Aviation Environmental Design Tool
Version 2b

Uncertainty Quantification Report

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Executive Summary

Overview

This document provides a summary of the Federal Aviation Administration's (FAA) uncertainty quantification effort for the Aviation Environmental Design Tool Version 2b (AEDT 2b). The intent of this documentation is to inform and educate the user regarding the thorough expert review, verification, validation, capability demonstration, parametric uncertainty/sensitivity analysis and other relevant testing that went into the development of AEDT 2b. The full length *AEDT Version 2b Uncertainty Quantification Report* provides complete documentation by delving into greater detail on the uncertainty quantification activities and their results. This document is intended to serve as a summary of the uncertainty quantification effort for AEDT 2b.

AEDT is a software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality consequences. This software has been developed by the FAA Office of Environment and Energy for public release. It is the next generation FAA environmental consequence tool. AEDT satisfies the need to consider the interdependencies between aircraft- related fuel consumption, emissions, and noise.

AEDT has been released in two phases. The first version, AEDT 2a, was released in March 2012 and was used for air traffic airspace and procedure actions where the study area is larger than the immediate vicinity of the airport, incorporates more than one airport, and/or includes actions above 3,000 feet above ground level (AGL). AEDT 2a replaces FAA's current analysis tool for these applicable analyses, the Noise Integrated Routing System (NIRS), and is able to perform environmental analysis for airspace actions under the National Environmental Policy Act (NEPA).

The second version, AEDT 2b, was released in May 2015. In addition to containing all of the capabilities of AEDT 2a, it replaces the following current public-use aviation air quality and noise analysis tools: the Emissions and Dispersion Modeling System (EDMS – single airport emissions analysis) and the Integrated Noise Model (INM – single airport noise analysis).

The AEDT development cycle includes rigorous testing of all levels of software functionality from the individual modules to the overall system. However, the FAA's Office of Environment and Energy sought a robust uncertainty quantification effort in addition to this test program.

This uncertainty quantification comprehensively assesses the accuracy, functionality, and capabilities of AEDT 2b during the development process. The major purposes of this effort are to:

- Contribute to the external understanding of AEDT 2b
- Build confidence in AEDT 2b's capability and fidelity (ability to represent reality)
- Help users of AEDT 2b to understand sensitivities of output response to variation in input parameters/assumptions
- Identify gaps in functionality
- Identify high-priority areas for further research and development

The uncertainty quantification consists of four major elements: expert review, verification and validation, capability demonstrations, and parametric uncertainty/sensitivity analysis. A summary of the work in each of these four areas is presented in the following sections. In the uncertainty quantification for AEDT 2b, the Use Case evaluations encompassed capability demonstration as well as verification and validation.

Expert Review

The FAA's Office of Environment and Energy has actively encouraged the input of academia, government agencies, and industry to guide the methodologies, algorithms, and processes implemented in the AEDT 2b software. This effort built on the AEDT 2a expert review with several key organizations conducting reviews of AEDT 2b's technical components and practical usability throughout its entire development cycle.

The AEDT Design Review Group, composed of a diverse international group of future users and stakeholders, met regularly during the AEDT 2b development process and provided valuable feedback to the development team through its use of development versions of the software.

SAE International's Aircraft Noise Measurement and Aircraft Noise/Aviation Emission Modeling Committee (A-21) and its publications[1,2,3,4,5] provided the basis for many of the core flight performance, noise, and emissions calculations in AEDT 2b.

European Civil Aviation Conference (ECAC) *Report on Standard Method of Computing Noise Contours around Civil Airport* (Document 29)[6] also guided the development of AEDT methodologies for noise and flight performance modeling. AEDT 2b has been built to comply with this internationally accepted noise modeling standard.

The International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP) Modeling and Database Task Force evaluated a range of current and proposed tools that model aircraft noise, air quality, and emissions, including AEDT. The effort assessed functionality of each tool and the tool's ability to meet the current and future modeling needs of CAEP. AEDT was evaluated in four areas: aircraft performance, aircraft noise, air quality, and emissions, as part of this exercise. The assessment showed that AEDT matched or exceeded the number of criteria satisfied by the other tools in each area. Additionally, ICAO *Recommended Method for Computing Noise Contours around Airports* (Document 9911[7]), shaped the development of noise calculation algorithms in AEDT.

Additionally, many of the modeling methodologies in AEDT 2b have been carried forward from legacy software tools NIRS, INM, and EDMS; and, consequently, AEDT 2b has gained from the extensive guidance and review that such organizations have provided to these legacy software tools and to the previous version of AEDT itself, AEDT 2a.

Use Case Evaluation

Since AEDT 2b replaces legacy software tools (e.g., INM, EDMS, and AEDT 2a), each Use Case was designed as a capability demonstration for executing AEDT 2b in the same capacity as the legacy tools it replaces. Within the capability demonstration, all of the relevant functionality specific to a given Use Case was evaluated to determine if it functioned as intended. Each Use Case conducted verification and validation by evaluating against the associated legacy tool in order to compare results with previous modeling approaches (the exception being Use Case F).

Use Case A: Inventory Analysis

The goal of this use case is to investigate the capability of the AEDT 2b application to replicate the functionality in the Noise and Emissions Analysis Tool (NEAT). One of the stated objectives of AEDT 2b was to allow large scale analyses to be conducted within the application, enabling the sunset of NEAT. As NEAT was composed of AEDT modules and databases, it was expected that the data-driven results would not change substantially. AEDT 2b was used to perform a large scale analysis consisting of approximately three million flights, and its runtime, fuel consumption, and noise contour area closely matched those for NEAT. Slight differences in fuel burn are explained by a change in the aircraft performance model.

Use Case B and C: NEPA/CAA Analysis

The purpose of Use Cases B and C is to provide a capability demonstration of AEDT 2b functionality and a comparison of AEDT 2b to the EDMS when conducting an analysis associated with the National Environmental Protection Act (NEPA) and the Clean Air Act (CAA). A comparison of the AEDT 2b and EDMS input parameters associated with the airport study showed that they are identical, therefore the functionality associated with importing those input parameters via ASIF is working as intended in AEDT 2b with two exceptions. The EDMS to AEDT importer does not import the taxi time and airport weather. Therefore, the users need to manually change the values of taxi time and airport weather if they need to match the EDMS and AEDT settings. Overall, AEDT 2b and EDMS have comparable results, although there are some noted differences. The fuel burn, CO_2, H_2O, SOx, NOx, CO, HC, VOC, NMHC, and TOG emissions inventory comparisons between AEDT 2b and EDMS are within a reasonable range, and the main reason for the difference is that AEDT 2b and EDMS use different fuel consumption models. The difference in PM estimation is relatively bigger and it is due to the fact that AEDT 2b uses FOA 3.0 while EDMS uses FOA 3.0 for the non-US airports and FOA 3.0a for the US airports to estimate PM. In addition, the AERMOD versions used in AEDT 2b and EDMS are different, resulting in different setup for AREA sources. This leads to the differences in CO and NOx pollutant concentrations between AEDT 2b and EDMS in the air quality dispersion analysis.

Use Case D: Part 150 Analysis

The purpose of this Use Case is to evaluate the capability in AEDT 2b to perform a Part 150 airport noise analysis, and to test other aircraft noise modeling functionality in AEDT 2b. Historically, Part 150 analyses were performed with the legacy INM tool. Since a key requirement for AEDT 2b was to sunset INM, Use Case D includes detailed comparisons between INM 7.0d su1 (the final version of INM) and AEDT 2b, to confirm that AEDT 2b performs as expected for Part 150 studies. Additional noise-related functionality included in AEDT and INM but not necessarily used for Part 150 analyses was also evaluated. Several different airport studies were compared, in order to focus on different noise functionalities in the tools.

A comparison of the AEDT 2b and INM 7.0d showed that the models have comparable noise results in most cases, although some differences were noted. Some differences highlighted differences in APM versions and contouring methods between the two models, as well as database updates/improvements in AEDT. Overall, the noise contour and receptor grid results are within a reasonable range, indicating that the noise functionality is operating as intended in AEDT 2b. For some test cases, the INM and AEDT results showed unreasonably large differences. Further investigations found that the differences were attributed to either or combinations of 1) a bug in AEDT's contouring algorithm and 2) differences in engine installation locations for some aircraft between INM and AEDT. The bug in AEDT's contouring algorithm was fixed for the AEDT 2c release. The updated Fleet DB in AEDT 2c SP3 also addressed the incorrect engine installation locations.

Use Case E Part 1: Air Traffic Airspace and Procedure Analysis

Use Case E Part 1 evaluated two large airspace analyses that were run in both AEDT 2a SP2 and AEDT 2b SP2 for the purposes of comparison. These analyses were based on real-world legacy studies, with modifications made to ensure an "apples-to-apples" comparison between AEDT 2a SP2 and AEDT 2b SP2. AEDT 2b was able to successfully complete a capability demonstration for an applicable NEPA analysis for an airspace redesign project. It has all the functionality needed to complete the required steps to fulfill the requirements under NEPA. Since the flight performance and noise models have evolved from those found in AEDT 2a SP2, some results are expected to be different, as they are driven by flight performance differences. The two tools show generally similar results, with expected differences driven by the fact that AEDT 2b SP2 implements different advanced algorithms and methods, particularly in flight performance calculations that affect noise exposure calculations.

Use Case E Part 2: Airspace Redesign Environmental Analyses

For Use Case E Part 2, an AEDT study based on one originally generated for an airspace re-design environmental analysis was run in both AEDT 2a SP2 and AEDT 2b SP2. The legacy study that served as a basis for the analysis was from the DC Metroplex Project (part of the FAA NextGen Metroplex initiative). The goal was to demonstrate that AEDT 2b SP2 is suitable for this use case. Intentional differences between AEDT 2a SP2 and AEDT 2b SP2, especially in the area of aircraft performance, resulted in noise and aircraft performance differences. These differences are expected and deemed acceptable. An analysis of the acoustic results revealed that perceived levels of noise at population point receptors was very similar in both versions of the tool, with the majority of population receptors reporting a decibel or less of a difference between the two versions of the tool. As a whole, a larger number of receptors reported a decrease in noise in AEDT 2b SP2 rather than an increase. There were a few, localized sets of population points that reported non-negligible differences (both decreases and increases in AEDT 2b SP2). An examination of emissions results pertinent to Use Case E (i.e., fuel-burn and CO_2) showed that most flight modes experienced only slight variances in computed emissions values. Only the "Above 10,000 feet AFE" flight mode experienced a significant difference in emissions. However, it was concluded that this difference is entirely expected based on aircraft performance improvements introduced into AEDT 2b SP2. Overall, AEDT 2b SP2 is capable of conducting a Use Case E analysis and the results produced from such an analysis are compatible and comparable with the analogous results produced by AEDT 2a SP2.

Use Case F: Full Functionality Single Study

Use Case F is designed to exercise as much AEDT 2b SP2 functionality as possible within a single study. Study KIAD was designed to utilize all of the available aircraft types, operations, and track definitions in order to generate the full list of available noise, fuel burn and emissions results and their associated reports. As this study does not represent real world operations, and since previous use cases have validated results from AEDT 2b SP2 against AEDT 2a SP2, validation and verification was not performed on study KIAD. Use Case F successfully demonstrated that AEDT 2b SP2 was able to exercise nearly all available input data in a single study, providing broad flexibility to conduct multiple types of noise and emissions analyses.

Parametric Uncertainty and Sensitivity Analysis

Finally, a global sensitivity analysis was conducted to quantify the degree to which variation in data inputs are propagated to tool outputs. The parametric uncertainty analysis was conducted at the vehicle level for an aircraft performing a single flight. The parametric uncertainty and sensitivity analysis was performed in order to identify main contributors to AEDT output uncertainties and gain better insights on the areas of future AEDT improvements. In order to achieve this objective, the following subtasks performed: 1) Review of prior AEDT UQ studies to properly define the problem and the analysis scope; 2) Uncertainty characterization to identify the source of the uncertainties among AEDT 2b input parameters, their variability, and the correlation among them; and 3) Sensitivity analysis and uncertainty propagation to quantify how individual and combined changes in AEDT input parameters impact AEDT outputs. Specifically, the parametric UQ study completed sensitivity analyses, surrogate modeling, Monte Carlo Simulation (MCS), and Global Sensitivity Analyses for mission fuel, mission NOx, terminal NOx, and departure and approach noise.

Results from the parametric sensitivity analysis show which inputs are of higher relative importance for conducting an accurate analysis. Sensitivity studies on mission fuel at two different stage lengths found that BADA fuel flow coefficients, ANP departure weight, and BADA parasite drag had the most significant effects on mission fuel consumption. All the input parameters that were important for mission fuel consumption were also important for mission NOx emissions. In addition, NOx emission indices (EI) for climb and takeoff were among the most important contributors to mission NOx emission. Expanded implementation of the improved approach would reduce uncertainties in terminal area NOx calculation. BADA version 4 from EUROCONTROL would provide an improved methodology and data for terminal area fuel consumption estimation. Changes in NPD curves had the strongest effects on both departure and approach noise. For departure contour area, NPD curves had the most impacts, followed by ANP climb thrust and ANP departure weight. ANP takeoff thrust had the strongest impact on departure contour width. Another significant conclusion from the parametric uncertainty analysis was that ignoring the physical correlation between AEDT input parameters can have a significant influence on the sensitivity results (this held for fuel consumption, NOx emissions, and noise calculations).

Conclusions

The AEDT 2b uncertainty quantification effort sought to quantify AEDT 2b's overall ability to meet its intended purpose as a software tool for evaluating the environmental consequences of aviation operations. This work was performed to build confidence in AEDT 2b's capability, fidelity, and connection to the precedent of the legacy tools it replaces. This confidence is derived from the expert review that has been conducted throughout the tool's development history, a verification and validation of the software's methodologies and performance in comparison with legacy models, a demonstration of its capability to conduct the analyses for which it was designed, and a parametric uncertainty/sensitivity analysis that informs both user and developer for future use and development, respectively.

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List of Terms

01C	Study runway designation - Center
01L	Study runway designation – Left
01R	Study runway designation – Right
A-21	SAE International's Aircraft Noise Measurement and Aircraft Noise/Emission Modeling Committee
A/C	Aircraft
AAD	Average Annual Day
AAM	Aircraft Acoustic Module
ADT	Approach Displacement Threshold
AEDT	Aviation Environmental Design Tool
AEM	Aircraft Emissions Module
AFE	Above Field Elevation
AIR	Aerospace Information Report
AIRMOD	European Civil Aviation Conference committee that prepared the third edition of Document 29
ANP	Aircraft Noise and Performance
APM	Aircraft Performance Module
ARP	Aerospace Recommended Practice
Arr	Arrival
ASIF	AEDT Standard Input File
BACK	BACK Aviation Solutions
BADA	Base of Aircraft Data
BCOP	Boeing Climb Out Program
BFFM2	Boeing Fuel Flow Method 2.0
BTS	Bureau of Transportation Statistics
CAA	Clean Air Act
CAEP	International Civil Aviation Organization's Committee on Aviation Environmental Protection
CAS	Calibrated Air Speed
CEXP	C-weighted Sound Exposure Level (noise metric)
CFDR	Cockpit Flight Data Recorder
CLE	Cleveland Hopkins Airport
CNEL	Community Noise Equivalent Level (noise metric)
CO	Carbon monoxide
CO_2	Carbon dioxide
DAFIF	Defense Aeronautical Flight Information File
DDT	Departure Displacement Threshold
ºC	Degrees Celsius
ºF	Degrees Fahrenheit
Dep	Departure
DLR	Deutsche Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DNL	Day Night Average Sound Level (noise metric)
DOT	Department of Transportation

DRG	Design Review Group
DSA	Distributional Sensitivity Analysis
DTW	Detroit Metropolitan Wayne County Airport
ECAC	European Civil Aviation Conference
EDMS	Emissions and Dispersion Modeling System
EI	Emissions Index
EPNL	Effective Perceived Noise Level (noise metric)
ETFMS	Enhanced Traffic Flow Management System
ETMS	Enhanced Traffic Management System
EUROCONTROL	European Organization for the Safety of Air Navigation
FAA	Federal Aviation Administration
FCM	Fuel Consumption Model
FDR	Flight Data Recorder
FOA	First Order Approximation
FOQA	Flight Operational Quality Assurance
FPM	Flight Performance Model
ft	Feet (unit of distance)
GEOS	Goddard Earth Observing System
GIS	Geographic Information System
GS	Glide Slope
GSA	Global Sensitivity Analysis
H_2O	Water
HC	Hydrocarbons
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
in-Hg	Inches of Mercury (pressure units)
INM	Integrated Noise Model
IOAG	Interagency Operations Advisory Group
ISA	International Standard Atmosphere
kt(s)	Knots (measure of speed)
LAEQ	A-weighted sound exposure level (noise metric)
LAEQD	A-weighted sound exposure level — 15-hour (0700-2200) day average (noise metric)
LAEQN	A-weighted sound exposure level — 9-hour (2200-0700) night average (noise metric)
LAMAX	Maximum A-weighted sound level (noise metric)
LCMAX	Maximum C-weighted sound level (noise metric)
LSA	Local Sensitivity Analysis
LTO	Landing and Take-Off
MAGENTA	Model for Assessing Global Exposure Noise of Transport Airplanes
MCS	Monte Carlo Simulations
MDG	CAEP Modeling and Database Group (formerly MODTF)
MIT	Massachusetts Institute of Technology
MODTF	CAEP Modeling and Database Task Force
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration

NASR	National Airspace System Resources
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NEPA	National Environmental Policy Act
NEF	Noise Exposure Forecast (noise metric)
NENG	New England Medium Hub (Study Airport Designation)
NIRS	Noise Integrated Routing System
NJ	New Jersey
NM	Nautical Mile
NOAA	National Oceanic and Atmospheric Administration
NOx	Oxides of Nitrogen
NPD	Noise-Power-Distance (Noise vs. Power vs. Distance)
NY	New York
OAG	Official Airline Guide
OEM	Original Equipment Manufacturer
Pa	Pascal (Unit of Pressure)
PDARS	Performance Data Analysis and Reporting System
PHL	Philadelphia
PIANO	Project Interactive Analysis and Optimization by Lissys Limited
PM	Particulate Matter emissions
PNLTM	Maximum perceived tone-corrected noise level (noise metric)
PWC	Percent Wind Change
RUC	Rapid Update Cycle
SAGE	System for Assessing Aviation's Global Emissions
SEL	Sound Exposure Level (noise metric)
SN	Smoke Number
SOx	Oxides of sulfur
SO_2	Sulfur dioxide
TALA	Time (in seconds) that an A-weighted noise level is above a user-defined sound level (noise metric)
TALC	Time (in seconds) that a C-weighted noise level is above a user-defined sound level (noise metric)
TAPNL	Time (in seconds) that a tone-corrected noise level is above a user-defined sound level (noise metric)
TCH	Threshold Crossing Height
THC	Total Hydrocarbons
TIGER	Topologically Integrated Geographic Encoding and Referencing system
TSFC	Thrust Specific Fuel Consumption
TSI	Total Sensitivity Index
U.K.	United Kingdom
U.S.	United States of America
V&V	Verification and Validation
WECPNL	Weighted Equivalent Continuous Perceived Noise Level (noise metric)
WEST	Mountain Medium Hub (Study Airport Designation)

1 Introduction

This report documents the Federal Aviation Administration's (FAA) uncertainty quantification (UQ) effort for the Aviation Environmental Design Tool Version 2b (AEDT 2b). The intent of this documentation is to inform and educate the user regarding the methodologies used in AEDT 2b, as well as the thorough expert review, verification, validation, capability demonstration, parametric uncertainty/sensitivity analysis and other relevant testing that went into the development of AEDT 2b.

AEDT is a software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality consequences. This software, developed by the FAA Office of Environment and Energy (AEE) for public release, is the next generation FAA environmental consequence tool. AEDT satisfies the need to consider the interdependencies between aircraft-related fuel consumption, emissions, and noise.

AEDT was released in two phases. The inaugural version, AEDT 2a, was released in March 2012 and replaced the Noise Integrated Routing System (NIRS) as the official FAA compliance tool for modeling aircraft noise, emissions, and fuel burn for air traffic airspace and procedural actions. The second version, AEDT 2b, was released in May 2015. In addition to the capabilities of AEDT 2a, AEDT 2b replaced the following aviation air quality and noise analysis tools: the Emissions and Dispersion Modeling System (EDMS – single airport emissions analysis) and the Integrated Noise Model (INM – single airport noise analysis).

In extension of the AEDT 2a UQ efforts, UQ was performed in order to assess the accuracy, functionality, and capabilities of AEDT 2b during the development process. The major purposes of this UQ effort were to:

- Contribute to the external understanding of AEDT 2b
- Build confidence in AEDT 2b's capability and fidelity (ability to represent reality)
- Help users of AEDT 2b to understand sensitivities of output response to variation in input parameters/assumptions
- Identify gaps in functionality
- Identify high-priority areas for further research and development

The UQ consists of the following elements:

Expert Review – FAA AEE has actively encouraged the input of academia, government agencies, and industry to guide the methodologies, algorithms, and processes implemented in the AEDT 2b software. As a result, key expert organizations have reviewed AEDT 2b throughout its entire development cycle.

Use Case Evaluation – Since AEDT 2b replaces legacy software tools (e.g., INM, EDMS, and AEDT 2a), each Use Case was designed as a verification/validation of the capability of AEDT 2b. Within the Use Case, all of the relevant functionality specific to a given algorithm was evaluated to determine if it functioned as intended. Each Use Case conducted verification and validation by evaluating against the associated legacy tool in order to compare results with previous modeling approaches. Although an exact match of analysis results is not expected, due to improvements in algorithms implemented in AEDT 2b, this comparison provides confidence that AEDT 2b is accurate and complete.

The Use Cases were also used to verify that AEDT 2b is suitable for analysis of compliance with the National Environmental Policy Act (NEPA) and other applicable laws and regulations. This was achieved by conducting analyses with AEDT 2b using sample problems based upon previous FAA airspace and other NEPA analyses. The results obtained using AEDT 2b were compared with results from legacy tools.

- Use Case A – Inventory Analysis: An analysis of AEDT 2b's ability to mirror the functionality in the Noise and Emissions Analysis Tool (NEAT)
- Use Case B & C – NEPA/CAA Analysis: A comparison of AEDT 2b to EDMS when conducting an analysis associated with NEPA and Clean Air Act (CAA)
- Use Case D – Part 150 Analysis: An analysis of AEDT 2b's ability to perform a Part 150 airport noise analysis as well as test other aircraft noise modeling functionality in a comparison to INM
- Use Case E – Part 1: Air Traffic Airspace and Procedure Analysis: An analysis of AEDT 2b's ability to perform noise impact, fuel consumption, CO_2 production, and emissions calculations in the regional airspace context in a comparison to AEDT 2a
- Use Case E – Part 2: Airspace Redesign Environmental Analyses: An analysis of AEDT 2b's ability to perform an airspace re-design environmental analysis in a comparison to AEDT 2a
- Use Case F – Full Functionality Capability Demonstration (a Single Study to present that all the functionalities are working together)

<u>Parametric Uncertainty and Sensitivity Analysis</u> – The parametric uncertainty/sensitivity analysis strives to quantify and identify how the algorithms and methodologies of AEDT 2b respond to variations in input. Global sensitivity analyses (GSA) were used to assess how changes to inputs contribute to output variability. Large scale Monte Carlo Simulations (MCS) were used to conduct these GSAs. These results serve to inform the user as to the expected variation and to focus and inform future tool development and refinement.

2 Expert Review

2.1 Definition and Purpose

The FAA's Office of Environment and Energy has actively encouraged the input of academia, government agencies, and industry to guide the methodologies, algorithms, and processes implemented in the AEDT 2b software. This effort built on the AEDT 2a expert review with several key organizations conducted reviews of AEDT 2b's technical components and practical usability throughout its entire development cycle. The next sections discuss the AEDT 2b Design Review Group (DRG) process and how participants provided feedback that influenced model development and capabilities. Section 2.2.2 details the stakeholder user experience engagement during initial AEDT 2b development and how it shaped design and implementation choices.

2.2 AEDT 2b Design Review Group (DRG)

2.2.1 Description of Group

Similar to AEDT 2a, the AEDT 2b DRG had a wide range of future AEDT users and stakeholders from government, private companies, and academic institutions in the Unites States and internationally. The AEDT 2b DRG started with a small group who provided the development team with detailed feedback on the user experience of AEDT 2a and expectations and desired for AEDT 2b. These input informed design decisions and helped refine and prioritize development requirements. Once AEDT 2b reached completed initial functionality, but while ongoing functionality was added, a wider DRG interaction was conducted. The DRG provided additional testing, detailed presentations of use case analyses and feedback on functionality implementation.

2.2.2 Role DRG Played in AEDT 2b Development

The DRG played two main roles in AEDT 2b development: improving the user experience through interaction with AEDT users and to validate AEDT through external user analysis and testing. These interactions provided a validation of the system requirements and a benchmark for user interaction with AEDT while fostering connection with the future AEDT 2b users.

User experience input started in 2012 with a small group of stakeholders. Additional follow up rounds of discussion took place in 2013 as AEDT 2b development progressed and initial design decisions completed. The driving question topic areas were: goals and value chain, daily tasks, comfort level - domain and technology, which tools and processes are used, challenges and frustrations, and opportunities. Information on these question topic areas were captured across the following eight personas or stakeholder group types:

- ➢ NEPA/CAA—Organization or client that must satisfy National Environmental Policy Act (NEPA)/ Clean Air Act (CAA) regulatory report preparation requirements.
- ➢ 14 CFR Part 150/161—Organization or client that must satisfy CFR Part 150 Airport Compatibility Planning or Part 161 Notice and Approval of Airport Noise and Access Restrictions regulatory requirements.

- Inventory—Organization or client that conducts national or global analyses, typically per annum.
- OAPM—Organization or client that conforms to the Optimization of Airspace and Procedures (OAPM) in the Metroplex initiative.
- PBN Procedures—Organization or client that conducts NextGen analyses for Performance Based Navigation (PBN) programs.
- NAS-wide Benefits—Organization or client that conducts analyses to model benefits National Air Space (NAS)-wide scenarios or programs.
- Aircraft Technology—Organization or client that conducts NextGen analyses to model new and upcoming aircraft technologies.
- Uncertainty Quantification—Organization or client that seeks to quantify the uncertainty in environmental consequence modeling.

Interviews with private industry, government and academia across the user types provided a range of response which informed prioritizing of requirements into three levels from nice to have to absolute. Additionally user preferences on how features should work were incorporated into product development workflows. The end result of the initial and follow up interviews were a comprehensive list of requirements, prioritization of development effort and understanding of user process with existing tools and preferences for AEDT 2b usability.

During AEDT 2b development the team followed an Agile software development process where a new version of AEDT was produced every three weeks. This new version was a fully built software package including an installer which the development team would test and validate though internal automated and manual tests. As such the internal development team stakeholders used development versions for analysis and further validation.

The Agile software development process was further used to conduct a more formal DRG process similar to AEDT 2a. This effort started in December of 2014 with a kickoff meeting. Sixty-eight stakeholders were invited to participate across the eight user experience types discussed previously from government, private industry and academia. During the kickoff meeting the DRG feedback process was explained along with exercises for the users to complete. The users were expected to complete a mandatory study in approximately one month and provided an optional study for further feedback. The studies focused on key AEDT 2b workflows which the development team wanted to validate and get feedback. If the users provided feedback to the mandatory study they would receive another software release in February of 2015 which contained further functionality. The users who participated in this second phase of the AEDT 2b DRG were then requested to use AEDT 2b for sample analysis along their typical business case and provide feedback.

The feedback received was collected on by the AEDT development team and prioritized based on design suggestions, functionality improvements and software bugs or issues which made the tool difficult to use. This feedback was incorporated into the development process and addressed in a prioritized order for the eventual release of AEDT later in 2015.

2.3 Expert Review Conclusions

Expert review throughout the development of AEDT has proved extremely valuable in enhancing the quality of the resulting tool. Publications by SAE A-21, ECAC, and ICAO CAEP have provided a strong basis for the modeling methods built into AEDT. Testing and validation work by the DRG and the CAEP MODTF/MDG drove continuous improvement throughout the development process to the final product. Engagement with expert review groups will continue as new methodologies and AEDT versions are brought forward for review.

3 Use Case A – Inventory Analysis

3.1 Description of Use Case

The goal of this use case is to investigate the capability of the AEDT 2b application to replicate the functionality in the Noise and Emissions Analysis Tool (NEAT). The requirements of AEDT 2a focused on the local and regional aspects of aircraft environmental modeling; that version was meant for analysis involving less than five airports (for this reason, Use Case A does not provide a comparison to AEDT 2a). NEAT was created to provide a way for large scale analyses to be conducted using AEDT modules and databases, in place of AEDT 2a. NEAT was created for the purpose of supporting ICAO CAEP's aircraft environmental certification standard development processes and therefore was not made available to the public. These large scale analyses typically came from two sources: 1) historical flight operations, which are estimated to track and review the evolution and environmental impact in the past[8], and 2) forecasted scenarios of future flight operations and how various technological enhancements / restrictions may impact the environment over time. Both of these analyses require detailed flight level fuel burn and emissions results, for every flight operation worldwide, for a given year. Thus, NEAT was required to compute noise, fuel consumption, and emissions results from tens of millions of flights.

A key requirement of AEDT 2b was to sunset two legacy models: the System for Assessing Aviation Global Emissions (SAGE)[8], and the Model for Assessing Global Exposure to the Noise of Transport Aircraft (MAGENTA)[9]. SAGE was developed to provide global inventories of fuel consumption and emissions for the entire operating condition of all flights worldwide; MAGENTA produced the contour area and population exposed to certain levels of aircraft noise for departure and arrival procedures (flight operations below 10,000 ft. Above Field Elevation, AFE). SAGE relied on external data to model aircraft operations; conversely, MAGENTA only required flight operation counts and used detailed ground track procedures obtained directly from airport authorities to determine the ground path of departure / arrival procedures. MAGENTA was designed to estimate the noise contour area and population exposed to Day-Night Average Sound Levels (DNL). Similar to SAGE, Use Case A relies on external data to provide fuel consumption / emissions estimates; the detailed ground track procedures from MAGENTA were incorporated for noise evaluations.

Global inventory-level analyses are composed of three parts:

1) the conversion of a variety of input data sources, including aircraft type and movements, as well as airport data, into a usable format for the analysis software (for instance, converting disparate schedule data into a single, cohesive movements database);
2) the computation of the desired results by the analysis software; and
3) the accumulation of the output from the analysis software into the desired metric(s).

The final two steps have been implemented as four core computational modules in the AEDT system (NEAT and AEDT 2b):

- Aircraft Performance (APM),
- Aircraft Emissions (AEM),

- Aircraft Acoustics (AAM), and
- Accumulated Metrics (AMM).

A high level schematic of the AEDT inventory process is shown in Figure 3-1. AEDT inventory processing is a data-driven, modular implementation with three primary input data sets (FLDB, APDB, MVDB), four core computational modules (APM, AEM, AAM, AMM), and a relationally linked output database of environmental consequence metrics.

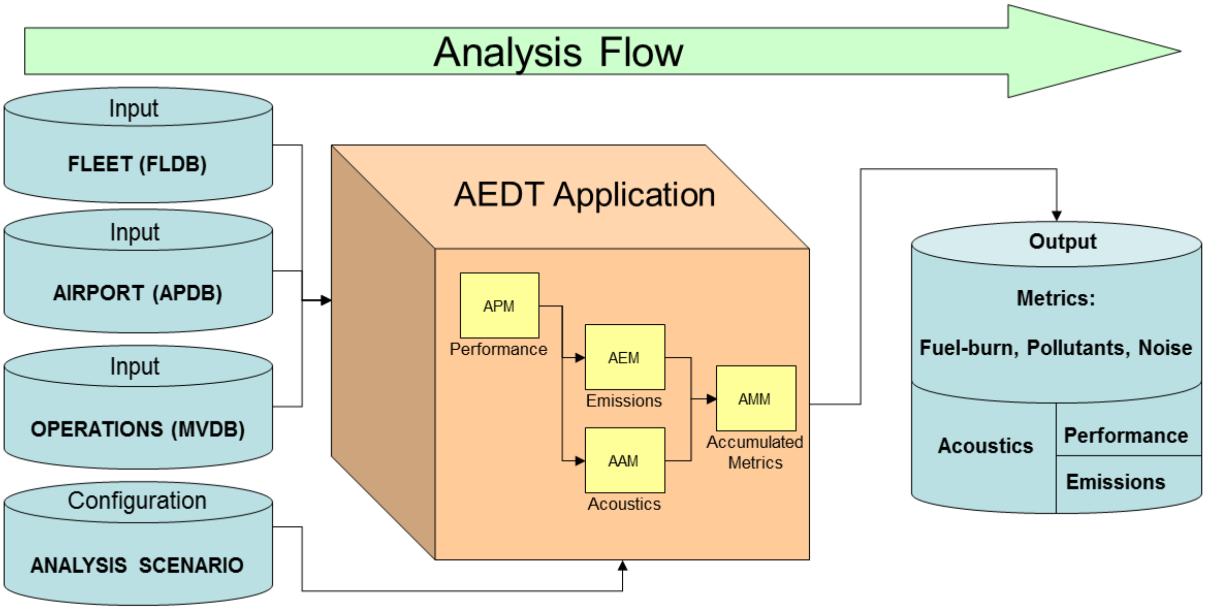


Figure 3-1. AEDT Inventory Process

Four internationally vetted algorithms were incorporated into the APM, AEM, AAM, and AMM, representing best-practice models and implemented in the AEDT computational modules. Specifically, the Society of Automotive Engineers (SAE) AIR-1845[10] method for computing performance and noise of aircraft operating in the vicinity of airports, i.e. the terminal area, was taken from the legacy INM[11]. The BFFM2[12]- adopted by ICAO CAEP for computing CO, HC, and NOx pollutants, and the EUROCONTROL Base of Aircraft Data (BADA)[13]- for computing aircraft performance above 10,000 ft AFE, were adopted from SAGE. Finally, the residual methods from European Civil Aviation Conference (ECAC) Doc-29, not already covered in SAE-AIR-1845, were adopted from MAGENTA[9], for computing noise around civil airports. This reconciled AIR-1845/Doc-29 aircraft model is henceforth referred to as an ANP model[14].

These models are mapped to specific implementations of the four AEDT computational modules as follows:

- APM: BADA, ANP (performance portion), and Flight Path Performance Module (FPPM) algorithms
- AEM: BFFM2 algorithms
- AAM: ANP (acoustic propagation portion)
- AMM: ANP (metric accumulation portion)

For this use case, fuel burn was accumulated as total fuel consumption. The AMM was not invoked.

One of the stated objectives of AEDT 2b was to allow such large scale analyses to be conducted within the application, allowing the sunset of NEAT. As NEAT was composed of AEDT modules and databases, it was expected that the data-driven results would not change substantially (as both 2b and NEATuse the APM, for instance). Use Case A explores any potential changes in results between NEAT and AEDT 2b, as well as the feasibility of performing these large-scale analyses in AEDT 2b.

3.1.1 Study Overview

Study preparation falls outside of the scope of this Use Case A, but nonetheless is important in its execution. An inventory-like study has three important components: fleet (detailed, aircraft-specific information); airports; and movements (schedule as well as trajectory information for all flights being considered).

Fleet: The first step in preparing flights to be modeled is to assign codes for the BADA, ANP, and ICAO engine identifiers on each operation. The Fleet Database (FLDB) provides mappings from the two external standards for aircraft specification, namely ICAO aircraft type and International Air Transport Association (IATA) aircraft type, which are coarse descriptions of the equipment being used. These mappings can be augmented with proportional distributions- where the operator (airline) is known, or directly assigned- where a registration number is known. In the former case, the analyst has discretion on whether to spread the operation across all suitable mappings or make a weighted random draw.

Airports: The second step is to confirm the departure and arrival airport codes with the Airport Database (APDB). Departure and arrival times can be provided in either UTC or local time, as the information necessary for conversion is maintained in the APDB. In situations where increased fidelity is desired in the terminal area, flight tracks (including altitude and speed controls) with grouped aircraft distribution assignments can be created following the ANP track protocol and stored in the APDB database. Where desired, operations can then be attached to these tracks to increase the fidelity of the environmental result.

Movements: The final step is to merge all input sources of movement data into one cohesive Movements Database (MVDB), incorporating aircraft-specific information from the FLDB and airport-specific information from the APDB. The Use Case A study only relied on the Enhanced Traffic Management System (ETMS) for schedule and 4-dimensional trajectory information. The FAA developed ETMS to monitor and report airborne congestion and delay. ETMS records the full path of an aircraft flight from the departure to arrival airport within North America. As ETMS provides all required data for Use Case A, no other external data sources were utilized.

