Dispersion Module (EDM) of AEDT uses the American Meteorological Society (AMS)/EPA Regulatory Model (AERMOD)¹⁹ to perform these calculations. AEDT sends input to and receives output from AERMOD and can create pollutant concentration maps near an airport.

2.2.4.1 AEDT and AERMOD Sources

In order to produce AERMOD input files, the EDM allocates the emissions from the AEDT operations into the spatially fixed emission sources required by AERMOD. The emissions from the AERMOD sources are collected for each modeling hour, and the respective hourly emissions rates are submitted into the AERMOD.

Each aircraft operation is associated with respective aircraft movements and consists of a set of the flight segments. Following the EDMS guidelines, the EDM distributes a flight segment's emissions between one or more rectangular AERMOD sources called AREA sources.

For the purpose of EDM, GSE, APU, and startup non-aircraft operations need to be associated with the appropriate gates or terminals in AEDT. Gates and terminals in AEDT are abstract concepts, which are designed in support of the Emissions Dispersion and Taxi Network modeling, and should not be mistaken with real airport gates and terminals.

Due to a variety of the geometrical and physical characteristics of stationary sources, the emissions from the respective operations could be allocated into VOLUME, AREAPOLY, and POINT sources. POINT sources are intended to model smokestacks with user-specified exhaust temperature, velocity and inside diameter.



Table 6. AERMOD Source Modeling

AEDT Source Type	AERMOD Source Type
Aircraft Operation: <ul style="list-style-type: none"> • Airborne segments • Ground roll segments • Taxi segments 	1 or more AREA(s)
Stationary Source	POINT, VOLUME, or AREAPOLY
Gate	VOLUME
Terminal	AREAPOLY
Parking Facility	1 or more AREAPOLY(s)
Roadway	1 or more AREA(s)
Background Concentration	BACKGRND

2.2.4.2 AEDT Map Projection

AEDT works with the geographic coordinate system (i.e. latitude and longitude), while AERMOD uses the projected coordinate system (the earth’s spherical surface projected onto a two-dimensional Cartesian coordinate plane), not the geographic coordinate system. Thus, it is necessary to convert coordinates between the geographic coordinate system and the projected coordinate system. Note that in this section, upper-case X,Y,Z refers to a particular coordinate system, and lower case x,y,z refers to a particular point in that system.

2.2.4.3 Emissions from Airborne and Ground Roll Flight Segments

Aircraft operations modeling in AEDT is always three-dimensional in space to represent a more realistic situation. For the purposes of dispersion modeling, AEDT translates these 3-dimensional segments into two components: a two-dimensional representation for the ground roll segments (arrival and departure) and a three-dimensional component that represents the airborne segments.

2.2.4.4 Applying Background Concentrations

When making a determination of conformity with air quality standards, such as the National Ambient Air Quality Standards (NAAQS)²⁰, AEDT it is necessary to consider the ambient emission levels in addition to those that are being specifically modeled from the airport sources. To support this type of analysis, AEDT incorporates AERMOD’s background concentration modeling capability and allows the user to specify concentrations as part of the metric results definition.



2.3 Gaps between NoiseMap and AEDT

The key differences in NoiseMap and AEDT physical modeling are summarized in Table 7.

Table 7. Contrast of NoiseMap and AEDT Physical Modeling

Noise Modeling Feature	NoiseMap	AEDT
Calculation Assumption	<ul style="list-style-type: none"> Integrated computation. 	<ul style="list-style-type: none"> Integrated computation. Has time based trajectory data internally which could be leveraged by the noise module if needed.
Reference Noise Sources	<ul style="list-style-type: none"> Most US military aircraft. Civilian aircraft from INM database. Directivity included for static noise emission. 	<ul style="list-style-type: none"> All commercial and subset of military aircraft and helicopters. Need to update database to include all NoiseMap sources. Only contains Right-Center-Left data for helicopters. No tiltrotor or VTOL capability.
Ground/Terrain Effects	<ul style="list-style-type: none"> More complex method for the inclusion of topography effects that include both changes in ground cover and ground elevation. Considers a mix of hard and soft ground covers in a binary manner. For elevation variation, utilizes three basic terrain cut types: flat, valley, and hill to determine the ground attenuation between the source and receiver. This ground effects modeling is accomplished whether the line-of-sight is blocked or not. Note, terrain effects are for A-weighted metrics only. 	<ul style="list-style-type: none"> Includes terrain line of sight blockage and ground altitude effects on slant range. Corrections for hard ground (water) only for propeller aircraft.
Weather Effects	<ul style="list-style-type: none"> Atmospheric absorption calculated on a OTO band basis by selecting the sixth least absorptive month based on monthly averages of Temperature, Relative Humidity, and Surface Pressure. Effects of wind and turbulence (refraction) is not included. 	<ul style="list-style-type: none"> Absorption via SAE-ARP-866a or SAE-ARP-5534.²¹ Corrections to spectral class data based on OTO band basis using specified meteorological conditions (Temp, %RH). Wind refraction and turbulence are not included.
Aircraft Performance Modeling	<ul style="list-style-type: none"> Accuracy of the flight trajectories is the responsibility of the user, which may result in inconsistent profiles among different users. 	<ul style="list-style-type: none"> More robust methodology for determining flight profiles by providing realistic, standard flight trajectories and a mechanism for



Noise Modeling Feature	NoiseMap	AEDT
	<ul style="list-style-type: none"> Flight profiles are not checked for physical correctness as no performance and flight kinematics modeling are performed. 	<p>creating profiles based on aircraft performance data.</p> <ul style="list-style-type: none"> Additionally, AEDT contains algorithms to screen aircraft-specific flight profiles for realism.
<p>Air Emissions and Air Quality Modeling</p>	<ul style="list-style-type: none"> Not included. 	<ul style="list-style-type: none"> AEDT integrates the calculation of noise with emissions and air quality with the same operational dataset. Weather impacts both the performance model's calculation of fuel consumption which subsequently impacts the emissions. Weather is also used for air quality dispersion driving the direction and characteristics of the plume.



3. Task 2: Input Data/Graphic User Interface

The second task provides a summary of the input data process and GUI support in the NoiseMap suite of programs and AEDT. Additionally, an overview of the gaps (or differences) between the input data process and current GUI capabilities of NoiseMap and AEDT are provided.

3.1 NoiseMap

A summary of the input data process for developing a NoiseMap case along with its primary GUI, BaseOps, are discussed in this section.

3.1.1 Input Data Process

The development of operational input data for a NoiseMap case normally involves the following steps:

- Description of the action to be modeled;
- Collection of operational data with interviews of airfield operators;
- Development of noise modeling operational data description (NMODD);
- Validation of NMODD.

3.1.1.1 Description of Action

The drivers of DOD airfield noise studies are determined by the type of action. If a noise study is required by a (NEPA) action, the action is described and defined in the Description of Proposed Actions and Alternatives (DOPAA). These types of studies occur for a proposed change in operations, which can consist of the introduction of a new aircraft type or significant changes in operational tempo. These actions can involve multiple scenarios at a single airfield or multiple homebases and auxiliary airfields. If the noise study supports an AICUZ study, then the action is normally based on current operations occurring at the airfield. For an AICUZ study, the supporting noise study will consider expected operations in a five- to ten-year projection. Sometimes an AICUZ study will include the introduction of a new aircraft type in anticipation of a reasonably-foreseen future NEPA action.

Once the action is defined and described, the bounds of the noise study are set, and the data collection and modeling can commence. During the data collection and modeling phase of the study, the action may be modified and refined based on the operational data that have been collected. These modifications and refinements normally occur to various degrees on all DOD noise studies.

3.1.1.2 Collection of Operational Data

The collection of operational data for a NoiseMap study is time consuming and requires a dedicated data collection trip to obtain accurate operational data. The data collection trip focuses on direct interviews of various operators at the airfield. These operators include aircrews, air traffic controllers



(ATC), base operations and airfield managers, squadron schedulers, ground maintenance personnel, transient alert, and flight safety personnel. The primary operators are aircrews of the based squadrons and ATC personnel. The interviews are used to obtain annual flight operational counts, nominal flight tracks, runway utilization, traffic flow distributions, flight profiles, flight type distributions, and acoustical day/night operational percentages. Other operational data include transient flight operations and ground run-up operations. For noise modeling, transient operations are usually modeled with several representative aircraft types to cover the average mix of transient aircraft.

Normally, all operational data are not obtained during the on-site interviews, so follow-up discussions are required to complete the data collection. These discussions typically involve operational assumptions such as the rate of closed patterns, sortie utilization rates, and flight profiles.

Typically radar or tracking data for military operations is not available for noise analysis. Over the past few decades attempts by various services to transition to a process that relies on tracking data in a manner that can be incorporated into the Noise Data Analysis and Display System (NDADS)²² have been unsuccessful.^{23,24} The reasons for this often include:

- Operations are often conducted in sorties with multiple aircraft with only the single lead aircraft 'squawking' so operational counts are not reliable;
- Radar and other tracking data are not retained nor stored at the facility;
- Tracking data are classified and not suitable for public disclosure;
- Operational profiles are not regular/repeatable/predictable as they are for civil air operations;
- Resistance and distrust of automated processes and a preference for the interview process.

3.1.1.3 Development of Noise Modeling Operational Data Description

After the onsite data collection interviews, an operational data package is developed. This data package is the NMODD, and it contains the noise modeling parameters and inputs required for a NoiseMap case. The development of the NMODD relies on data entry with NoiseMap's GUI BaseOps, which is a Windows based program. The BaseOps GUI is a combination of standard Windows-based ribbon, buttons, and pull-down menus, as highlighted in Figure 5. It is structured to walk a user through the required operational data parameters as well as supporting data that aids in the development of flight tracks and flight profiles. It is a flexible interface that provides ease of use for an experienced user. However, it does require some learning for an inexperienced user to understand some of the functionality and data entry locations.



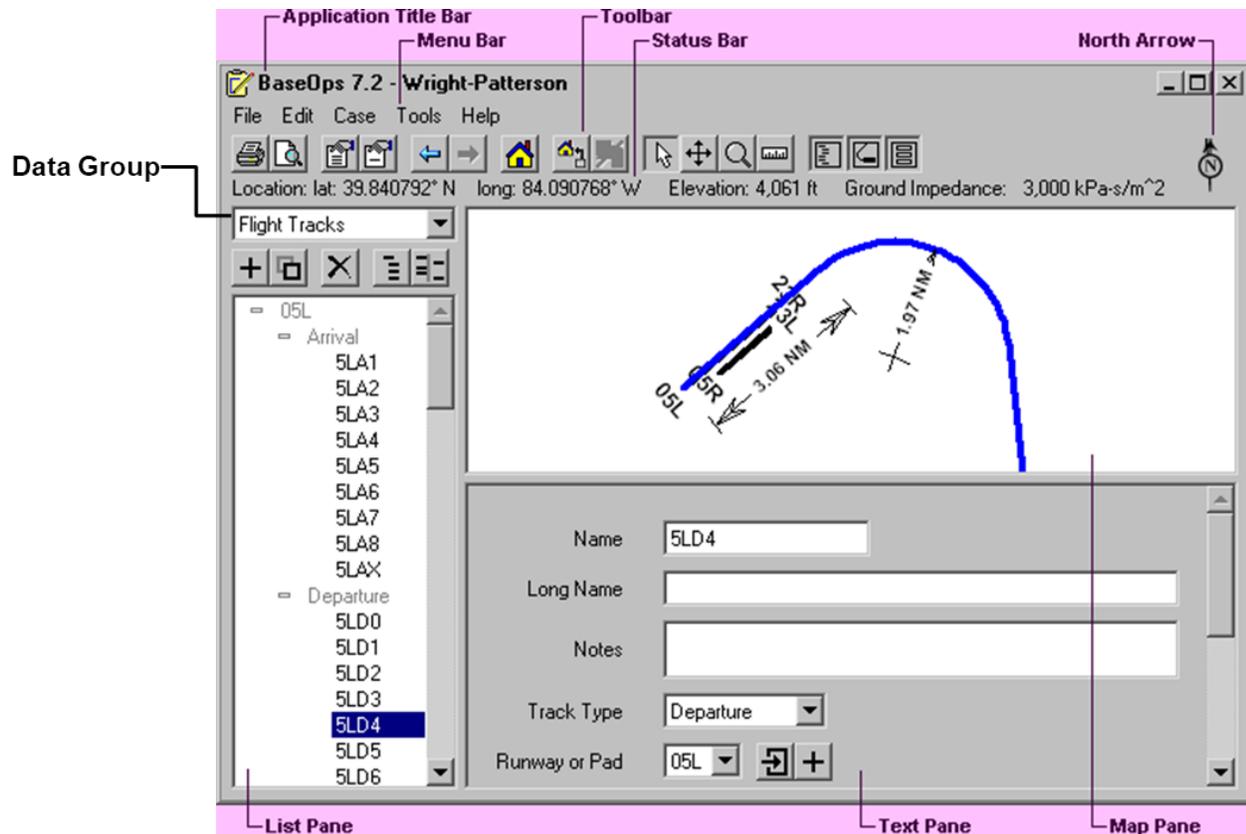


Figure 5. Example of the BaseOps GUI with Call Outs

For developing a case, a user has the option to select background images. These images can be RASTER maps, Shapefiles, and/or georeferenced graphics. Such images give the user perspective when developing tracks and profiles. In addition, users can populate and show various airfield data such as DME arcs, radials, NAVAIDS, and waypoints (which are generally publicly available for an airfield). An example of these visual aids is provided in Figure 6.