3.2 Description of Testing

The test dataset for this use case was a subset of an historical US inventory of aviation's environmental impact: a single month of flights (October 2012), US-based (departing from the US, to observe fuel consumption and emissions), and the 94 airports present in MAGENTA with departures/arrivals from the entire 2012 year (to observe noise). The flight data came from ETMS, including schedule and radar-based 4-dimensional flight trajectories, and consisted of three million flights. These flights were imported into an AEDT 2b study by two different methods: 1) directly as air operations with the radar-based trajectories converted into sensor paths; and 2) as annualized departure/arrival operations (represented as air operations), with the ground-based track procedures imported from MAGENTA.

AEDT 2b results were expected to resemble (and potentially improve on) NEAT in terms of: runtime, total fuel consumption for the month, as well as contour area associated with the DNL 55, 60, and 65 dB value. Runtime was predicted to be relatively close, as the underlying architecture of how aircraft performance and emissions / noise remained consistent between NEAT and AEDT 2b. However, as NEAT implemented AEDT components and processes that were still in active development in the AEDT 2b effort, it was expected that fuel consumption, emissions, and noise results would change. The implementation of BADA 3 inside of AEDT 2b was being reviewed; assumptions on how certain BADA 3 equations and practices during the descent portion of flight were implemented in AEDT were changed. Additionally, source data in the FLDB were being updated with the addition of new aircraft data from ANP. However, the transition from NEAT to AEDT 2b is merely a transition of a pathway from source and input data through AEDT processes, and thus the use of an actual application (NEAT or AEDT 2b) was not expected to produce significant differences. Any significant fuel consumption, emissions, or noise differences identified would be tracked back to specific changes in AEDT computations.

The size and runtime requirements of this data set prohibit it from being included as a standard test data set. Rather, this data set can be used as a reference check in the future versions of AEDT.

3.3 Outcomes/Results of Testing

The first issue in running the test data set through the AEDT 2b application was invoking the APM properly. In NEAT (and the legacy SAGE tool) all flights were forced to fly SAE-AIR-1845 standard procedures in the terminal area (below 10,000 ft AFE). When inputting a sensor path trajectory into the AEDT 2b application, the APM uses radar data for the entire flight (including terminal area). This created three problems: 1) significant gaps in the input data (in the terminal area) resulted in a large number of flights being discarded; 2) non-standard procedures in the terminal area (i.e., non-1845) caused a significant rise in fuel burn; and 3) a significant increase in runtime. While it could ultimately be advantageous to rely on actual radar data in the terminal area, the Use Case A scope was limited to replicating NEAT functionality. Thus, it became necessary to run the APM in a similar fashion to how it ran in NEAT: forcing 1845 profiles in the terminal area. To achieve this, a new operation type (gate-to-gate) was added to the air operation table for the APM.

The second issue discovered during Use Case A was the understanding and implementation of 1845 profiles in the APM and AAM. The 1845 documentation specifies altitude, ground distance covered, and thrust values for several points along a departure / arrival procedure. In INM these points were interpreted as sample points along the trajectory of the flight: the thrust value along a segment was defined as a linear relationship between 1845-specified values. A later clarification of 1845 determined that thrust values are meant to be interpreted as step thrust values: each thrust value at a point should be interpreted as the thrust value for the subsequent flight segment.

The AEDT 2b application then provided both approaches: the legacy INM linear interpolation method, and the step thrust approach. For Use Case A, the legacy INM approach was invoked.

The final issue was extracting results. Due to the sheer number of flights (3 million flights modeled for fuel consumption / emission results, and 94 airports for noise), it would have been impractical to interact with the results using the GUI. Specific flights (and groups of flights) need to be queried in a SQL environment, and the contour area data must be stored for nearly 100 airports. Thus, the study was run to store fuel consumption and emissions data to the RSLT_EMISSIONS_SEGMENT table and extract the contours from the GUI. All results could then be queried.

In the end, on a comparable development workstation, the one month study took 60 hours to complete (as compared to 72 hours for NEAT, a notable runtime benefit), and 59 minutes for the noise efforts (nearly identical to NEAT runtime).

The total fuel burn for the month increased by 0.83%. This change in fuel consumption was attributed to a change in the APM: in previous versions of the APM, BADA 3 descent fuel flow equations were assigned to all portions of the flight during en-route descent. In the current version of the APM (and the APM invoked in this user study), these descent equations are only enforced as minimum fuel flow values; BADA performance equations are instead used to determine fuel flow. For instance, it is common for a flight to experience a steady-state hold or cruise segment at some point during descent; in the previous APM, fuel burn for this segment was calculated using descent values; in the current APM, this segment is correctly calculated as a steady-level flight segment. As a result of this change in the APM, a slight rise in fuel burn was observed between NEAT and AEDT 2b. No discernable increase nor decrease in fuel consumption could be attributed to the change from NEAT to AEDT 2b (outside of changes in the APM).

The noise contours were well aligned between NEAT and AEDT 2b. Table 3-1 provides the difference in contour area for the DNL 55, 60, and 65 dB levels.

Table 3-1. Changes in Contour Area

DNL Value	Differences in Contour Area
55 dB	0.9%
60 dB	1.1%
65 dB	1.2%

3.4 Conclusions

The objective of Use Case A was to verify that the results from AEDT 2b and NEAT were comparable and that AEDT 2b has the ability to perform a large scale analysis.

AEDT 2b was used to perform a large scale analysis consisting of approximately three million flights, and its runtime, fuel consumption, and noise contour areas closely matched NEAT results. Slight difference in fuel burn is explained by a change in the APM.

4 Use Case B and C– NEPA/CAA Analysis

4.1 Description of Use Case B and C

The purpose of Use Cases B and C is to provide verification and validation AEDT 2b functionality and a comparison of AEDT 2b to the Emissions and Dispersion Modeling System (EDMS) when conducting an analysis associated with the National Environmental Policy Act (NEPA) and Clean Air Act (CAA).

The V&V efforts consist of two components. The first component, Use Case B, is to ensure that AEDT 2b operates as intended when executing its functionality. The second component, Use Case C, is to ensure that AEDT 2b is able to fully execute an emissions inventory and air quality dispersion analysis. The comparison of AEDT 2b to EDMS serves as a validation exercise to ensure that the results of the AEDT 2b fuel burn, emissions inventory, and air quality dispersion analysis are reasonably comparable to the legacy tool. It is not expected that the AEDT 2b emissions inventory and air quality dispersion results will be exactly the same as those produced by EDMS. A discussion of the main causes of observed differences is discussed in Section 4.4.

Use Cases B and C utilize a single airport study for testing the AEDT 2b functionality and comparing the fuel burn, emissions inventory, and air quality dispersion results to EDMS. The difference between the two Use Cases is how aircraft activity is modeled. Use Case B utilizes operational profiles, which distribute aircraft operations on quarter hourly, daily, and monthly basis. A detailed schedule of aircraft operations is utilized for Use Case C.

In conducting the modeling for Use Cases B and C, different release versions of AEDT 2b were utilized as computational bugs were identified during modeling. As bug fixes were implemented to address functionality required to conduct each Use Case analysis, the version of AEDT 2b was fixed for that specific Use Case. In addition, in this UQ study Use Case B&C were used as the test cases to verify if the bugs were successfully fixed. Table 4-1 lists the AEDT 2b versions utilized for each Use Case. The testing of Use Case B began using AEDT 2b. During testing, it was discovered that the distribution of flights associated with the operational profiles functionality was not working properly in AEDT 2b. This issue was resolved in AEDT 2b Service Pack 2 (SP2), and the Use Case B was re-run using AEDT 2b SP2. Use Case C was run with a modified version of AEDT 2b Service Pack 1.

Table 4-1. AEDT 2b Versions Used in Use Cases B and C

	AEDT 2b Version	EDMS Version
Use Case B	Service Pack 2 62.3.43546.1	5.1.4.1
Use Case C	Service Pack 1 62.3.43302.1	

4.2 Description of Testing

4.2.1 Airport Study Overview

Use Cases B and C compare the fuel burn, emissions inventory, and dispersion functionality in AEDT 2b to EDMS through the comparison emissions inventory analysis, and air quality dispersion analysis for carbon monoxide (CO), nitrogen oxides (NOx) and Particulate Matter 2.5 ($PM_{2.5}$).

The studies used for both Use Cases B and C consist of 117,856 operations which equate to a single year of departures and arrivals operating at T.F. Green Airport (PVD). Both Use Case B and C studies consist of 85 unique airframe-engine combinations and 14 stationary sources (Table A-1). AEDT 2b studies for Use Cases B and C were converted from EDMS studies using the EDMS to ASIF converter, a tool internal to AEDT 2b. Table 4-2 lists the study properties of the PVD airport study utilized for Use Cases B and C in both AEDT 2b and EDMS. Among them, FOA3a properties were utilized because EDMS uses FOA 3a method to calculate PM and thus FOA 3a was selected to be used by AEDT as well for an apple-to-apple comparison. As part of the functionality testing of AEDT 2b, the study properties were checked to ensure that the Use Case B and C EDMS studies retained the same study properties after being imported into AEDT 2b.

Table 4-2. PVD Study Properties of Use Cases B and C

Study Properties	Use Cases B and C
# of Operations	117,856
# of Aircraft/Engine Combos	85
# of Stationary Sources	14
Mixing Height	2,226 feet
# of Runways	2
# of Taxiways	47
# of Buildings	1
# of Discrete Cartesian Receptors	38
FOA 3.0a Sulfur-to-Sulfate Conversion Rate	.05
FOA 3.0a Fuel Sulfur Content	.00068

Figure 4-1 displays the airport layout for PVD in an EDMS study, and Figure 4-2 displays the airport layout for PVD in an AEDT 2b study, including the location of gates, stationary sources, taxiways, runways, and receptors. The EDMS Use Case B and C studies were imported into AEDT 2b correctly and were confirmed to be identical.

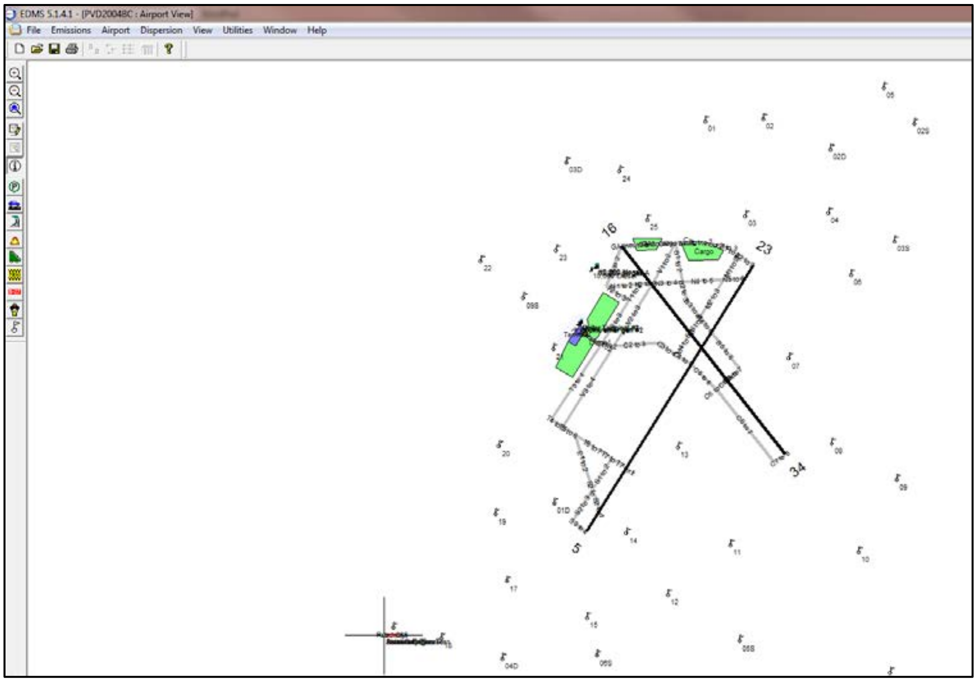


Figure 4-1. EDMS PVD Airport Layout for Use Case B and C

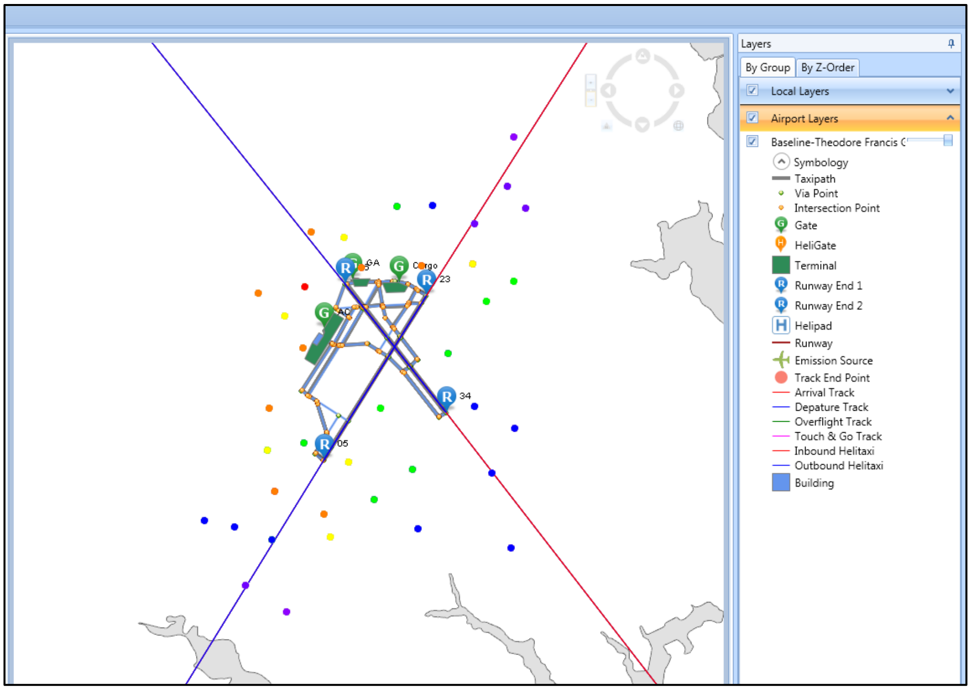


Figure 4-2. AEDT PVD Airport Layout for Use Case B and C

4.2.2 Study Input Parameters

The airport study input parameters are common for both Use Case B and Use Case C. As previously mentioned, the primary difference between the two use cases is that Use Case B utilizes operational profiles to distribute aircraft operations throughout a single year on a quarter hourly, daily, and monthly basis. Use Case C utilizes a detailed schedule for which each aircraft operation is assigned a specific date and time. The following parameters are associated with Use Cases B and C:

- Aircraft Sources
- Auxiliary Power Units (APUs)
- Ground Support Equipment (GSE)
- Stationary Sources
- Gates and Buildings
- Operational Profiles
    - Aircraft (Use Case B only)
    - GSE
    - APU
- Configuration
- Receptors

Each input parameter listed above has underlying functionality associated with it and is compared between AEDT 2b and EDMS to ensure consistency in each study.

4.2.2.1 Aircraft Sources

Table A-1 lists each unique aircraft utilized for Uses Cases B and C. The ACCODE (Aircraft model identification code) and Engine Code columns exist in EDMS database files as ACCODE and Engine UID (ICAO engine code), respectively. ACCODE ties an EDMS aircraft to an Airframe ID in AEDT 2b, and Engine UID ties an EDMS engine to an AEDT 2b Engine ID through the Engine Code column in AEDT 2b.

The Aircraft ID column is specific to each AEDT 2b study and is used to assign an Equipment ID to each operation in that study. An Equipment ID in AEDT 2b defines a combination of aircraft, engine, and engine modification, and is the value required to assign a unique airframe and engine directly to an operation in an AEDT 2b study. The Description column provides a more detailed definition of the airframes and engines.

4.2.2.2 APUs

Table 4-3 lists the APUs for Use Cases B and C. In EDMS and AEDT 2b, APUs are assigned directly to an aircraft and engine combination, and emissions are calculated based on an assigned duration of operation during departures and arrivals. Though most units were used in both cases, APU equipment assignments were specific to each Use Case.

Table 4-3. List of APUs for Use Cases B and C

AEDT APU ID	APU Name	Use Case
1	APU 131-9	B and C
6	APU GTCP 36 (80HP)	B and C
7	APU GTCP 36-100	B and C
8	APU GTCP 36-150[]	B and C
9	APU GTCP 36-150[RR]	B and C
10	APU GTCP 36-300 (80HP)	B and C
11	APU GTCP 36-4A	C
13	APU GTCP 85 (200 HP)	B and C
17	APU GTCP331-200ER (143 HP)	B and C
20	APU GTCP85-129 (200 HP)	B and C
21	APU GTCP85-98 (200 HP)	B and C

4.2.2.3 GSE

Table 4-4 lists the GSE modeled in Use Case B. There is no GSE activity in Use Case C, as GSE were not included with the detailed schedule data. All GSE activity in Use Case B is associated with either a landing or takeoff aircraft operation in the study. The Source Name provides a description of each GSE and includes the type of fuel consumed by that unit. The Default Horsepower column in Table 4-4 defines the default rated horsepower for the engine of the associated GSE. The Default Load Factor is the ratio of the default average operational horsepower output of a GSE engine to its rated brake horse power. Default Usage Per Year, also in Table 4-4, is the number of hours in a year that one unit of the associated GSE operates.

Table 4-4. List of GSE for Use Case Base B

GSE ID	Source Name	Default Horsepower	Default Load Factor	Default Usage Per Year
8	Diesel - Stewart & Stevenson TUG GT-35, Douglas TBL-180 - Aircraft Tractor	88	0.8	800
10	Diesel - Stewart & Stevenson TUG GT-50H - Aircraft Tractor	190	0.8	628
11	Diesel - Stewart & Stevenson TUG MC - Aircraft Tractor	86	0.8	800
13	Gasoline - Stewart & Stevenson TUG MA 50 - Baggage Tractor	107	0.55	1500
14	Diesel - Stewart & Stevenson TUG 660 - Belt Loader	71	0.5	1300
14	Gasoline - Stewart & Stevenson TUG 660 - Belt Loader	107	0.5	1300
17	Diesel - Hi-Way F650 - Cabin Service Truck	210	0.53	1600
21	Gasoline - Taylor Dunn - Cart	25	0.5	100

GSE ID	Source Name	Default Horsepower	Default Load Factor	Default Usage Per Year
29	Diesel - F750, Dukes Transportation Services, DART 3000 to 6000 gallon - Fuel Truck	175	0.25	564
30	Diesel - (None specified. EPA default data used.) - Generator	158	0.82	1630
32	Diesel - TLD, 28 VDC - Ground Power Unit	71	0.75	1600
31	Gasoline - TLD - Ground Power Unit	107	0.75	1600
35	Diesel - F250 / F350 - Hydrant Truck	235	0.7	1527
36	Diesel - TLD 1410 - Lavatory Truck	56	0.25	1492
38	Diesel - (None specified. EPA default data used.) - Lift	115	0.5	341
39	Diesel - (None specified. EPA default data used.) - Other	140	0.5	1646
41	Diesel - F250 / F350 - Service Truck	235	0.2	840

4.2.2.4 Stationary Sources

Table 4-5 lists the Stationary sources for Use Cases B and C. Stationary Source ID is a column in the AEDT 2b study database that defines the Category ID and Category Name for each source. The Stationary Source Name column defines each source as it was designated in the EDMS studies for Use Cases B and C.

Table 4-5. List of Stationary Sources for Use Cases B and C

Stationary Source ID	Category ID	Category Name	Stationary Source Name
323	1	Boiler/Space Heater	Boiler Terminal #1
324	1	Boiler/Space Heater	Boiler Terminal #2
320	2	Emergency Generator	600kw Emergency Generator #1
321	2	Emergency Generator	600kw Emergency Generator #2
326	3	Incinerator	Incinerator
322	4	Aircraft Engine Testing	Aircraft Engine Test
319	5	Fuel Tank	10,000 Avgas
316	5	Fuel Tank	10,000 Diesel
318	5	Fuel Tank	10,000 Mogas
317	5	Fuel Tank	50,000 gal. Jet A
329	6	Surface Coating/Painting	Surface Coating
325	7	Deicing Area	Deice1
328	8	Solvent Degreaser	Solvent Degreaser
327	9	Sand/Salt Pile	Sand/Salt Piles

4.2.2.5 Gates and Buildings

Table 4-6 contains the names and locations of the gates at PVD that are used in Use Cases B and C. The studies for Use Cases B and C contain a single building at PVD. Table 4-6 contains three points of location numbered in sequence that define a traversal around the building.

Table 4-6. List of Gates for Use Cases B and C

Gate ID	Gate Name	Latitude	Longitude	Elevation (m)	Release Height (m)
1	AC	41.7435012896053	-71.4115157955542	55	4.92
2	Cargo	41.7481481948087	-71.4015361860266	55	4.92
3	GA	41.7484842656246	-71.407729066794	55	4.92

4.2.2.6 Operational Profiles

Table A-2 lists the quarter hour operational profiles for Use Cases B. It is important to note that operational profiles for aircraft operations are only applied in Use Case B, as aircraft operations in Use Case C are schedule based. However, the same operational profiles are used for non-aircraft sources, such as GSE and APU, for both Use Case B and C. Table A-3 lists the daily operational profiles for Use Cases B and C. Table A-4 lists the monthly operational profiles for Use Cases B and C. All operational profiles (i.e., quarter-hour, daily, and monthly) are the same for both AEDT 2b and EDMS studies.

4.2.2.7 Airport Configuration

The airport configuration controls the airport capacity, i.e., the number of arrivals or departures that can occur in a single hour as the distribution of aircraft to specific runways. Table 4-7 lists the airport capacity for each gate, and Table 4-8 lists the airport runway configuration associated with the Use Case B and C airport study.

Table 4-7. Airport Capacity

Gate ID	Departures per Hour	Arrivals per Hour
1	27	52
2	52	27
3	52	27

Table 4-8. Airport Runway Configuration

Aircraft Size	Runway Name	AEDT Runway End ID	Arrival Weight	Departure Weight	Touch and Go Weight
S	16	3000002	0.0080	0.0132	0.0000
S	23	3000001	0.5074	0.5233	0.5000
S	34	3000003	0.1304	0.0806	0.1500
S	5	3000000	0.3542	0.3829	0.3500
L	16	3000002	0.0080	0.0132	0.0000

Aircraft Size	Runway Name	AEDT Runway End ID	Arrival Weight	Departure Weight	Touch and Go Weight
L	23	3000001	0.5074	0.5233	0.5000
L	34	3000003	0.1304	0.0806	0.1500
L	5	3000000	0.3542	0.3829	0.3500
H	16	3000002	0.0080	0.0132	0.0000
H	23	3000001	0.5074	0.5233	0.5000
H	34	3000003	0.1304	0.0806	0.1500
H	5	3000000	0.3542	0.3829	0.3500

4.2.2.8 Receptors

Table A-5 contains the ID and locations of the receptors (i.e., latitude/Longitude for AEDT 2b and local coordinates for EDMS) for modeling air quality dispersion in Use Cases B and C.

4.3 Results

4.3.1 Emissions Inventory Utilizing Average Annual Weather

Table 4-9 and Table 4-10 list the AEDT 2b and EDMS emissions inventory results from Use Cases B and C, respectively, using average annual weather defined within each model. Inventories are presented for each emissions source as inventory types and are accumulated as total emissions from all sources at PVD. For each inventory type and for accumulated results, the percent difference between AEDT 2b and EDMS is calculated as the percent increase or decrease of the AEDT 2b result compared to the EDMS result. AEDT 2b results are discussed in the following sections as an increase or decrease relative to the EDMS results. The causes to the difference in emission inventory between AEDT and EDMS will be further investigated in Section 4.4. Emissions inventory results are provided for aircraft activity related to all parts of departure and arrival operations occurring below the study's mixing height. The emissions inventory data related to starting aircraft engines are reported as a separate source, as are APU, GSE, and stationary source emissions.

4.3.1.1 Use Case B

Table 4-9 shows that in the category of aircraft emissions, fuel consumption, CO_2, H_2O, and SOx, emissions are 14% higher for AEDT 2b compared to EDMS. The difference in these metrics is expected to be the same since CO_2, H_2O, and SOx aircraft emissions are calculated as factors of fuel consumed. NOx emissions are 15% higher in AEDT 2b, as compared to EDMS for aircraft emissions. Emissions of HC, TOC, VOC, and NMHC from aircraft are 3% lower for AEDT 2b, as compared to EDMS. Aircraft emissions of PMNV, PMSO, and PMFO from AEDT 2b are lower by 22%, 17%, and 26%, respectively, as compared to EDMS. $PM_{2.5}$ and PM_{10} both are 19% lower for AEDT 2b, as compared to EDMS. The difference in emission inventory between AEDT and EDMS will be further investigated and discussed in Section 4.4. There are virtually no differences in the overall emissions inventory for APUs, aircraft engine start-up, GSE, and stationary sources between AEDT 2b and EDMS.

Table 4-9. Use Case B Emissions Inventory from AEDT 2b and EDMS Utilizing Average Annual Weather

Inventory Type	Model	Fuel (kg)	CO2 (kg)	CO (kg)	NOx (kg)	PM 2.5 (kg)	PM 10 (kg)	SOx (kg)	H2O (kg)	HC (kg)	TOC (kg)	VOC (kg)	NMHC (kg)	PMNV (kg)	PMSO (kg)	PMFO (kg)
Aircraft	AEDT	19,256,812	60,755,240	249,545	276,464	2,960	2,960	24,880	23,820,676	34,344	39,386	38,924	39,190	431	1,457	985
	EDMS	16,882,492	53,264,263	251,243	240,176	3,641	3,641	21,812	20,883,643	35,255	40,438	39,970	40,241	555	1,758	1,328
	% Difference	14%	14%	-1%	15%	-19%	-19%	14%	14%	-3%	-3%	-3%	-3%	-22%	-17%	-26%
Aircraft Engine Startup	AEDT									10,997	12,715	12,649	12,715			
	EDMS									10,997	12,715	12,649	12,715			
	% Difference									0%	0%	0%	0%			
APU	AEDT			6250	3,469	572	572	558		342	395	393	395			
	EDMS			6,253	3,472	573	573	558		342	396	393	396			
	% Difference			0%	0%	0%	0%	0%		0%	0%	0%	0%			
GSE	AEDT			148,957	18,283	481	499	1,519			5,984	5,418	5,205			
	EDMS			148,795	18,278	481	499	1,520			5,979	5,414	5,201			
	% Difference			0%	0%	0%	0%	0%			0%	0%	0%			
Stationary Source	AEDT			9,243	21,571	4,909	4,931	2,501		1,272,453	1,482,159	1,155,055	1,233,520			
	EDMS			9,243	21,571	4,932	4,932	2,501		1,272,054	1,481,745	1,154,697	1,265,598			
	% Difference			0%	0%	0%	0%	0%		0%	0%	0%	-3%			
Total (All Sources)	AEDT	19,256,812	60,755,240	413,995	319,787	8,922	8,962	29,458	23,820,676	1,318,136	1,540,639	1,212,439	1,291,025	431	1,457	985
	EDMS	16,882,492	53,264,263	415,534	283,497	9,627	9,645	26,391	20,883,643	1,318,648	1,541,273	1,213,123	1,324,151	555	1,758	1,328
	% Difference	14%	14%	0%	13%	-7%	-7%	12%	14%	0%	0%	0%	-3%	-22%	-17%	-26%

4.3.1.2 Use Case C

Results in Use Case C run with average annual weather, found in Table 4-10, follow a similar pattern to Use Case B in the overall differences observed between AEDT 2b and EDMS, with the exception of aircraft engine startup emissions, which show a slight (2%) difference from EDMS, when run with schedule data. Like Use Case B, the main differences in the overall emissions inventory for Use Case C between AEDT and EDMS result from aircraft sources. The causes of the difference in emission inventory will be further investigated in Section 4.4. There are virtually no differences between APU and Stationary source emissions.

Table 4-10. Use Case C Emissions Inventory from AEDT 2b and EDMS Utilizing Average Annual Weather

Inventory Type	Model	Fuel (kg)	CO2 (kg)	CO (kg)	NOx (kg)	PM 2.5 (kg)	PM 10 (kg)	SOx (kg)	H2O (kg)	HC (kg)	TOC (kg)	VOC (kg)	NMHC (kg)	PMNV (kg)	PMSO (kg)	PMFO (kg)
Aircraft	AEDT	19,274,440	60,810,858	248,661	276,975	2,960	2,960	24,903	23,842,482	34,293	39,330	38,870	39,135	432	1,453	984
	EDMS	16,842,200	53,137,139	250,873	239,058	3,632	3,632	21,760	20,833,801	35,286	40,474	40,277	40,277	550	1,754	1,329
	% Difference	14%	14%	-1%	16%	-19%	-19%	14%	14%	-3%	-3%	-3%	-3%	-21%	-17%	-26%
Aircraft Engine Startup	AEDT									11,270	13,031	12,963	13,031			
	EDMS									10,997	12,715	12,649	12,715			
	% Difference									2%	2%	2%	2%			
APU	AEDT			17,367	11,130	1,789	1,789	1,762		1,055	1,220	1,213	1,220			
	EDMS			17,367	11,130	1,789	1,789	1,762		1,055	1,220	1,213	1,220			
	% Difference			0%	0%	0%	0%	0%		0%	0%	0%	0%			
Stationary Source	AEDT			9,243	21,571	4,909	4,931	2,501		1,272,453	1,482,159	1,155,055	1,233,520			
	EDMS			9,243	21,571	4,932	4,932	2,501		1,272,054	1,481,745	1,154,697	1,265,598			
	% Difference			0%	0%	0%	0%	0%		0%	0%	0%	-3%			
Total (All Sources)	AEDT	19,274,440	60,810,858	275,271	309,676	9,658	9,680	29,166	23,842,482	1,319,071	1,535,740	1,208,101	1,286,906	432	1,453	984
	EDMS	16,842,200	53,137,139	277,483	271,759	10,353	10,353	26,023	20,833,801	1,319,392	1,536,154	1,208,836	1,319,810	550	1,754	1,329
	% Difference	14%	14%	-1%	14%	-7%	-7%	12%	14%	0%	0%	0%	-2%	-21%	-17%	-26%

4.3.2 Emissions Inventory Utilizing Detailed Weather

Table 4-11 and Table 4-12 detail the AEDT 2b and EDMS emissions inventory results from Use Cases B and C using detailed weather. Detailed weather data supports the aircraft performance module and airport runway configurations to provide greater precision when performing an emissions inventory. In EDMS, if detailed weather data is used, the user must supply surface data for each hour, as well as twice-daily upper-air observations, one of which must be an early morning sounding. The surface and upper-air observations are processed with the meteorological preprocessor, AERMET. The AERMET Wizard, initiated from the Weather dialog, steps the user through loading the two types of weather data and then merges them into a format that AERMOD can use. Three files are output from the AERMET Wizard are: the AERMOD surface file (.SFC), the AERMOD profile file (.PFL), and the intermediate AERMET surface observation file (.MET). In AEDT, these three files must be copied to the OUTPUT_Files folder of the corresponding study.

Inventory results are provided for aircraft activity related to all parts of departure and arrival operations occurring below the study's mixing height. Emissions related to starting aircraft engines are reported as a separate source, as are APU and stationary source emissions.

4.3.2.1 Use Case B

Table 4-11 shows that in the category of aircraft emissions, fuel consumption, CO_2, H_2O, and SOx, emissions are 15% higher for AEDT 2b, as compared to EDMS. HC, TOC, VOC, and NMHC aircraft emissions are 3% lower for AEDT 2b, as compared to EDMS. NOx aircraft emissions are 18% higher for AEDT 2b, as compared to EDMS. Aircraft emissions of PMNV, PMSO, and PMFO from AEDT 2b are lower by 21%, 16%, and 26%, respectively, as compared to EDMS. $PM_{2.5}$ and PM_{10} aircraft emissions are both 18% lower for AEDT 2b, as compared to EDMS. The causes to the difference in emission inventory between AEDT and EDMS will be further investigated in Section 4.4. There are virtually no differences in the overall emissions inventory for APUs, aircraft engine start-up, GSE, and stationary sources between AEDT 2b and EDMS.

Table 4-11. Use Case B Emissions Inventory from AEDT 2b and EDMS Utilizing Detailed Weather

Inventory Type	Model	Fuel (kg)	CO2 (kg)	CO (kg)	NOx (kg)	PM 2.5 (kg)	PM 10 (kg)	SOx (kg)	H2O (kg)	HC (kg)	TOC (kg)	VOC (kg)	NMHC (kg)	PMNV (kg)	PMSO (kg)	PMFO (kg)
Aircraft	AEDT	19,308,882	60,919,522	243,773	267,184	2,972	2,972	24,947	23,885,087	33,988	39,983	38,530	38,792	437	1,472	977
	EDMS	16,828,157	53,092,837	253,621	226,502	3,630	3,630	21,742	20,816,431	35,046	40,192	39,721	39,991	554	1,752	1,324
	% Difference	15%	15%	-4%	18%	-18%	-18%	15%	15%	-3%	-1%	-3%	-3%	-21%	-16%	-26%
Aircraft Engine Startup	AEDT									10,994	12,711	12,645	12,711			
	EDMS									10,997	12,715	12,649	12,715			
	% Difference									0%	0%	0%	0%			
APU	AEDT			6250	3,469	572	572	558		342	395	393	395			
	EDMS			6,253	3,472	573	573	558		342	396	393	396			
	% Difference			0%	0%	0%	0%	0%		0%	0%	0%	0%			
GSE	AEDT			148,957	18,283	481	499	1,519			5,984	5,418	5,205			
	EDMS			148,795	18,278	481	499	1,520			5,979	5,414	5,201			
	% Difference			0%	0%	0%	0%	0%			0%	0%	0%			
Stationary Source	AEDT			9,243	21,571	4,909	4,931	2,501		1,272,566	1,482,375	1,155,268	1,233,732			
	EDMS			9,243	21,571	4,910	4,932	2,501		1,272,178	1,481,983	1,154,933	1,265,832			
	% Difference			0%	0%	0%	0%	0%		0%	0%	0%	-3%			
Total (All Sources)	AEDT	19,308,882	60,919,522	408,223	310,507	8,934	8,974	29,525	23,885,087	1,317,890	1,541,448	1,212,254	1,290,835	437	1,472	977
	EDMS	16,828,157	53,092,837	417,912	269,823	9,594	9,634	26,321	20,816,431	1,318,563	1,541,265	1,213,110	1,324,135	554	1,752	1,324
	% Difference	15%	15%	-2%	15%	-7%	-7%	12%	15%	0%	0%	0%	-3%	-21%	-16%	-26%

4.3.2.2 Use Case C

Results for Use Case C run with detailed weather are found in Table 4-12. The results are similar to Use Case B in the overall differences observed between AEDT 2b and EDMS, with the exception of aircraft engine startup emissions, which show no difference from EDMS in Use Case B, but show a 14% difference in Use Case C. As with Use Case B, the main differences in the overall emissions inventory for Use Case C are due to aircraft sources. The difference in emission inventory between AEDT and EDMS will be further investigated and discussed in Section 4.4. There are virtually no differences between APU and Stationary source emissions.

Table 4-12. Use Case C Emissions Inventory from AEDT 2b and EDMS Utilizing Detailed Weather

Inventory Type	Model	Fuel (kg)	CO2 (kg)	CO (kg)	NOx (kg)	PM 2.5 (kg)	PM 10 (kg)	SOx (kg)	H2O (kg)	HC (kg)	TOC (kg)	VOC (kg)	NMHC (kg)	PMNV (kg)	PMSO (kg)	PMFO (kg)
Aircraft	AEDT	19,317,501	60,946,715	243,698	267,937	2,969	2,969	24,958	23,895,748	35,325	40,531	40,071	40,340	436	1,472	976
	EDMS	16,787,057	52,963,163	253,573	225,417	3,622	3,622	21,689	20,765,589	35,092	40,243	39,771	40,042	548	1,748	1,326
	% Difference	15%	15%	-4%	19%	-18%	-18%	15%	15%	1%	1%	1%	1%	-20%	-16%	-26%
Aircraft Engine Startup	AEDT									12,587	14,553	14,477	14,553			
	EDMS									10,997	12,715	12,649	12,715			
	% Difference									14%	14%	14%	14%			
APU	AEDT			17,367	11,130	1,789	1,789	1,762		1,055	1,220	1,213	1,230			
	EDMS			17,367	11,130	1,789	1,789	1,762		1,055	1,220	1,213	1,230			
	% Difference			0%	0%	0%	0%	0%		0%	0%	0%	0%			
Stationary Source	AEDT			9,243	21,571	4,909	4,931	2,501		1,272,566	1,482,375	1,155,268	1,233,732			
	EDMS			9,243	21,571	4,910	4,932	2,501		1,272,178	1,481,983	1,154,933	1,265,832			
	% Difference			0%	0%	0%	0%	0%		0%	0%	0%	-3%			
Total (All Sources)	AEDT	19,317,501	60,946,715	270,308	300,638	9,667	9,689	29,221	23,895,748	1,321,533	1,538,679	1,211,029	1,289,855	436	1,472	976
	EDMS	16,787,057	52,963,163	280,183	258,118	10,321	10,343	25,952	20,765,589	1,319,322	1,536,161	1,208,566	1,319,819	548	1,748	1,326
	% Difference	15%	15%	-4%	16%	-6%	-6%	13%	15%	0%	0%	0%	-2%	-20%	-16%	-26%

4.3.3 Air Quality Dispersion Analysis Results

4.3.3.1 Use Case B

Table A-6 through Table A-11 list the 1 hour CO, 8 hour CO, 1 hour NOx, Annual NOx, 24 hour $PM_{2.5}$, and Annual $PM_{2.5}$ pollutant concentrations of AEDT 2b and EDMS for Use Case B. Also listed in the tables are the percentage difference in pollutant concentrations between AEDT 2b and EDMS, receptor ID, receptor location, and date/hour of the reported concentration.

4.3.3.2 Use Case C

Table A-12 through Table A-17 list the 1 hour CO, 8 hour CO, 1 hour NOx, Annual NOx, 24 hour PM2.5, and Annual PM2.5 pollutant concentrations of AEDT 2b and EDMS for Use Case C. Also listed in the tables are the percentage difference in pollutant concentrations between AEDT 2b and EDMS, receptor ID, receptor location, and date/hour of the reported concentration.

4.4 Results Analysis

In this section, further analysis is conducted to investigate the difference in fuel burn, emission inventory and dispersion between AEDT 2b and EDMS. Since the objective of this study is to investigate the fuel burn, emission difference between AEDT and EDMS, and the difference between Use Case B and C for a specific tool is quite small, either Use Case B or C can be used for the investigation. In this analysis, Use Case B is used. In addition, the results produced by the average annual weather versus detailed weather are very close, thus only the average annual weather is used in this investigation.

As can be seen from Table 4-9 through Table 4-12, the differences in emission inventory mainly result from the aircraft sources, there are only small differences for engine startup and stationary sources, and no difference in emission results for GSE and APU between AEDT 2b and EDMS. Thus the investigation for emission inventory will be focused on the fuel burn and emissions differences for aircraft, engine startup and stationary sources.

For air quality dispersion analysis, Table A-6 to Table A-17 shows that there are big differences between AEDT and EDMS. The emission differences estimated by the two models definitely have big impact on the emission dispersion. However, the difference in some pollutant concentration is as large as 76% (e.g. CO 1 HR concentration) for Use Case B between AEDT and EDMS, other causes that lead to the big difference in emission concentration will be investigated.

The AEDT version used in this investigation is: 62.3.43772.1 and the EDMS version used is: 5.1.4.1.

4.4.1 Emission Inventory

4.4.1.1 Aircraft

Section 4.3.1 and 4.3.2 show that for emission inventory analysis of the aircraft sources, the difference in fuel consumption, CO2, H2O, and SOx is about 14~15% between AEDT 2b and

EDMS for Use Case B&C with annual average or detailed weather. The difference in HC, TOC, VOC, and NMHC aircraft emissions is about -3%, and the difference in NOx is about 15~19%. PM features the largest difference between AEDT 2b and EDMS, ranging from -18 to -26%. For emission inventory analysis of non-aircraft sources, the fuel burn and emission results are very close. The results for APU and GSE are actually identical between AEDT and EDMS, and there are slight difference (-3%) only in NMHC for stationary sources.

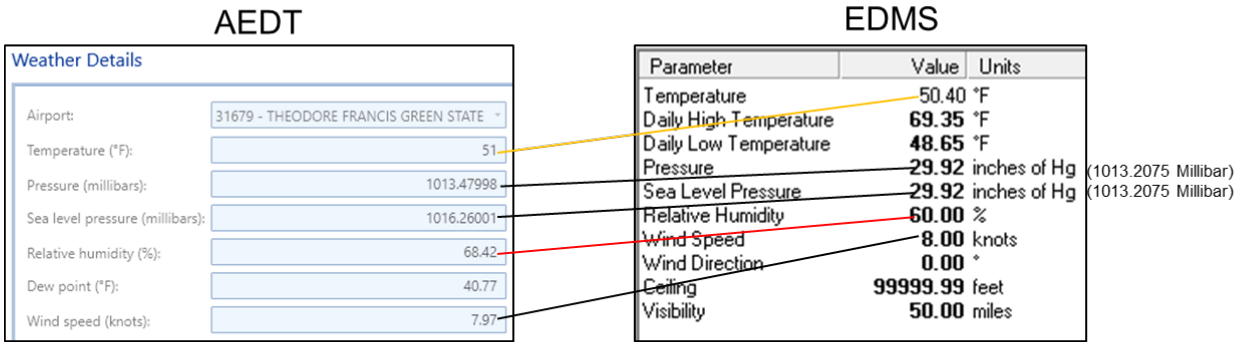
In the air quality dispersion analysis discussed in 4.3.3, the difference in pollutant concentration can be as large as 76% (e.g. CO 1 HR concentration) for Use Case B between AEDT and EDMS. The difference in concentration for Use Case C is smaller than Use Case B. In addition, the longer duration results in the smaller difference in concentration (such as 1 Hour vs. Annual) for both Use Case B and C.

The goal is to investigate the causes that lead to the difference between AEDT and EDMS by comparing

- Weather
- Engine Emission Databank (EDB) coefficients
- ANP coefficients, flight procedure and trajectory
- Taxi time
- Aircraft and operation type
- Operation modes
- Fuel burn and emissions calculation methods

4.4.1.1.1 Weather

This analysis is to make sure both AEDT and EDMS use the same weather profile when calculating fuel burn and emissions since weather can have a significant effect on the results. Figure 4-3 shows the weather used by AEDT and EDMS respectively. As can be seen, AEDT uses different temperature, pressure, sea level pressure, relative humidity and wind speed than EDMS.



AEDT

Weather Details

Airport: 31679 - THEODORE FRANCIS GREEN STATE

Temperature (°F): 51

Pressure (millibars): 1013.47998

Sea level pressure (millibars): 1016.26001

Relative humidity (%): 68.42

Dew point (°F): 40.77

Wind speed (knots): 7.97

EDMS

Parameter	Value	Units
Temperature	50.40	°F
Daily High Temperature	69.35	°F
Daily Low Temperature	48.65	°F
Pressure	29.92	inches of Hg (1013.2075 Millibar)
Sea Level Pressure	29.92	inches of Hg (1013.2075 Millibar)
Relative Humidity	60.00	%
Wind Speed	8.00	knots
Wind Direction	0.00	°
Ceiling	99999.99	feet
Visibility	50.00	miles

Figure 4-3. EDMS PVD Airport Layout for Use Case B and C

To enable a commensurable comparison, weather in AEDT was edited to match the weather in EDMS. AEDT was re-run after the weather was matched, and Table 4-13 shows that, for aircraft sources, the difference in fuel burn and all emissions except for NOx improved slightly.

Table 4-13. Fuel Burn and Emissions Results After Weather was Matched

Type	Source	Fuel (kg)	CO (kg)	HC (kg)	TOG (kg)	VOC (kg)	NMHC (kg)	NOx (kg)	PMNV (kg)	PMSO (kg)	PMFO (kg)	CO2 (kg)	H2O (kg)	SOx (kg)	PM 2.5 (kg)	PM 10 (kg)
Aircraft	AEDT: Unmatched Weather (UW)	19256812	249545	34344	39386	38924	39190	276464	431	1457	985	60755240	23820676	24880	2960	2960
	AEDT: Matched Weather (MW)	19254935	249562	34359	39404	38942	39207	279692	431	1457	985	60749319	23818354	24877	2959	2959
	EDMS	16880887	251244	35252	40435	39966	40237	240222	554	1758	1329	53259199	20881657	21810	3641	3641
	Diff: AEDT w/ UW EDMS	14.07%	-0.68%	-2.58%	-2.59%	-2.61%	-2.60%	15.09%	-22.25%	-17.11%	-25.88%	14.07%	14.07%	14.08%	-18.70%	-18.70%
	Diff: AEDT w/ MW-EDMS	14.06%	-0.67%	-2.53%	-2.55%	-2.56%	-2.56%	16.43%	-22.18%	-17.10%	-25.90%	14.06%	14.06%	14.06%	-18.72%	-18.72%
Stationary Sources	AEDT: Unmatched Weather (UW)	0	9243	1272453	1482159	1155055	1233520	21571	0	0	0	0	0	2501	4909	4931
	AEDT: Matched Weather (MW)	0	9243	1272442	1482138	1155034	1233500	21571	0	0	0	0	0	2501	4909	4931
	EDMS	0	9243	1272054	1481745	1154697	1265598	21571	0	0	0	0	0	2501	4910	4932
	Diff: AEDT w/ UW EDMS	0%	0%	0.03%	0.03%	0.03%	-2.53%	0%	0%	0%	0%	0%	0%	0%	-0.01%	-0.02%
	Diff: AEDT w/ MW-EDMS	0%	0%	0.03%	0.03%	0.03%	-2.54%	0%	0%	0%	0%	0%	0%	0%	-0.01%	-0.02%

Table 4-13 also shows that all the fuel burn and emissions produced by AEDT and EDMS for stationary sources are the same except for NMHC (-2.5% difference).

4.4.1.1.2 Engine Emission Databank (EDB) Coefficients

Both AEDT and EDMS use Emission Indices (EIs) to calculate emission inventory for aircraft and non-aircraft sources. EI is the emissions produced per unit fuel consumed which are available in the ICAO engine emission certification databank (EDB). The EDB is a living DB and the data is continuously updated as new data becomes available. EIs have direct impact on the emission inventory results and it is necessary to compare the EDB coefficients (EIs) between AEDT and EDMS.

For each engine, the AEDT Fleet database contains the EIs and fuel flow values corresponding to the standard landing-and-takeoff (LTO) cycle modes, including takeoff, climbout, approach, and idle. In EDMS, EIs are stored in system data table ENG_EMIS.dbf. It was observed that AEDT 2b Sprint 65 and EDMS 5.1.4.1 uses different version of EDB. The EDB coefficients of AEDT and EDMS were compared, with part of the comparison results shown in Table 4-14. The blank cells in Table 4-14 indicate the EI values are the same for the specific engine, and the percentage represents the relative difference in EI between AEDT and EDMS for that engine. As can be seen from Table 4-14, for most of the engines the EI values are the same. For some of the engines, however, AEDT and EDMS use very different EIs, such as the engines of Bell 206 and Bell UH-1. This indicates that the difference in EIs contribute to the difference in emissions results produced by AEDT and EDMS.

4.4.1.1.3 ANP coefficients, flight profile and trajectory

Additional AEDT and EDMS assumptions and inputs were also compared, including ANP coefficients and flight profile. Both AEDT and EDMS use the STANDARD flight procedure and same ANP coefficients for all the aircraft. The flight trajectories generated by AEDT and EDMS were compared to investigate possible differences in the APM used by AEDT and EDMS for example, shows the trajectory comparison for an Airbus A320 STANDARD departure procedure. It should be noted that EDMS does not store trajectory information, but EDMS uses the same APM module as INM. Therefore, the trajectory labeled as EDMS in Figure 4-4 was actually generated by INM. One can see that the trajectories are almost identical except that AEDT calculates more segments. This implies that there is no major difference in the APM between AEDT and EDMS. Thus, ANP coefficients, flight profile and APM did not contribute to the difference in fuel burn and emissions for AEDT and EDMS.

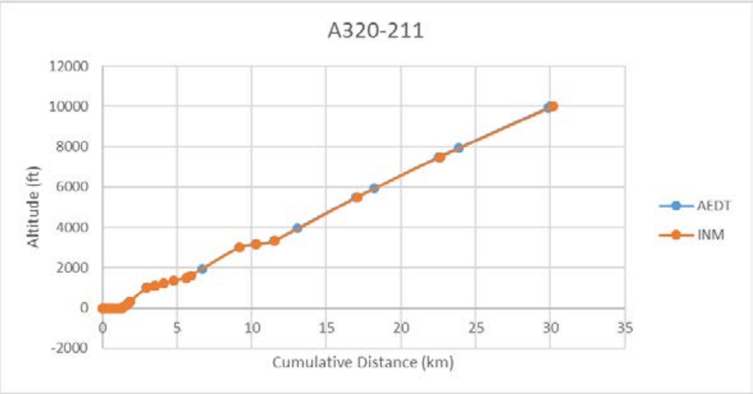


Figure 4-4. Flight Trajectory Generated by AEDT and EDMS for A320

Table 4-14. Engine Emission Data Bank (EDB) Comparison between AEDT and EDMS

AIRCRAFT NAME	ENG_CODE	UA_RWF_TO	UA_RWF_	UA_RWF_	UA_RWF_	CO_REI_T	CO_REI_C	CO_REI_A	CO_REI_ID	HC_REI_T	HC_REI_C	HC_REI_A	HC_REI_ID	NOX_REI_	NOX_REI_	NOX_REI_	NOX_REI_	SN_TO	SN_CO	SN_AP	SN_ID
Airbus A319-100 Series 3CM028	3CM028																				
Airbus A319-100 Series 3IA006	3IA006																				
Airbus A320-100 Series 1IA003	1IA003																				
Airbus A320-200 Series 1CM008	1CM008																				
Airbus A321-100 Series 3CM025	3CM025																				
Bell 206 JetRanger 250B17	250B17	-0.03%	-0.10%	-2.64%	0.48%	0.02%	0.00%	2.94%	0.31%	-11.95%	-8.16%	-0.45%	0.79%	0.06%	-0.01%	1.60%	42.86%				
Bell UH-1 Iroquois T400	T400	-0.01%	-0.01%	0.00%	-2.43%			-26.74%	9.90%			-28.57%				5.58%	-2.07%				
Boeing 727-200 Series 1PW010	1PW010																		-100.00%	-100.00%	-100.00%
Boeing 737-200 Series 1PW011	1PW011																		-100.00%	-100.00%	-100.00%
Boeing 737-300 Series 1CM004	1CM004																				
Boeing 737-300 Series 1CM007	1CM007																				
Boeing 737-400 Series 1CM005	1CM005																				
Boeing 737-500 Series 1CM004	1CM004																				
Boeing 737-500 Series 1CM007	1CM007																				
Boeing 737-700 Series 3CM031	3CM031																				
Boeing 757-200 Series 4PW072	4PW072																				
Boeing 757-200 Series 3RR028	3RR028																				
Boeing 757-300 Series 4PW073	4PW073																				
Boeing DC-9-30 Series 1PW007	1PW007																		-100.00%	-100.00%	-100.00%
Boeing MD-81 1PW017	1PW017																		-100.00%	-100.00%	-100.00%
Boeing MD-82 1PW017	1PW017																		-100.00%	-100.00%	-100.00%
Boeing MD-82 4PW068	4PW068																		-100.00%	-100.00%	-100.00%
Boeing MD-82 4PW069	4PW069																		-100.00%	-100.00%	-100.00%
Boeing MD-83 4PW068	4PW068																		-100.00%	-100.00%	-100.00%
Boeing MD-87 1PW017	1PW017																		-100.00%	-100.00%	-100.00%
Boeing MD-88 4PW071	4PW071																				
Bombardier CRJ-100 5GE084	5GE084																				
Bombardier CRJ-200 5GE084	5GE084																				
Bombardier CRJ-700 5GE083	5GE083																				
Bombardier Challenger 600 5GE	5GE084																				
Bombardier Challenger 604 5GE	5GE084																				
Bombardier Global Express 4BR	4BR009																				
Bombardier Learjet 25 CJ6106	CJ6106																				
Bombardier Learjet 31 1AS001	1AS001																				
Bombardier Learjet 35 1AS001	1AS001																				
Bombardier Learjet 35A/36A (C-	1AS001																				
Cessna 150 Series O200	O200					0.01%	0.01%	-0.01%	0.06%	0.05%	0.05%	0.05%	0.02%	0.01%	0.01%	3.39%	-1.40%				
Cessna 172 Skyhawk TSIO36	TSIO36	-0.24%	0.32%			0.18%	-0.02%	0.01%	0.03%	0.03%	0.50%	2.83%	0.19%	0.25%	0.50%	1.91%	0.69%				
Cessna 208 Caravan P6114A	P6114A				-0.04%				0.00%				0.00%				0.00%				
Cessna 337 Skymaster TSIO36	TSIO36	-0.24%	0.32%			0.18%	-0.02%	0.01%	0.03%	0.03%	0.50%	2.83%	0.19%	0.25%	0.50%	1.91%	0.69%				

4.4.1.1.4 *Taxi time*

In the LTO operations, taxi in/out segments are important since these segments contribute approximately 30% of the terminal-area fuel consumption. The fuel burn for a taxi segment is calculated by multiplying the taxi time by the fuel flow. In order to compare the fuel burn and emission between AEDT and EDMS, one must make sure both tools use the same taxi time. To investigate the impact of taxi time, one small study was built consisting of six aircraft selected from Use Case C, and run through AEDT and EDMS respectively. Identical taxi times were assigned to the operations of the six aircraft, with taxi out time as 19 minutes and taxi in time as 7 minutes. Figure 4-5 illustrates the fuel burn, NOx and PM comparison for departure and arrival operations between AEDT and EDMS for this study. It can be seen that, even with the same taxi time, for most of the aircraft the fuel burn and emission results produced by AEDT and EDMS still have large difference.

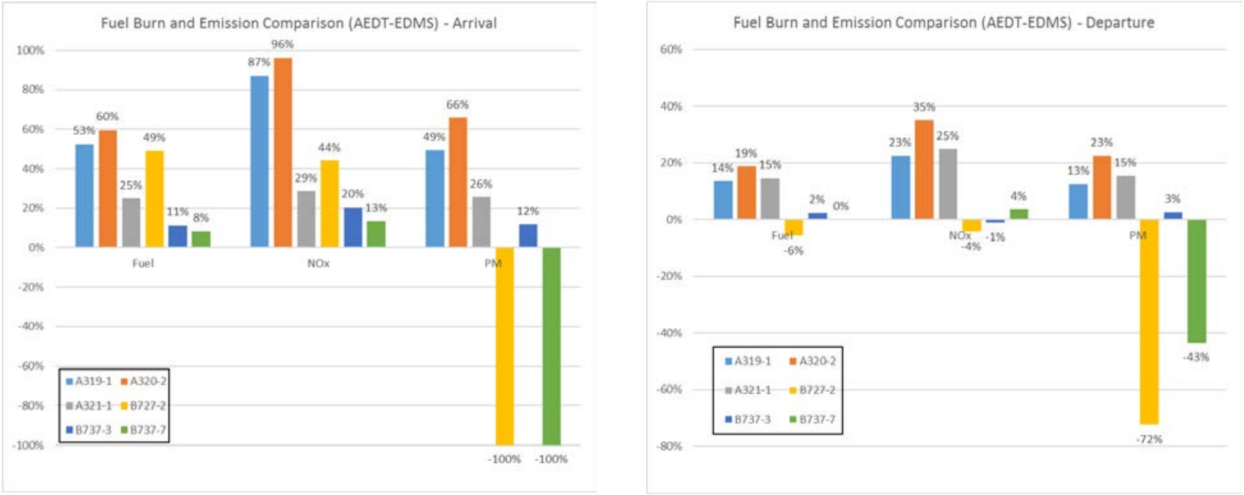


Figure 4-5. Fuel Burn, NOx and PM Comparison with the Same Taxi Time

4.4.1.1.5 *Aircraft and operation type*

Another observation that can be drawn from the analysis conducted using the study presented in section 4.4.1.1.4 is that Boeing aircraft showed better agreement in fuel burn and emissions than Airbus aircraft. In addition, fuel burn and emissions calculated for departure operations showed much better agreement than those calculated for arrival operations by AEDT and EDMS. For example, as shown in Figure 4-6, the difference in fuel burn and NOx between AEDT and EDMS is very small for Boeing aircraft, especially, Boeing 737-300 (2%, 1% for fuel burn and NOx respectively).

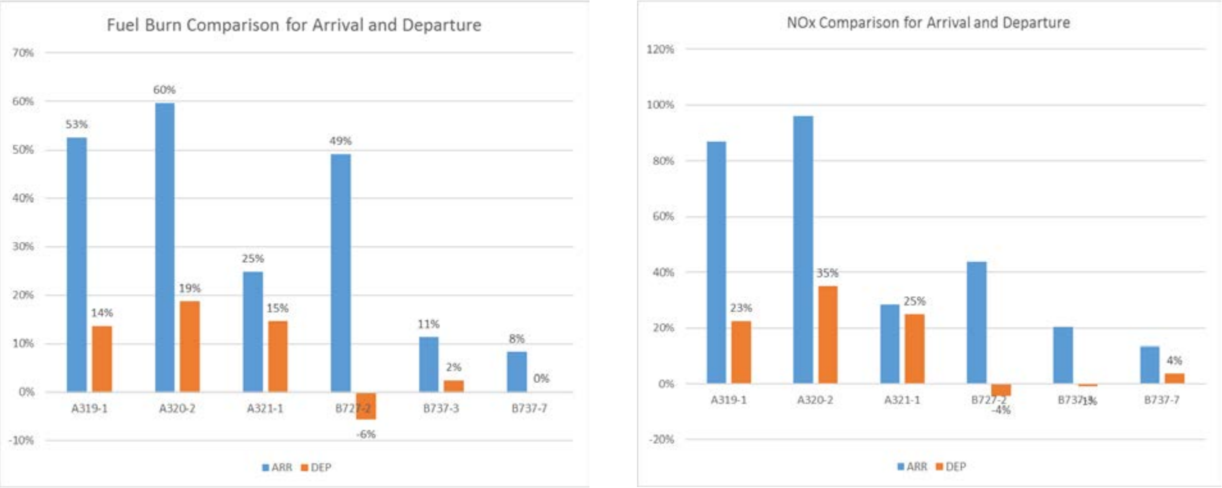


Figure 4-6. Fuel Burn and NOx Comparison for Different Aircraft and Operation Types

4.4.1.1.6 Operation mode

Figure 4-6 shows that the Airbus 320-200 featured the biggest difference in fuel burn and NOx among the six aircraft, in this analysis a further investigation was conducted to better understand the causes of the difference. A single A320-200 flight study was built, consisting of a departure and arrival operation. The study was run in AEDT and EDMS, and the fuel burn results was compared by mode, as shown in Table 4-15. It can be seen that AEDT produced much more fuel burn for climb out and approach modes, while EDMS produced more fuel burn for taxi modes. In order to verify this finding, another single flight study was built using Boeing 737-700, and the fuel burn results was compared by mode, as shown in Table 4-16. The comparison also indicated the same trend as found in the A320-200 single flight study.

Table 4-15. Fuel Burn Comparison by Mode for Airbus A320-200

	Mode	Fuel Consumption (kg)		
		EDMS	AEDT	Diff
Departure	Startup	0	0	0%
	Taxi Out	45.89	25.55	-44%
	Takeoff	201.11	234.62	17%
	Climb Out	28.99	67.06	131%
Arrival	Approach	74.03	153.97	108%
	Taxi In	63.73	41.39	-35%

Table 4-16. Fuel Burn Comparison by Mode for Boeing 737-700

	Mode	Fuel Consumption (kg)		
		EDMS	AEDT	Diff
Departure	Startup	0	0	0%
	Taxi Out	51.098	26.5306	-48%
	Takeoff	152.204	146.1827	-4%
	Climb Out	78.701	129.0524	64%
Arrival	Approach	93.44	171.3457	83%
	Taxi In	61.851	20.1436	-67%

4.4.1.1.7 Fuel burn and emissions calculation methods

Based on the analysis in section 4.4.1.1.6, it can be seen that AEDT and EDMS produce very different fuel burn for each LTO mode. Further investigation was done by reviewing the AEDT and EDMS manuals to understand the methods used for calculating fuel burn and emissions. The methods are summarized in Table 4-17. It can be seen that except fuel burn, both AEDT and EDMS use the same methods to calculate the emissions (for PM, they both used FOA 3a). AEDT can use three different models for fuel consumption, and EDMS only uses BFFM2 as the fuel consumption model. Based on the AEDT technical manual, for terminal area modeling, AEDT uses

- the Senzig-Fleming-Iovinelli (SFI) fuel burn model when the proper coefficients are available;
- BADA fuel burn model when coefficients for the SFI fuel burn model are not available;
- BFFM2 when other sources for fuel consumption data are not available or when thrust is not a parameter in the aircraft's performance profile (TTO aircraft).

The mathematic equations of these three methods are presented in Appendix A. In Use Case B and C, SFI coefficients are available for all the aircraft, therefore AEDT used SFI method to calculate the fuel consumption, while EDMS used BFFM2 to calculate the fuel consumption. The different fuel consumption models is the main cause that lead to the difference in fuel burn between AEDT and EDMS, which sequentially causes the difference in emissions calculated via EIs operating on the per segment fuel consumption.

Table 4-17. Fuel Burn and Emission Methods Used by AEDT and EDMS

Fuel Burn/Emissions	AEDT	EDMS
Fuel Burn	Senzig-Fleming-Iovinelli (SFI)	BFFM2
	BADA fuel burn model	
	BFFM2	
NOx, HC, and CO	BFFM2	BFFM2
PM	FOA 3.0	FOA 3.0 - Non-US airport
	FOA 3a	FOA 3a - US airport
SOx, CO2	Fuel composition-based factors	Fuel composition-based factors
NMHC, VOC, TOG	Derivative factors	Derivative factors

In AEDT 2b, thrust setting type rather than pounds thrust are recognized as 'other', and the aircraft use such thrust setting in AEDT are denoted as TTO aircraft. To further verify this conclusion, a TTO aircraft emission analysis study was conducted. This is a single airport (DULLES airport) study consisting of 119 TTO aircraft, mainly military aircraft. Originally, the fuel burn difference between AEDT and EDMS is about -51%. After the weather, emission indices, ANP coefficients, flight procedure, flight trajectory, and taxi time were matched between the AEDT and EDMS studies, the fuel difference reduced to -5%, as shown in Table 4-18. Since the study is for TTO aircraft, AEDT uses the same fuel consumption model as EDMS uses – BFFM2. This implies that with all the assumptions and inputs matched, AEDT and

EDMS shows good agreement on fuel burn and emissions result if they use the same fuel burn methods.

Table 4-18. Fuel Burn and Emission Comparison with Same Fuel Consumption Method

	Fuel (lb)	CO (lb)	HC (lb)	TOG (lb)	VOC (lb)	NMHC (lb)	NOx (lb)	CO2 (lb)	SOx (lb)	PM 2·5 (lb)	PM 10 (lb)
AEDT 2b	278449	9788	5909	6829	6790	6826	2335	878507	326	77	77
EDMS 5.1.4	293438	10323	6213	7181	7141	7179	2532	925796	379	320	320
Diff	-5.11%	-5.18%	-4.89%	-4.91%	-4.92%	-4.92%	-7.79%	-5.11%	-13.98%	-76.01%	-76.01%

4.4.1.2 Engine Start-up

The start-up emissions inventories for Use Case C utilizing average annual weather and detailed weather show that there are differences between AEDT 2b and EDMS, as shown in Table 4-10 and Table 4-12. In Use Case C for average annual weather emission inventory, there is a 2% difference between AEDT 2b and EDMS for pollutants associated with aircraft engine start-up. For the detailed weather emission inventory, there is a 14% difference between AEDT 2b and EDMS for the pollutants associated with aircraft engine start-up emissions. This is a bug of AEDT 2b SP1 which was used for USE Case C. The cause of this issue was identified during the UQ analysis and was resolved with AEDT 2b SP2. Additional analysis was conducted using AEDT 2b SP2 and it was verified that the bug was fixed and the pollutants associated with aircraft engine start-up emissions generated by AEDT 2b and EDMS for Use Case C are identical.

4.4.1.3 Stationary Source

It was observed from Table 4-10 to Table 4-12 that there is a -3% difference between AEDT 2b and EDMS in NMHC emissions associated with stationary sources, while there is no difference between the two models for other pollutants. In Use Case B and C, there are 14 stationary sources, as shown in Table 4-5, and the emissions generated by these sources are independent on the weather and aircraft operations. Additional analysis was conducted to investigate the difference for NMHC associated with the stationary sources, and the emission results were compared one by one for the sources, as shown in Table 4-19. Table 4-19 shows that there are 7 stationary sources which produce different emission results between AEDT 2b and EDMS. These stationary sources include 10000 Avgas fuel tank, 10000 Mogas fuel tank, 600kw emergency generator #1 and #2, Deice1 deicing area, Sand/Salt Pile, and Solvent Degreaser. Though the 600kw emergency generator #1 and #2 and Deice1 have big differences in NMHC between AEDT and EDMS (34%, 34%, 12% respectively), the Solvent Degreaser which has -4.27% difference in NMHC, dominates the total NMHC difference for the study since it produces almost 60% of the NMHC of all stationary sources. A closer look at the properties of the Solvent Degreaser in AEDT and EDMS shows that their properties are identical for these two models. Thus, the difference in NHMC for the Solvent Degreaser most likely results from the difference in the calculation method or emission factor of NMHC for Solvent Degreaser used by AEDT 2b and EDMS. Further investigations were conducted and these bugs have been fixed.

Table 4-19. Emissions Comparison for Stationary Sources Between AEDT and EDMS

Equipment Type		CO (kg)	HC (kg)	TOG (kg)	VOC (kg)	NMHC (kg)	NOx (kg)	SOx (kg)	PM 2.5 (kg)	PM 10 (kg)
10000 Avgas	AEDT		516.26	961.36	961.36	951.27				
	EDMS		516.26	960.52	960.52	950.43				
	Diff		0%	0.09%	0.09%	0.09%				
10000 Diesel	AEDT		0.91	1.53	1.36	1.4				
	EDMS		0.91	1.53	1.36	1.4				
	Diff		0%	0%	0%	0%				
10000 Mogas	AEDT		194.74	636.43	636.43	629.75				
	EDMS		194.74	635.58	635.58	628.91				
	Diff		0%	0.13%	0.13%	0.13%				
50000 gal Jet A	AEDT		83.34	87.41	77.36	79.72				
	EDMS		83.34	87.42	77.36	79.72				
	Diff		0%	0%	0%	0%				
600kw emer gen #1	AEDT	2030.1	763.8	763.8	653.81	675.2	9380	623.1	668.66	668.66
	EDMS	2030.1	570	570	487.92	503.88	9380	623.1	668.66	668.66
	Diff	0%	34.00%	34.00%	34.00%	34.00%	0%	0%	0%	0%
600kw emer gen #2	AEDT	2030.1	763.8	763.8	653.81	675.2	9380	623.1	668.66	668.66
	EDMS	2030.1	570	570	487.92	503.88	9380	623.1	668.66	668.66
	Diff	0%	34.00%	34.00%	34.00%	34.00%	0%	0%	0%	0%
Aircraft Engine Test	AEDT	0	0	0	0	0	0	0	0	0
	EDMS	0	0	0	0	0	0	0	0	0
	Diff	0%	0%	0%	0%	0%	0%	0%	0%	0%
Boiler Terminal #1	AEDT	91.58	43.38	47.15	20.75	16.97	655.52	2.41	28.92	28.92
	EDMS	91.58	43.38	47.15	20.75	16.98	655.52	2.41	28.92	28.92
	Diff	0%	0%	0%	0%	0%	0%	0%	0%	0%
Boiler Terminal #2	AEDT	91.58	43.38	47.15	20.75	16.97	655.52	2.41	28.92	28.92
	EDMS	91.58	43.38	47.15	20.75	16.98	655.52	2.41	28.92	28.92
	Diff	0%	0%	0%	0%	0%	0%	0%	0%	0%
Deice1	AEDT		9.65	35.13	31.3	9.65				
	EDMS		8.6	31.3	27.89	8.6				
	Diff		12.23%	12.23%	12.23%	12.23%				
Incinerator	AEDT	5000	8875.74	8875.74	1500	1739.64	1500	1250	3500	3500
	EDMS	5000	8875.74	8875.74	1500	1739.65	1500	1250	3500	3500
	Diff	0%	0%	0%	0%	0%	0%	0%	0%	0%
Sand/Salt Piles	AEDT								14.24	35.61
	EDMS								14.57	36.65
	Diff								-2.26%	-2.86%
Solvent Degreaser	AEDT		759173.22	791300	480477.36	726729.92				
	EDMS		759173.22	791300	480477.36	759173.22				
	Diff		0%	0%	0%	-4.27%				
Surface Coating	AEDT		501974.07	678618.45	670000	501974.07				
			501974.07	678618.45	670000	501974.07				
			0%	0%	0%	0%				

4.4.2 Air Quality Dispersion

As discussed in Section 4.4.1.1.7, AEDT and EDMS used different fuel consumption models to calculate fuel burn, which sequentially results in the difference in the emissions concentrations estimated by the models since the fuel burn and emissions have significant impact on emission dispersion. In addition, Table A-6 to Table A-17 show that the difference in some pollutant concentration is as large as 76% (e.g. CO 1 HR concentration) for Use Case B between AEDT and EDMS. This magnitude of difference may not be only from the emission difference. Thus, additional causes that lead to these significant differences in emission concentrations shall be investigated in this section.

Since AERMOD needs the hourly emission rate and MET data to conduct emission dispersion analysis, it is necessary to investigate the hourly emission rate file (HRE file) and understand how emissions are allocated spatially and temporally in both models.

4.4.2.1 Flight Tracks

Different flight tracks can have significant impact on the hourly emission rate and how the emissions are allocated spatially and temporally. Based on the EDMS technical manual, the aircraft fly straight-in straight-out in EDMS. Upon investigation of the flight tracks, and it was found that AEDT also uses straight-in/straight-out tracks for the PVD airport, as shown in Figure 4-7. Thus, flight track does not contribute to the observed differences in emission concentrations between AEDT and EDMS in this case.

Figure 4-7. Flight Track of PVD Airport in AEDT for Use Case B and C

4.4.2.2 AREA Source

One of the basic inputs to AERMOD is the source information, such as the source location, size, orientation, etc. The source has multiple types, including POINT, VOLUME, AREAPOLY, and AREA source. The emissions from the AERMOD sources are collected for each modeling hour, and the respective hourly emissions rates are submitted into the AERMOD through the HRE file. Each aircraft operation is associated with respective aircraft movements and consists of a set of the flight segments. The EDMS distributes a flight segment's emissions between one or more rectangular AERMOD sources called AREA sources. Since the difference in emission dispersion is mainly from aircraft operation, the investigation shifted focus to the area sources.

The area sources data are available in the AERMOD.INP file (also in HRE and SRC files). After comparing the area source data between AEDT and EDMS, it was found that the area sources are constructed differently in these two tools. In AEDT, the size of ground source and airborne source are defined as 20(m)x20(m) and 200(m)x200(m) respectively, and the orientation angle for these sources are 0 (i.e. the sources align with the X (east) Y (north) directions), as shown in

Table 4-20. On the other hand, in EDMS the size and orientation of the ground source and airborne source depend on the runways, as shown in Table 4-21.

Table 4-20. Size and Orientation of AREA Source in AEDT

SOURCE	WIDTH	LENGTH	ANGLE
Ground	20	20	0
Airborne	200	200	0

Table 4-21. Size and Orientation of AREA Source in EDMS

SOURCE		WIDTH	LENGTH	ANGLE
Ground	RUNWAY_TAKEOFF 5	20	48.98	32.07
	RUNWAY_LANDING 5	20	48.98	32.07
	RUNWAY_TAKEOFF 16	20	49.11	141.66
	RUNWAY_LANDING 16	20	49.11	141.66
Airborne	AIRBORNE_TAKEOFF 5	20	200	32.07
	AIRBORNE_LANDING 5	20	200	32.07
	AIRBORNE_TAKEOFF 16	20	200	141.66
	AIRBORNE_LANDING 16	20	200	141.66
	AIRBORNE_TAKEOFF 23	20	200	-147.93
	AIRBORNE_LANDING 23	20	200	-147.93
	AIRBORNE_TAKEOFF 34	20	200	-38.34
	AIRBORNE_LANDING 34	20	200	-38.34

The different area sources defined in AEDT and EDMS also lead to the different emission allocation to these sources, as shown in Figure 4-8, which is a major contributor to the difference in emission dispersion between AEDT and EDMS.

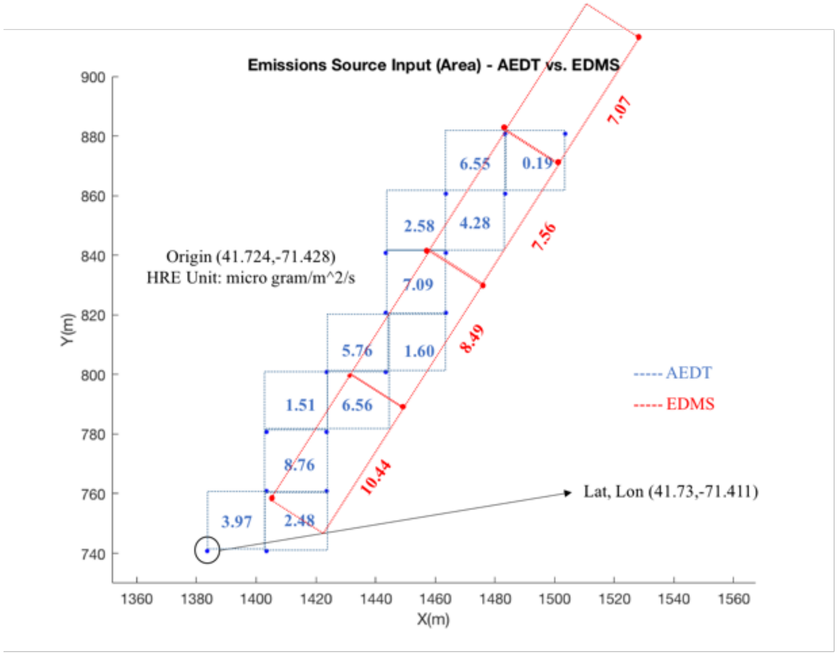


Figure 4-8. Emission Assignments of Area Sources in AEDT and EDMS

Figure 4-9 shows an example of concentration comparison between AEDT and EDMS at each receptor location. It is CO 2nd highest 1-HR average concentration for all sources. It can be seen that the difference in area source definition between AEDT and EDMS has a big impact on the concentration value of the receptors.