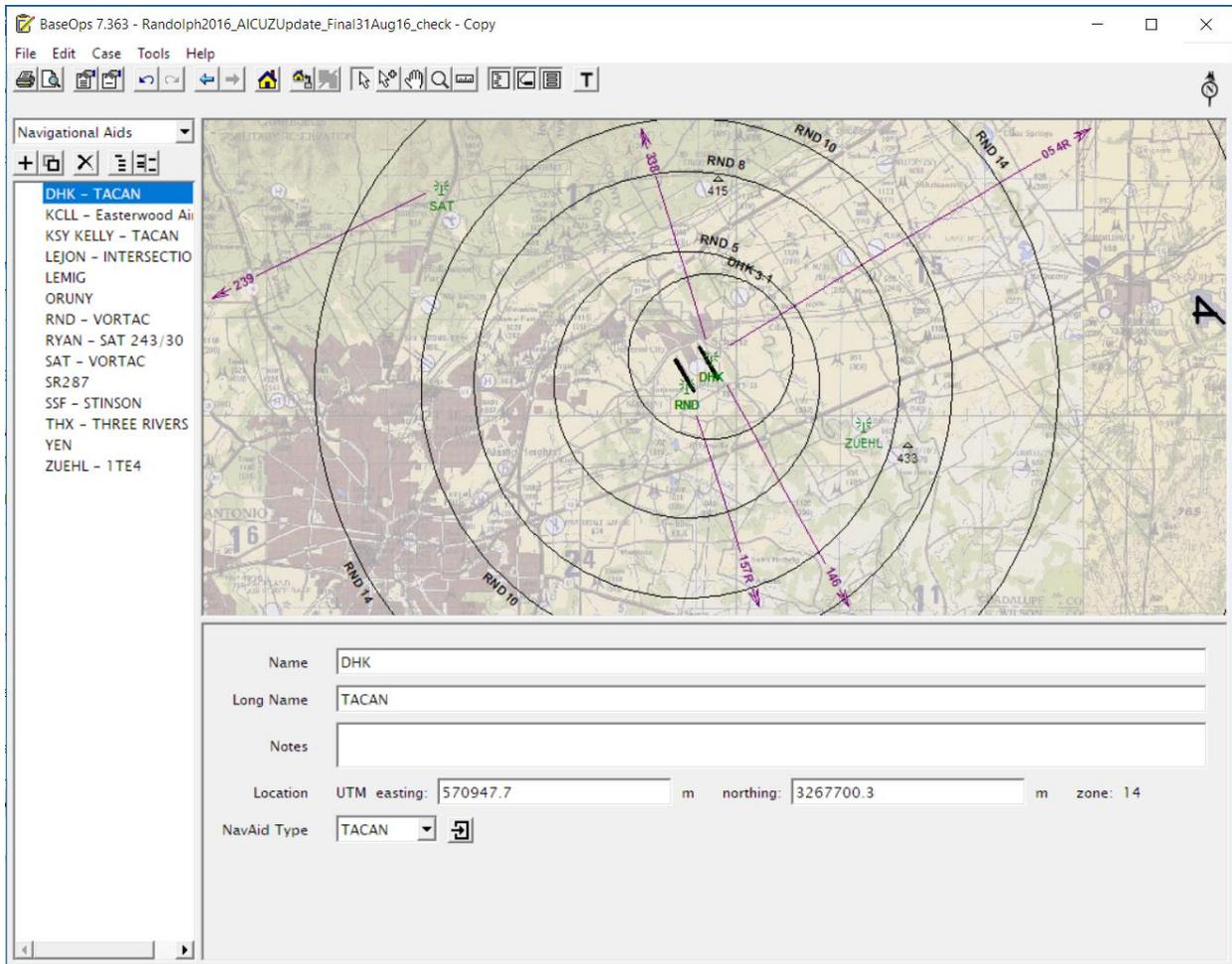


Figure 6. Example of a Basic BaseOps Background of Visual Aids for Data Entry

3.1.1.3.1 Airfield Data

This section includes the runway endpoints, airfield reference point, NAVAID and waypoint locations, and average monthly temperature and relative humidity. These data are obtained from public sources, and they are generally gathered before the onsite data collection for verification during the interviews. A user manually enters these data via BaseOps.

3.1.1.3.2 Flight Operations

Annual flight operational counts are developed through a combination of historical Air Traffic Activity Reports (ATAR), squadron estimates, and, potentially, Military Aviation Simulation Model (NASMOD). For the DoD, no data product is available that documents individual military flight operations. The annual estimates are generally based on an “average sortie” or “training mission type” concept. For each one of these concepts, a single sortie or mission includes one departure and one arrival along with an estimated average number of closed patterns. Next, the normal or average weekly or monthly sortie rate is determined for a squadron. The data and/or methods used to estimate a squadron’s sortie rate



varies significantly across aircraft and squadron types. The final parameter is the average number of flying days at the home airfield for each based squadron. From these estimates, the total annual operations can be estimated for each squadron, and the resulting total annual operations can be compared to the historical operational tempo.

These operational parameters are entered into a spreadsheet to translate the annual operations into the average daily distributed individual flight operations for input into the NoiseMap case. DoD currently has no standard format for these spreadsheets, so the format varies by user and noise study. Once the assumptions for the estimated annual flight operational counts are verified, the operations are distributed to individual flight profiles based on the following distributions:

- Runway utilization,
- Traffic flow,
- Squadron type,
- Operation flight type, and
- Acoustical day/night.

Runway utilizations, traffic flow distributions, and acoustical day/night operational percentages are developed together with aircrew and ATC inputs. Aircrews are the source for the distribution of operational types. Once the spreadsheet is developed, the resulting average daily flight operations can be directly imported from the operational spreadsheet with a properly formatted *.xml file or they can be hand entered, which is not desirable for most cases. An operational distribution spreadsheet is included in a noise study's NMODD.

3.1.1.3.3 Flight Tracks

Flight tracks are compiled from current published approach and departure plates and interviews with aircrews and ATC. For instrument flight rules (IFR) operations, ATC generally provide the best data source since the procedures follow the published approach plates. For visual flight rules (VFR), both aircrews and ATC inputs are required to develop accurate flight tracks. For closed patterns, aircrews provide the better data source although ATC does provide verification for the bounds of closed patterns.

Once the flight track data are collected, the tracks are developed manually within BaseOps with a combination of hand data entry and pointer tools. Flight tracks are constructed by combinations of straight and circular arc segments. Straight segments are simply defined by a distance, and circular arcs are defined by a turn radius and angle. Once a basic track is constructed, modifications can be accomplished with pointer tools. A user can populate the visual display in BaseOps to provide geophysical reference points such as NAVAIDS, waypoints, arcs and radials to assist in developing flight tracks. Figure 7 provides an example of a flight track constructed within BaseOps.



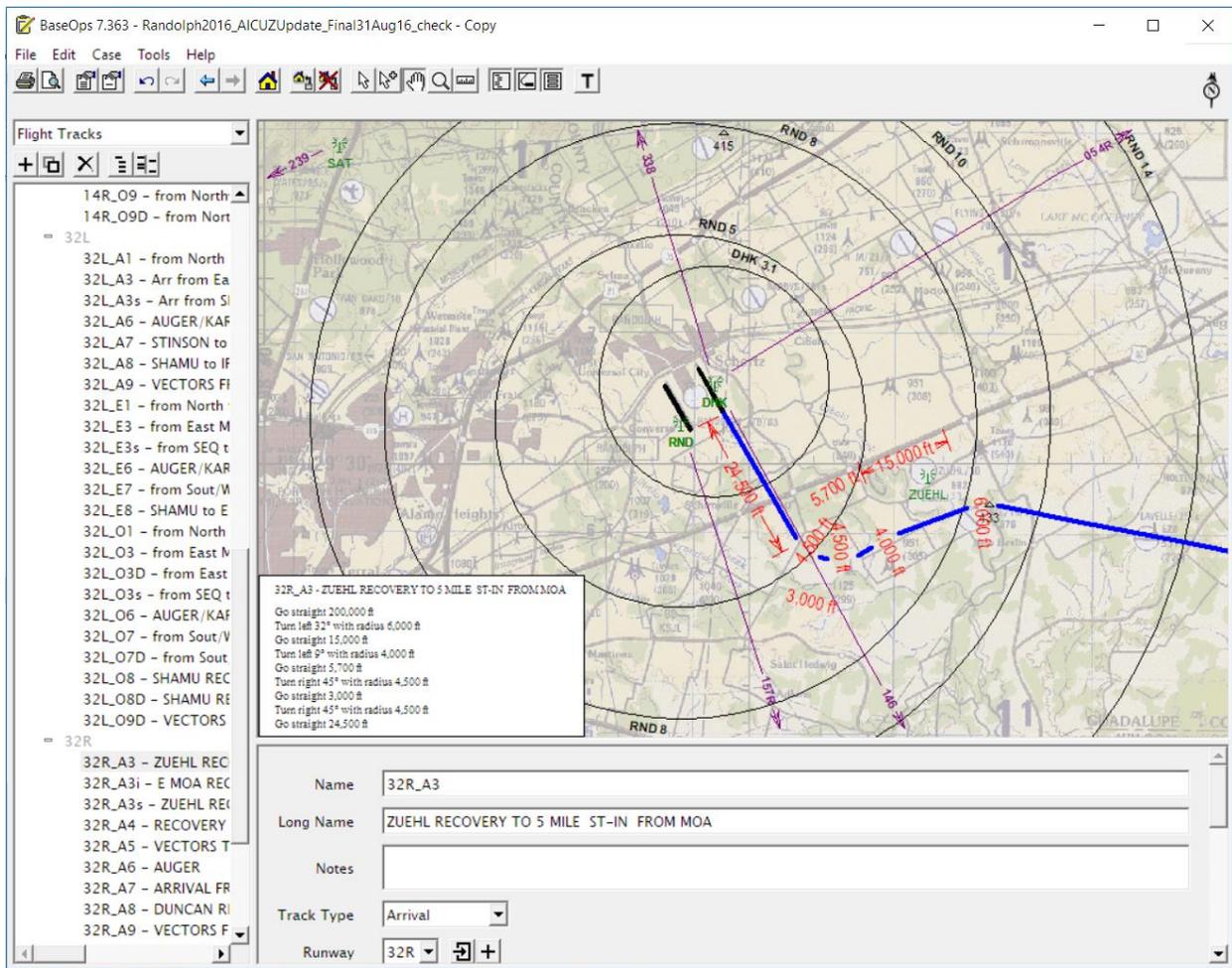


Figure 7. Example of a Flight Track Constructed within BaseOps

Once all of the flight tracks are constructed, a report function within BaseOps can generate flight track graphics for inclusion into the NMODD for further review. The flight tracks are generally ordered by the associated operational type (departure, arrival, closed pattern, and interfacility) and runway. The flight tracks can be displayed as summary figures, as shown in Figure 8, or as individual figures depending on the number of flight tracks and runways used at an airfield.

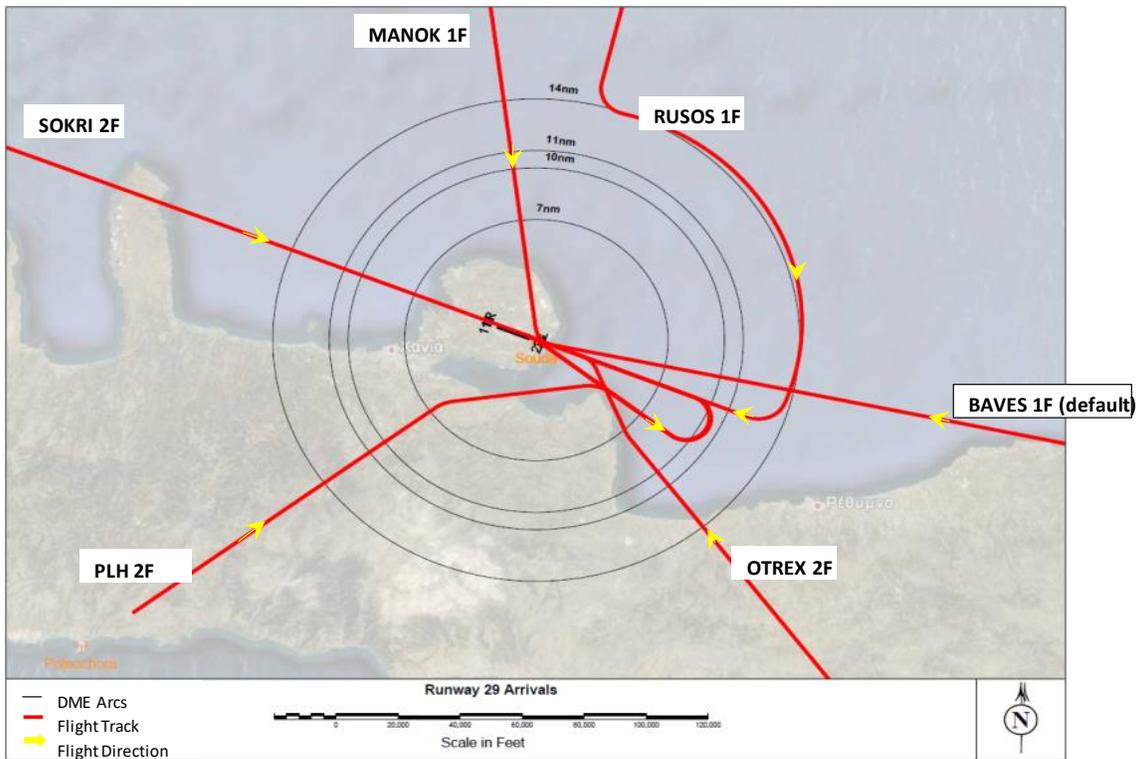


Figure 8. Summary of Arrival Flight Tracks to a Single Runway at an Airfield

3.1.1.3.4 Flight Profiles

The current process for flight profile development requires a good dialog between the aircrews and noise modeler, since flight procedures vary from airfield to airfield even for the same aircraft and squadron types. As such, this process is the weakest link in the NoiseMap process. A noise modeler needs to translate flight procedures as described by the aircrews into the format required by NoiseMap. One of the primary concerns for the flight profiles is the variation in engine power settings along a flight track. For large transports, aircrews normally know their engine power settings and procedures, so the process is straight-forward. For tactical fighters, most aircrews do not directly know their engine power settings since they fly primarily by airspeed vector. For engine power management, pilots primarily use throttle lever angle or fuel flow, which usually is not an available engine power parameter in the NoiseFile database. For this situation, the aircrews will be asked to note their engine power settings during their next few sorties to verify the modeled profiles. Other aircraft types generally fall somewhere between these two situations.