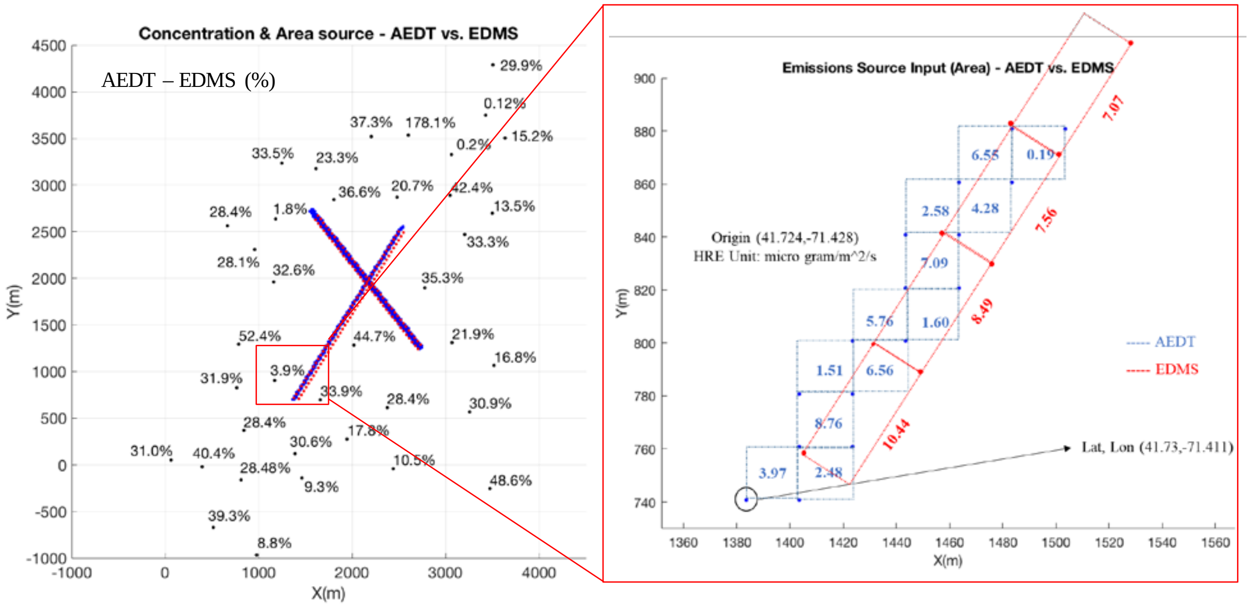


Figure 4-9. Concentration Comparison between AEDT and EDMS at Each Receptor

4.4.2.3 Aircraft Operations

It was found that the difference in emission concentrations for Use Case C was smaller than Use Case B. This is due to how the operations are modeled. Use Case B uses operation profile while Use Case C uses the detailed flight schedule. For Use Case B, both AEDT and EDMS use a fixed random seed value to develop the pseudo-schedule. Because of the difference in how flights are handled computationally, AEDT 2b and EDMS do not generate the same exact pseudo-schedule. The number of operations and aircraft types are both the same in the EDMS and AEDT 2b airport studies, but the times at which those aircraft operate will vary between the two models due to the way the random generator for the pseudo-schedule is applied. It is important to note that the overall schedule will follow the assigned operational profiles in AEDT 2b. In addition, due to the differences in the generation of the pseudo-schedule, aircraft operations may take different taxi-paths as well as take-off and land on different runways in the two models. These all are major contributors to the difference in the emission concentrations between AEDT and EDMS.

4.5 Conclusions

Capability Demonstration and Functionality Examination

The results of Use Cases B and C show that AEDT 2b is capable of executing an airport air quality analysis associated with NEPA and CAA. A comparison of the AEDT 2b and EDMS input parameters associated with the airport study showed that they are identical, therefore, the functionality associated with importing those input parameters is working as intended in AEDT

2b with two exceptions. The EDMS to AEDT importer does not import the taxi time and airport weather. Therefore, the users need to manually change the values of taxi time and airport weather if they need to match the EDMS and AEDT settings.

During the modeling of Use Cases B and C, there were a number of issues and bugs that were identified and addressed in order to complete the analysis. The first issue, associated with the aircraft engine start-up emissions when running Use Case B, was resolved with AEDT 2b Service Pack 2. Note that this issue *is* observed in the Use Case C results, due to it being run with AEDT 2b Service Pack 1. The cause of this issue was identified during the UQ analysis and was resolved with AEDT 2b Service Pack 2. Additional analysis verified that the bug was fixed in AEDT 2b SP2 and the emission inventories generated by AEDT and EDMS are identical for engine start-up.

The second issue is associated with the reporting of output metrics for the concentration. A report created by AEDT did not have the annual NOx and $PM_{2.5}$ concentrations, even though they were successfully modeled with AEDT 2b. These results were able to be obtained from an AERMOD.OUT file which is produced after AERMOD is executed. Related to this output reporting issue, when reviewing the 1-hour, 8-hour, and 24-hour concentration output, AEDT will properly display the appropriate pollutant concentration values, but the date and time associated with the pollutant concentration value is not reported by AEDT in the GUI. The date and time information is able to be obtained in the .PLT files and AERMOD.OUT file generated by AERMOD.

The third issue is that the differences observed in the emissions inventory and concentrations of PM_{10} and $PM_{2.5}$ for Use Cases B and C is quite big between AEDT and EDMS. It should be noted that FOA3a was selected in both the AEDT 2b and EDMS airport studies. This difference also mainly results from the difference in fuel consumption model used by AEDT and EDMS. In addition, AEDT 2b does not have Smoke Number (SN) for some of the engines while EDMS does, which will impact the PM results calculated by these two tools.

Another issue is related to the NMHC emissions for stationary sources. For both Use Cases B and C emissions inventories of NMHC, there is a consistent -3% difference between AEDT 2b and EDMS, while there is no difference between the two models for the other pollutants. Additional analysis shows that the difference comes from one of the stationary sources, Solvent Degreaser, which has a -4.27% difference and mainly impacts the NMHC results of the stationary sources for the Use Cases.

Table 4-22 summarizes the issues and bugs that were identified in AEDT 2b in the process of Use Case B and C analyses discussed above, and their status are also listed in the table.

In addition to the issues and bugs listed in Table 4-22, other issues and bugs were identified and addressed in order to complete the analysis AEDT 2b and are not listed in the table above. Furthermore, AEDT 2b cannot import taxi time of the aircraft operations of an EDMS study, and user has to manually check and update taxi time to make sure that it is consistent between AEDT and EDMS. Thus, it will be helpful if the taxi time can also be automatically imported when importing an EDMS study.

Table 4-22. List of AEDT 2b Issues and Bugs Identified in Use Case B and C

Issue or Bug in AEDT 2b	Status
Aircraft engine start-up emissions	Resolved in the AEDT 2b SP2 release
AEDT does not report annual NOx and PM2.5 concentrations in the concentration report	Resolved in the AEDT 2c release
AEDT does not report date and time for 1, 8, 24 hour concentration output in the concentration report	Resolved in the AEDT 2c release
AEDT does not have smoke number for some engines which results in inaccurate calculation for PM_{10} and $PM_{2.5}$	Updated Fleet DB has SNs for most engine types
Difference in Emission Inventory Associated with Stationary Sources between AEDT and EDMS	Will be resolved in the AEDT 2d release

Results Comparison of AEDT 2b with EDMS

The emissions inventory results of Use Cases B and C show that there are differences between AEDT 2b and EDMS. The differences associated with the emissions inventories are mainly attributed to aircraft sources. The main reason for differences between the aircraft sources is due to the fact that AEDT and EDMS use different fuel consumption models. In addition, there is some difference in the APM that may cause some additional difference as well. Previous testing and comparisons of AEDT 2b to EDMS at the flight and segment level have shown that AEDT 2b produces higher fuel burn, specifically at climb-out and approach modes. This is aircraft-dependent and is the primary reason why fuel burn, CO_2, H_2O, SOx, and NOx emissions are higher for AEDT 2b than EDMS. Overall, the PM_{10} and $PM_{2.5}$ aircraft emissions are approximately 18%-19% lower for AEDT 2b, as compared to EDMS for the airport study evaluated. The CO and HC emissions were slightly lower for AEDT 2b, as compared to EDMS, and are within a 1% to 4 % difference across both Use Cases.

Overall, the fuel burn, CO_2, H_2O, SOx, NOx, CO, HC, VOC, NMHC, and TOG emissions inventories comparison between AEDT 2b and EDMS show a certain degree of differences given the differences in the fuel burn models used by the two tools. In addition, AEDT doesn’t have SN for some engines while EDMS does, which also has affected the PM results.

There are also differences between the pollutant concentrations reported by AEDT 2b and EDMS associated with air quality dispersion modeling as shown in section 4.3. Dispersion results vary between EDMS and AEDT 2b due to the different fuel consumption calculated by the two models. Also, the area source size and orientations differ between the two models for ground and airborne sources. In AEDT 2b, the area sources for airborne sources are 200 meters by 200 meters (width x length), while EDMS airborne sources are 20 meters x 200 meters (width x length). AEDT ground sources are 20(m)x20(m), but the size of EDMS ground sources depend on the runways. In addition, the orientation angles of AEDT sources are 0, while the orientation angles of EDMS sources also depend on the runways. The different area sources in AEDT and EDMS lead to the difference in emission assignments for these two tools. Most importantly, the largest contributor to pollutant concentration differences are specific to Use Case B. For Use Case B, operational profiles are utilized to distribute aircraft operations annually on a quarter-hour, daily, and monthly basis. For EDMS, there is a fixed random seed value which is used to develop the pseudo-schedule. A similar approach is utilized in AEDT 2b, but due to the difference in how flights are handled computationally compared to EDMS, AEDT 2b and EDMS do not generate the same exact pseudo-schedule. The number of operations and aircraft types are both the same in the EDMS and AEDT 2b airport studies, but the times at which those aircraft operate will vary between the two models due to the way the random generator for the pseudo-schedule is applied. It is important to note that the overall schedule will follow the assigned operational profiles in AEDT 2b. Due to the differences in the generation of the pseudo-schedule, aircraft operations may take different taxi-paths as well as take-off and land on different runways in the two models.

With the exception of PM_{10} and $PM_{2.5}$, the differences in pollutant concentrations of CO and NOx between AEDT 2b and EDMS are within an acceptable range, especially for Use Case C. This indicates that the air quality dispersion functionality is operating as intended. The primary cause of any differences in the pollutant concentration results of AEDT 2b and EDMS are associated with fuel consumption models. Additional analysis was conducted to evaluate the pollutant concentrations by source group. Pollutant concentrations associated with GSE and Stationary Sources were essentially identical between the models, and those results are consistent with emission inventory results.

For Use Case B, the differences in pollutant concentrations between the two models were greater compared to Use Case C. Once again, this can mainly be attributed to the difference in how the pseudo-schedule is generated for Use Case B between AEDT 2b and EDMS. The $PM_{2.5}$ and PM_{10} annual and 24-hour concentrations mirror what was observed in the emissions inventory. AEDT 2b $PM_{2.5}$ and PM_{10} concentrations are consistently lower than the EDMS results, which is partially due to PM values produced by AEDT are lower than EDMS.

5 Use Case D – Part 150 Analysis

5.1 Description of Use Case

The purpose of this Use Case is to evaluate the capability in AEDT 2b to perform a Part 150 airport noise analysis, and to test other aircraft noise modeling functionality in AEDT 2b. Historically, Part 150 analyses were performed with the legacy Integrated Noise Model (INM) tool. Since a key requirement for AEDT 2b was to sunset INM, Use Case D includes detailed comparisons between INM 7.0d su1 (the final version of INM) and AEDT 2b, to confirm that AEDT 2b performs as expected for Part 150 studies.

Use Case A provides a description of the internationally vetted methods incorporated into AEDT and the corresponding modules used to model aircraft noise in AEDT. The APM, AAM, AMM and the AEDT system databases are specifically tested by Use Case D. Since the main focus of Use Case D is to verify aircraft acoustic modeling functionality in AEDT, aircraft performance modeling algorithms were not specifically investigated. Instead, outputs from the APM were treated solely as inputs to the acoustic algorithms. However, any aircraft performance related differences that translate to changes in the acoustic output of AEDT were identified and noted.

The Use Case D analysis was performed in multiple phases. Since not all of the acoustic modeling functionality was available in AEDT until the final release, a two-staged testing schedule was established to accommodate multiple releases and split up the testing. This was further expanded to a three-staged testing to accommodate some functionality updates in AEDT 2b Service Pack 2 (AEDT 2b SP2).

The main focus of a Part 150 analysis is to establish the location and area of the day-night sound level (DNL) 65 dB contour in the vicinity of an airport due to aircraft operations. The functionality evaluated under Phase 1 of Use Case D includes:

1. Standard ANP commercial aircraft
2. Standard/default airport and runway information
3. Standard approaches and departures
4. Default airport-specific average weather conditions (SAE-AIR-1845)
5. Tracks
6. Lateral attenuation with soft ground absorption (SAE-AIR-5662)
7. Current start of takeoff roll noise directivity (SAE-AIR-1845)
8. Bank angle (on and off)
9. DNL and LAMAX noise metrics
10. Noise contour maps and area, standard grid and location point results
11. INM importing (ASIF)

All of these functionalities are available in the AEDT 2b release (May 29, 2015), which was utilized for the Phase 1 testing.

Phase 2 tested the specialized functionality that consists of other noise modeling functionalities that are not always included in Part 150 studies, but may be used in specialized noise analyses. These include, but are not limited to:

1. Standard ANP helicopters
2. Standard military aircraft
3. User-defined commercial, helicopter and military aircraft
4. User-defined airport and runway information
5. User-defined approaches and departures
6. Touch-and-go, circuit and level flight profiles (also taxi for helicopters)
7. Dispersed tracks
8. Runup operations for commercial and military aircraft[1]
9. Atmospheric absorption adjustment over a range of meteorological conditions (SAE-ARP-5534, SAE-ARP-866A) [2]
10. Hard ground absorption and lateral attenuation (SAE-AIR-5662) (soft ground absorption off for props and helicopters)
11. All noise metrics (including ambient file metrics, and user-defined noise metrics)[3]
12. Detailed grid results
13. Population counts inside noise contours
14. Dynamic and fixed noise contours
15. Importing INM studies into AEDT (GUI, ASIF)

All of the functionality used in the Phase 2 analysis is available in the AEDT 2b release.

Phase 3 tested the specialized terrain modeling functionality that is not always included in Part 150 studies, but may be used in specialized noise analyses. This includes:

1. Terrain shielding (on/off, multiple file types, terrain fill)

An issue with the terrain functionality was resolved in the AEDT 2b SP2 release (December 22, 2015), which was utilized exclusively for the Phase 3 testing.

5.2 Description of Testing

5.2.1 Function Testing

In addition to the AEDT automated release testing, the Use Case D software tests can verify that the desired functionality is operational in AEDT. The bugs or issues identified during this testing were reported to the AEDT development team for further investigation. These tests are described in more detail in Section 5.3 of this report.

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[1] Helicopter runups are not supported in AEDT 2b.

[2] Functionality includes switching between SAE-ARP-5534 and SAE-ARP-866A for atmospheric absorption, as well as modeling with unadjusted levels.

[3] Does not include TAUD or DDOSE.

5.2.2 UQ Testing

The focus of Use Case D is on the comparison between AEDT 2b and INM 7.0d su1 for several studies that utilize the functionality typically modeled in Part 150 analyses and on testing a range of aircraft types, study geometries, standard profiles and meteorological conditions. Additional studies were developed to test other noise functionality not typically covered by Part 150 airport noise analyses.

5.2.2.1 Overview of Airport Studies

For Phase 1, the legacy INM Test Suite consisting of INM studies for ANC, JFK, PHL and SFO were run in INM 7.0d su1, imported via ASIF into AEDT 2b, run in AEDT 2b and compared. Historically, these four studies were run in each new version of INM and then compared against previous versions in order to characterize the differences between the two versions of the software. PHL is a basic aircraft study that was first used as a testing example in INM version 4.11. SFO is a slightly more complicated airport study that was added as a testing example in INM version 5.0. AEDT example study "Study_INM" is quite similar to this SFO study. JFK and ANC are much more complex airport studies that were added to the test suite for INM Version 7.0, in order to include more elaborate, realistic airport studies to the test suite. These studies are described below.

Table 5-1. ANC Study Properties of Use Case D – Phase 1

Study Properties	Use Case D
Airport	ANC
Operations	2,266
Aircraft/Engine Combos	34
Runways	9
Tracks	182
Grid Size (DNL)	16 nmi x 16 nmi
Grid Points (DNL)	9,604
Discrete Receptors (Location Points)	4,887

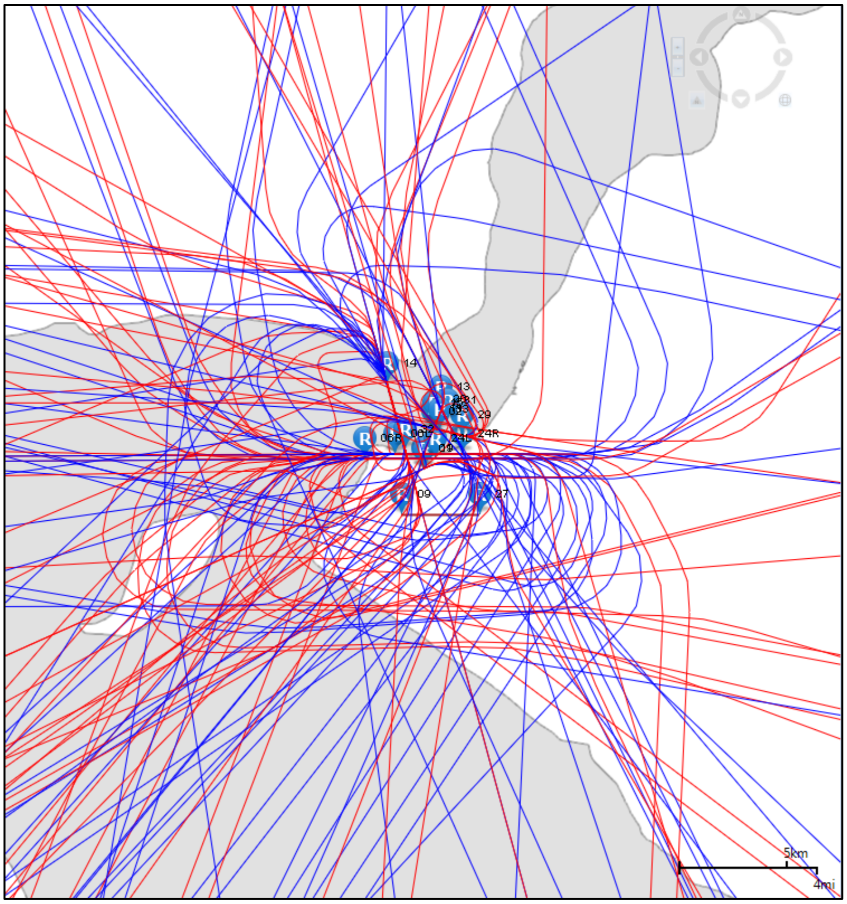

Figure 5-1. ANC Use Case D – Phase 1 Flight Tracks

Table 5-2. JFK Study Properties of Use Case D – Phase 1

Study Properties	Use Case D
Airport	JFK
Operations	6,069
Aircraft/Engine Combos	41
Runways	8
Tracks	151
Grid Size (DNL)	18 nmi x 17 nmi
Grid Points (DNL)	11,440
Discrete Receptors (Location Points)	25

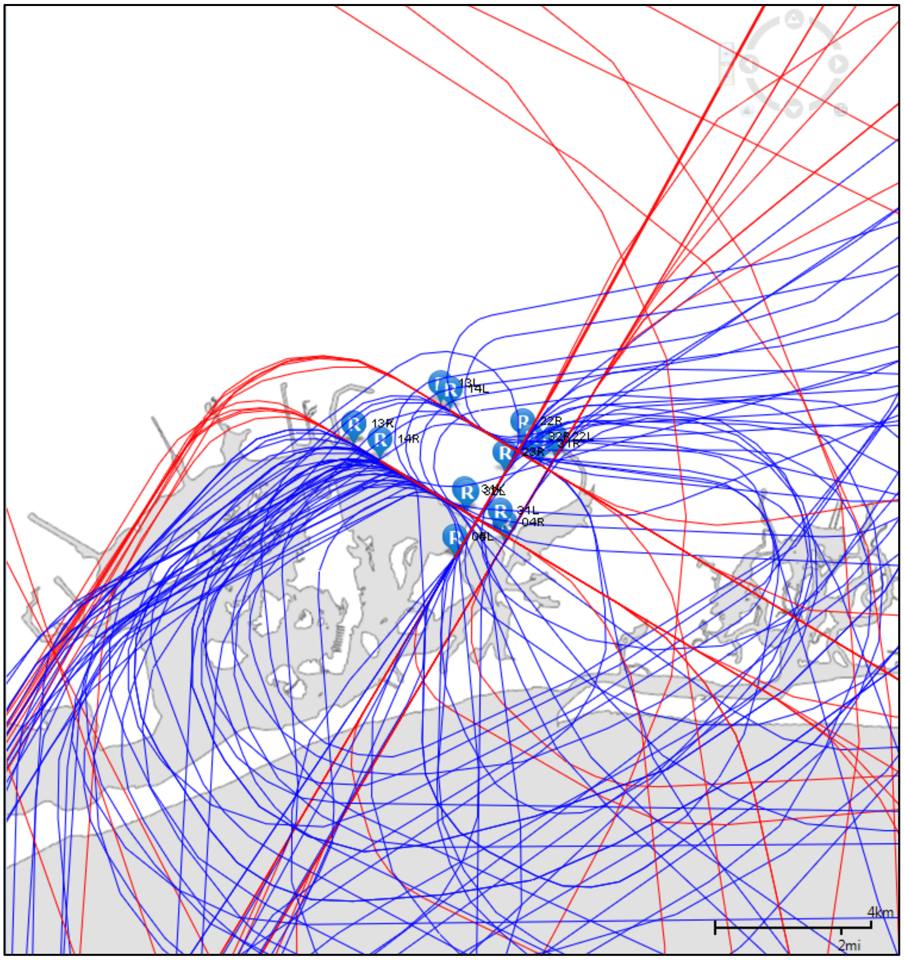

Figure 5-2. JFK Use Case D – Phase 1 Flight Tracks

Table 5-3. PHL Study Properties of Use Case D – Phase 1

Study Properties	Use Case D
Airport	PHL
Operations	1189
Aircraft/Engine Combos	11
Runways	3
Tracks	12
Grid Size (DNL)	16 nmi x 25 nmi
Grid Points (DNL)	14,896
Discrete Receptors (Location Points)	0

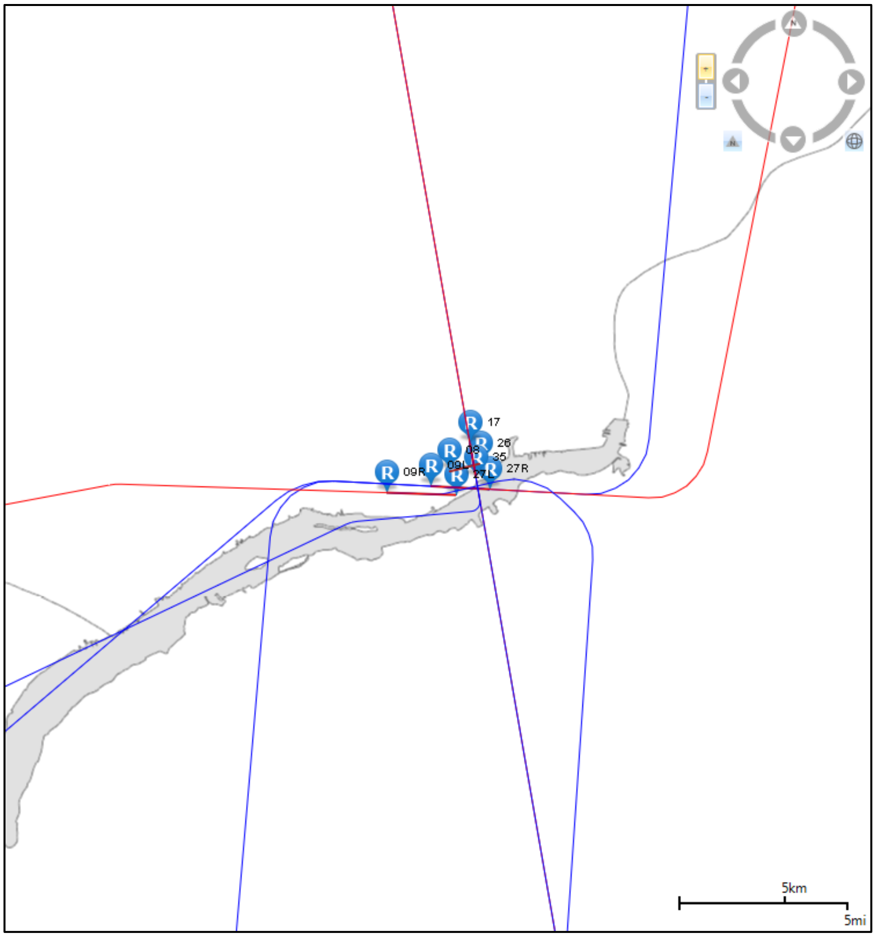

Figure 5-3. PHL Use Case D – Phase 1 Flight Tracks

Table 5-4. SFO Study Properties of Use Case D –Phase 1

Study Properties	Use Case D
Airport	SFO
Operations	304
Aircraft/Engine Combos	11
Runways	4
Tracks	14
Grid Size (DNL)	20 nmi x 16 nmi
Grid Points (DNL)	11,956
Discrete Receptors (Location Points)	36

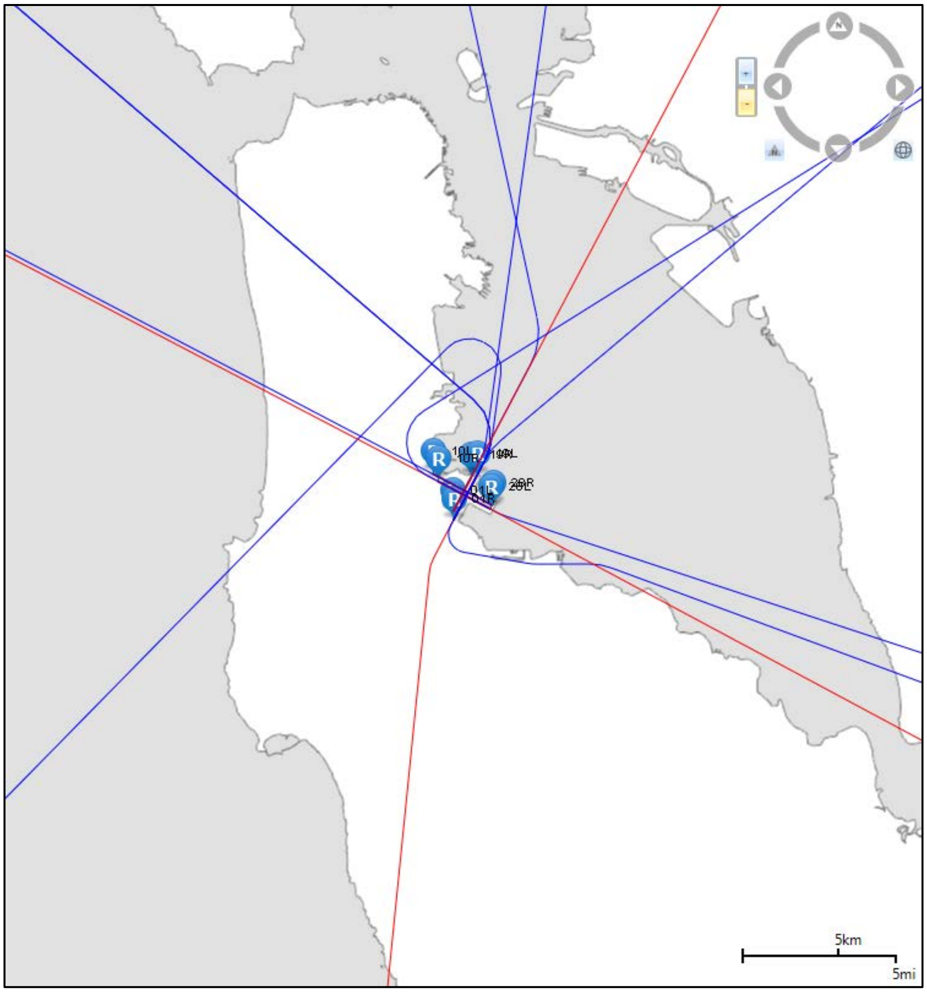

Figure 5-4. SFO Use Case D – Phase 1 Flight Tracks

For Phase 2, several different airport studies were built to test specialized acoustic functionality in AEDT 2b. These studies were built and run in INM 7.0d-su1, imported via ASIF into AEDT 2b, run in AEDT 2b and compared. These studies included:

- The AIRMOD ECAC Doc 29 Volume 3 test cases[4]: 12 test cases that consist of straight and curved approach and departure operations for three user-defined "generic" aircraft (jet with wing-mounted engines, jet with fuselage mounted engines, heavy propeller aircraft). This suite of test cases tests the following functionality: user-defined airport, user-defined runways, user-defined aircraft, standard tracks, user-defined profiles (fixed point profiles), noise metric DNL, dispersed tracks, and contours (generation and area).
- Additional test cases to test specialized functionality in AEDT 2b:

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[4] At the time of this analysis, these test cases were still being finalized by AIRMOD. In addition, these test cases will most likely be implemented in ICAO Doc 9911 as well.

  - UCD-Com tests commercial aircraft runups, touch-and-go and circuit profiles, level flight profiles, atmospheric absorption, and various noise metrics;
  - UCD-Helis tests ANP helicopters, user-defined helicopters, taxi profiles, soft ground absorption and lateral attenuation (SAE-AIR-5662);
  - UCD-Mil tests ANP military aircraft, and user-defined military aircraft;
  - UCD-DispTrack tests dispersed approach and departure tracks for several different track dispersion schema; and
  - UCS-Ambient tests sample ambient file(s) for different noise metrics and ambient file features (TALA, TALC, and TAPNL).

These studies are described below.

Table 5-5. AIRMOD Study Properties of Use Case D – Phase 2

Study Properties	**Use Case D**
Airport	Virtual Airport
Operations	12
Aircraft/Engine Combos	3
Runways	1
Tracks	4
Grid Size (DNL)	16 nmi x 5.6 nmi
Grid Points (DNL)	105,240
Discrete Receptors (Location Points)	18

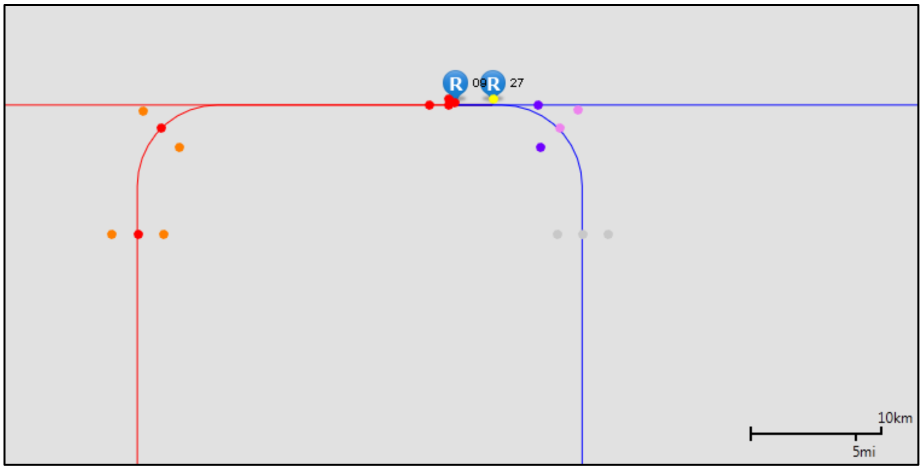

Figure 5-5. AIRMOD Use Case D – Phase 2 Flight Tracks

Table 5-6. UCD-Com Study Properties of Use Case D – Phase 2

Study Properties	Use Case D
Airport	CWA
Operations	8
Aircraft/Engine Combos	1
Runways	2
Tracks	8
Grid Size (DNL)	20 nmi x 16 nmi
Grid Points (DNL)	47,580
Discrete Receptors (Location Points)	8

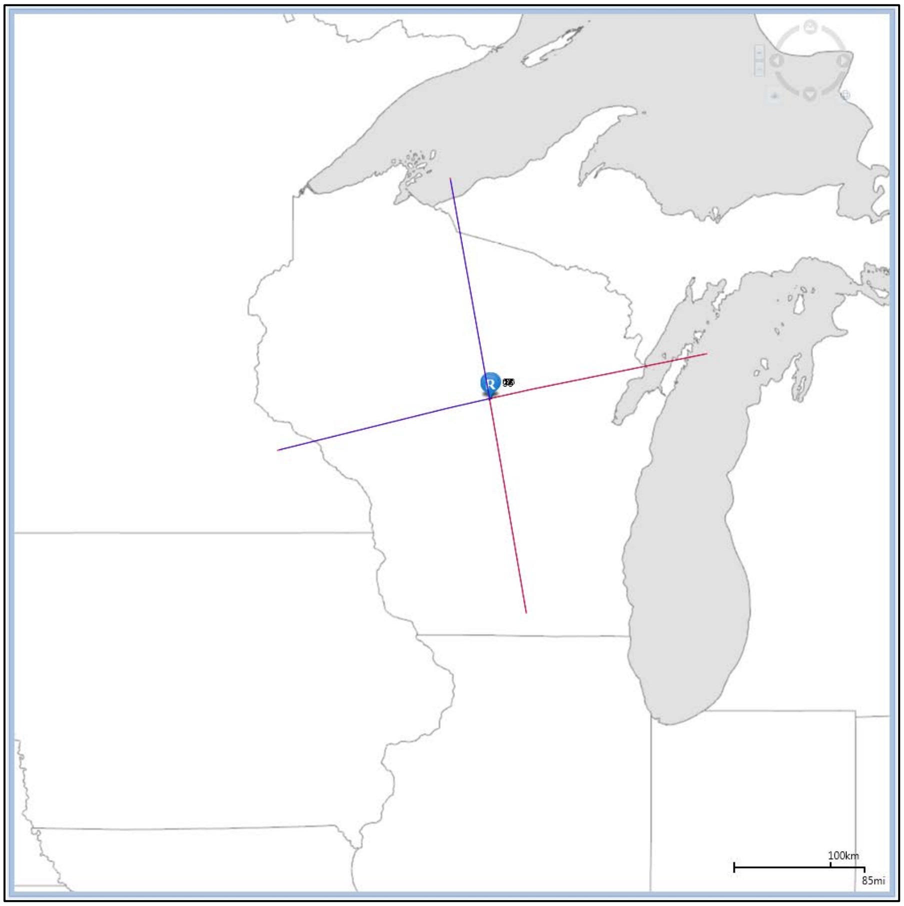

Figure 5-6. UCD-Com Use Case D – Phase 2 Flight Tracks

Table 5-7. UCD-Heli Study Properties of Use Case D – Phase 2

Study Properties	Use Case D
Airport	CWA
Operations	9
Aircraft/Engine Combos	3
Runways/Helipads	2/1
Tracks	5
Grid Size (DNL)	28 nmi x 36 nmi
Grid Points (DNL)	149,358
Discrete Receptors (Location Points)	8

Figure 5-7. UCD-Heli Use Case D – Phase 2 Flight Tracks

Table 5-8. UCD-Mil Study Properties of Use Case D – Phase 2

Study Properties	Use Case D
Airport	CWA
Operations	8
Aircraft/Engine Combos	2
Runways	2
Tracks	8
Grid Size (DNL)	16 nmi x 16 nmi
Grid Points (DNL)	38,205
Discrete Receptors (Location Points)	8