Flight profiles are developed manually within BaseOps with a combination of hand data entry and pointer tools. A flight profile consists of a series of points along a selected flight track that represent changes in altitude, airspeed, engine power settings, and/or NoiseFile interpolation state. Changes in altitude and airspeed are interpolated between two points, and engine power and interpolation states are discrete changes at the point. Again, a user can populate the visual display in BaseOps to provide geophysical reference points such as NAVAIDS, waypoint, arcs and radials to assist in setting the proper flight profiles points. Figure 9 provides an example flight profile developed within BaseOps. Once a



profile is developed, a user can use pointer tools to move the location of a point along the track. This functionality helps when profile points are aligned with certain DME arcs.

NoiseMap has no internal performance modeling embedded within BaseOps. A user is required to ensure the input flight profiles are realistic and match local course rules. Additionally, NoiseMap does not provide any feedback on the physical correctness of the flight profiles. With the addition of topography effects, a flight profile can be erroneously defined to be underneath the ground.

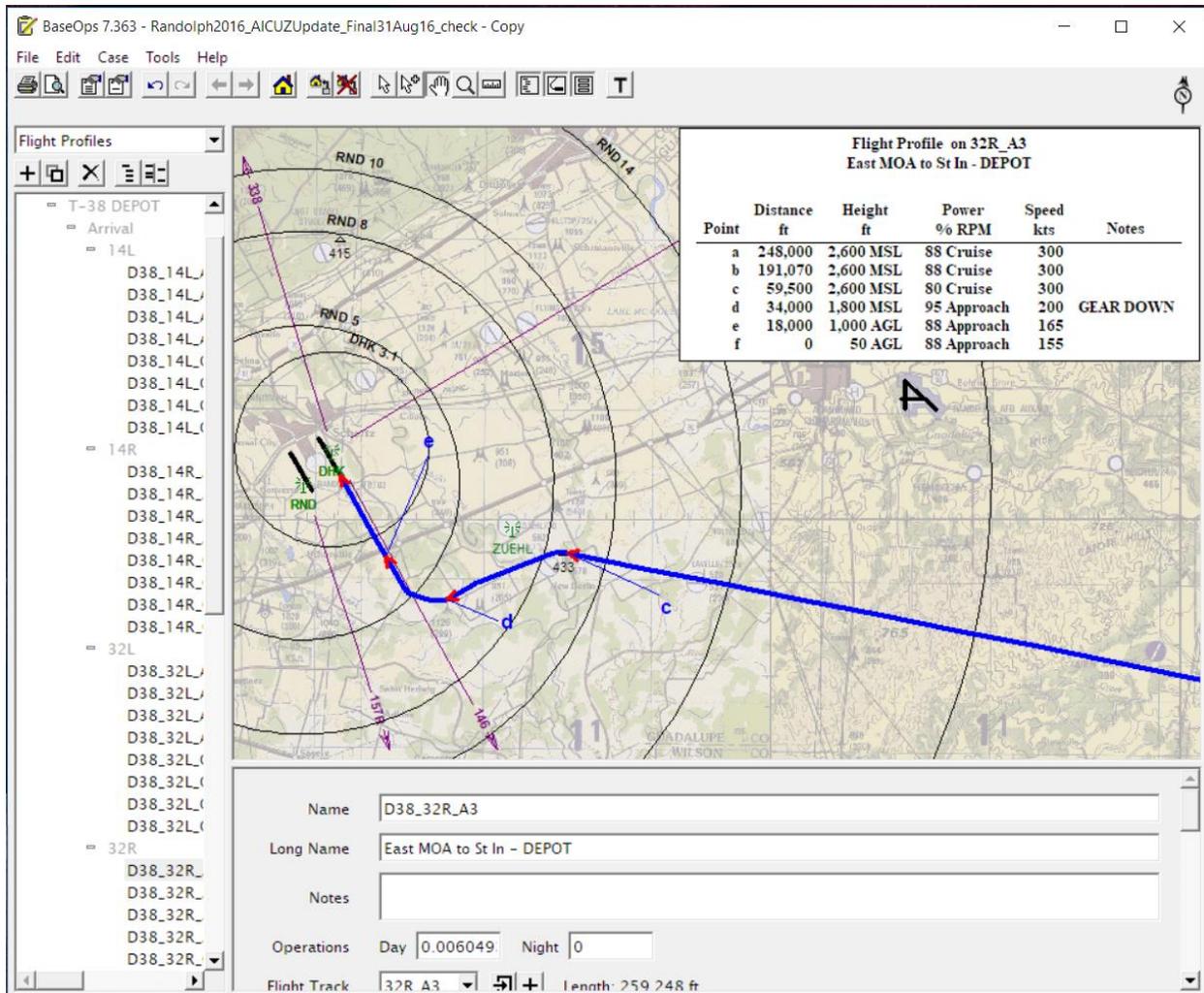


Figure 9. Example of the Flight Profile Developed within BaseOps

Once all of the flight profiles are constructed, a report function within BaseOps can generate flight profile graphics for inclusion into the NMODD. This report documents the modeled flight profiles for the based aircraft (transient aircraft may also be included if they are a major contributor to the airfield noise or they have a high level of operations at the airfield). For most noise studies, representative profiles are used to document the various flight operations for each based squadron. However, for airfields with flight procedures that varying depending on traffic flow direction, each individual flight profile may be provided in the NMODD.



3.1.1.3.5 Ground Run-Up Operations

Two basic types of ground operations are modeled for a NoiseMap case: Flight-associated and Maintenance. For the flight-associated ground run-up, nominal locations and headings are modeled within a squadron's parking spaces and at spots near the departure end of the runway, if required. The development of operational tempos for these ground operations is straight-forward since they are directly related to the flight operations. Additionally, these operations typically only involve low engine power and rarely contribute to the overall noise at an airfield.

Ground maintenance operations are modeled at each high-power turn area, since these are associated with higher engine powers and longer durations. These turn areas range from basic holdback stands to hush houses, which encloses the whole aircraft for high-power engine runs. The operations are normally defined on an annual or monthly basis, which is converted to an annual average-day basis. Additionally, each unique ground maintenance operation is modeled with a script of engine power settings and durations. These data are manually entered into the NoiseMap case through BaseOps. For inclusion into the NMODD, a BaseOps report is generated that shows the ground run-up locations and static profile details. The profile details are ordered by aircraft type.

3.1.1.4 Validation of NMODD

Once the initial NMODD is completed, it is sent back to the airfield operators for verification and validation. At this stage in the process, a few of the operational parameters may still be tentative because of conflicting information or low documentation. During the review process, these items are discussed and addressed with the appropriate operators. Once all operational parameters are verified and validated, the NMODD is finalized and the data are ready for modeling with NoiseMap.

3.1.2 Additional BaseOps Tools

Once the required operational data have been validated for the NoiseMap case, BaseOps provides run control of the NoiseMap suite of programs, which includes Rotorcraft Noise Model (RNM), AAM, and Military Operations Area and Military Training Route NoiseMap Model (MRNMap). BaseOps allows a user to select the acoustic metric, computational model, and the associated elevation and impedance files for a basic calculation. BaseOps will then generate the proper internal input files for each stage of the computational process. Once the calculation is complete, BaseOps provides a user a link to NMPlot for visualizing the results.



In addition to the basic data entry and computational functioning, BaseOps provides a few other helpful tools for a noise study. These tools include aircraft substitution, data grouping, and operational scenarios. The aircraft substitution tool allows a user to create an aircraft name and associate it with an aircraft currently in NoiseFile. The data grouping tool allows a user to develop unique groups for various parameters. The most common grouping is for aircraft flight profiles. BaseOps has a standard grouping for flight profiles of BASED, CIVILIAN, and TRANSIENT, but often this grouping is expanded to individual squadrons or squadron types at an airfield. The grouping tool is very useful in the scenario tool, which allows a user to develop different operational scenarios. These scenarios can scale flight and static operations based on any of the operational parameters. The flight profile grouping of individual squadrons allows a user to develop many scenarios with different tempos and mixes of squadrons for assessing alternative within a single NoiseMap case.

3.2 AEDT

Similar to BaseOps, AEDT includes a GIS-based GUI (Figure 10) which permits the user to set up analysis studies and define operational scenarios which include the following information:

- Airfield Data (including runway, landing fields),
- Aircraft information,
- Operational data (including ground tracks, profiles, operational tempo),
- Meteorological Data (weather and terrain),
- Results (define desired output metrics and formats).



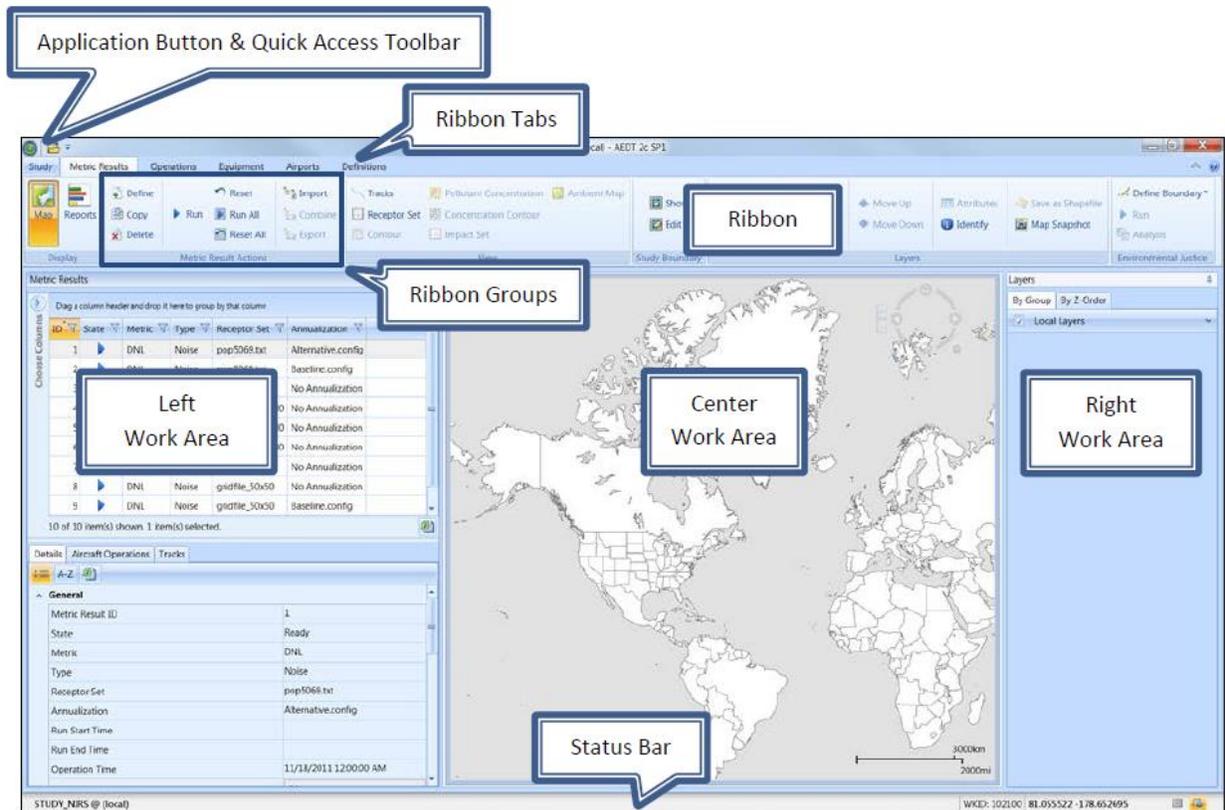
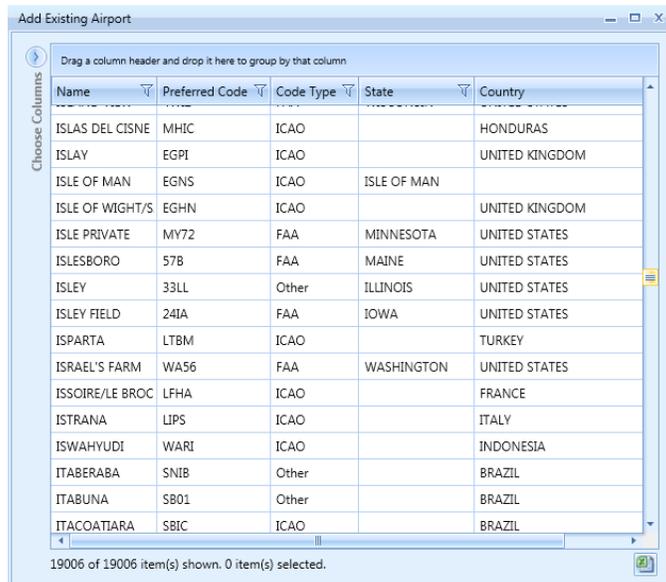


Figure 10. AEDT Graphical User Interface

3.3 Airfield Data

Airfield or airport data are contained within the AEDT AIRPORT Database and can be accessed through the AEDT GUI. When a user first develops an airport study an airport can be chosen through the *Airports* tab. The *Airports* tab supports adding airports, viewing airport layouts, editing airport layout components, adding new components in the airport layout designer, and creating operation configurations. Figure 11 displays an example of the list of available airports within AEDT in the *Add Existing Airport Pane*. When a user chooses an existing airport the latitude and longitude of the runways and/or helipads will be provided by the AIRPORT Database. A user can also choose to create a new airport and provide information such as the coordinates of runways and helipads on their own. In either case, whether the user chooses an existing airport or creates their own, the airport can be edited to add runways, taxiways, helipads, and gates.