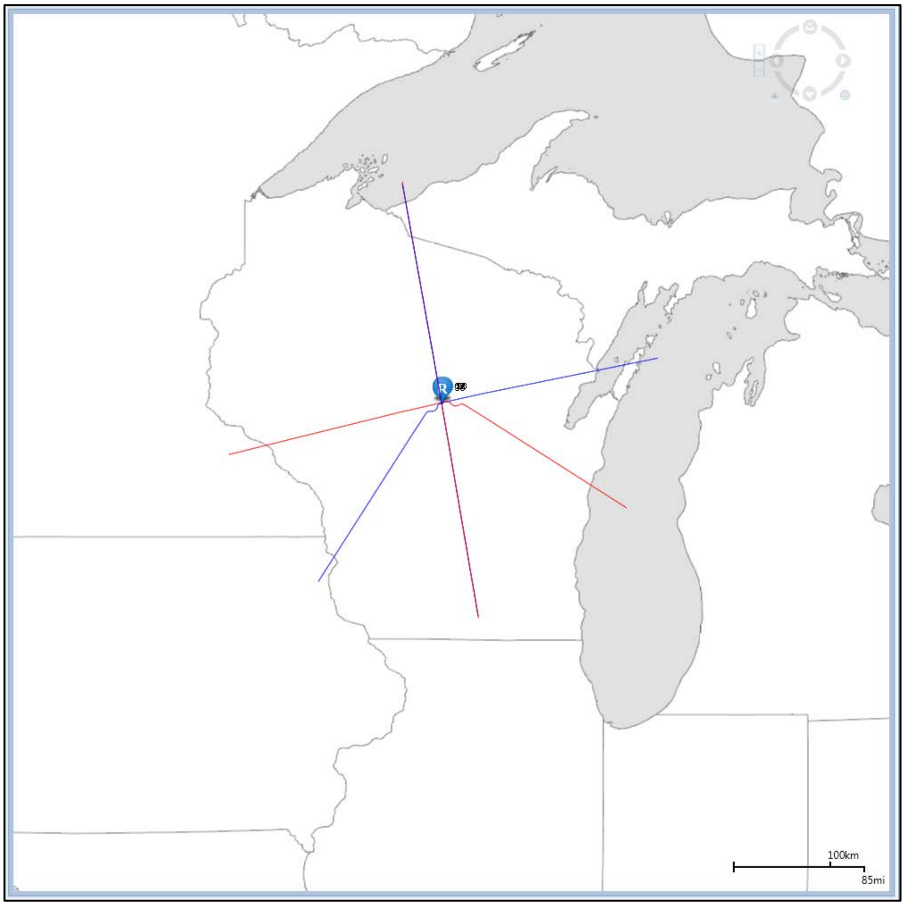

Figure 5-8. UCD-Mil Use Case D – Phase 2 Flight Tracks

Table 5-9. UCD-DispTrack Study Properties of Use Case D – Phase 2

Study Properties	Use Case D
Airport	CWA
Operations	24 (dispersed)
Aircraft/Engine Combos	1
Runways	2
Tracks/Subtracks	4/24
Grid Size (DNL)	16 nmi x 19 nmi
Grid Points (DNL)	45,045
Discrete Receptors (Location Points)	8

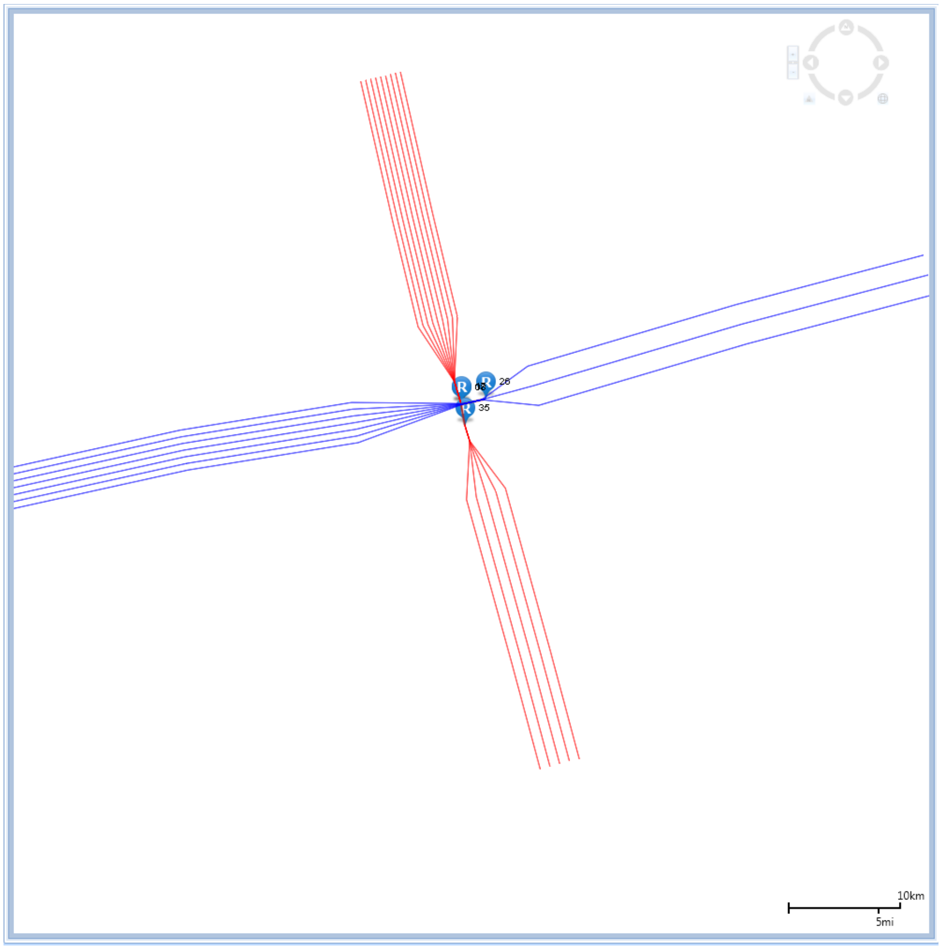

Figure 5-9. UCD-DispTrack Use Case D – Phase 2 Flight Tracks

Table 5-10. UCD-Ambient Study Properties of Use Case D – Phase 2

Study Properties	Use Case D
Airport	CWA
Operations	8
Aircraft/Engine Combos	3
Runways	2
Tracks	8
Grid Size (TALA)	20 nmi x 20 nmi
Grid Points (DNL)	14,884
Discrete Receptors (Location Points)	8

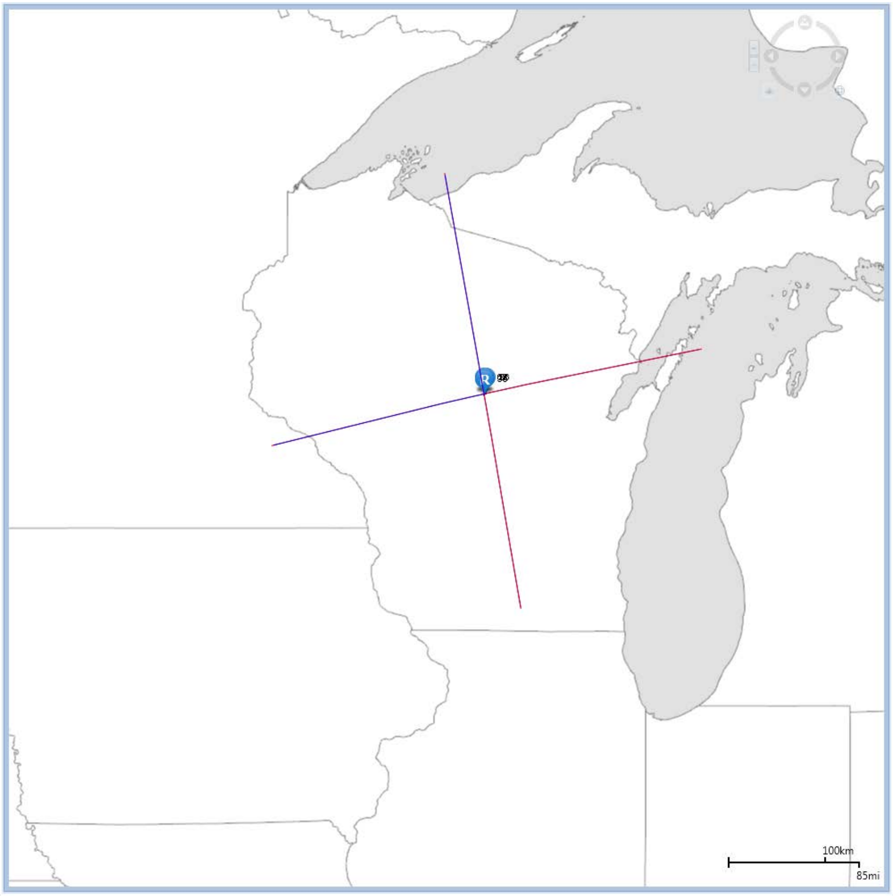

Figure 5-10. UCD-Ambient Use Case D – Phase 2 Flight Tracks

For Phase 3, several additional existing airport studies that utilize terrain were run in INM 7.0d-su1, imported via ASIF into AEDT 2b SP2, run in AEDT and compared. These studies test the terrain-related noise adjustments in AEDT (line-of-sight blockage, terrain fill, acoustic impedance, and change of study geometry), and are described below.

Table 5-11. UCD-PSP Study Properties of Use Case D – Phase 3

Study Properties	Use Case D
Airport	PSP
Operations	54
Aircraft/Engine Combos	7 commercial aircraft + 3 helicopters
Runways	4 runways + 1 Helipad
Tracks	12
Grid Size (DNL)	28 nmi x 34 nmi
Grid Points (DNL)	22,36
Discrete Receptors (Location Points)	21

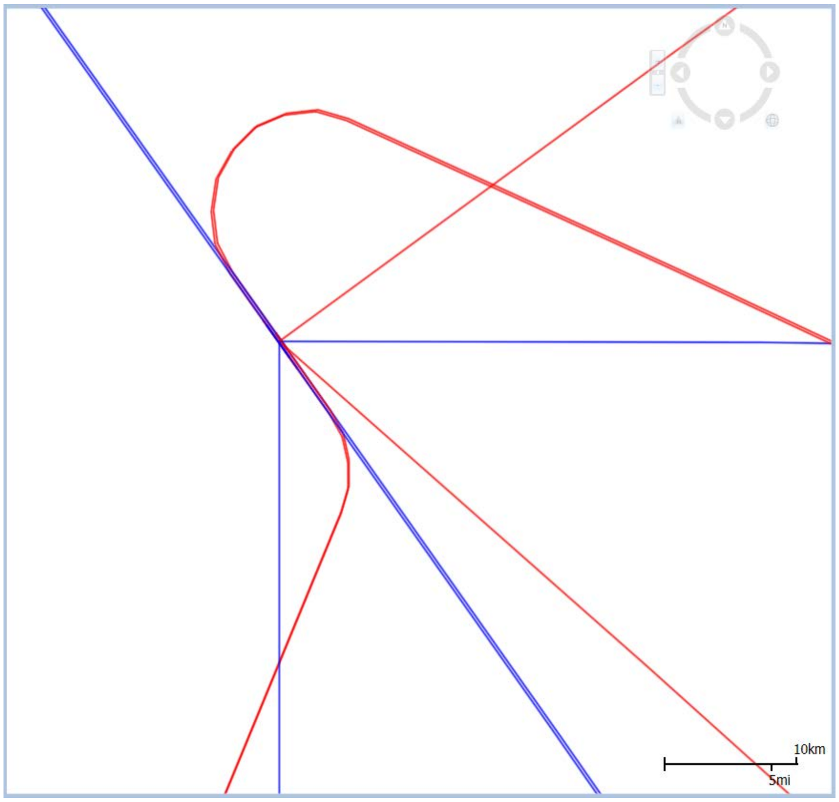

Figure 5-11. UCD-PSP Use Case D – Phase 3 Flight Tracks

Table 5-12. UCD-SLC Study Properties of Use Case D – Phase 3

Study Properties	Use Case D
Airport	SLC
Operations	30
Aircraft/Engine Combos	4 commercial aircraft + 1 helicopter
Runways	8 runways + 1 helipad
Tracks	14
Grid Size (DNL)	21 nmi x 22 nmi
Grid Points (DNL)	4,288
Discrete Receptors (Location Points)	19

5.2.2.2 Phase 1 Testing

Phase 1 testing focused on typical Part 150 noise analysis by reviewing full airport studies. The Phase 1 analysis included the four airport studies that made up the legacy INM test suite. Future analyses could include additional airport studies. For Phase 1 testing, the following test matrix was used.

Table 5-13. Phase 1 Testing Matrix

Study	Metrics	Contours	Recursive/Fixed Contour Grid	Standard/ Detailed Grids	Location Points	Population Points	Bank Angle
ANC	LAMAX, DNL	YES	REC	STND	*	-	-
ANC	LAMAX, DNL	YES	FIXED	STND	*	-	-
ANC Bank	LAMAX, DNL	YES	REC	STND	*	-	YES
ANC Bank	LAMAX, DNL	YES	FIXED	STND	*	-	YES
JFK	LAMAX, DNL	YES	REC	-	*	-	-
JFK	LAMAX, DNL	YES	FIXED	-	*	-	-
JFK Bank	LAMAX, DNL	YES	REC	-	*	-	YES
JFK Bank	LAMAX, DNL	YES	FIXED	-	*	-	YES
PHL	LAMAX, DNL	YES	REC	STND, DTL	YES	-	-
PHL	LAMAX, DNL	YES	FIXED	STND, DTL	YES	-	-
PHL Bank	LAMAX, DNL	YES	REC	STND, DTL	YES	-	YES
PHL Bank	LAMAX, DNL	YES	FIXED	STND, DTL	YES	-	YES
SFO	LAMAX, DNL, CEXP, LCMAX, NEF, PNLTmax	YES	REC	STND, DTL	YES	YES	-
SFO	LAMAX, DNL, CEXP, LCMAX, NEF, PNLTmax	YES	FIXED	STND, DTL	YES	YES	-
SFO Bank	LAMAX, DNL, CEXP, LCMAX, NEF, PNLTmax	YES	REC	STND, DTL	YES	YES	YES
SFO Bank	LAMAX, DNL, CEXP, LCMAX, NEF, PNLTmax	YES	FIXED	STND, DTL	YES	YES	YES

Phase 1 testing should be repeated, if any of the following trigger conditions occur during future AEDT development:

- General updates to the APM or AAM;
- General updates to standard profiles;
- Updates to the AEDT Fleet database (update dependent);
- Updates to gridding or contouring methods; and
- Updates to INM importing methods.

It is important to note that after review, differences between AEDT 2b and INM of greater than 1.0 dB or 10% difference in contour area may still be acceptable, but that acceptability should be determined on a case-by-case basis.

5.2.2.3 Phase 2 Testing

For Phase 2, additional test studies were built in INM that employ the remaining functionality. These studies were built and run in INM, imported into AEDT 2b and run, and then compared. These studies may be supplemented by existing legacy airport and National Parks studies in the future. The following test matrix was used:

Table 5-14. Phase 2 Testing Matrix

Study	Study Variation	Metrics	Contours	Recursive /Fixed /Dynamic Contour Grid	Standard/ Detailed Grids	Bank Angle	Fully imported by the ASIF	Comments
AIRMOD	AIRMOD	DNL	-	-	Both	-	YES	User-defined commercial aircraft, user-defined airport and user-defined runways
UCD-Com	UCD-Com2	DNL	YES	Fixed	-	YES	YES	Commercial aircraft
	UCD-Com2-866A-CH	DNL	YES	Fixed	-	YES	YES	Commercial aircraft with non-standard atmosphere (cold and humid)
	UCD-Com2-866A-CL	DNL	YES	Fixed	-	YES	YES	Commercial aircraft with non-standard atmosphere (cold and dry)
	UCD-Com2-866A-HH	DNL	YES	Fixed	-	YES	YES	Commercial aircraft with non-standard atmosphere (hot and humid)
	UCD-Com2-866A-HL	DNL	YES	Fixed	-	YES	YES	Commercial aircraft with non-standard atmosphere (hot and dry)
	UCD-Com2-866A-MM	DNL	YES	Fixed	-	YES	YES	Commercial aircraft with non-standard atmosphere (temperate)

Study	Study Variation	Metrics	Contours	Recursive /Fixed /Dynamic Contour Grid	Standard/ Detailed Grids	Bank Angle	Fully imported by the ASIF	Comments
UCD-Com	UCD-Com2-metrics	DNL, CEXP, CNEL, EPNL, LAEQ, LAEQD, LAEQN, LAMAX, LCMAX, NEF, PNLTM, SEL ,TALA, TALC, TAPNL, WECPNL	YES	Fixed	-	YES	YES	Commercial aircraft with all noise metrics in AEDT
	UCD-Com2-metrics-UD	DNL, CDNL	YES	Fixed	-	YES	YES	Commercial aircraft with user-defined noise metric *(receptor set output not supported in AEDT)*
	UCD-Com2-runups	DNL	YES	Fixed	-	YES	YES	Commercial aircraft runup operations
UCD-Helis	UCD-Helis	DNL	YES	Fixed	-	YES	YES	Helicopter operations, including taxi
	UCD-Helis-user	DNL		Fixed	-	YES	No	User-defined helicopter *(not supported by INM to ASIF Converter)*
UCD-Mil	UCD-Mil	DNL	YES	Fixed	-	YES	YES	Military aircraft operations
	UCD-Mil-user	DNL		Fixed	-	YES	No	User-defined military aircraft *(not supported by INM to ASIF Converter)*
	UCD-Mil-runup	DNL	No	Fixed	-	YES	No	Military aircraft runup operations *(not supported by AEDT)*
UCD-DispTrack	UCD-DispTrack	DNL	YES	Fixed	-	YES	YES	Applied track dispersion
UCD- Ambient	UCD-Ambient	TALA, TALC, TAPNL	YES	Fixed	-	YES	YES	Used ambient files

Phase 2 testing should be repeated, if any of the following trigger conditions occur during future AEDT development:

- Functionality specific updates to the GUI, AAM, AMM, Wx, and APM;
- Updates to the AEDT Fleet database (aircraft-specific tests); and
- Updates to track dispersion and ambient modeling methods.

It is important to note that after review, differences between AEDT 2b and INM of greater than 1.0 dB or 10% difference in contour area may still be acceptable, but that acceptability should be determined on a case-by-case basis.

5.2.2.4 Phase 3 Testing

For Phase 3, additional test studies were created in INM that use terrain modeling features with terrain files. These studies may be supplemented by existing legacy airport and/or National Parks studies in the future.

The following test matrix was used:

Table 5-15. Phase 3 Testing Matrix

Study	Study Variation	Metrics	Contours	Recursive /Fixed /Dynamic Contour Grid	Standard/ Detailed Grids	Terrain	LOS + Fill	Bank Angle	Fully imported by the ASIF	Comments
PSP	PSP-Flat	DNL	Yes	Fixed	-	-	-	Yes	YES	Baseline study without terrain, includes helicopters
	PSP-Terrain	DNL	Yes	Fixed	-	Yes	-	Yes	YES	Study includes terrain
	PSP-LOS+Fill	DNL	Yes	Fixed	-	Yes	Yes	Yes	YES	Study includes terrain, LOS blockage and terrain fill
SLC	SLC-Flat	DNL	Yes	Fixed	-	-	-	Yes	YES	Baseline study without terrain, includes helicopters
	SLC-Terrain	DNL	Yes	Fixed	-	Yes	-	Yes	YES	Study includes terrain
	SLC-LOS+Fill	DNL	Yes	Fixed	-	Yes	Yes	Yes	YES	Study includes terrain, LOS blockage and terrain fill

Phase 3 testing should be repeated, if any updates to the terrain modeling methods occur during future AEDT development. It is important to note that after review, differences between AEDT 2b and INM of greater than 1.0 dB or 10% difference in contour area may still be acceptable, but that acceptability should be determined on a case-by-case basis.

5.3 Outcomes/Results of Testing

The results for the Use Case D AEDT 2b and INM noise comparisons are presented in this section. It is important to note that there are several underlying differences between AEDT and

INM that can lead to differences in noise results. Some of these computational/functional differences that may impact noise results are listed below.

1. The noise contours in this analysis were generated using fixed grids. AEDT and INM utilize different contouring methods, which can result in differences when comparing contours from the two different models, especially in areas that show large changes in sound pressure level over a short distance (i.e., highest contour level).
2. In addition, both AEDT and INM utilize different methods for "smart contouring", or methods that utilize GIS techniques and noise level change analysis to trim out grid points that are unnecessary for developing noise contours, and therefore reduce computation time. In AEDT, this method is called "dynamic gridding"; in INM it is called "recursive gridding". Dynamic and recursive gridding are fundamentally different gridding methods used to achieve similar goals. Since they are different, INM recursive grids cannot be imported into AEDT as dynamic grids. Since the purpose of this analysis is to compare AEDT and INM results using the same or similar inputs, recursive and dynamic grids were not included in this analysis. If they were, they could result in differences when comparing contours from the two different models, especially in areas that show large changes in sound pressure level over a short distance (i.e., highest contour level).
3. AEDT and INM use slightly different methods for assigning grid point positions in a study. In both INM and AEDT, a set of fixed grids is created by defining the numbers of points being generated to X and Y directions from a reference point and the spaces among the points. The set of generated points forms a flat planar surface, and they are projected down to the Earth surface to assign the latitude and longitude coordinates to each of the grid points. The X-Y plane of the grids and the Earth surface make contact at a point, used as the projection origin. INM and AEDT use different projection origins to create this map projection. INM uses the airport origin as the projection origin, whereas AEDT uses the grid origin (the south-west corner of the X-Y plane). This can result in different coordinate locations for what is supposed to represent the same grid point, even if a grid is imported from INM. The differences in the grid coordinate locations don't necessarily impact noise contours as long as the grid resolutions are fine enough. However, care must be made when noise results are compared on a receptor point-by-receptor point basis. An update to AEDT 2c was made to use the airport reference point as the projection origin.
4. The flight path segmentation in AEDT and some additional functionality in the APM are different from the segmentation and performance methods used in INM. This can result in small changes to flight path segment geometry, speed and thrust, which in turn can have small effects on noise levels.
5. The default weather data used in AEDT resides in the airport database. Even when an INM study with user-defined weather data (or even INM default weather data) is imported into AEDT, the AEDT data are utilized unless explicitly edited by the user in AEDT after the importation. Differences in weather data can result in differences in noise levels, even if

default atmospheric absorption is used (SAE-AIR-1845). Of particular note is headwind. INM assumes a default 8 kts headwind, whereas AEDT uses airport-specific headwind data.

6. Updates to AEDT's aircraft performance and noise database can lead to different noise results. The AEDT's fleet database are constantly updated in order to incorporate the best available information. Since the INM database does not receive the same updates, improvements in the AEDT database can lead to differences in aircraft performance data (ANP coefficients) and noise data (NPD curves) between AEDT and INM.
7. AEDT and INM calculate the directivity in lateral attenuation of noise accounting for engine installation locations for jet aircraft. In INM, the engine installation location values are associated with the spectral class database. Since separate spectral classes were used for approach and departure operations for any given aircraft, there existed the possibility that an aircraft could (incorrectly) have different engine installation directivity adjustments for approach and departure operations. This issue was resolved in AEDT with decoupling of engine installation location and spectral class. Therefore, only a single engine installation location is referenced for each aircraft, and therefore the same engine installation directivity adjustment is guaranteed to be used for approach and departure operations in AEDT 2b. However, this means that engine installation location value for several aircraft in the test cases used for AEDT UQ Use Case D will not be consistent between AEDT and INM. Implications of the differences in engine installation locations will be discussed in Sections 5.4.

Some of these differences are further discussed in more detail in Section 5.5. These potential differences should be kept in mind when comparing AEDT and INM noise results.

5.3.1 Phase 1 Testing Results

The four Phase 1 test cases were used to evaluate AEDT 2b noise computation functionality typically encountered in airport Part 150 analyses. The Phase 1 test cases were run in both INM 7.0d su1 and AEDT 2b with and without bank angle. The results are compared in the following tables and graphics, which include:

- Contour plots, and
- Contour area comparison tables.

Where appropriate, grid-point-difference plots and grid-point-difference statistic tables are also presented. DNL and LAMAX noise results are presented in this section, but results for additional metrics may be provided, upon request. Although not presented in this report, additional results are available for detailed grid results, location points and population points for some of the studies, upon request.

As mentioned in Section 5.3, AEDT dynamic grids and INM recursive grids were not included in this analysis. All the Phase 1 tests were conducted using the standard weather for INM and airport specific weather for AEDT. Both INM and AEDT used the SAE-AIR-1845 atmospheric absorption model, which does not adjust the NPDs for non-standard day weather.

5.3.1.1 Phase 1 Testing Results – ANC

ANC was run in both INM 7.0d su1 and AEDT 2b with and without bank angle. All the results without the bank angle are provided in Appendix B. The following DNL and LAMAX noise results for contours and standard grids were generated:

Table 5-16. ANC – DNL with Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	268.233	278.475	-10.242	3.6
60	94.780	101.163	-6.383	6.3
65	43.234	45.291	-2.057	4.5
70	20.246	20.992	-0.746	3.6
75	8.993	9.284	-0.291	3.1
80	3.919	4.069	-0.150	3.7
85	1.295	0.358	0.937	N/A[5]

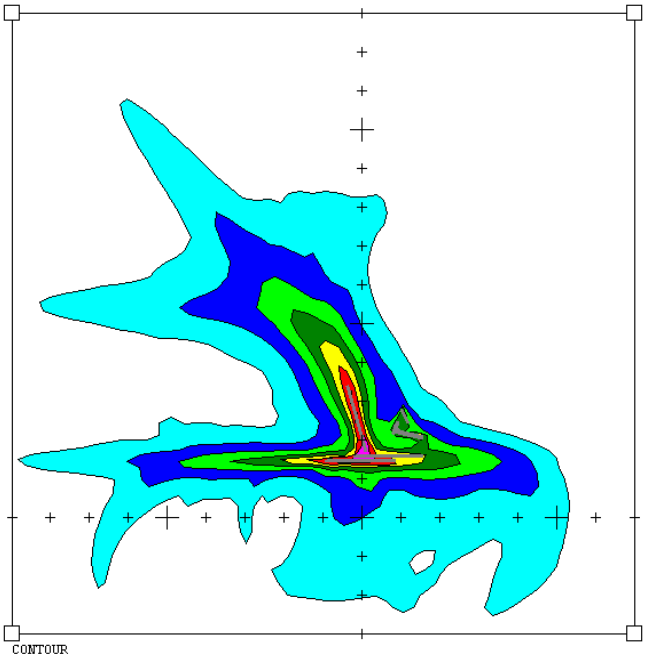

Figure 5-12. ANC – DNL with Bank Angle INM Contours

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[5] At higher noise levels that produce smaller contour areas (e.g., 85 dB DNL), the differences between AEDT and INM contours often becomes large (greater than 10-20%). This is attributed to differences in contouring methods and contour resolution. In addition, AEDT does not plot contours that intersect the study boundary, which can be problematic when comparing large contour areas (e.g., 55 dB DNL). When these differences became greater than 50%, they were not included in this analysis, and they were earmarked to be revisited in the future, through an investigation of contour/grid resolution.

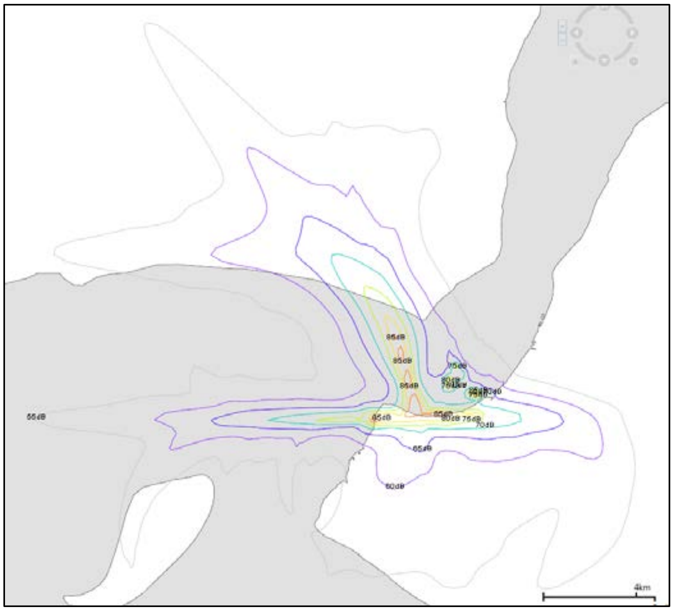

Figure 5-13. ANC – DNL with Bank Angle AEDT 2b Contours

Table 5-17. ANC – DNL with Bank Angle, INM-AEDT 2b Grid Point Differences

	Difference (INM-AEDT) for Grid Points		
	x (m)	**y (m)**	**Noise Level (dB)**
min	-127.770622	32.392692	-4.8
max	0.445718	157.051044	0.5
avg	-64.104722	75.632245	-0.2
stdev	38.91014321	39.41584654	0.4

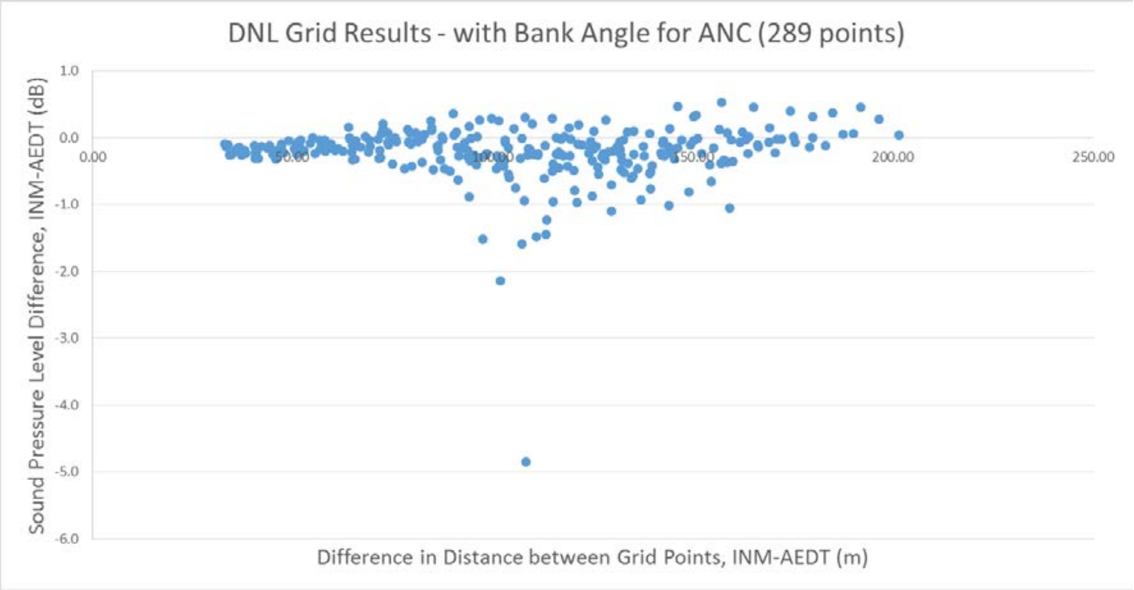

Figure 5-14. ANC – DNL with Bank Angle Grid Results

For the ANC study with bank angle turned on, the differences between the AEDT 2b and INM DNL contour area results were less than 6.3% for the contour areas of interest (with the difference for the DNL 65 dB contour being 4.5%). A visual comparison of the contour plots showed that the AEDT 2b and INM contours had similar shapes. At higher noise levels that produce smaller contour areas (e.g., 85 dB DNL), the differences became greater than 10%, but this is attributed to differences in contouring methods and contour resolution.

The DNL results from the INM standard grid (289 points) in INM and AEDT 2b were also compared for ANC with bank angle. An average of -0.2 dB difference (with a standard deviation of 0.4 dB) was observed, indicating that AEDT produced only slightly louder results. These differences in noise levels are attributed to the differences in the INM and AEDT algorithms and database as discussed in more detail later in this section. However, one of the reasons for the differences in the DNL values at the grid points is the fact that noise grid points defined in INM and AEDT were different. While reviewing these grid results, a difference between the INM grid point coordinates and the coordinates imported into AEDT (from the same INM source) was observed. Figure 5-14 shows the differences in the DNL levels at the 289 grid points used in INM and AEDT. Due to the differences in the latitude and longitude coordinates assigned to the grid points, the INM grids and the corresponding AEDT grids were separated from each other by at least 20 meters or up to 200 meters. Everything being equal, calculating noise at different locations will yield different noise results. Therefore, when such a grid-point by grid-point noise comparison is needed between INM and AEDT, the users must ensure that the grid points actually correspond to the same locations.

Table 5-18. ANC – LAMAX with Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
90	119.890	N/A	N/A	N/A
95	53.532	55.234	-1.702	3.1
100	30.104	30.119	-0.015	0.0
105	12.955	12.599	0.356	-2.8
110	5.577	4.999	0.578	-11.6
115	2.835	2.329	0.506	-21.7
120	1.286	0.917	0.369	-40.2

For the ANC study with bank angle turned on, the differences between the AEDT 2b and INM LAMAX contour area results were less than 3% for the contour areas that were greater than 6 sq. km. A visual comparison of the contour plots showed that the AEDT 2b and INM contours had similar shapes. At higher noise levels that produce smaller contour areas (e.g., 110 dB LAMAX), the differences became greater than 10%, but this is attributed to differences in contouring methods and contour resolution.

The observed differences in the noise results between INM and AEDT are caused by combinations of updates to the APM module, airport weather data, aircraft performance data, and different noise grid locations. The average temperature at ANC used in AEDT is much colder than the standard weather used in INM as shown in Table 5-19. The ANC study was rerun after modifying the AEDT weather to match the standard weather used in INM. The noise results in

Table 5-20 show much better agreement in DNL contour areas between INM and AEDT with a 1.66% difference for DNL 65 dB.

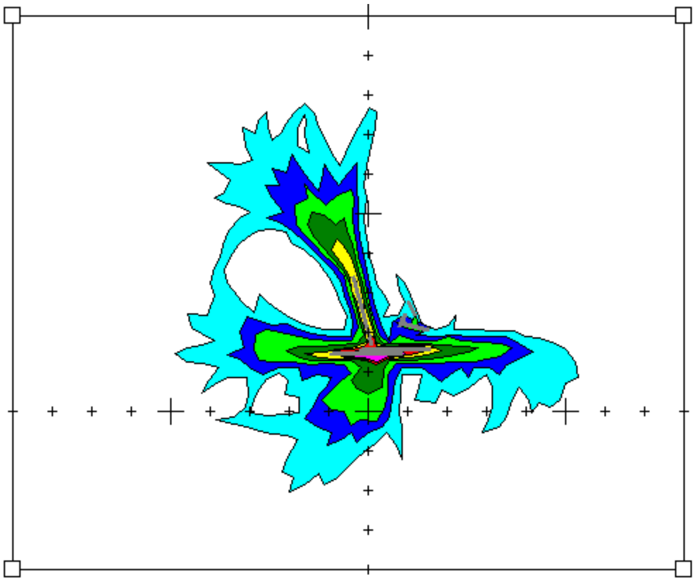

Figure 5-15. ANC – LAMAX with Bank Angle INM Contours

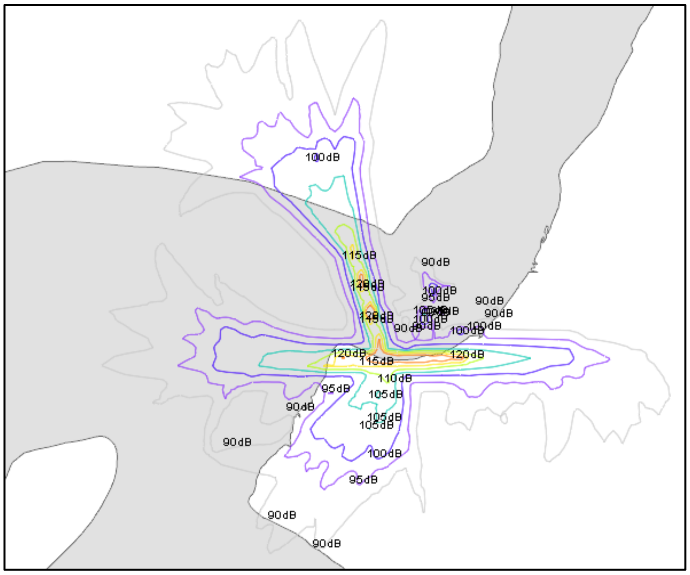

Figure 5-16. ANC – LAMAX with Bank Angle AEDT 2b Contours

Differences in the airport weather can cause differences in noise results for two reasons. Different temperature, pressure, and head wind cause differences in flight performance and trajectories. Different temperature, pressure, and humidity can also cause differences in how the noise from the aircraft propagates through the atmosphere to reach the receptor points. The former is dictated by the APM module, and the latter is governed by the acoustics module depending on the user choice of an atmospheric absorption model. All the tests in Use Case D used the SAE-AIR-1845 model, which does not adjust the NPD curves for non-standard day weather. Therefore, the differences in the AEDT 2b noise results with the different weather are purely due to the differences in flight performance.

In addition, the ANC study had a small portion of operations by Boeing 727-200 and MD-11. Those two aircraft types are among the aircraft with different engine installation locations between INM and AEDT as listed in Table 5-63. As discussed in Section 5.4 with greater detail, the incorrect engine location of 727-200 in AEDT can lead to significant differences in noise results.

Table 5-19. ANC Annual Average Weather in AEDT 2b vs the Standard Weather in INM

Parameters	AEDT 2b	INM 7.0
Temperature(°F)	36	59
Pressure (millibars)	1003.05	1013.2
Head Wind (knots)	6.34	8

Table 5-20. ANC – DNL with Bank Angle Testing Results after Matching the Airport Weather

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	268.233	266.021	2.212	-0.83
60	94.78	97.914	-3.134	3.20
65	43.234	43.965	-0.731	1.66
70	20.246	20.257	-0.011	0.05
75	8.993	8.989	0.004	-0.04
80	3.919	3.939	-0.02	0.51

5.3.1.2 Phase 1 Testing Results – JFK

JFK was run in both INM 7.0d su1 and AEDT 2b with and without bank angle. All the results without the bank angle are presented in Appendix B. The following DNL and LAMAX noise results for contours were generated:

Table 5-21. JFK – DNL with Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	329.804	316.054	13.750	-4.4
60	140.853	140.707	0.146	-0.1
65	49.602	54.670	-5.068	9.3
70	20.426	0.011	20.415	N/A
75	9.644	9.905	-0.261	2.6
80	4.630	0.099	4.531	N/A
85	1.885	1.887	-0.002	0.1

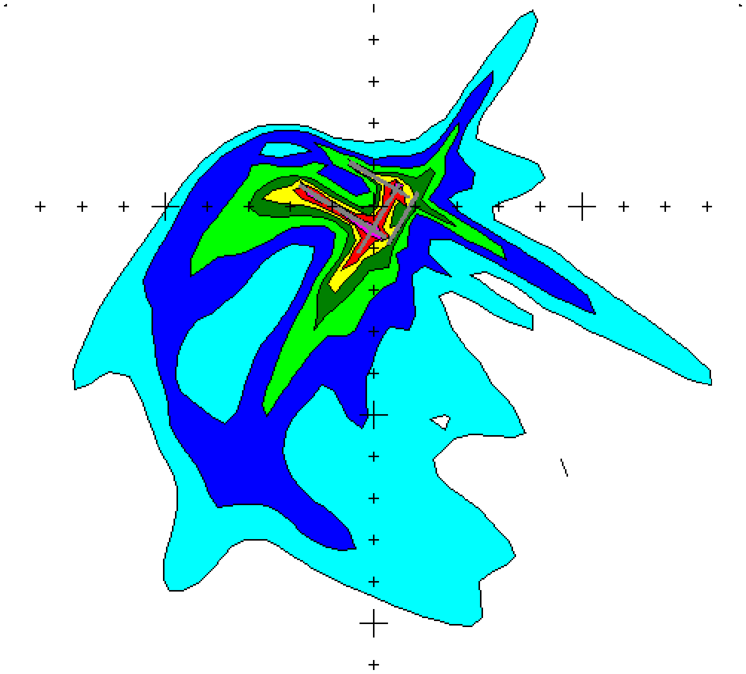

Figure 5-17. JFK – DNL with Bank Angle INM Contours

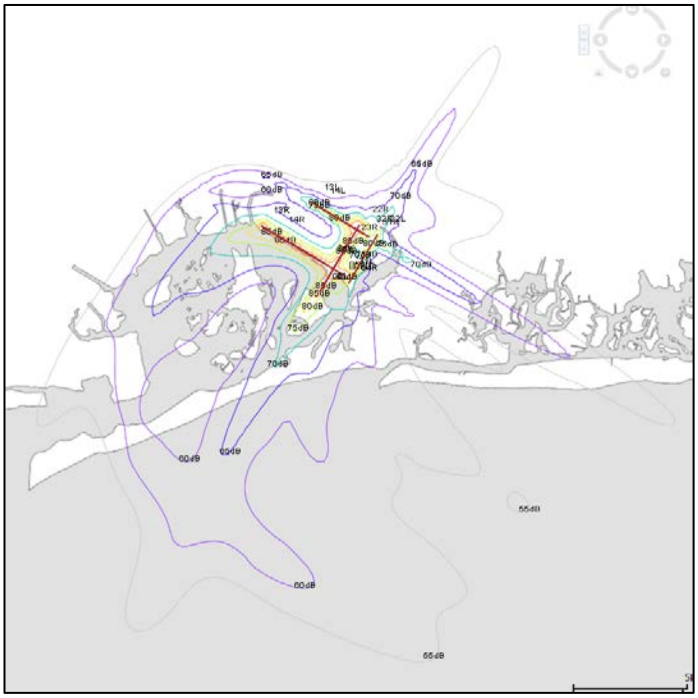

Figure 5-18. JFK – DNL with Bank Angle AEDT 2b Contours

For the JFK study with bank angle turned on, the difference between the AEDT 2b and INM DNL contour area results were less than 9.3% for the contour areas of interest (with the difference for the DNL 65 dB contour being 9.3%). A visual comparison of the contour plots showed that the AEDT 2b and INM contours had similar shapes.

It is important to note that several contours in AEDT 2b were unrealistically small (DNL 70 and 80 dB). After an investigation, it was found that the unrealistically small contours were caused by a bug in AEDT's contouring algorithm. The AEDT's contouring algorithm was found to work properly most of the time when the contour shapes are relatively simple. However, when contour shapes become complex due to multiple runways and turning tracks, the contouring algorithm could fail to capture all the features of a complex contour such as contour holes and islands. This bug was fixed for the AEDT 2c release.

Table 5-22. JFK – LAMAX with Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
90	414.225	327.409	86.816	-26.5
95	217.282	165.730	51.552	-31.1
100	84.634	83.120	1.514	-1.8
105	37.598	45.025	-7.427	16.5
110	22.865	25.478	-2.613	10.3
115	16.185	0.000	16.185	0.0
120	10.328	9.806	0.522	-5.3

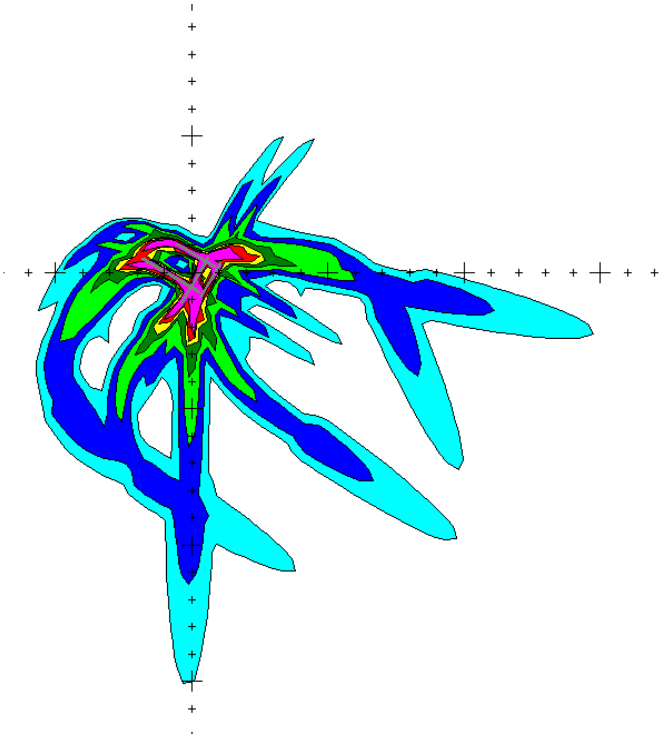

Figure 5-19. JFK – LAMAX with Bank Angle INM Contours

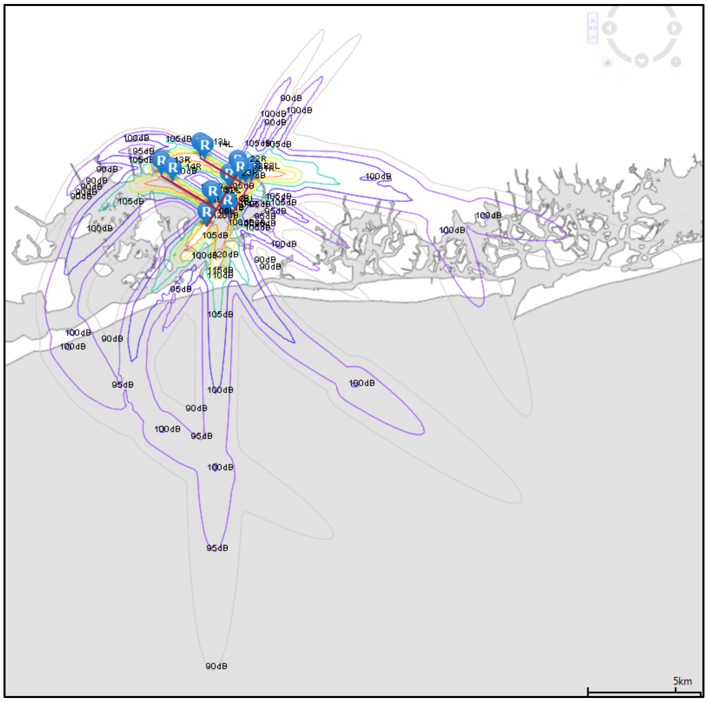

Figure 5-20. JFK – LAMAX with Bank Angle AEDT 2b Contours

For the JFK study with bank angle turned on, large differences between the AEDT 2b and INM LAMAX contour results were observed for some of the contour levels. In these cases, the AEDT 2b results were much lower than INM. Upon visual inspection, the contour shapes still look quite similar. The cause of these small contours in AEDT 2b is the aforementioned bug in AEDT's contouring algorithm.

5.3.1.3 Phase 1 Testing Results – PHL

PHL was run in both INM 7.0d su1 and AEDT 2b with and without bank angle. All the results without the bank angle are provided in Appendix B. The following DNL and LAMAX noise results for contours and standard grids were generated:

Table 5-23. PHL – DNL with Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	214.660	259.810	-45.150	17.4
60	83.491	106.298	-22.807	21.5
65	36.198	46.158	-9.960	21.6
70	18.146	21.397	-3.251	15.2
75	9.293	11.097	-1.804	16.3
80	4.446	5.349	-0.903	16.9
85	2.309	2.671	-0.362	13.6

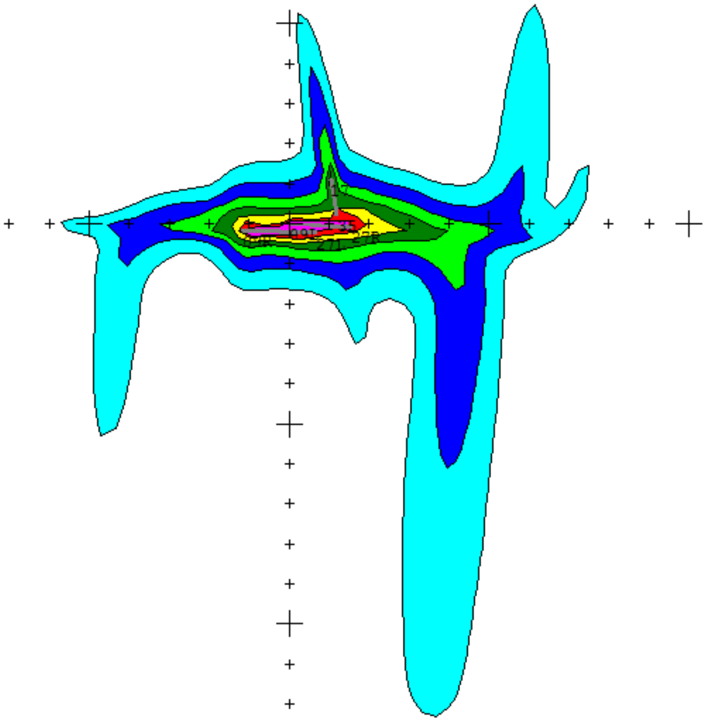

Figure 5-21. PHL – DNL with Bank Angle INM Contours

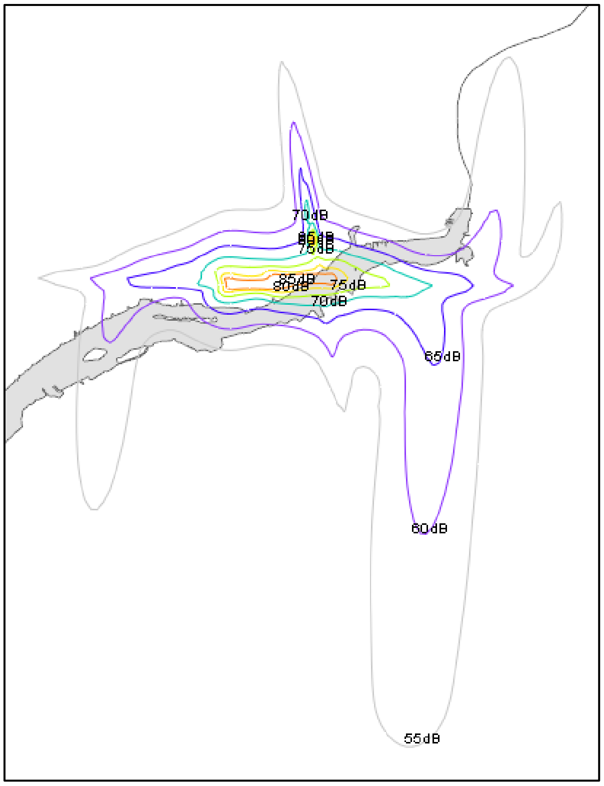

Figure 5-22. PHL – DNL with Bank Angle AEDT 2b Contours

For the PHL study with bank angle turned on, the differences between the AEDT 2b and INM DNL contour area results were less than 21.6% for the contour areas of interest (with the difference for the 65 dB DNL contour being 21.6%). For all contour levels, AEDT 2b contours were slightly larger than the INM contours. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes, but the AEDT 2b contours do appear to be larger, especially in the right half of the study.

Further investigations revealed a change in the AEDT 2b database was primarily responsible for this difference. Please, see Section 5.4 for the details on the investigation. In short, due to the updates in AEDT database from INM, some AEDT aircraft have different engine installation locations from the engine locations of corresponding INM aircraft. Those aircraft are listed in Table 5-63. The differences in engine installation directivity adjustments between several aircraft in AEDT and INM can explain some of the differences observed in the Use Case D analysis, especially for Phase 1 studies PHL and SFO, which have a significant number of operations from those aircraft. Table 5-24 shows the list of aircraft that were included in the PHL study along with the number of departures and arrivals. Among the 11 aircraft types used for the PHL study, 727Q15, MD81, and SABR80 have different engine installation locations between INM and AEDT as identified in Table 5-63. In the PHL study, operations by these three aircraft types accounted for more than 40% of total operations. Specifically, Boeing 727-100 (ANP ID 727Q15) accounted for more than 26% of the flights. As shown in Section 5.4, the incorrect engine locations of Boeing 727-100 in AEDT resulted in more than 20% differences in SEL and LAMAX contour areas. This error in AEDT database seemed to be the main cause of the differences in the DNL contour areas in PHL. To verify this, the PHL study was repeated in INM and AEDT after eliminating all the 727Q15 operations. The DNL contour area results are provided in Table 5-25. After removing the 727Q15 operations, the DNL contour areas between INM and AEDT are very close for most DNL levels. For DNL 65 dB, the difference was less than 1%. The difference was more than 21% with 727Q15. Therefore, the test confirmed that the 727Q15 was mainly responsible for the differences in noise results for PHL. Other differences, such as different engine locations for MD81 and SABR80 and the use of different weather between INM and AEDT studies also contributed to the differences in the noise results.

Table 5-24. Number of Operations by Aircraft Types for PHL

Airframe	Departure	Arrival	% of Total Ops
Airbus A300B4-200 Series	6	6	1.0%
Boeing 727-100 Series	151	160	26.2%
Boeing 737-300 Series	5	4	0.8%
Boeing 757-200 Series	8	14	1.9%
Boeing DC-8 Series 70	44	48	7.7%
Boeing DC-9-30 Series	148	148	24.9%
Boeing MD-10-30	27	48	6.3%
Boeing MD-81	9	9	1.5%
Raytheon Beech Baron 58	94	94	15.8%
Rockwell Sabreliner 80	98.2	54	12.8%
Boeing 747-200 Series	6.6	6	1.1%
Sum	**596.8**	**591**	**100%**

Table 5-25. PHL – DNL with Bank Angle Testing Results without 727Q15

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	87.356	87.923	-0.567	-0.64
60	36.28	38.241	-1.961	-5.13
65	17.092	17.21	-0.118	-0.69
70	7.919	7.883	0.036	0.46
75	3.407	3.423	-0.016	-0.47
80	1.419	1.566	-0.147	-9.39
85	0.414	0.339	0.075	22.12

Table 5-26. PHL – LAMAX with Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
90	23.303	27.341	-4.038	14.8
95	14.475	15.974	-1.499	9.4
100	8.371	9.800	-1.429	14.6
105	3.847	4.372	-0.525	12.0
110	2.336	2.195	0.141	-6.4
115	1.486	0.942	0.544	-57.7
120	0.649	0.323	0.326	N/A

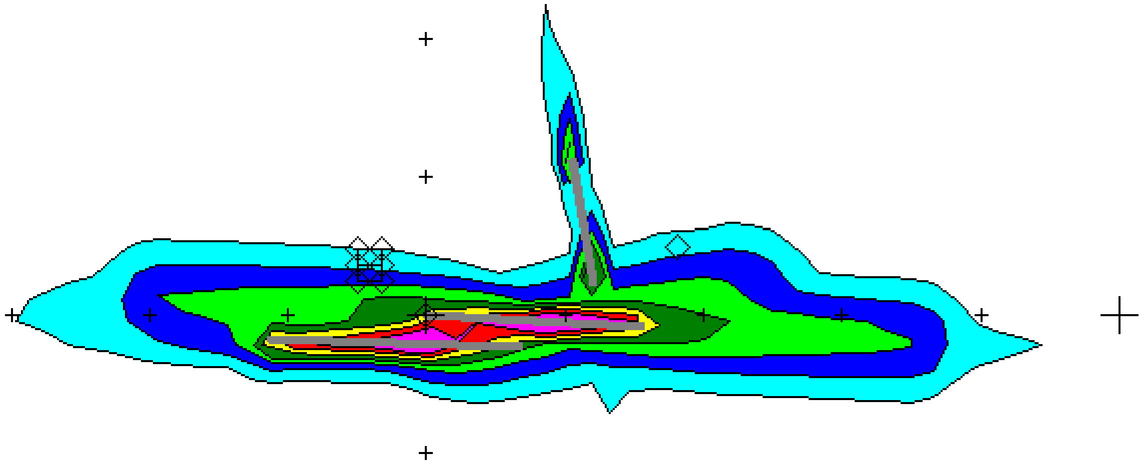

Figure 5-23. PHL – LAMAX with Bank Angle INM Contours

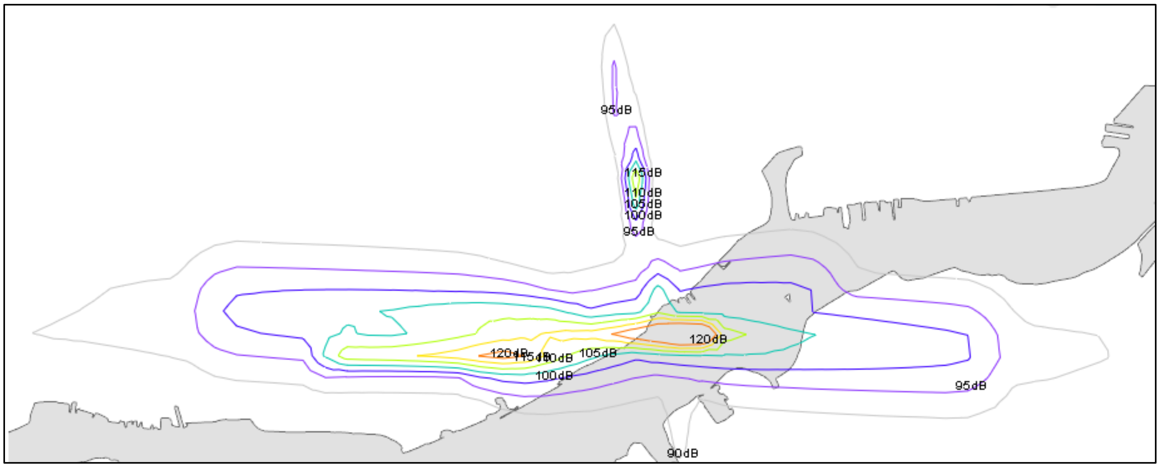

Figure 5-24. PHL – LAMAX with Bank Angle AEDT 2b Contours

For the PHL study with bank angle turned on, the differences between the AEDT 2b and INM LAMAX contour area results were less than 14.8% for the contour areas of interest. For all the contours with areas greater than 3 sq. km, the AEDT 2b contours were slightly larger than the INM contours, following a similar trend as is seen with the DNL results.

5.3.1.4 Phase 1 Testing Results – SFO

SFO was run in both INM 7.0d su1 and AEDT 2b with and without bank angle. All the results without the bank angle are provided in Appendix B. The following DNL and LAMAX noise results for contours and standard grids were generated:

Table 5-27. SFO – DNL with Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	184.733	195.075	-10.342	5.3
60	82.658	91.143	-8.485	9.3
65	33.035	36.657	-3.622	9.9
70	16.158	18.038	-1.880	10.4
75	7.178	8.160	-0.982	12.0
80	3.194	3.648	-0.454	12.4
85	1.066	1.272	-0.206	16.2

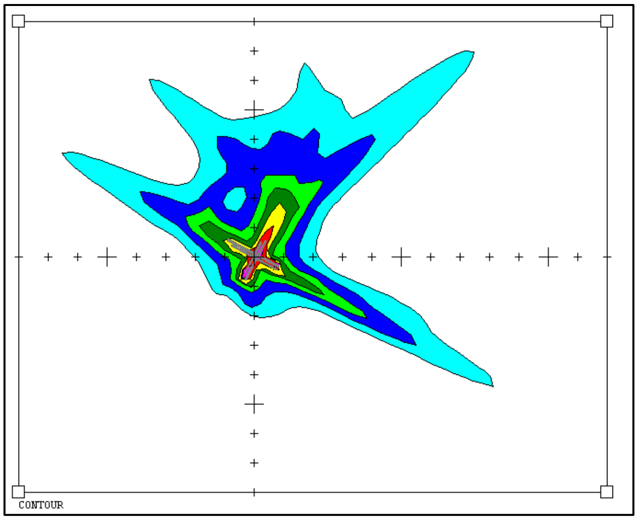

Figure 5-25. SFO – DNL with Bank Angle INM Contours

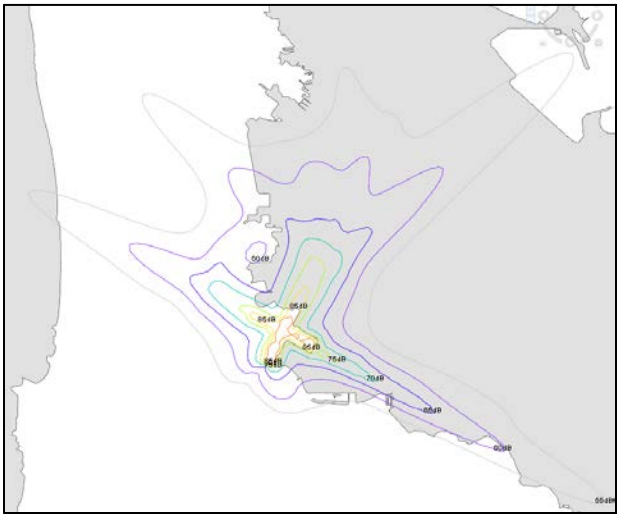

Figure 5-26. SFO – DNL with Bank Angle AEDT 2b Contours

For the SFO study with bank angle turned on, the differences between the AEDT 2b and INM DNL contour area results were less than 10.4% for the contour areas of interest (with the difference for the 65 dB DNL contour being 9.8%), with the higher contours with areas smaller than 8.2 sq. km having a larger difference. For all the contour levels, the AEDT 2b contours were slightly larger than the INM contours. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

Table 5-28. SFO – LAMAX with Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
85	92.950	106.653	-13.703	12.8
90	45.903	52.751	-6.848	12.9
95	28.005	31.822	-3.817	11.9

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
100	16.329	19.008	-2.679	14.1
105	6.014	7.127	-1.113	15.6
110	3.111	3.609	-0.498	13.8
115	1.519	1.951	-0.432	22.1
120	0.761	0.935	-0.174	18.6
125	0.365	0.448	-0.083	18.5

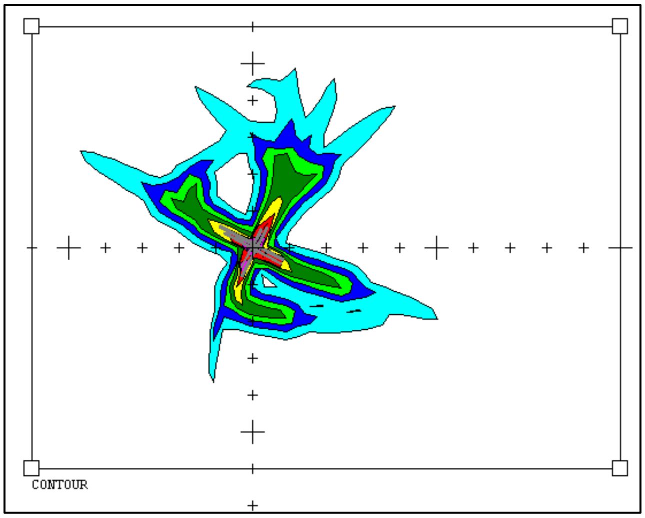

Figure 5-27. SFO – LAMAX with Bank Angle INM Contours

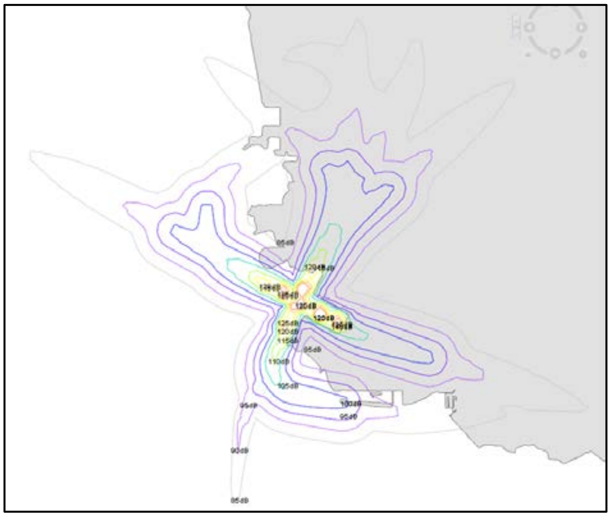

Figure 5-28. SFO – LAMAX with Bank Angle AEDT 2b Contours

For the SFO study with bank angle turned on, the differences between the AEDT 2b and INM LAMAX contour area results were less than 15.6% for the contour areas of interest, with the higher contours with areas smaller than 2 sq. km having a larger difference. For all the contour levels, the AEDT 2b contours were slightly larger than the INM contours. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

Similar to the PHL study, the main reason for the larger DNL and LAMAX contour areas in AEDT is the incorrect engine installation location of Boeing 727-100 in AEDT. Boeing 727-100 contributed to 11.5% of the total operations for the SFO study. In addition, the different engine locations of MD11 with 7.5% of the operations at SFO also contributed to the differences in noise results. Furthermore, updates to airport weather data, updates to the APM module, and differences in the noise grid locations caused small differences in noise results.

5.3.2 Phase 2 Testing Results

The Phase 2 test cases were used to evaluate AEDT 2b noise computation functionality that is not typically encountered in airport Part 150 analyses. The Phase 2 test cases were run in both INM 7.0d su1 and AEDT 2b with bank angle. The results are compared in the following tables and graphics, which include:

- Contour plots, and
- Contour area comparison tables.

Where appropriate, grid-point-difference plots and grid-point-difference statistic tables are also presented.

5.3.2.1 Phase 2 Testing Results - AIRMOD

The AIRMOD study was setup as part of an analysis conducted with ECAC AIRMOD, and leveraged for AEDT UQ. The AIRMOD study tests compliance with the test cases in ECAC AIRMOD Volume 3, currently under development. It includes three user-defined aircraft (one jet with wing-mounted engines [JETF], one jet with fuselage-mounted engines [JETW], and one propeller aircraft [PROP]), user-defined profiles, a user-defined airport and user-defined runways. The airport is setup to have a straight in approach track, a curved approach track, a straight-out departure track and a curved departure track.

The AIRMOD study was run in both INM 7.0d su1 and AEDT 2b with and without bank angle. Each of the three aircraft were modeled as a single event on each flight track, resulting in 12 single event scenarios to evaluate (e.g., JETF on a curved approach is labeled “JETFAC”). The following SEL noise results for 18 specific receptors and standard grids were generated and presented below. Table 5-29 presents the SEL difference between INM and AEDT (in dB) at key receptor locations surrounding the flight tracks. The grid cells highlighted in yellow indicate the receptor locations that ECAC Doc 29 Volume 3 specifies as appropriate for evaluating noise levels for a given single event study. The difference in SEL between INM and AEDT 2b is also plotted as a function of SEL in AEDT in Figure 5-29.

Table 5-29. AIRMOD Testing Results

Receptor	JETFAC	JETF AS	JETF DC	JETF DS	JETW AC	JETW AS	JETW DC	JETW DS	PROP AC	PROP AS	PROP DC	PROP DS
R01	-0.06	-0.01	-0.06	-0.04	-0.07	-0.03	-0.05	-0.07	-0.05	-0.04	-0.04	-0.08
R02	0.00	0.00	-0.02	-0.02	-0.01	-0.01	-0.02	-0.02	-0.09	-0.09	-0.09	-0.09
R03	-0.05	-0.05	-0.02	-0.09	-0.06	-0.06	-0.02	-0.10	-0.06	-0.06	-0.02	-0.02

R04	-0.06	-0.06	-0.01	-0.01	-0.07	-0.07	-0.02	-0.02	-0.08	-0.08	-0.08	-0.08
R05	-0.03	-0.03	-0.04	-0.06	-0.04	-0.04	-0.07	-0.10	-0.03	-0.02	-0.06	-0.08
R06	0.01	-0.06	-0.07	-0.06	-0.01	-0.07	-0.01	-0.01	-0.03	-0.01	-0.06	-0.08
R07	0.00	-0.09	-0.07	-0.04	-0.01	0.00	-0.03	-0.06	-0.09	-0.06	0.01	-0.09
R08	-0.03	-0.04	-0.06	-0.07	-0.05	-0.06	-0.02	-0.08	0.00	-0.07	0.00	-0.06
R09	0.02	0.02	0.08	-0.08	-0.01	-0.01	-0.04	-0.07	-0.08	-0.01	-0.05	-0.14
R10	-0.04	0.04	0.03	-0.11	0.04	0.02	0.08	-0.03	-0.01	-0.02	-0.02	0.03
R11	-0.02	0.00	0.09	-0.08	0.05	-0.03	0.04	-0.13	0.00	-0.02	-0.03	-0.07
R12	-0.02	-0.01	-0.16	-0.07	-0.02	-0.01	-0.26	-0.09	-0.10	0.00	-0.01	-0.09
R13	-0.04	-0.09	-0.20	-0.10	0.00	-0.06	-0.20	-0.02	-0.05	0.04	-0.05	-0.04
R14	-0.03	-0.04	-0.16	-0.03	0.00	0.00	-0.16	-0.05	-0.04	-0.07	0.00	-0.09
R15	0.03	0.02	-0.25	-0.07	-0.13	0.02	-0.27	-0.11	-0.05	0.02	-0.08	-0.08
R16	-0.07	0.06	-0.30	-0.11	-0.08	0.05	-0.32	-0.15	-0.07	0.03	-0.06	0.00
R17	-0.06	0.06	-0.24	-0.08	-0.07	0.07	-0.26	-0.12	-0.09	-0.01	-0.07	-0.03
R18	-0.05	-0.05	-0.04	-0.04	-0.01	-0.01	-0.05	-0.05	-0.09	-0.09	-0.04	-0.03

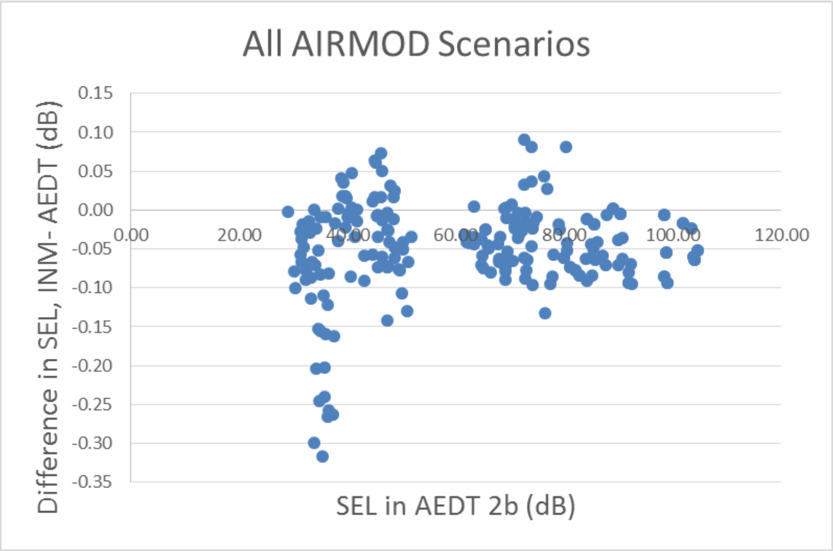

Figure 5-29. AIRMOD Test SEL Difference

A regularly spaced grid of receptors (resulting in 105,241 points) was also modeled for each of the 12 AIRMOD scenarios. The grid results from AEDT 2b and INM were compared, and statistics on the differences between the AEDT 2b and INM SEL results computed. The statistics for the JETFAC scenario are presented in Table 5-30 as an example.

Table 5-30. AIRMOD JETFAC Scenario Testing Results

	SEL (dB)
min	-0.11
max	0.13
avg	-0.03
stdev	0.04

Both the 18 specific receptors and the standard grids showed very good agreement between INM and AEDT 2b for the AIRMOD study. In most cases, AEDT and INM agreed within 0.2 dB SEL.

5.3.2.2 Phase 2 Testing Results - UCD-Com2

UCD-Com2 is a simple airport study with commercial aircraft operations on approach and departure tracks. It is meant to be the baseline study, on which all the other UCD-Com2 studies are built. UCD-Com2 was run in both INM 7.0d su1 and AEDT 2b with bank angle.

It should be noted that although UCD-Com2 focuses on modeling commercial aircraft operations, not all commercial aircraft nor all aircraft profiles in the AEDT Fleet database were included in this analysis. This analysis is meant to check the noise computation functionality related to commercial aircraft in AEDT, and not specifically review the contents of the AEDT 2b databases.

The following DNL noise results for contours were generated:

Table 5-31. UCD-Com2 – DNL Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	83.926	84.621	-0.695	0.8
60	31.467	31.694	-0.227	0.7
65	10.863	N/A	N/A	N/A
70	3.782	3.786	-0.004	0.1
75	1.473	1.544	-0.071	4.6
80	0.542	0.581	-0.039	6.7
85	0.144	0.115	0.029	-25.5

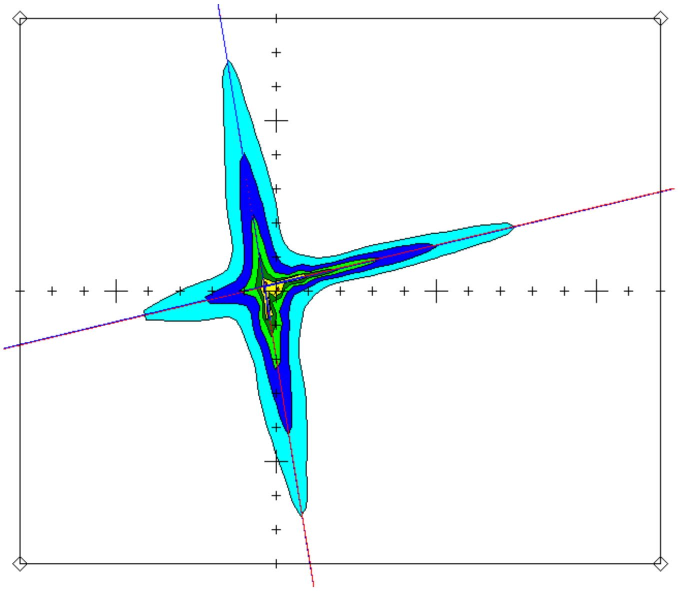

Figure 5-30. UCD-Com2 – DNL with Bank Angle INM Contours

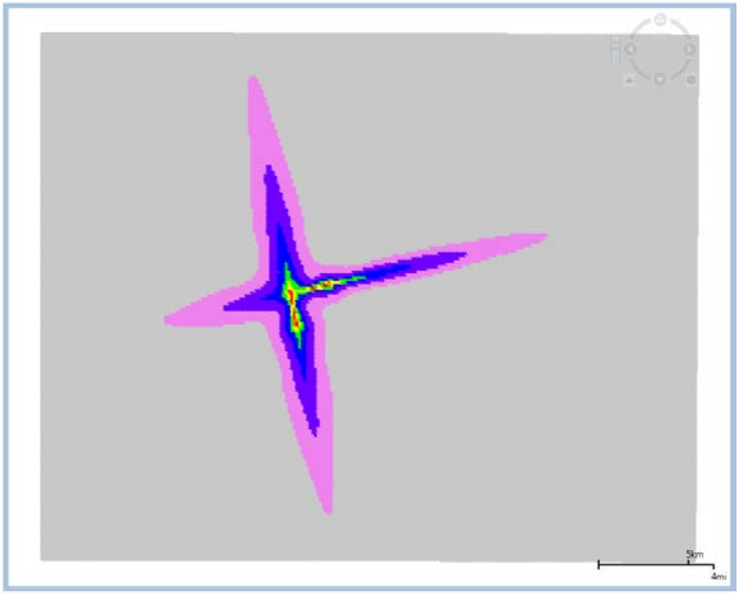

Figure 5-31. UCD-Com2 – DNL with Bank Angle AEDT 2b Contours

For UCD-Com2, the differences between the AEDT 2b and INM DNL contour area results were less than 4.6% for the contour areas of interest, with the higher contours with areas smaller than 0.6 sq. km having a larger difference. For all the contour levels, the AEDT 2b contours were slightly larger than the INM contours. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes. It should be noted that AEDT 2b failed to produce a 65 dB contour for this study. This failure was due to the bug in AEDT's contouring algorithm that was previously mentioned in Section 5.3.1.2. With the updated algorithm with the bug fix, the DNL 65 dB contour area was 10.957 km^2, which is only 0.8% different from the INM result.