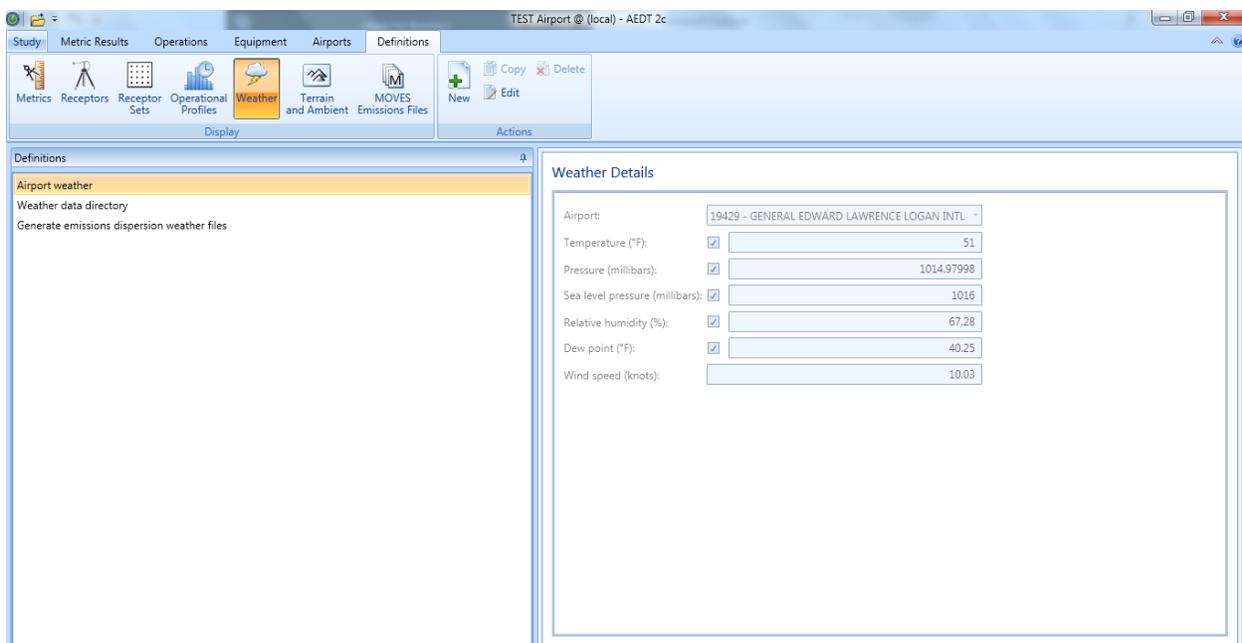


Name	Preferred Code	Code Type	State	Country
ISLAS DEL CISNE	MHIC	ICAO		HONDURAS
ISLAY	EGPI	ICAO		UNITED KINGDOM
ISLE OF MAN	EGNS	ICAO	ISLE OF MAN	
ISLE OF WIGHT/S	EGHN	ICAO		UNITED KINGDOM
ISLE PRIVATE	MY72	FAA	MINNESOTA	UNITED STATES
ISLESBORO	57B	FAA	MAINE	UNITED STATES
ISLEY	33LL	Other	ILLINOIS	UNITED STATES
ISLEY FIELD	24IA	FAA	IOWA	UNITED STATES
ISPARTA	LTBM	ICAO		TURKEY
ISRAEL'S FARM	WA56	FAA	WASHINGTON	UNITED STATES
ISSOIRE/LE BROC	LFHA	ICAO		FRANCE
ISTRANA	LIPS	ICAO		ITALY
ISWAHYUDI	WARI	ICAO		INDONESIA
ITABERABA	SNIB	Other		BRAZIL
ITABUNA	SB01	Other		BRAZIL
ITACOATIARA	SBIC	ICAO		BRAZIL

Figure 11. Add Existing Airport Pane

3.4 Meteorological Data

Meteorological data for each airport is available for the airports that are included in the AEDT AIRPORT database. If the user selects an existing airport from the AIRPORT database for the study, the average annual weather data of the airport can be viewed by clicking on the *Weather* display button in the *Definitions* and then selecting *Airport weather*. The weather data can be edited in the GUI as well. Figure 12 displays the Airport Weather Pane within the AEDT GUI.



Parameter	Value
Airport:	19429 - GENERAL EDWARD LAWRENCE LOGAN INTL
Temperature (°F):	51
Pressure (millibars):	1014.97998
Sea level pressure (millibars):	1016
Relative humidity (%):	67.28
Dew point (°F):	40.25
Wind speed (knots):	10.03

Figure 12. Airport Weather Pane



3.5 Aircraft Information

Aircraft data is contained within AEDT’s FLEET database. The FLEET database has approximately 4,600 airframe and engine combinations and approximately 400 non-aircraft emissions sources such as ground support equipment (GSE), stationary power sources, fueling equipment, and APUs. The aircraft data in the FLEET databases, which is used for fuel burn, noise and emissions modeling, has three general representations: EDB, ANP, and BADA.

The combination of all three of these datasets yields a unique *Equipment* type in AEDT. When building a study, the *Equipment* tab manages the aircraft equipment, non-aircraft equipment, and equipment groups. The user is able to browse through the available equipment types and view the individual aircraft parameters. A user-defined aircraft can be created by copying data from an existing aircraft and modifying the data for the new aircraft. User-defined aircraft can be deleted. System aircraft cannot be deleted. Aircraft data can also be exported to a partial AEDT Standard Input Format (ASIF). The exported partial ASIF can be used as a template to create new user-defined aircraft. The exported partial ASIF cannot be successfully re-imported into AEDT without first making changes to the data.

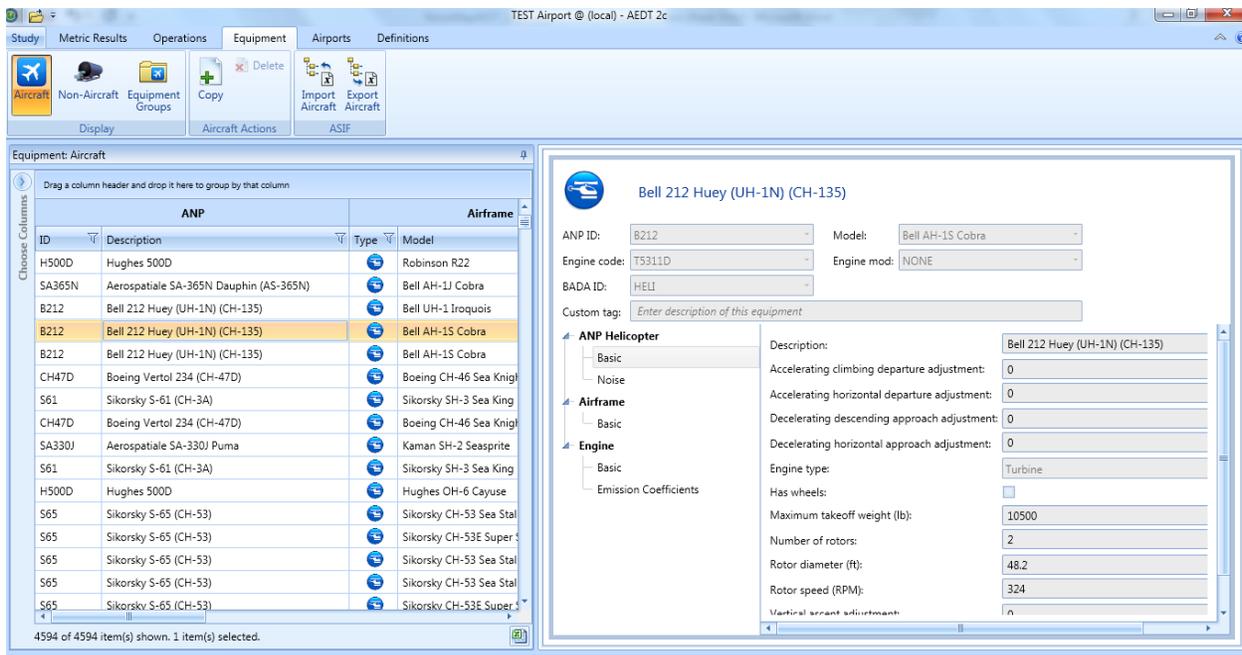


Figure 13. Equipment Pane

3.6 Operations Data

Data associated with aircraft operations can either be entered through the GUI, ASIF files, or directly input into the study database. Components of operations data will include:

- Number of Aircraft Operations by Equipment Type and Time of Day for the Study:



Each equipment type will need to have a number of operations assigned to it. For noise analyses, the operations count will typically be a value associated with the Average Annual Day (AAD) and for emission analyses the operations count value will typically be a value associated with annual operations. AEDT is flexible in that the user can create a detailed schedule with timestamps associated with each individual aircraft operation or some other representation of aircraft operations such as peak month, average day or AAD. The aircraft annualization defines the time period that is to be modeled and the aircraft weightings that are to be applied.

- Stage Length and Flight Profiles:

The user has the ability to select a stage length and flight profile through the AEDT GUI. The user can also import their own profile points and define the procedure steps through the AEDT ASIF.

- Flight Tracks:

AEDT does contain straight in and straight out flight tracks associated with each runway for the airport study. However, if the user wants to model with flight tracks derived from other sources then the flight track data must be imported through the ASIF or directly into the study database. Users can provide flight track data in various forms including: point tracks, vector tracks, and sensor path data. Flight tracks must be assigned to each aircraft operation that is to be modeled.

Figure 14 displays the Create Aircraft Operation pane using the AEDT GUI. The items shown in the left side of the figure are the steps involved to create an aircraft operation. At a minimum an equipment type, operation time, flight profile, and flight track need to be chosen in order for that operation to be modeled.

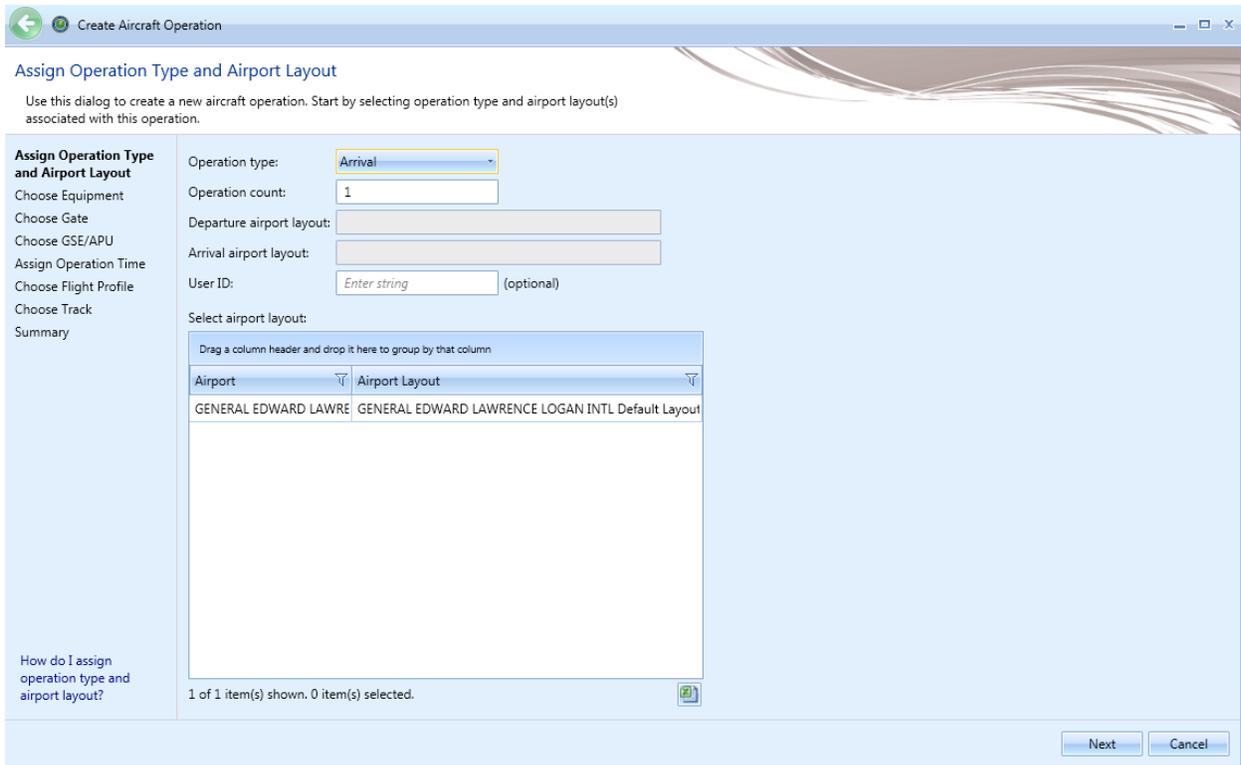


Figure 14. Create Aircraft Operation Pane



3.7 Results

The *Metric Results* tab is where the user chooses the desired modeled output. There are four metric types within AEDT:

- Noise: Requires Receptors
- Fuel Consumption
- Emissions
- Emissions Dispersion: Requires Receptors

After selecting the desired Metric Results, the user must select the annualization to be modeled and for the noise and emission dispersion Metric Types a Receptor Set is required to be chosen. Figure 15 displays the Define Metric Results pane within the AEDT GUI.