5.3.2.3 Phase 2 Testing Results - UCD-Com2-866A-CH

UCD-Com2-866A-CH is a simple airport study with commercial aircraft operations on approach and departure tracks that is modeled for cold and humid weather conditions using SAE-ARP-866A (40 F and 90% humidity). UCD-Com2-866A-CH was run in both INM 7.0d su1 and AEDT 2b with bank angle. The study was not run using SAE-ARP-5534, because INM does not include the SAE-ARP-5534 adjustment. The following DNL noise results for contours were generated:

Table 5-32. UCD-Com2-866A-CH - DNL Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	117.813	117.511	0.302	-0.3
60	40.570	40.343	0.227	-0.6
65	12.955	12.901	0.054	-0.4
70	4.180	4.197	-0.017	0.4
75	1.613	1.620	-0.007	0.4
80	0.582	0.612	-0.030	4.8
85	0.115	0.087	0.028	-32.4

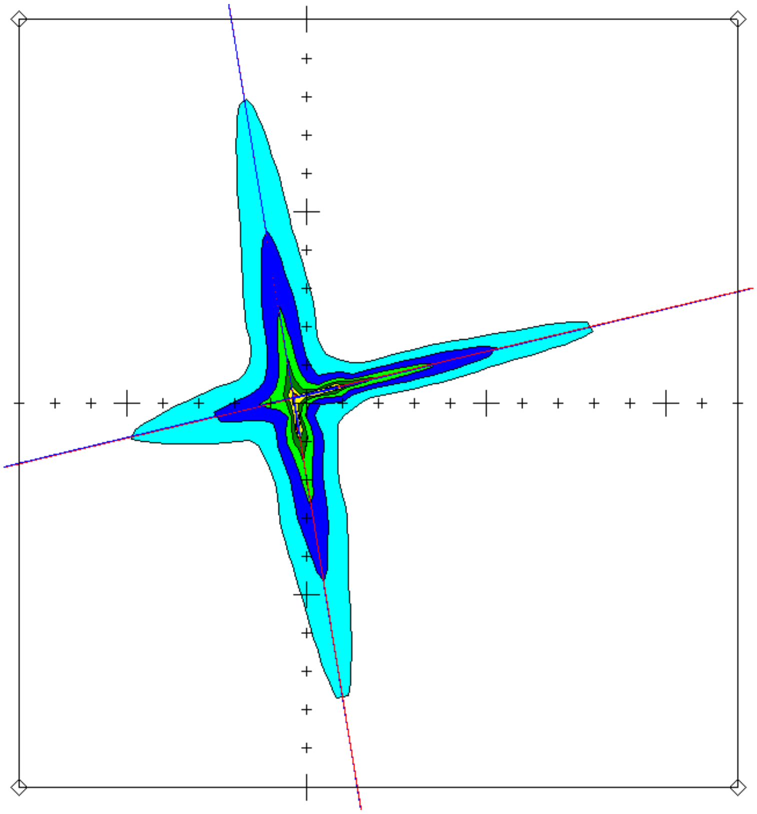

Figure 5-32. UCD-Com2-866A-CH – DNL with Bank Angle INM Contours

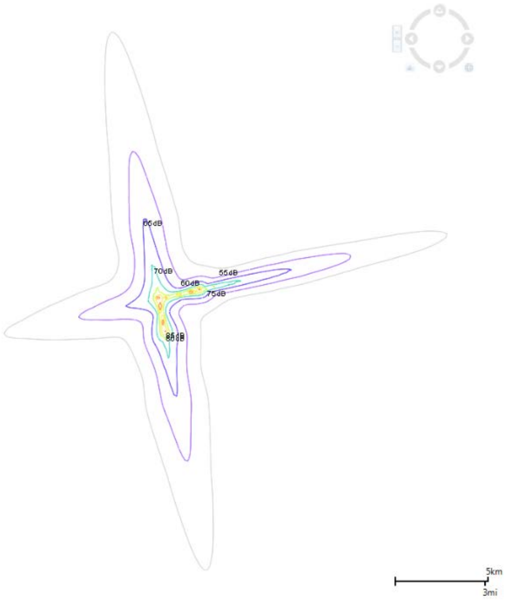

Figure 5-33. UCD-Com2-866A-CH – DNL with Bank Angle AEDT 2b Contours

For UCD-Com2-866A-CH, the differences between the AEDT 2b and INM DNL contour area results were less than 4.9% for the contour areas of interest, with the higher contours with areas smaller than 0.12 sq. km having a larger difference. The 65 dB DNL contour results showed a difference of -0.42% between INM and AEDT 2b. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

5.3.2.4 Phase 2 Testing Results - UCD-Com2-866A-CL

UCD-Com2-866A-CL is a simple airport study with commercial aircraft operations on approach and departure tracks that is modeled for cold and dry weather conditions using SAE-ARP-866A (40 F and 25% humidity). UCD-Com2-866A-CL was run in both INM 7.0d su1 and AEDT 2b with bank angle. The study was not run using SAE-ARP-5534, because INM does not include the SAE-ARP-5534 adjustment. The following DNL noise results for contours were generated:

Table 5-33. UCD-Com2-866A-CL DNL Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	48.988	48.748	0.240	-0.5
60	17.839	17.741	0.098	-0.5
65	6.480	6.483	-0.003	0.0
70	2.599	2.606	-0.007	0.3
75	1.211	1.207	0.004	-0.4
80	0.445	0.461	-0.016	3.4
85	0.082	0.053	0.029	-55.6

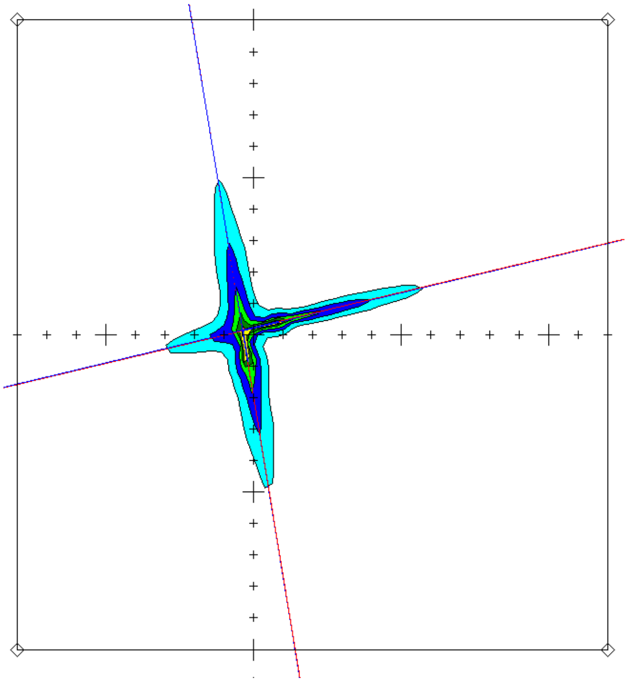

Figure 5-34. UCD-Com2-866A-CL – DNL with Bank Angle INM Contours

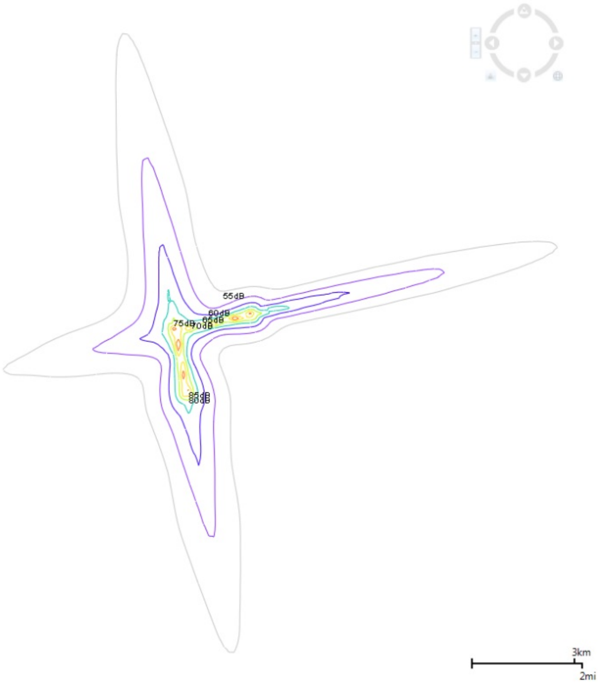

Figure 5-35. UCD-Com2-866A-CL – DNL with Bank Angle AEDT 2b Contours

For UCD-Com2-866A-CL, the differences between the AEDT 2b and INM DNL contour area results were less than 3.4% for the contour areas of interest, with the higher contours with areas smaller than 0.1 sq. km having a larger difference. The 65 dB DNL contour results showed a difference of -0.05% between INM and AEDT 2b. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

5.3.2.5 Phase 2 Testing Results - UCD-Com2-866A-HH

UCD-Com2-866A-HH is a simple airport study with commercial aircraft operations on approach and departure tracks that is modeled for hot and humid weather conditions using SAE-ARP-866A (90 F and 90% humidity). UCD-Com2-866A-HH was run in both INM 7.0d su1 and AEDT 2b with bank angle. The study was not run using SAE-ARP-5534, because INM does not include the SAE-ARP-5534 adjustment. The following DNL noise results for contours were generated:

Table 5-34. UCD-Com2-866A-HH – DNL Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	67.616	67.539	0.077	-0.1
60	26.129	26.064	0.065	-0.3
65	9.219	9.200	0.019	-0.2
70	3.200	3.191	0.009	-0.3
75	1.258	1.301	-0.043	3.3
80	0.446	0.466	-0.020	4.4
85	0.081	0.050	0.031	-63.6

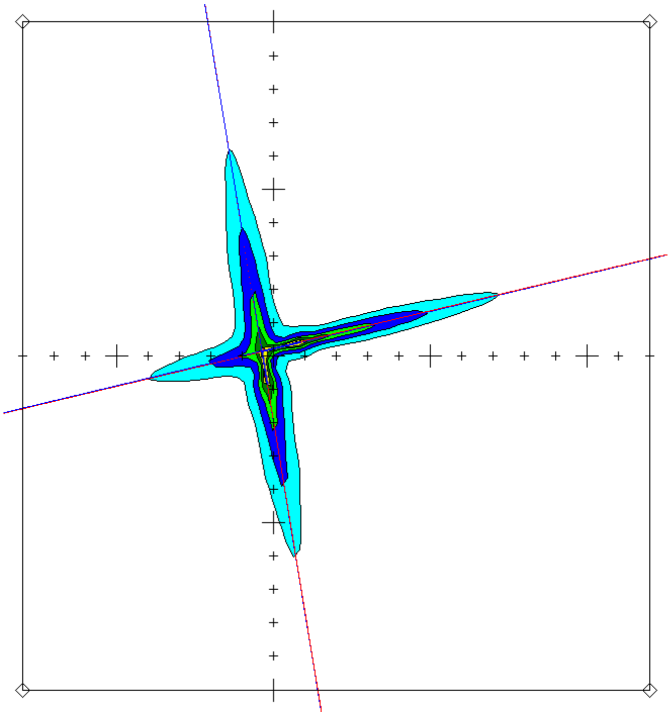

Figure 5-36. UCD-Com2-866A-HH – DNL with Bank Angle INM Contours

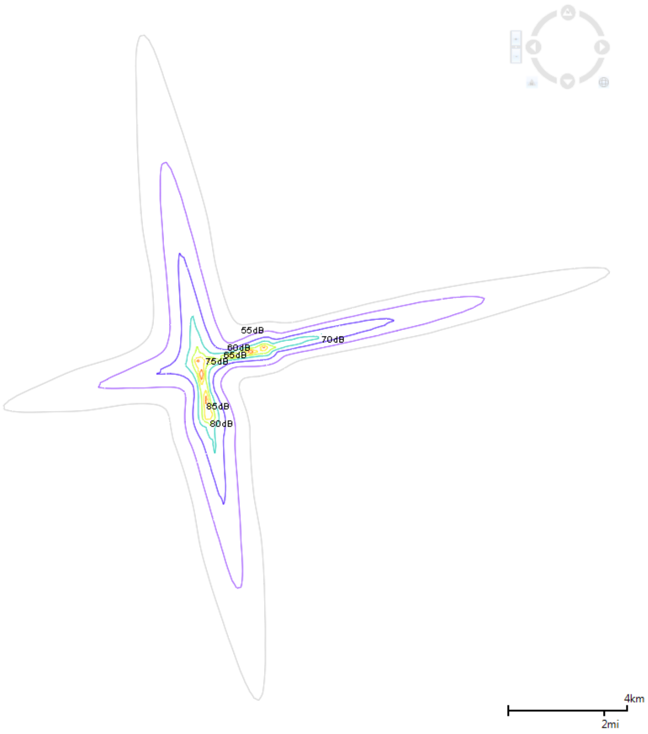

Figure 5-37. UCD-Com2-866A-HH – DNL with Bank Angle AEDT 2b Contours

For UCD-Com2-866A-HH, the differences between the AEDT 2b and INM DNL contour area results were less than 4.4% for the contour areas of interest, with the higher contours with areas smaller than 0.1 sq. km having a larger difference. The 65 dB DNL contour results showed a difference of -0.21% between INM and AEDT 2b. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

5.3.2.6 Phase 2 Testing Results - UCD-Com2-866A-HL

UCD-Com2-866A-HL is a simple airport study with commercial aircraft operations on approach and departure tracks that is modeled for hot and dry weather conditions using SAE-ARP-866A (90 F and 25% humidity). UCD-Com2-866A-HL was run in both INM 7.0d su1 and AEDT 2b with bank angle. The study was not run using SAE-ARP-5534, because INM does not include the SAE-ARP-5534 adjustment. The following DNL noise results for contours were generated:

Table 5-35. UCD-Com2-866A-HL - DNL Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	66.529	66.422	0.107	-0.2
60	25.270	25.217	0.053	-0.2
65	8.777	8.788	-0.011	0.1
70	3.109	3.100	0.009	-0.3
75	1.242	1.284	-0.042	3.3
80	0.439	0.461	-0.022	4.7
85	0.080	0.049	0.031	-64.6

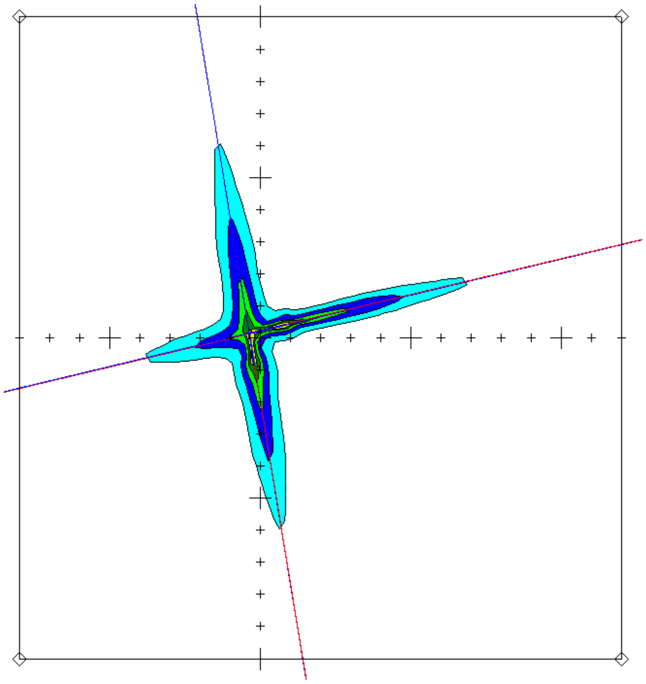

Figure 5-38. UCD-Com2-866A-HL – DNL with Bank Angle INM Contours

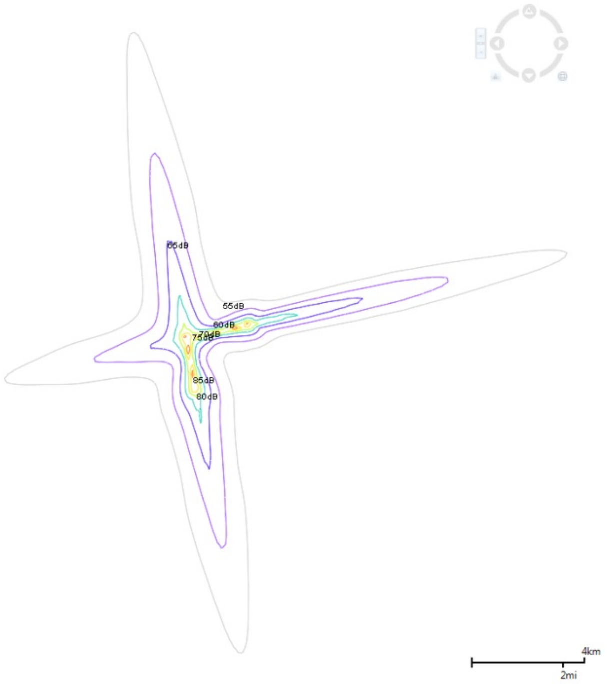

Figure 5-39. UCD-Com2-866A-HL – DNL with Bank Angle AEDT 2b Contours

For UCD-Com2-866A-HL, the differences between the AEDT 2b and INM DNL contour area results were less than 4.7% for the contour areas of interest, with the higher contours with areas smaller than 0.1 sq. km having a larger difference. The 65 dB DNL contour results showed a difference of 0.12% between INM and AEDT 2b. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

5.3.2.7 Phase 2 Testing Results - UCD-Com2-866A-MM

UCD-Com2-866A-MM is a simple airport study with commercial aircraft operations on approach and departure tracks that is modeled for temperate weather conditions (54.4 F with 70% humidity) using SAE-ARP-866A. UCD-Com2-866A-MM was run in both INM 7.0d su1 and AEDT 2b with bank angle. The study was not run using SAE-ARP-5534, because INM does not include the SAE-ARP-5534 adjustment. The following DNL noise results for contours were generated:

Table 5-36. UCD-Com2-866A-MM – DNL Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	105.404	105.104	0.300	-0.3
60	37.970	37.760	0.210	-0.6
65	12.568	12.519	0.049	-0.4
70	4.089	4.101	-0.012	0.3
75	1.587	1.593	-0.006	0.4
80	0.590	0.617	-0.027	4.3
85	0.116	0.087	0.029	-33.4

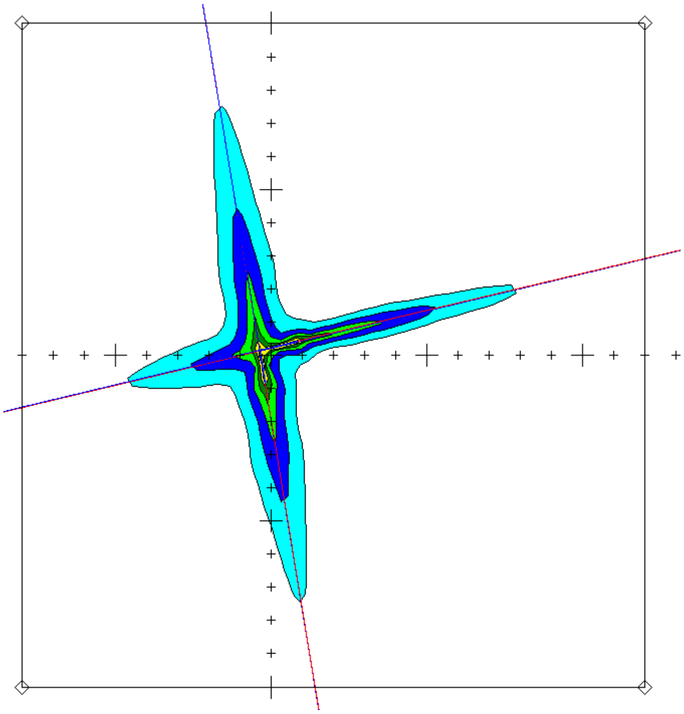

Figure 5-40. UCD-Com2-866A-MM – DNL with Bank Angle INM Contours

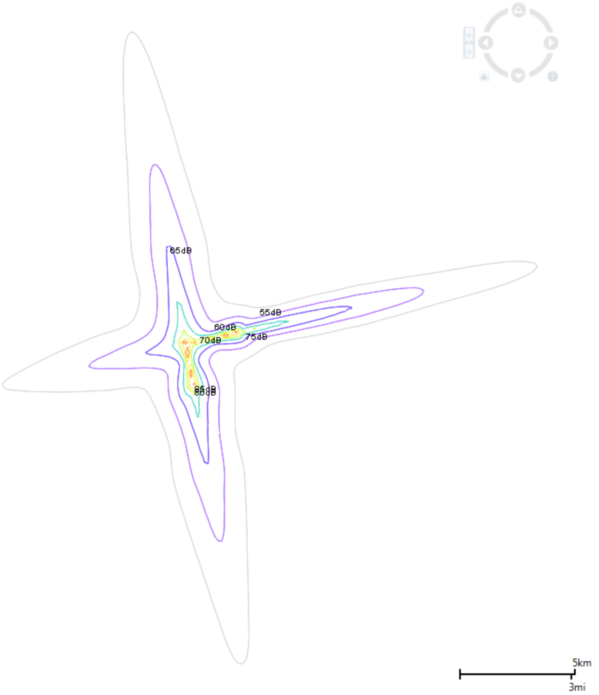

Figure 5-41. UCD-Com2-866A-MM – DNL with Bank Angle AEDT 2b Contours

For UCD-Com2-866A-MM, the differences between the AEDT 2b and INM DNL contour area results were less than 4.3% for the contour areas of interest, with the higher contours with areas smaller than 0.12 sq. km having a larger difference. The 65 dB DNL contour results showed a difference of -0.39% between INM and AEDT 2b. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

5.3.2.8 Phase 2 Testing Results - UCD-Com2-metrics

The study UCD-Com2-metrics includes all the noise metrics available in both AEDT and INM, except DNL, which is covered in other studies in Use Case D. These noise metrics are: CEXP, CNEL, EPNL, LAEQ, LAEQD, LAEQN, LAMAX, LCMAX, NEF, PNLTM, SEL, TALA, TALC, TAPNL, and WECPNL. These test cases not only evaluate the noise metric definitions, but they also test that the appropriate metric-specific NPDs are being used for the noise computations in AEDT 2b. Separate noise contours were generated for each noise metric.

Table 5-37. UCD-Com2-metrics – CEXP Phase 2 Testing Results

CEXP Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
105	76.813	77.701	-0.888	1.1
110	21.714	21.954	-0.240	1.1
115	5.966	6.036	-0.070	1.2
120	2.166	2.214	-0.048	2.2
125	0.945	0.951	-0.006	0.6
130	0.242	0.252	-0.010	3.9
135	0.056	0.007	0.049	N/A

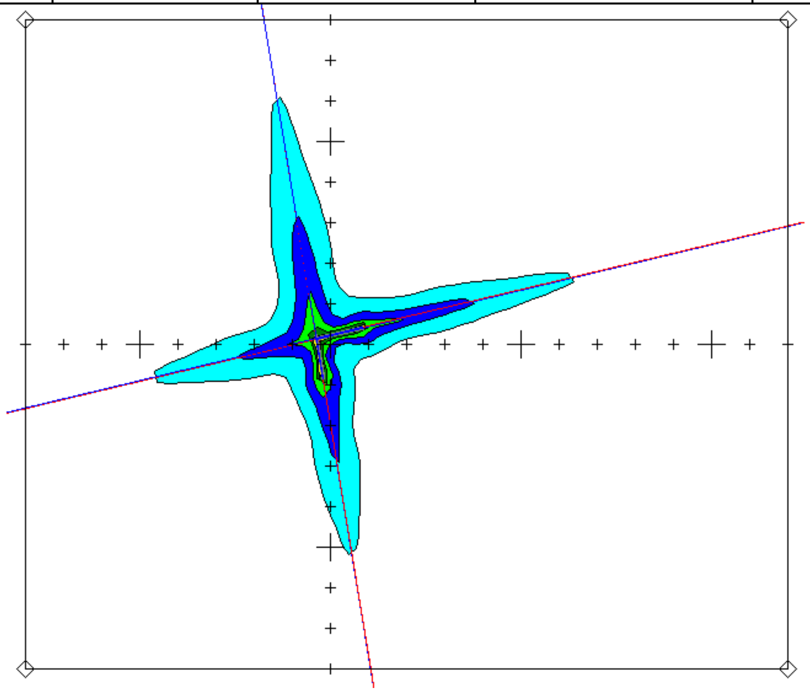

Figure 5-42. UCD-Com2-metrics – CEXP INM Contours

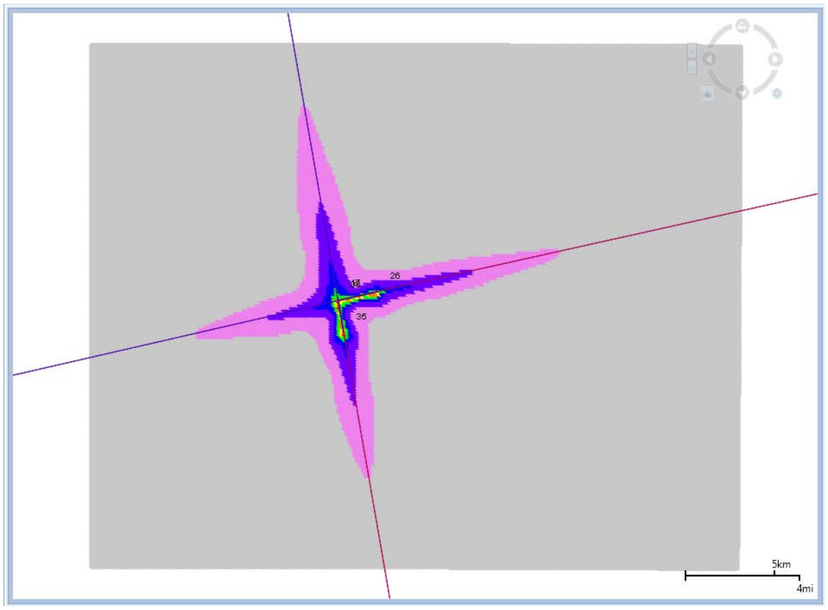

Figure 5-43. UCD-Com2-metrics – CEXP AEDT 2b Contours

For UCD-Com2-metrics, the differences between the AEDT 2b and INM CEXP contour area results were less than 3.9% for the contour areas of interest, with the higher contours with small areas having a larger difference. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

Table 5-38. UCD-Com2-metrics – CNEL Phase 2 Testing Results

CNEL Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	89.146	89.909	-0.763	0.8
60	33.592	33.834	-0.242	0.7
65	11.648	11.751	-0.103	0.9
70	4.032	4.061	-0.029	0.7
75	1.575	1.632	-0.057	3.5
80	0.603	0.620	-0.017	2.8
85	0.159	0.138	0.021	-15.1

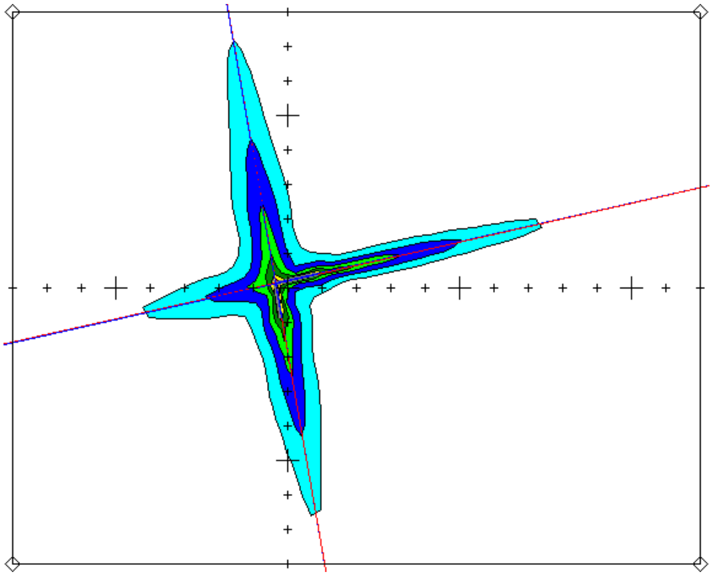

Figure 5-44. UCD-Com2-metrics – CNEL INM Contours

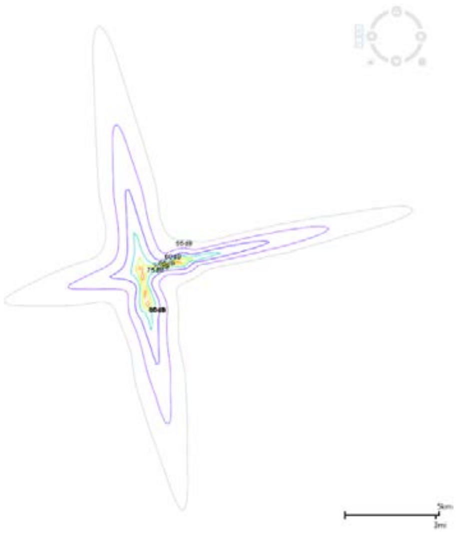

Figure 5-45. UCD-Com2-metrics – CNEL AEDT 2b Contours

For UCD-Com2-metrics, the differences between the AEDT 2b and INM CNEL contour area results were less than 3.5% for the contour areas of interest, with the higher contours with small areas having a larger difference. The 65 dB CNEL contour showed a difference of 0.88%. For most of the contours, the AEDT 2b contours were slightly larger than the corresponding INM contours. However, a visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

Table 5-39. UCD-Com2-metrics – EPNL Phase 2 Testing Results

EPNL Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
100	82.091	82.563	-0.472	0.6
105	34.862	35.017	-0.155	0.4
110	13.230	13.328	-0.098	0.7
115	4.866	4.927	-0.061	1.2
120	1.982	2.010	-0.028	1.4
125	0.908	0.930	-0.022	2.4
130	0.243	0.255	-0.012	4.8
135	0.056	0.008	0.048	N/A

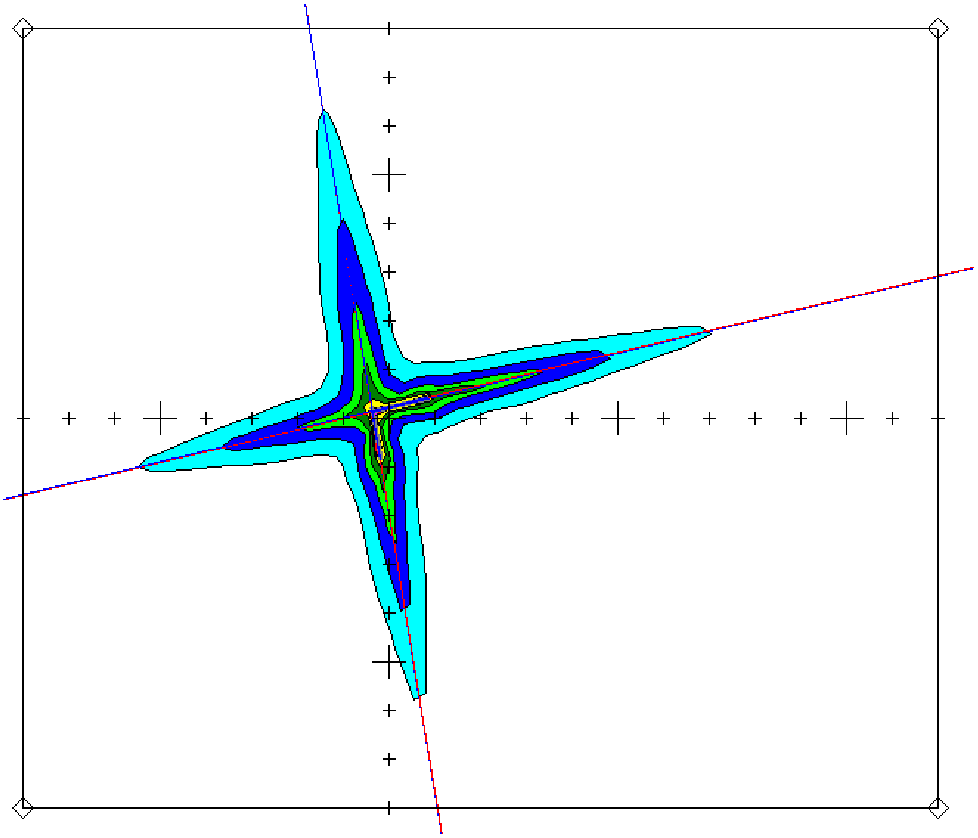

Figure 5-46. UCD-Com2-metrics – EPNL INM Contours

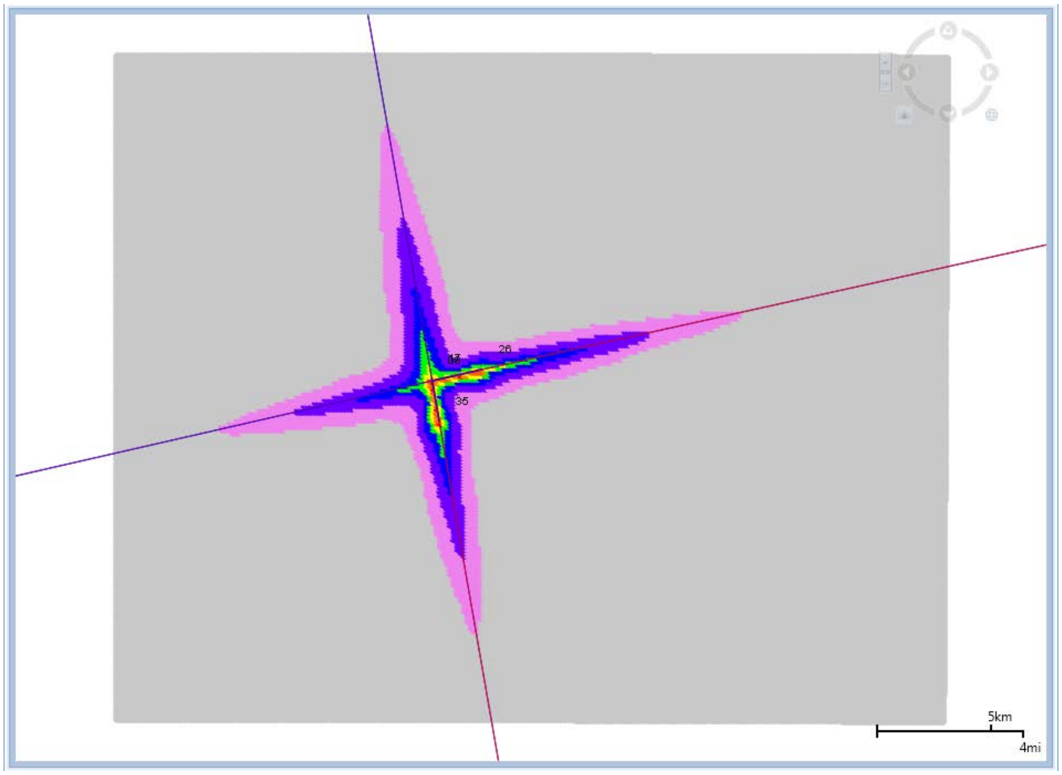

Figure 5-47. UCD-Com2-metrics – EPNL AEDT 2b Contours

For UCD-Com2-metrics, the differences between the AEDT 2b and INM EPNL contour area results were less than 4.8% for the contour areas of interest, with the higher contours with small areas having a larger difference. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