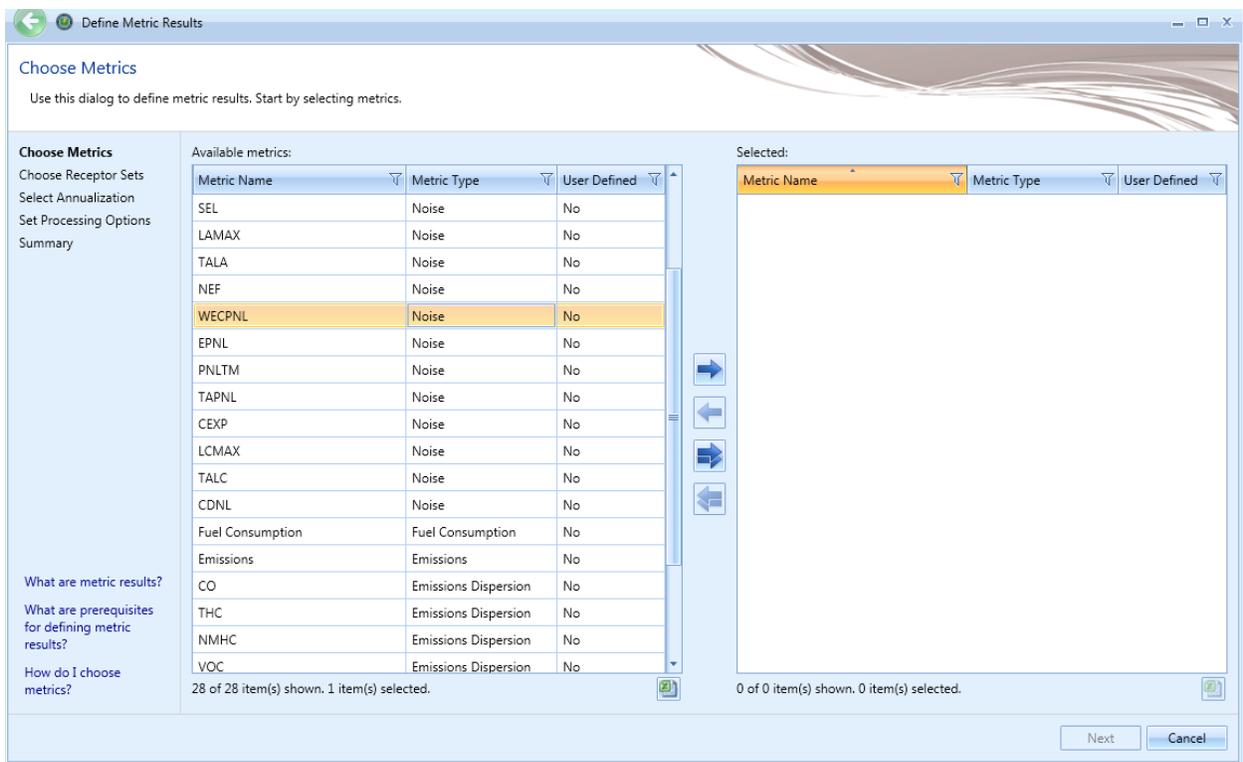


Figure 15. Define Metric Result Pane



3.8 Gaps between NoiseMap and AEDT

The key differences in NoiseMap and AEDT physical modeling are summarized in Table 8.

Table 8. Contrast of NoiseMap and AEDT Input Data Process and GUI

Data Input Feature	NoiseMap	AEDT
Airfield data	<ul style="list-style-type: none"> • Online and Local. 	<ul style="list-style-type: none"> • ICAO and International Air Transport Association (IATA) airport codes including their time history of changes. • Historical averages of meteorological data from weather sensors (US only). • Airport surface structures, e.g. runways, taxiways, gates, buildings. • Airspace geographical content on procedures, e.g. ground-tracks, altitude controls, etc.
Aircraft data	<ul style="list-style-type: none"> • Reference aircraft noise data are contained in NoiseFile. Currently it contains flight and ground run-up noise data for 158 military aircraft/engine combinations, and flight noise data for 96 civilian aircraft/engine combinations. • NoiseMap does not have any emissions or fuel burn data. 	<ul style="list-style-type: none"> • Fleet database has ~4,600 aircraft (airframe/engine combinations) & ~400 non-aircraft emissions sources (ground support equipment, stationary power and fuel equipment, and auxiliary power units). Aircraft performance parameters are specific to the three representations: <ul style="list-style-type: none"> ○ ICAO EDB. ○ ICAO ANP. ○ Eurocontrol BADA.
Operations data	<ul style="list-style-type: none"> • Basic overall historical annual operations data via ATAR. Detailed operational data developed with operator input. Limited projected operational data. Data entry and development is done with user created spreadsheet (no standard format other than *.xml format for importing into BaseOps). 	<ul style="list-style-type: none"> • Comparable operations definition data to NoiseMap accessible through the GUI, external ASIF files, or direct database input. • Includes user-customizable annualization scenario capability and standard scenarios (peak month, average day, annual average day, etc.).
Flight Track	<ul style="list-style-type: none"> • Published Approach Plates and Instrument Departure procedures. VFR flight tracks developed through interviews with ATC and aircrews. Data entry is manual with drawing tools provided within BaseOps. 	<ul style="list-style-type: none"> • Flight tracks are provided by the user. Users can provide data in various forms including: point tracks, vector tracks, and sensor path data. For global studies, users some time use great circles.



Data Input Feature	NoiseMap	AEDT
Flight Profiles	<ul style="list-style-type: none"> Developed through interviews with aircrews. Very limited standard profiles that are accurate. Data Entry is manual with tools provided by BaseOps. 	<ul style="list-style-type: none"> Profile points (user defined). Procedure Steps. Sensor Path modeling (fits user supplied sensor path profile using physics based performance analysis).
Error Checking	<ul style="list-style-type: none"> Very limited. No physics based error checking. 	<ul style="list-style-type: none"> Considerable checking of aircraft performance and input. Includes documented standard recovery for some common errors.
GUI	<ul style="list-style-type: none"> Flexible and easy to use for experienced user. Provides multiple options for display and data entry. 	<ul style="list-style-type: none"> Comparable functionality to BaseOps.
Scenario Tool	<ul style="list-style-type: none"> Grouping option allows very flexible development of optional scenarios. 	



4. Task 3: Output Capabilities

The third task provides a summary of the output capabilities of the NoiseMap suite of programs and AEDT. For output capabilities, the two models offer similar outputs with significant overlap. An overview of the gaps (or differences) between the output data process of NoiseMap and AEDT are provided.

4.1 NoiseMap

This section discusses NoiseMap's output capabilities, along with its primary output module, NMPlot, including: the noise metrics generated, various output formats, NMPlot, and specialized output tools.

4.1.1 Noise Metrics

NoiseMap calculates two types of noise metrics: cumulative metrics and supplemental metrics. The cumulative metrics have been included since the creation of the model to address community noise exposures. Recently, the calculation of supplemental metrics has been added to the output capabilities of NoiseMap.²⁵ The use of supplemental metrics for DOD noise studies is guided by two technical reports from the DoD Noise Working Group (DNWG).^{26,27} Noise metrics may be calculated on a grid basis and/or on specific points of interest (POI).

4.1.1.1 Cumulative Metrics

NoiseMap provides the option to calculate the following primary cumulative metrics:

- Day-Night Average Sound Level (DNL),
- Community Noise Equivalent Level (CNEL),
- Noise Exposure Forecast (NEF),
- Weighted Equivalent Continuous Perceived Noise Level (WECPNL),
- Equivalent Continuous Sound Level ($L_{eq,24hr}$).

4.1.1.2 Supplemental Metrics

Supplemental metrics describe additional aspects of the cumulative noise environment or individual single events. The cumulative-based supplemental metrics include the following:

- **Equivalent Continuous Sound Level on an Hourly Basis ($L_{eq,xhr}$):** a user can select the number of hours (from 1 to 24 hours). However, as a caution, a user must adjust the operations to match the modeled time window for the selected $L_{eq,xhr}$. This metric is used to describe the daytime $L_{eq,15hr}$, nighttime $L_{eq,9hr}$, school day $L_{eq,8hr}$, or various hourly $L_{eq,xhr}$'s.
- **Number of Events Above (NA)** is used to assess the potential for classroom and speech interference. A user can select the threshold basis as either $L_{A,Max}$ or SEL. These different bases are denoted as $NA_{xxx}ALM$ or $NA_{xxx}SEL$, respectively, where "xxx" denotes the actual level



selected such that 65 dBA would result in NA065ALM or NA065SEL.

- **Probability of Awakening (PA)** requires a user to input the proper operations into the nighttime period for either a two or three period day when entering the operational data. For the PA metric, NoiseMap uses the American National Standards Institute's S12.9-2008/Part 6 to estimate the probability of a single awakening during acoustical nighttime operations. Currently, PA is only provided at POIs.
- **Time Above (TA)** is denoted as TAx_{xx}ALM and the threshold is $L_{A,Max}$. The TA metric is the least reliable supplemental metric in NoiseMap because of the integrated modeling assumption. Thus, the TA metrics generated by NoiseMap are rough estimates only and should primarily be used to denoted differences between scenarios and not as definitive estimates of time above.

As a simulation based model, AAM provides improved output on the calculation of supplemental metrics, audibility analysis, and acoustic animations. For supplemental metrics, AAM's output provides a more direct calculation of the supplemental metrics compared to NoiseMap. This improvement is especially seen in the calculation of TA, which AAM calculates directly without any general assumptions required. The origin of AAM is RNM, which was developed by the National Aeronautics and Space Administration.²⁸ Part of RNM included the capability to calculate the audibility of a single flight. This feature has applications to civilian flights when potential impacts to National Parks need to be considered. The calculation of the Percent Time Audibility can be at a specific receiver point or a grid of points.

4.1.2 Output Data Formats

4.1.2.1 Noise Grids & Contours

The standard output format for NoiseMap is a georeferenced grid of receiver locations. The format of the grid file is described by the NMGF Standard (version 2.5).²⁹ This format allows for post-processing of multiple noise model outputs at the same location. This post-processing includes combining multiple grid outputs to produce an overall noise grid. This combining of grids is common for joint use airfields where the military aircraft noise is calculated by NoiseMap and civilian aircraft noise by AEDT. Additionally, a NMGF formatted noise grid file also imbeds modeled operational data into a grid file. These data include runways, flight tracks, static pads, NAVAIDS, Waypoints, POIs, avoidance areas, and Special Use Airspace.

The standard grid is based on a georeferenced airfield reference point with a regularly-spaced, Cartesian XY grid of points. The number of points and spacing can be defined separately for both X (east-west) and Y (north-south) axes. The parameters of the noise grids are not set by any standard, but current practice utilizes a grid spacing of 500 feet and a sufficient number of points to cover the appropriate noise level of the primary cumulative noise metric (see below).

4.1.2.2 Points of Interest

In addition to the standard noise grid, NoiseMap generates an ASCII file for a list of specific points a user



may enter. A POI is defined by its location and height as well as the expected noise reduction for both windows opened and closed. It should be noted that NoiseMap assumes a 5 ft high receiver even if a user inputs a different receiver height, but AAM does account for variations in receiver heights relative to the ground. The calculated results include a summary of the selected cumulative metric at the defined POI along with a list of the top 25 “noisiest” operations occurring at each point. This top 25 list provides operational details such as airspeed, altitude, slant distance at the CPA for each listed operation. The top 25 contributor list is based either on an operations contribution to the overall cumulative metric or on its single event number. Currently, NoiseMap limits the number of POIs to 100.

4.1.3 NMPlot Tools

NMplot is the primary tool to display noise contours and additional visual features. NMplot provides a flexible user interface that offers functionality similar to the BaseOps’ interface. NMPlot can combine separate NMGF grid files into a single grid file by either adding or merging the two grids. The combining of grids does not require two grid files to have the exact same grid points. NMPlot can combine files with different grid spacing and spatial coverage. When combining grids, a user has the option to include either the union or the intersection of the two grids.

Figure 16 provides a sample screen shot of NMPlot showing DNL contours at an airfield along with a background map. For this example, NMplot reads in a NMGF file and generates noise contours based on user inputs, and the user can link a georeferenced background map to provide spatial context to the noise contours. In addition to the basic presentation of noise contours, NMPlot can also add features included in the NMGF grid to the visual display. Figure 17 provides an example of the visualization with departure flight tracks added along with the DNL contours and background map. The ability to visualize the noise contours along with the modeled operational data provides an efficient review tool to verify the modeled results.

Another feature of NMPlot is the ability to generate color gradient plots of the calculated noise grid. This feature helps to demonstrate the continuous variation of the calculated noise metric both within and outside of the selected noise contours. Figure 18 provides an example of the color gradient for the sample case. In this figure, the color gradient is based on a color transitions from dark red (highest levels at 90 dBA DNL) to cyan (lowest levels at 45 dBA DNL). This visualization provides a better interpretation of the variation in the calculated noise that discrete contours can sometimes obscure.



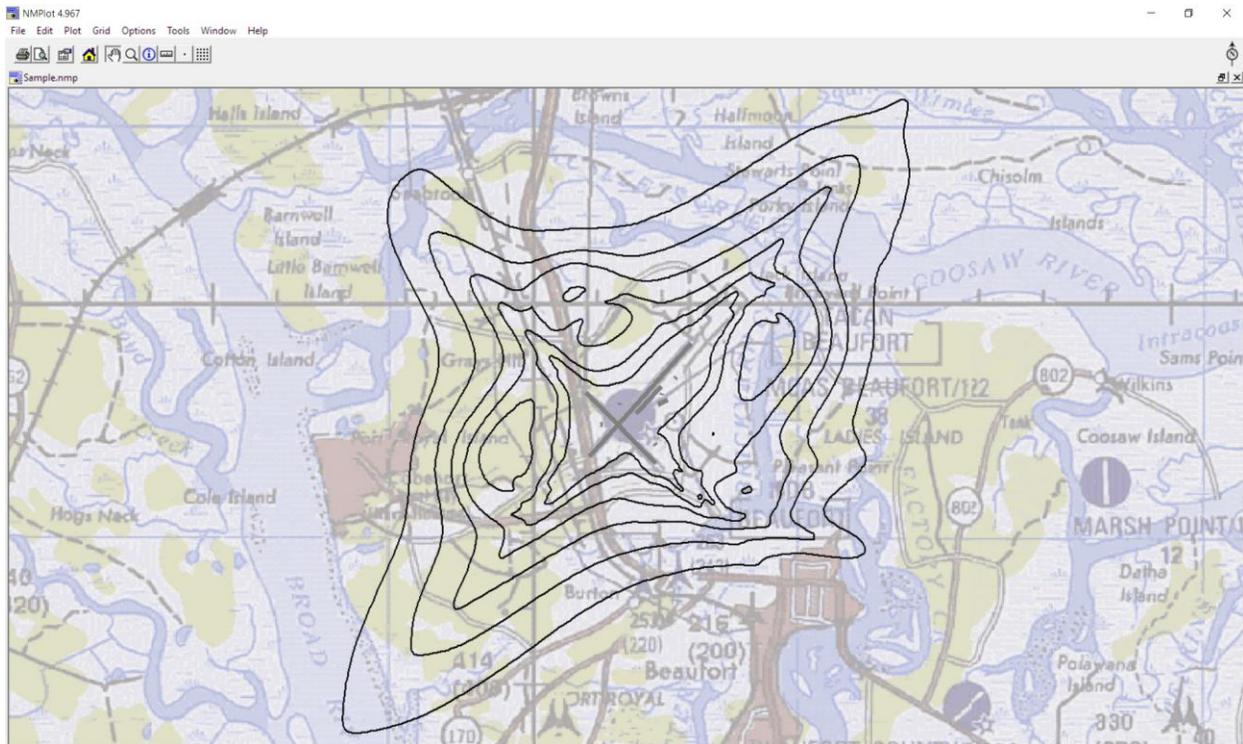


Figure 16. Sample of NMPlot User Interface

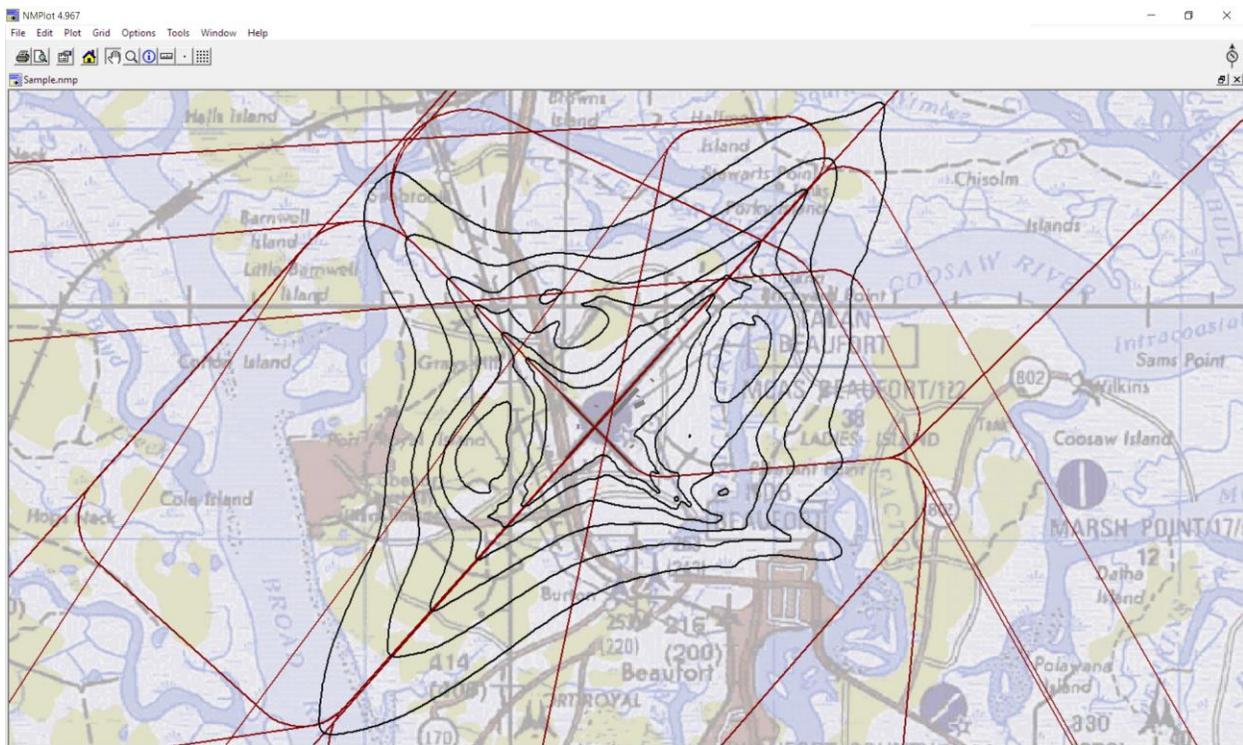


Figure 17. Sample Case with DNL Contours with Departure Flights



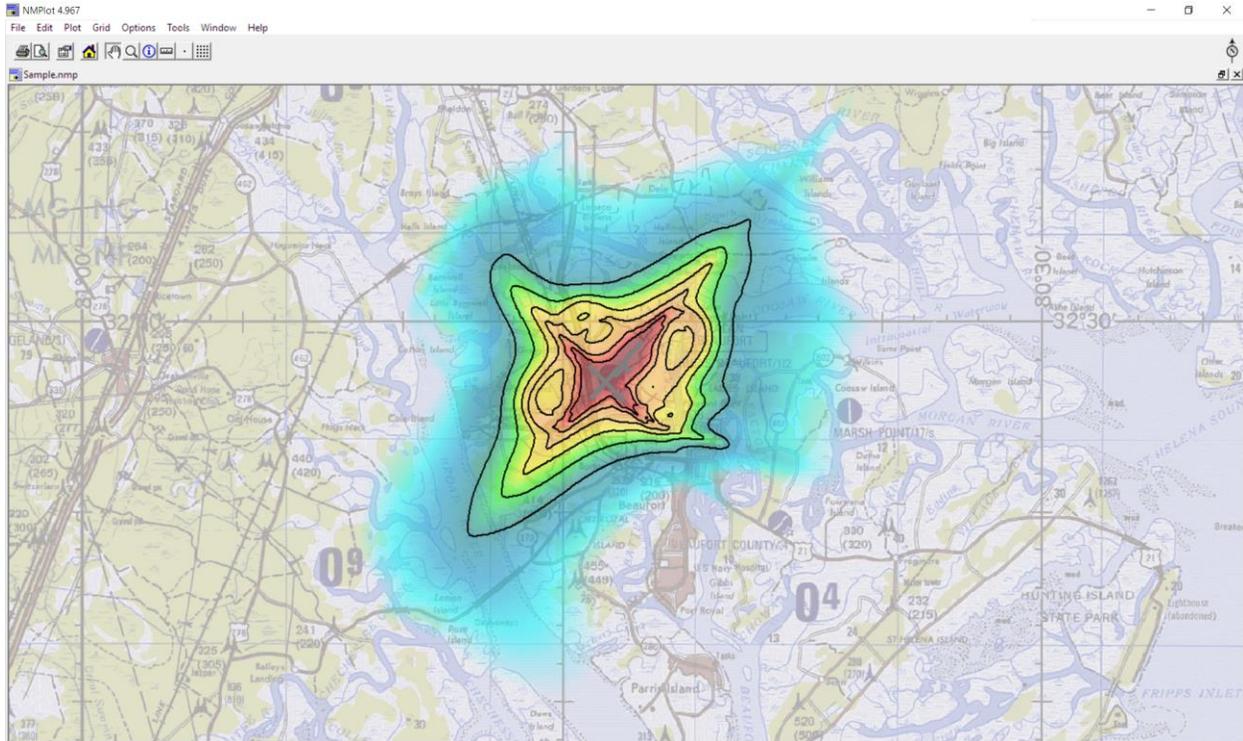


Figure 18. Example of Color Gradient with DNL Contours

4.1.4 Special Output Tools

4.1.4.1 AAM Acoustic Animations

Acoustic animations based on AAM time history output has been utilized by DoD for presentations of aircraft noise to both operators and the public. Acoustic animations were first developed by Plotkin³⁰ as part of the NoiseMap 7 validation effort. A screen capture of the original Narvik animation is provided in Figure 19, which shows an F-16 departure at Narvik, Norway. This validation project led to the development of NMSim,³¹ and this capability was incorporated into RNM and AAM. DoD uses these animations to help people better understand the generation and propagation of noise from aircraft during normal flight operations. For most Air Installation Compatible Use Zones studies, DoD will include a series of animations for demonstrations to the public.



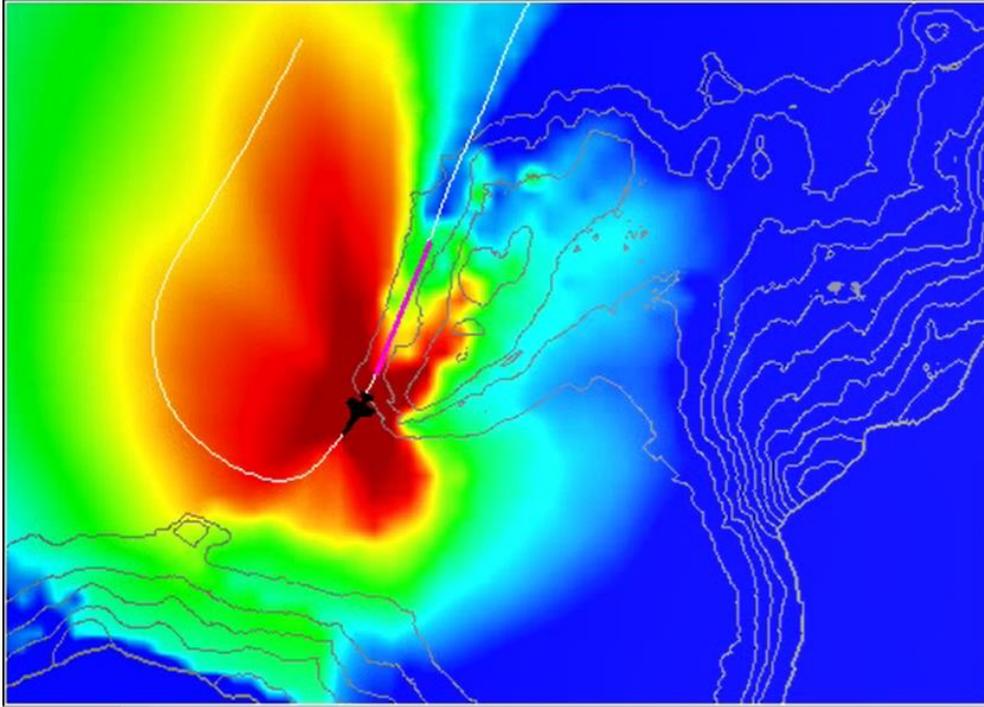


Figure 19. Screen Capture of Narivk Acoustic Animation

4.1.4.2 FLT Optimizer

The additional optional tools under the NoiseMap suite provide detailed outputs for specialized noise analysis. The FLT Optimizer, developed by Blue Ridge Research and Consulting, LLC under a Navy research grant, provides optimized trajectories and/or ground tracks based on a balanced minimization of noise, fuel burn, and emissions. This output can be used to determine new flight procedures to reduce or balance these environmental factors while fitting flight operations within the current operational and safety constraints of an airfield and its surrounding airspace.

4.1.5 Emissions and Air Quality Output

For emissions and air quality, NoiseMap does not have any direct output since it is only a noise model. The output provided by FLT Optimizer is limited to variations for a single flight operation. Thus, it currently has limited application to overall modeling of emissions and air quality.

4.2 AEDT

This section describes the output formats and metrics, both for noise and emissions that are produced by AEDT. The same set of input aircraft operational data can be used to compute noise and emissions results, which facilitates the evaluation of interdependencies. AEDT's output capabilities include noise metrics, various output formats, metric plotting and visualization, and GIS tools.



4.2.1 Noise Metrics

AEDT computes noise from a series of individual aircraft operations (known as single-event noise), and then accumulates these single-event noise levels across all of the events in an AEDT study into cumulative noise levels for the study. This is done according to the following steps:

1. Accept aircraft-specific data (equipment, noise, position, and operational data) and study-specific data (weather, terrain, boundary, or ambient data) as input;
2. Determine the unadjusted noise values at the receptors;
3. Apply adjustments to account for environmental, meteorological, operational and position effects;
4. Compute the single-event base metrics at the receptors;
5. Repeat steps one through four for each unique, single event in the AEDT study;
6. Accumulate the noise output and compute the appropriate noise metrics and
7. Annualize noise results.

The noise, aircraft flight profile and flight path computation methodologies implemented in AEDT Version 2c are compliant with European Civil Aviation Conference (ECAC) Doc 29 (3rd Edition) “Report on Standard Method of Computing Noise Contours around Civil Airports”¹¹ and the International Civil Aviation Organization (ICAO) Doc 9911 (1st Edition), “Recommended Method for Computing Noise Contours Around Airports.”³² Both ECAC Doc 29¹¹ and ICAO Doc 9911³² are currently in the process of being updated, however it is expected that AEDT Version 2c will be compliant with both updated versions (Doc 29 4th Edition and Doc 9911 2nd Edition).

AEDT can be used to compute a variety of noise metrics of the following types: exposure-based, maximum-level-based, or time-based. Noise values are computed at receptors, or grid points, which are either user-specified on regularly-spaced fixed rectangular grids, or determined by AEDT through a dynamic gridding process. Receptor grids are specified by entering an origin, number of points (x and y), and the spacing between adjacent points (also x and y).

4.2.1.1 Cumulative Metrics

AEDT provides the option to calculate the following primary cumulative metrics:

- DNL,
- CNEL,
- NEF,
- WECPNL,
- $L_{eq,24hr}$.

4.2.1.2 Supplemental Metrics

AEDT’s supplemental noise metrics include the following:

- Equivalent Continuous Sound Level for a 15-hour day ($L_{eq,D}$),
- Equivalent Continuous Sound Level for a 9-hour night ($L_{eq,N}$),



- C-weighted day, night average sound level (CDNL),
- C-weighted Sound Exposure Level (multi-event) (CEXP),
- LAMAX,
- Maximum C-weighted Sound Level (multi-event) (LCMAX),
- PNLTM,
- SEL,
- TALA,
- TALC,
- TAPNL,
- Time-Audible (TAUD),
- Time-Audible Percent (TAUDP),
- Time-Audible with Overlapping Events Method (Statistical Compression) (TAUDSC), and
- Time-Audible Percent with Overlapping Events Method (Statistical Compression) (TAUDPSC).

In addition, time-audible metrics with overlapping events method and number-above noise level metrics are also available. For time audible noise metrics, either an ambient threshold or ambient noise files are required depending on the noise metrics selected. All of these files include geospatial ambient noise data corresponding to a specific study area (and may also reflect specific study or operational conditions).

4.2.2 Emissions Metrics

In addition to computing noise from aircraft, emissions can be modeled for all airport sources. These emissions results can be presented in terms of their total mass (i.e. an emissions inventory) or their concentration at a user-defined location over a user-defined timescale.

The following pollutants are modeled by AEDT:

- CO,
- NMHC,
- NO_x,
- Particulate Matter less than 10 microns in diameter (PM₁₀),
- Particulate Matter less than 2.5 microns in diameter (PM_{2.5}),
- SO_x,
- Total Hydrocarbons (THC),
- Total Organic Gases (TOG),
- VOC,
- H₂O, and
- SOG, including HAPs.

AEDT significant Output features include:

1. Pollution concentration,
2. Pollution concentration contours (dispersion contours),
3. Impact change analyses (the NIRS-based chart output of population change impact at different



- noise levels),
4. Ambient maps,
 5. AEDT works with ArcGIS, so the full range of working with GIS layers and the ability to manipulate those layers is available to the users. This is also true of the Inputs, where the user can work in the GIS window to manipulate difference inputs – runways, taxiways, tracks, etc.

4.2.3 Environmental Justice

AEDT includes an Environmental Justice module that 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 US Census Bureau, American Community Survey (ACS) data** in conjunction with or without other metric results (including noise, fuel burn, and emissions) produced by AEDT over various maps. The environmental justice analysis results can be exported to geospatial (Shapefile) and spreadsheet (CSV) formats for use outside of AEDT.

4.2.4 Output Data Formats

AEDT produces both tabular results as well as ArcGIS-connected gridded and contour plots for both noise and emissions. The user is also able to select from the wide-range of available ArcGIS-compatible background maps to support the presentation of their results. Layers are used within AEDT to allow the user to select the desired features to be displayed, and a snapshot of the visualized results can be taken to support offline presentation.

The following output formats are supported:

- ESRI shapefiles,
- Noise Model Grid Format (NMGF) – allows results to be displayed in NMPlot,
- AERMOD Plot files (for emissions dispersion results only) and
- Comma separated value text file (CSV).

In addition, results can be accessed directly from SQL Server data tables. When displayed on a map, contours and results from individual receptor locations can be displayed, on a user-defined scale, using user-selected colors. Figure 20 provides an example noise contour visualization and Figure 21 is an emissions dispersion example with results shown at individual receptor locations.

** <https://www.census.gov/programs-surveys/acs/>



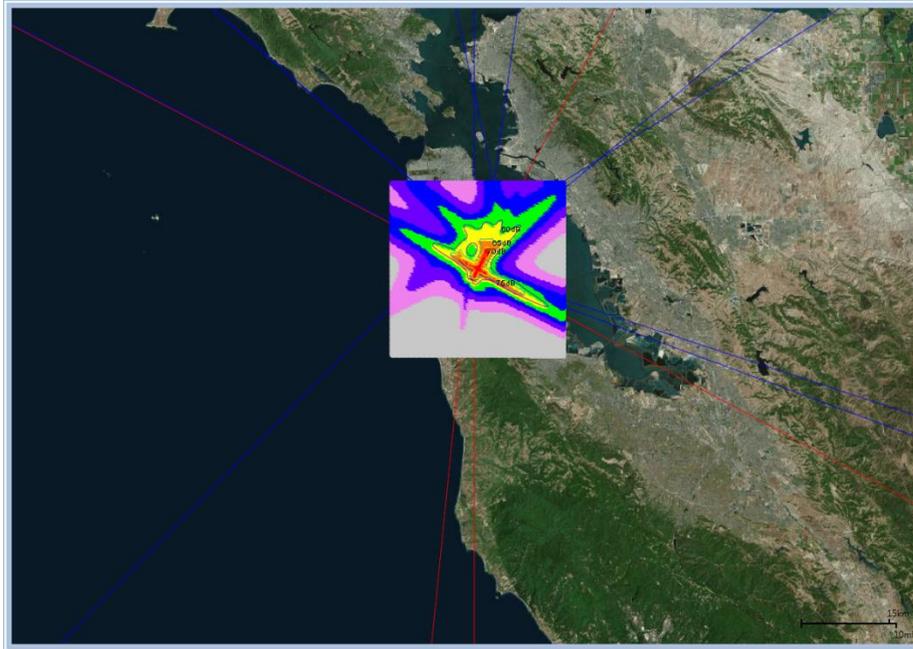


Figure 20. Example Noise Contours Superimposed on Satellite Image with Arrival and Departure Tracks

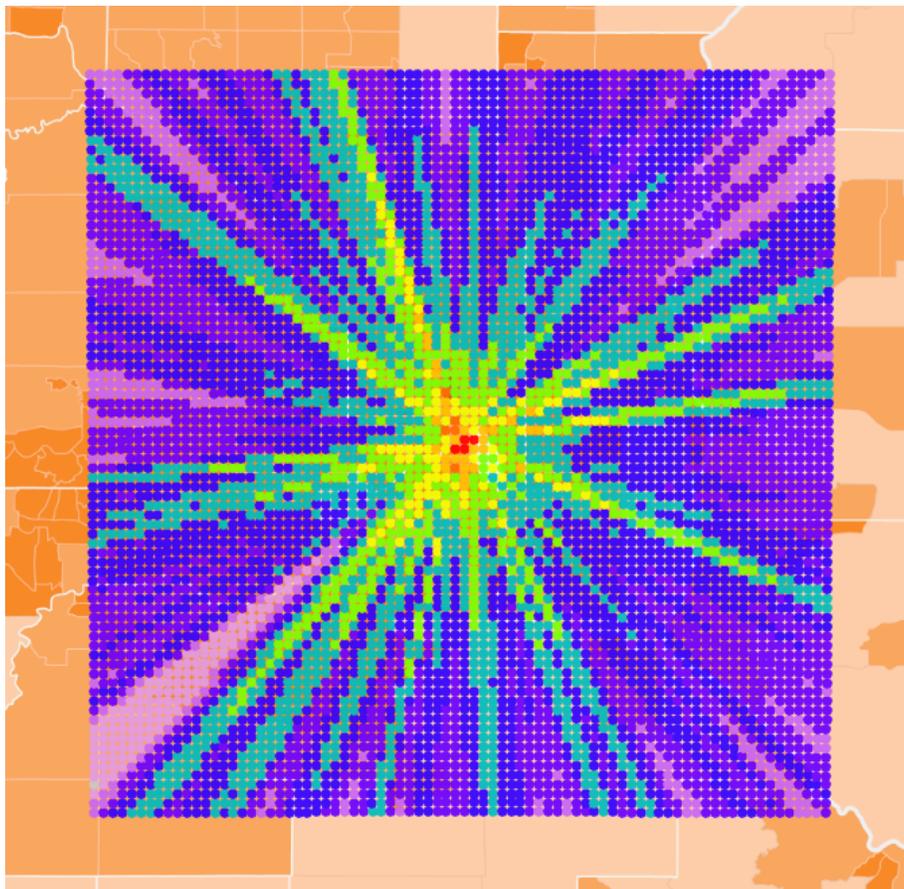


Figure 21. Sample Peak 1-Hour Emission Concentration Results Superimposed on a Map Showing Persons Per Square Mile



4.2.4.1 Noise Reports and Contours

Noise metric calculations using a receptor grid are available in a tabulated form called a noise report. These reports include geodetic coordinates (latitude, longitude and elevation) of each receptor and the associated noise levels. Metric type and name are also included, and the reports can be exported directly to spreadsheet format. Population exposure reports can also be generated for noise metric results with a grid receptor set. US Census data are required for the population exposure report and must be downloaded separately. Noise contours can also be exported in shapefile format, which is an open file format used in GIS applications.

4.2.4.2 Visualization Tools

Noise metric data can be visualized within AEDT together with base maps by utilizing AEDT's layers interface. Metric values can be viewed directly as color-coded points for each receptor, or as contours of constant metric value. Contours, receptor grids, and base maps can be overlaid and the transparency of each layer varied independently to produce many types of images. In Figure 22, SEL values calculated using a rectangular grid are combined with a street map. The receptor grid spacing is fairly dense, and the receptor layer is partially transparent to aid in visualization. Contours of SEL are presented in Figure 23, together with a population density map.

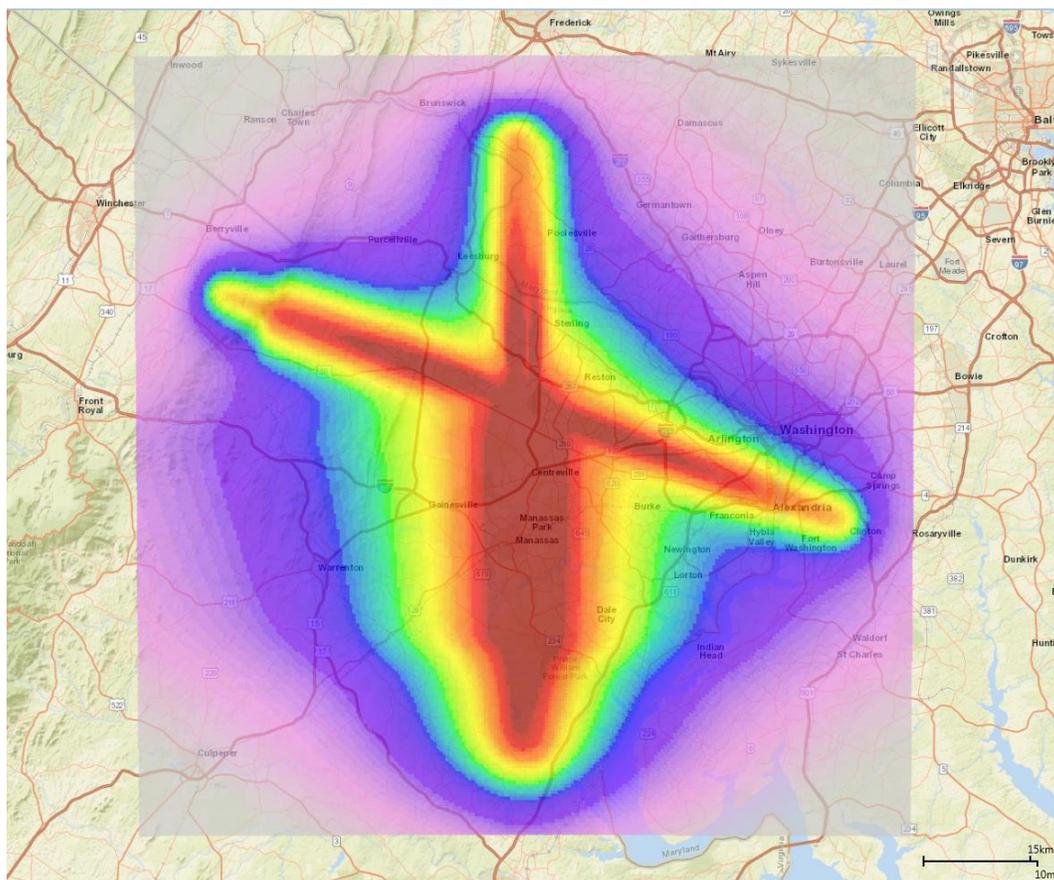


Figure 22. Example of a Rectangular SEL Receptor Grid Overlaid on Street Map in AEDT



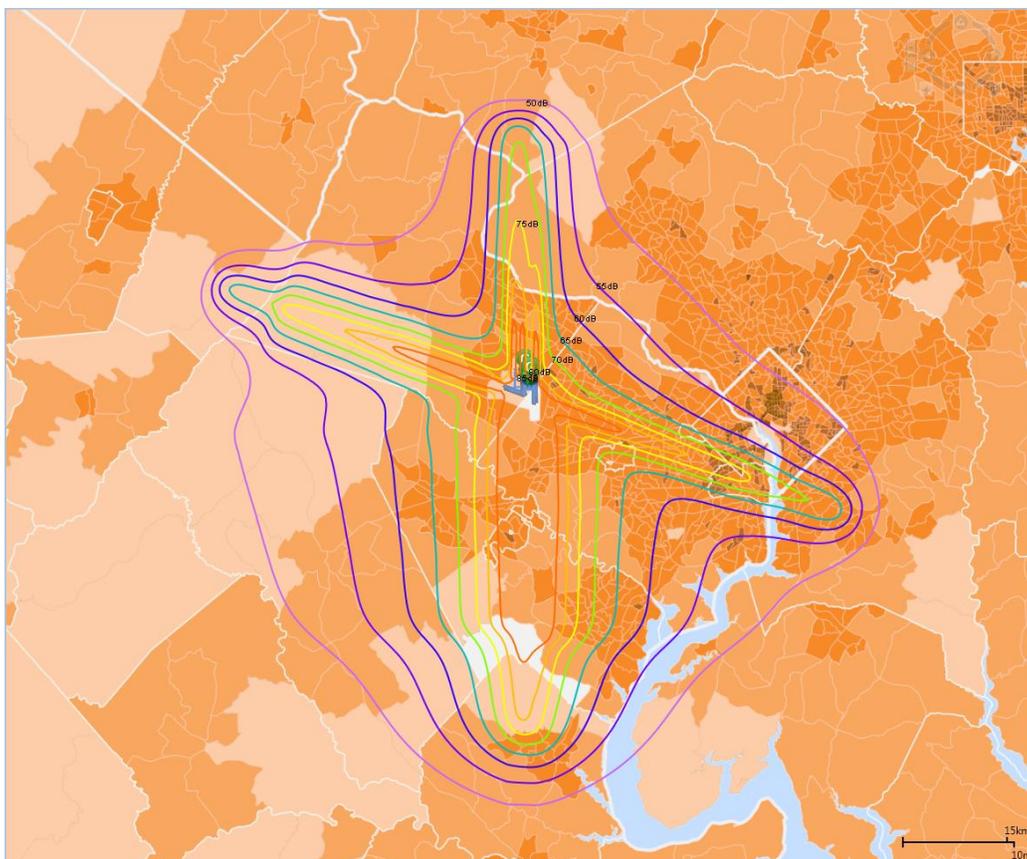


Figure 23. SEL Contour Lines Plotted Over US Demographics Map in AEDT

4.2.4.3 Dynamic grid generation

In addition to direct definition of a regular grid of receptors, AEDT also provides a dynamic gridding capability. The dynamic grid feature automatically adjusts the size of a receptor grid to achieve a completely closed contour for the lowest contour level specified by the user.

Noise levels are first computed for the starting receptor grid and then compared to the specified expansion level. If any noise level exceeds the minimum expansion level, the dynamic grid expands in that direction by adding a new grid which is exactly the same size as the starting grid. This is done for all four sides of the starting grid. This process continues until no noise levels on the edges of the grids exceed the expansion level and the contour is closed. Dynamic receptor grids have the advantage of comprising a smaller number of points within irregularly shaped noise metric distributions. These grids can also be reused in subsequent metric calculations. An example of a dynamic grid result is shown in Figure 24, together with a satellite image. A comparison of fixed grid with a dynamic grid for a single operation is given in Figure 25, illustrating that the number of points can be substantially reduced in the latter case.



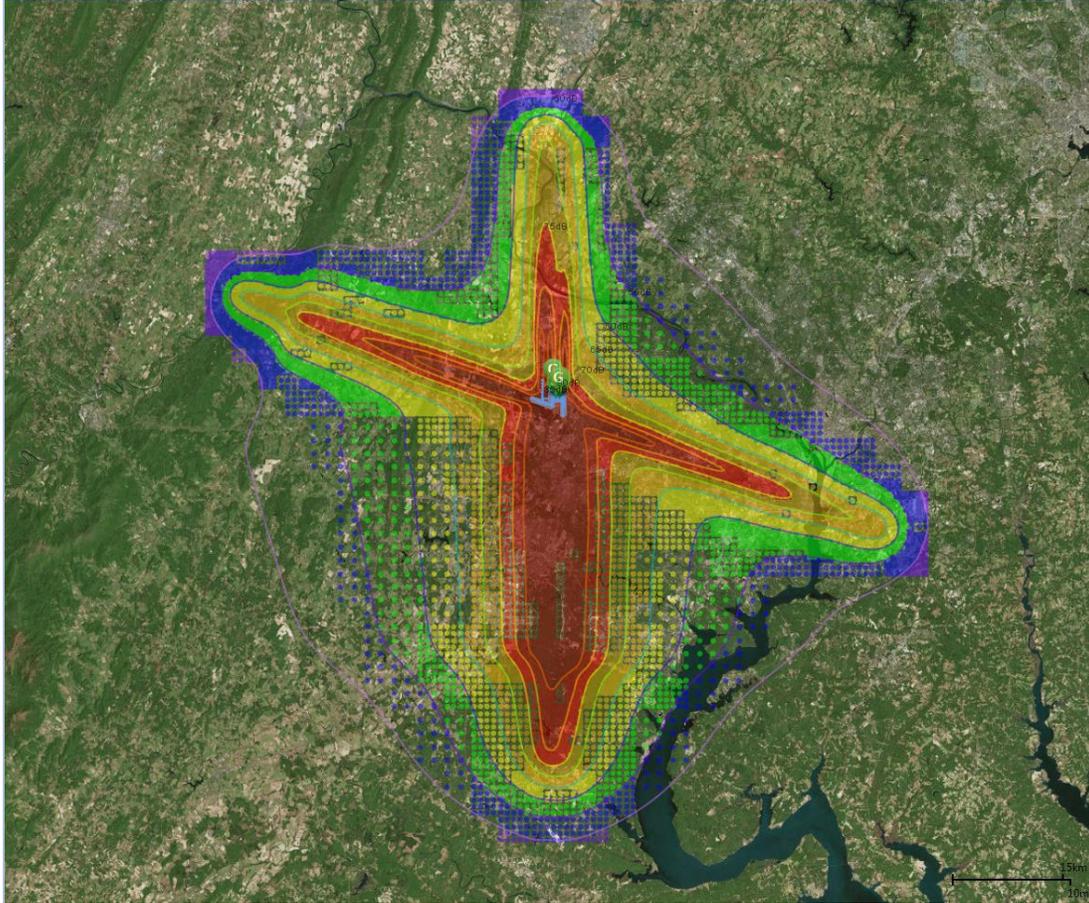


Figure 24. Dynamically-generated Receptor Grid with Associated SEL Contours, Compared with Satellite Images in AEDT

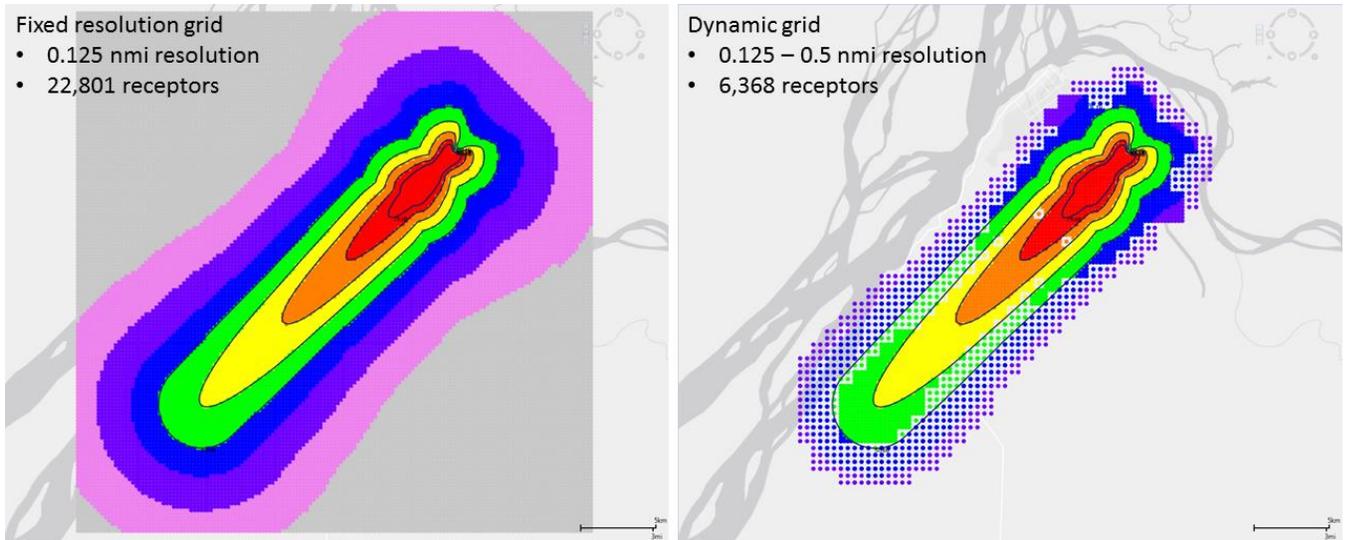


Figure 25. Comparison of Fixed Rectangular and Dynamic Grid Output in AEDT

4.3 Summary of Similarities and Gaps between NoiseMap and AEDT

The key similarities and differences in NoiseMap and AEDT output capabilities are summarized in Table 9.

Table 9. Similarities and Gaps between NoiseMap and AEDT Output Capabilities

Output Feature	NoiseMap	AEDT
Output Formats	<ul style="list-style-type: none"> Standard NoiseMap outputs are a standard NMGF noise grid and an ASCII text file for POI results. 	<ul style="list-style-type: none"> Outputs include ESRI Shapefiles, standard NMGF noise grid, and CSV files. All data can also be directly extracted from the underlying study database.
Primary Noise Metrics	<ul style="list-style-type: none"> Primary noise metrics are DNL, CNEL, NEF, WECPNL, and $L_{eq,24hr}$. 	<ul style="list-style-type: none"> Primary metrics are exposure based A-weighted exposure based (SEL, DNL, CNEL, LAEQ) or C-weighted (CDNL, CEXP) or Tone-corrected perceived (EPNL, NEF, WECPNL, PNLTM). Maximum level (LAMAX, NANL).
Supplemental Noise Metrics	<ul style="list-style-type: none"> Supplemental metrics calculated on a grid or for POI are $L_{eq,xhr}$, NA, and TA. PA calculated for POIs only. 	<ul style="list-style-type: none"> Time-Based (TALA, TAUD, TALC, TAPNL).
Plotting Tools	<ul style="list-style-type: none"> NMPlot is a plotting tool. It provides the noise contours for a calculated noise grid, as well as overlaying background maps and operational features, such as runways, NAVAIDS, and flight tracks. 	<ul style="list-style-type: none"> AEDT includes a GIS-contouring capability . NMPlot compatible. Ability to overlay and add noise grids from other models (NMGF format).
Combining Grids	<ul style="list-style-type: none"> NMPlot allows the combining of non-matching NMGF grids into a single grid file. 	<ul style="list-style-type: none"> Allows combining of NMGF grids with common metrics.
Color Gradients	<ul style="list-style-type: none"> NMPlot produces color gradient plots for a noise grid. 	<ul style="list-style-type: none"> Includes colored receptor points. Users can define the color scheme and binning of the receptor points.
Background Maps	<ul style="list-style-type: none"> NMPlot requires a user to import background maps as ESRI Shapefiles, georeferenced graphic files, or compressed ARC Digitized Raster Graphics. No background map data is provided with NMPlot. 	<ul style="list-style-type: none"> The GIS capabilities allow users to import any geo-referenced base map. Base maps are accessible through the ESRI internet services. Alternative map services can be used and additional map layers can be imported as a reference in a variety of data formats including ESRI Shapefiles and raster formats.



Output Feature	NoiseMap	AEDT
Specialized Tools	<ul style="list-style-type: none"> • FLT Optimizer provides “best” flight profile/track to balance noise, emissions, and fuel burn for given flight operations. • AAM provides higher resolution of supplemental metrics, TA ambient and audibility analysis, and acoustic animations. 	<ul style="list-style-type: none"> • Does not include an optimizer capability for noise. • Includes audibility analysis including assessment against user-supplied backgrounds. • No acoustic animations. • Time audible calculated with ambient noise maps. • Includes ability to compare metric results against Environmental Justice (EJ) demographic variables. • Emissions dispersion through AERMOD (EPA’s regulatory model).



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