Table 5-40. UCD-Com2-metrics – LAEQ Phase 2 Testing Results

LAEQ Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	27.136	27.321	-0.185	0.7
60	9.068	9.162	-0.094	1.0
65	3.169	3.211	-0.042	1.3
70	1.367	1.402	-0.035	2.5
75	0.453	0.519	-0.066	12.7
80	0.109	0.062	0.047	-76.3

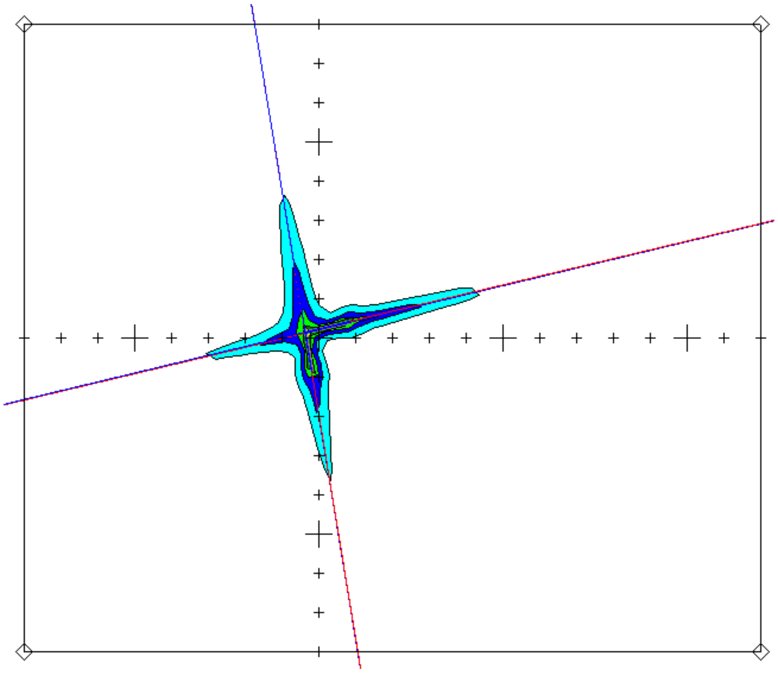

Figure 5-48. UCD-Com2-metrics – LAEQ INM Contours

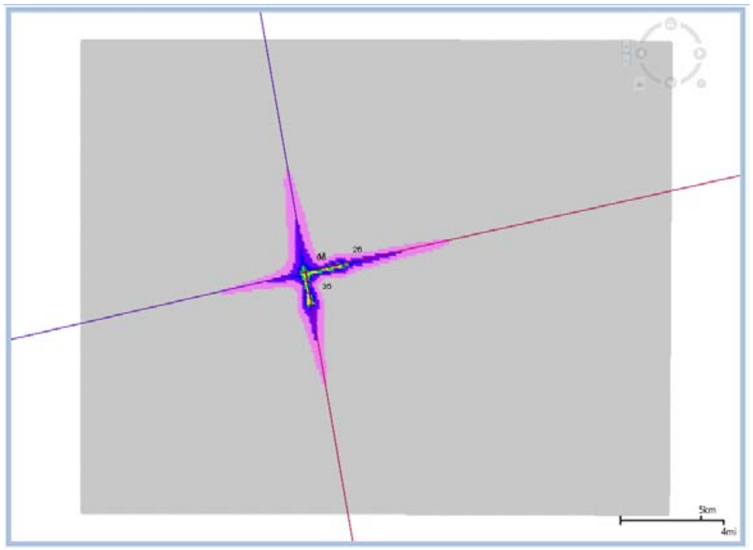

Figure 5-49. UCD-Com2-metrics – LAEQ AEDT 2b Contours

For UCD-Com2-metrics, the differences between the AEDT 2b and INM LAEQ contour area results were less than 2.52% for the contour areas of interest, with the higher contours with small areas having a larger difference. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

Table 5-41. UCD-Com2-metrics – LAEQD Phase 2 Testing Results

LAEQD Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	29.849	30.038	-0.189	0.6
60	10.002	10.119	-0.117	1.2
65	3.462	3.488	-0.026	0.7
70	1.467	1.510	-0.043	2.8
75	0.524	0.602	-0.078	12.9
80	0.122	0.077	0.045	-58.0

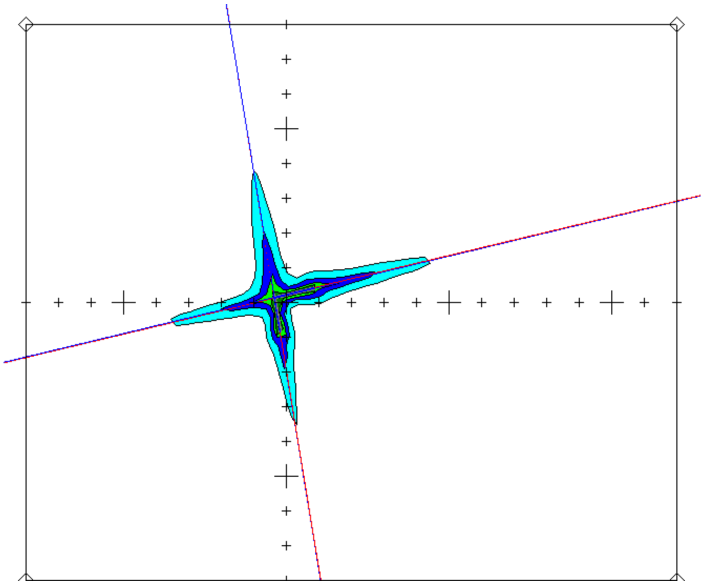

Figure 5-50. UCD-Com2-metrics – LAEQD INM Contours

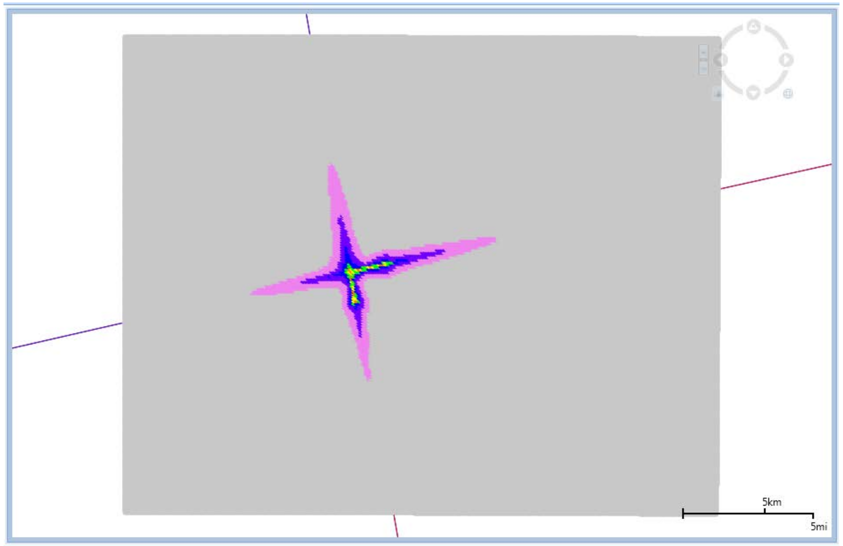

Figure 5-51. UCD-Com2-metrics – LAEQD AEDT 2b Contours

For UCD-Com2-metrics, the differences between the AEDT 2b and INM LAEQD contour area results were less than 2.8% for the contour areas of interest, with the higher contours with small areas having a larger difference. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

Table 5-42. UCD-Com2-metrics – LAEQN Phase 2 Testing Results

LAEQN Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	22.488	22.638	-0.150	0.7
60	7.703	7.770	-0.067	0.9
65	2.696	2.722	-0.026	0.9
70	1.021	1.045	-0.024	2.3
75	0.363	0.415	-0.052	12.5
80	0.079	0.041	0.038	-93.2
85	0.009	0.000	0.009	N/A

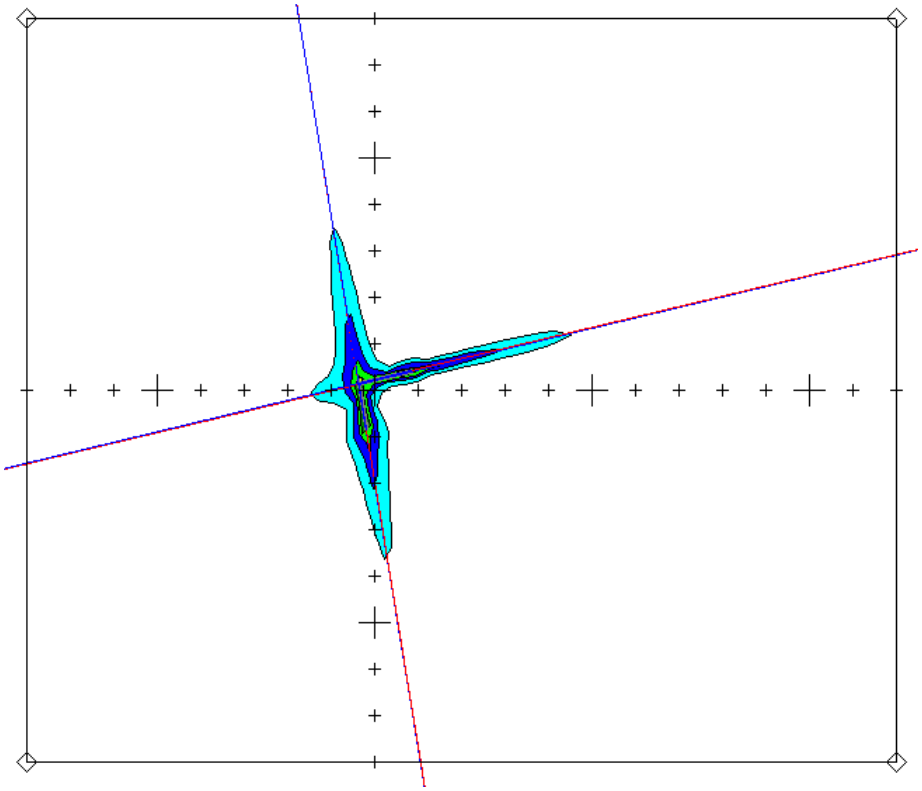

Figure 5-52. UCD-Com2-metrics – LAEQN INM Contours

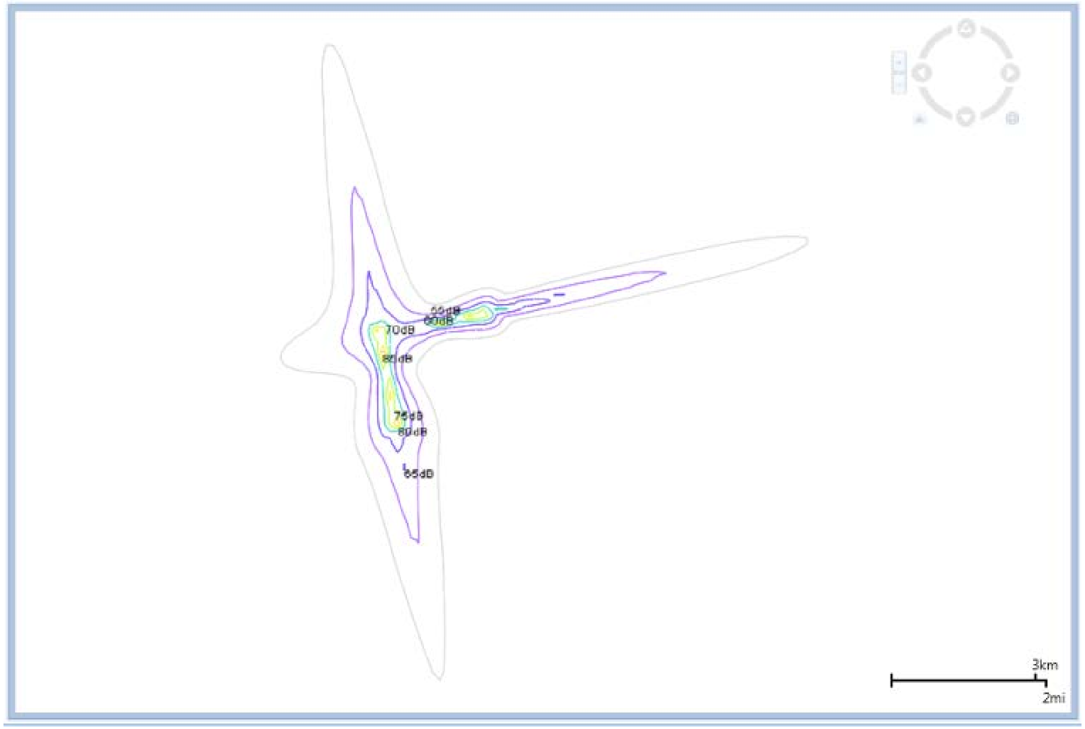

Figure 5-53. UCD-Com2-metrics – LAEQN AEDT 2b Contours

For UCD-Com2-metrics, the differences between the AEDT 2b and INM LAEQN contour area results were less than 2.3% for the contour areas of interest, with the higher contours with small areas having a larger difference. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

Table 5-43. UCD-Com2-metrics – LAMAX Phase 2 Testing Results

LAMAX Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
70	64.183	64.518	-0.335	0.5
75	29.245	29.397	-0.152	0.5
80	13.158	13.255	-0.097	0.7
85	5.498	5.535	-0.037	0.7
90	2.533	2.551	-0.018	0.7
95	1.282	1.362	-0.080	5.9
100	0.643	0.687	-0.044	6.4
105	0.265	0.254	0.011	-4.5
110	0.110	0.078	0.032	-40.6

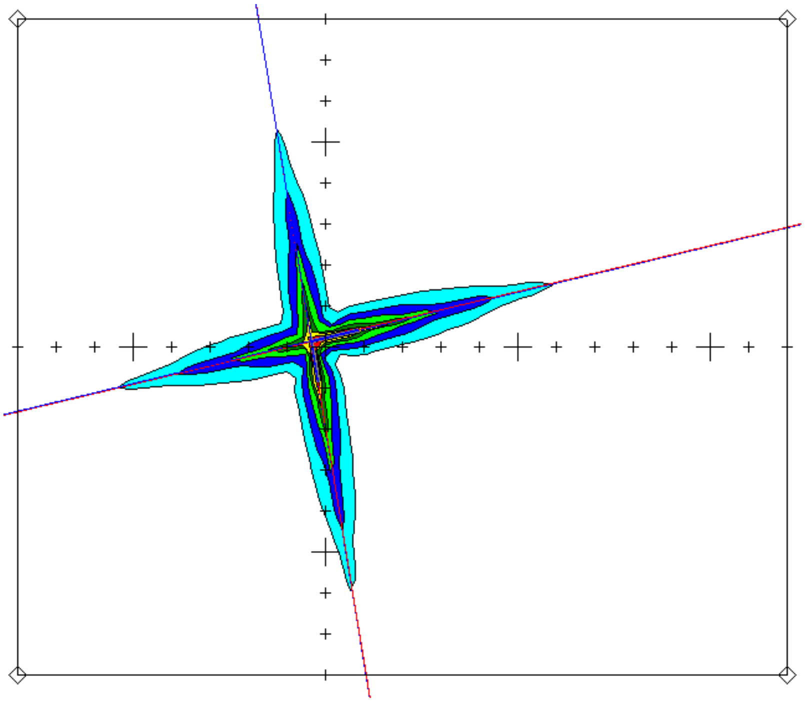

Figure 5-54. UCD-Com2-metrics – LAMAX INM Contours

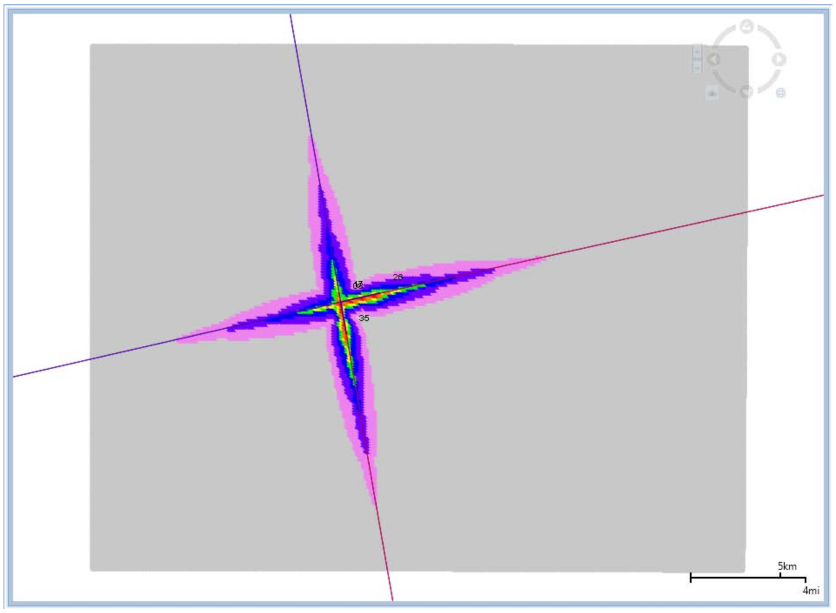

Figure 5-55. UCD-Com2-metrics – LAMAX AEDT 2b Contours

For UCD-Com2-metrics, the differences between the AEDT 2b and INM LAMAX contour area results were less than 6.4% for the contour areas of interest, with the higher contours with small areas having a larger difference. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

Table 5-44. UCD-Com2-metrics – LCMAX Phase 2 Testing Results

LCMAX Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
75	72.025	72.375	-0.350	0.5
80	27.100	27.282	-0.182	0.7
85	10.637	10.724	-0.087	0.8
90	3.983	4.008	-0.025	0.6
95	1.815	1.883	-0.068	3.6
100	1.053	1.092	-0.039	3.6
105	0.449	0.473	-0.024	5.0
110	0.198	0.171	0.027	-15.5
115	0.076	0.049	0.027	-54.3
120	0.022	0.010	0.012	N/A

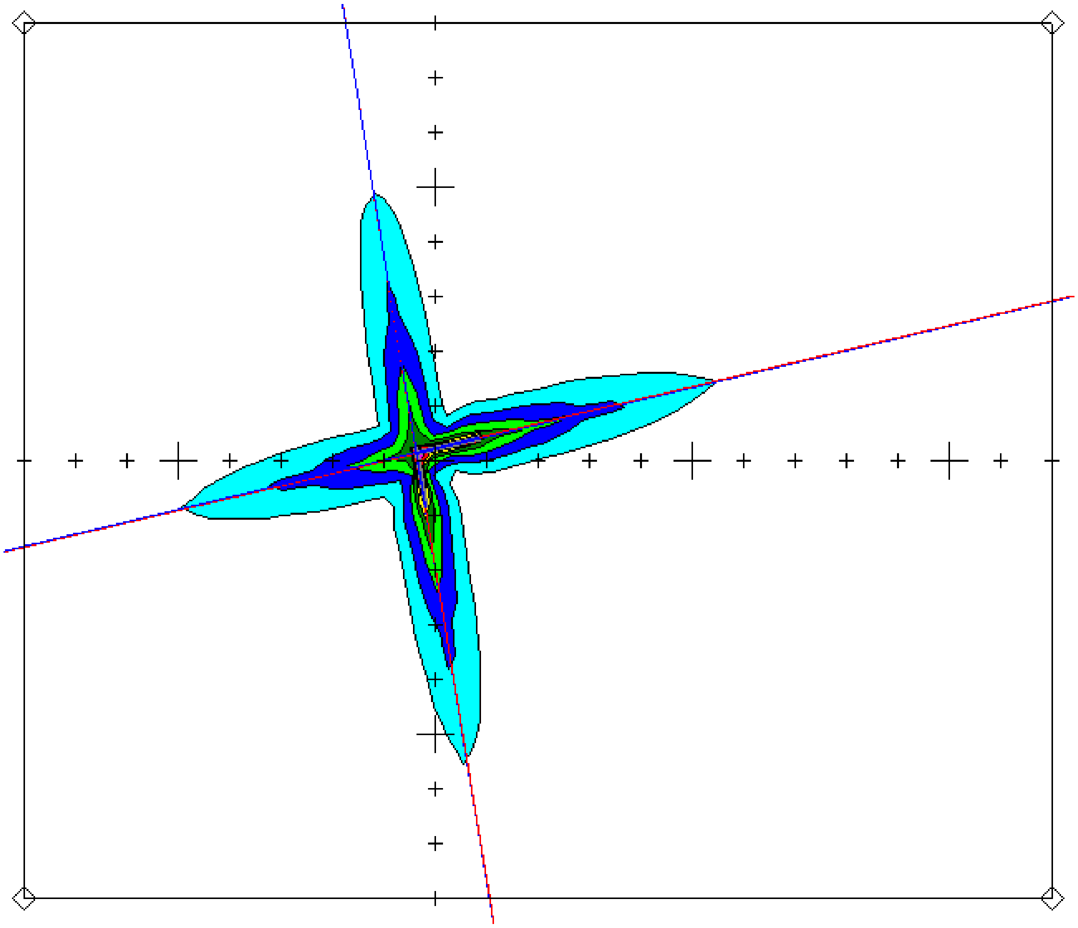

Figure 5-56. UCD-Com2-metrics – LCMAX INM Contours

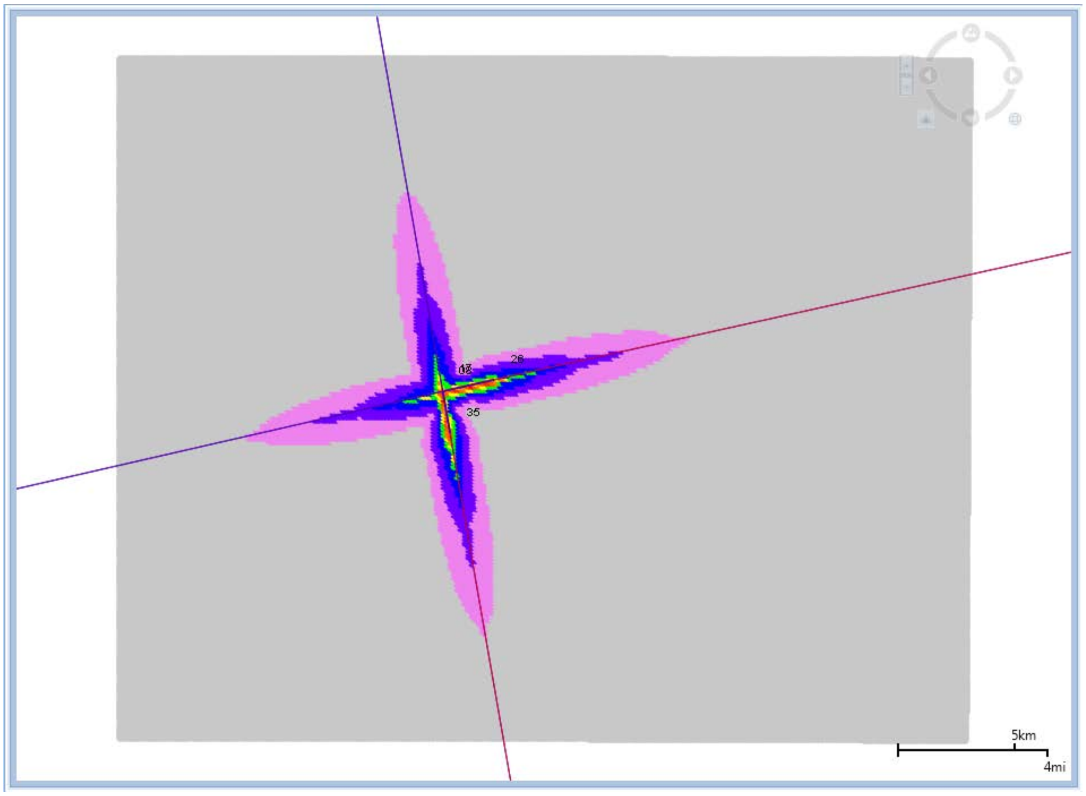

Figure 5-57. UCD-Com2-metrics – LCMAX AEDT 2b Contours

For UCD-Com2-metrics, the differences between the AEDT 2b and INM LCMAX contour area results were less than 5.0% for the contour areas of interest, with the higher contours with small areas having a larger difference. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

Table 5-45. UCD-Com2-metrics – NEF Phase 2 Testing Results

NEF Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
20	76.058	76.464	-0.406	0.5
25	32.071	32.218	-0.147	0.5
30	12.391	12.465	-0.074	0.6
35	4.641	4.646	-0.005	0.1
40	1.833	1.884	-0.051	2.7
45	0.762	0.771	-0.009	1.6
50	0.226	0.236	-0.010	4.3

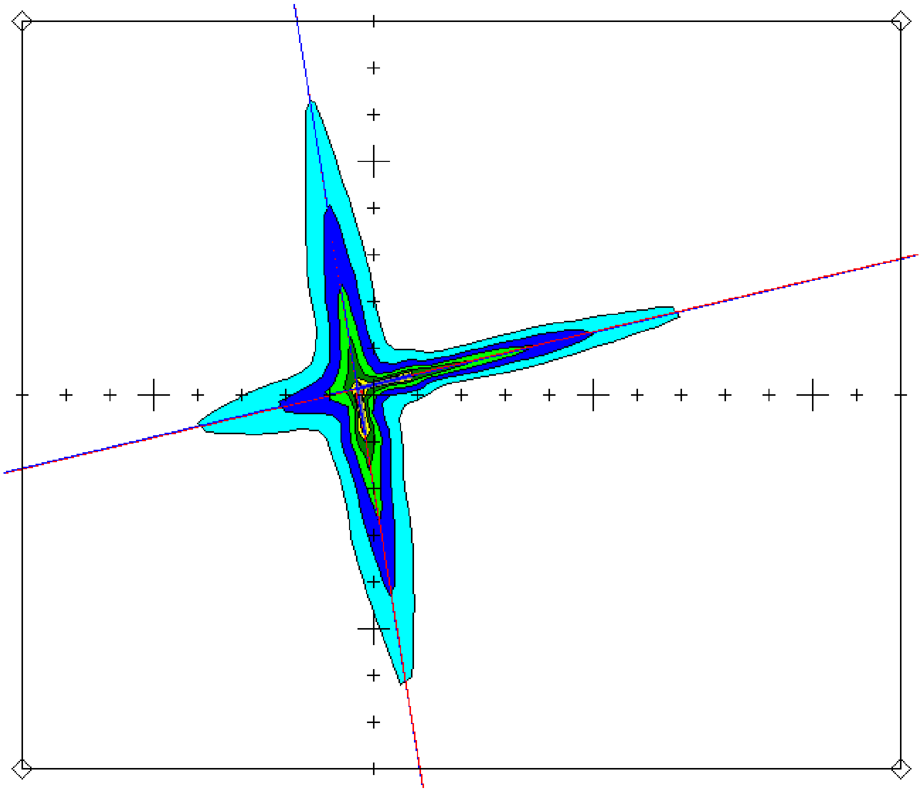

Figure 5-58. UCD-Com2-metrics – NEF INM Contours

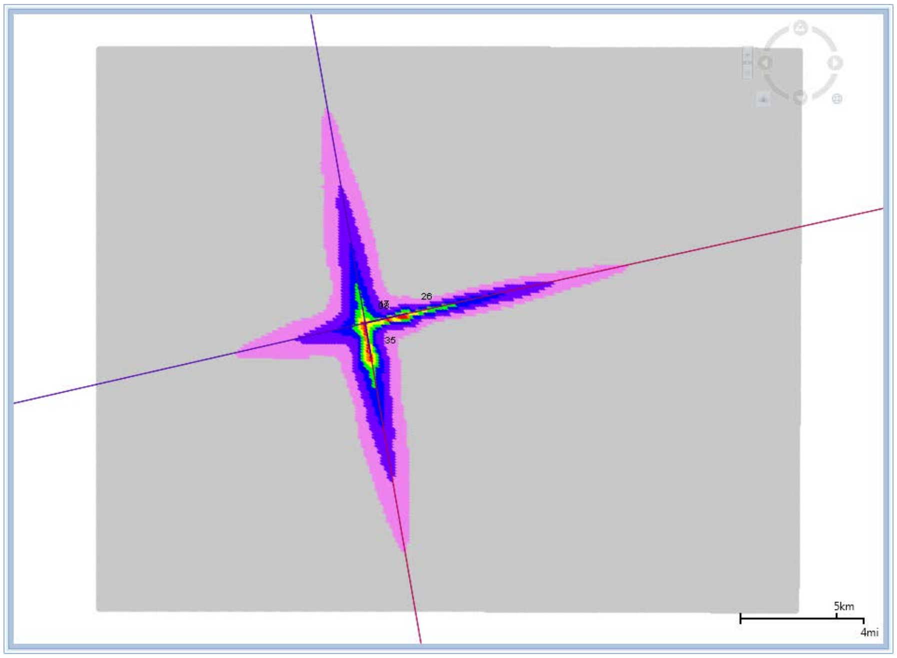

Figure 5-59. UCD-Com2-metrics – NEF AEDT 2b Contours

For UCD-Com2-metrics, the differences between the AEDT 2b and INM NEF contour area results were less than 4.3% for the contour areas of interest, with the higher contours with small areas having a larger difference. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

Table 5-46. UCD-Com2-metrics – PNLTM Phase 2 Testing Results

PNLTM Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
80	74.374	74.617	-0.243	0.3
85	35.922	36.079	-0.157	0.4
90	18.060	18.136	-0.076	0.4
95	8.095	8.147	-0.052	0.6
100	3.755	3.774	-0.019	0.5
105	1.901	1.917	-0.016	0.8
110	1.011	1.020	-0.009	0.9
115	0.569	0.570	-0.001	0.1
120	0.347	0.350	-0.003	1.0

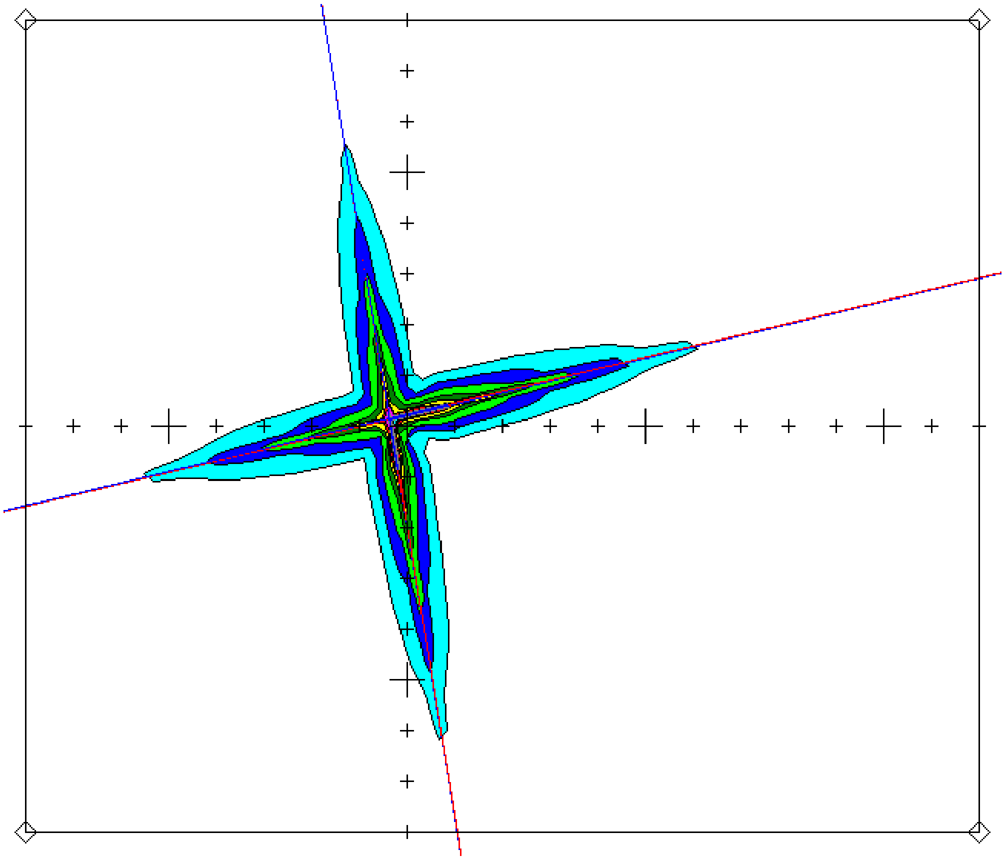

Figure 5-60. UCD-Com2-metrics – PNLTM INM Contours

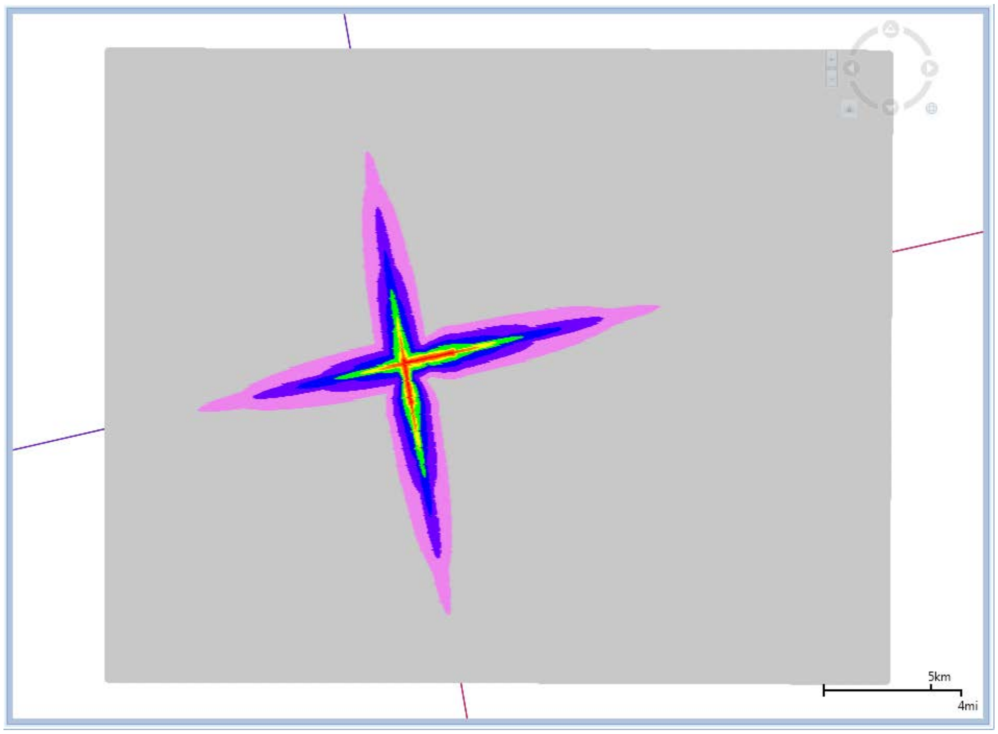

Figure 5-61. UCD-Com2-metrics – PNLTM AEDT 2b Contours

For UCD-Com2-metrics, the differences between the AEDT 2b and INM PNLTM contour area results were less than 0.98% for the contour areas of interest, with the higher contours with small areas having a larger difference. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

Table 5-47. UCD-Com2-metrics – SEL Phase 2 Testing Results

SEL Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
100	65.005	65.504	-0.499	0.7
105	23.744	23.887	-0.143	0.6
110	7.909	7.987	-0.078	1.0
115	2.834	2.858	-0.024	0.8
120	1.186	1.195	-0.009	0.8
125	0.544	0.548	-0.004	0.8
130	0.150	0.160	-0.010	6.2
135	0.026	0.028	-0.002	7.6

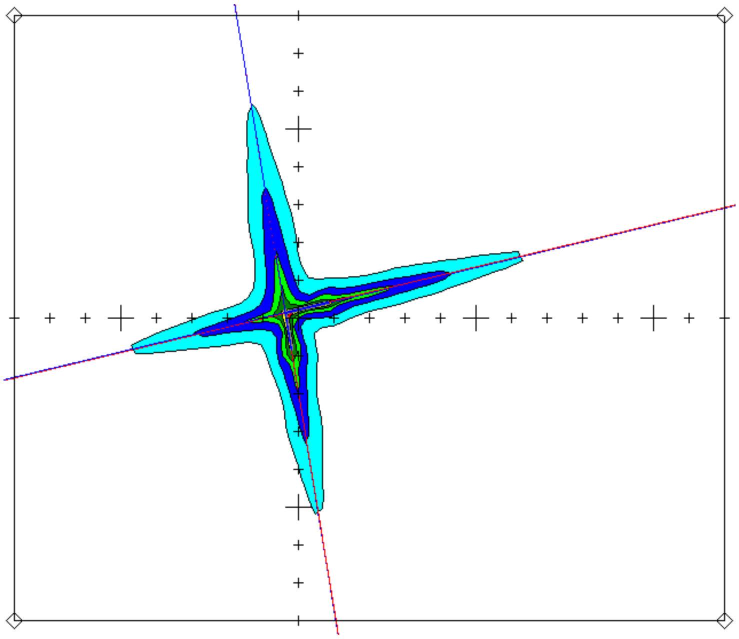

Figure 5-62. UCD-Com2-metrics – SEL INM Contours

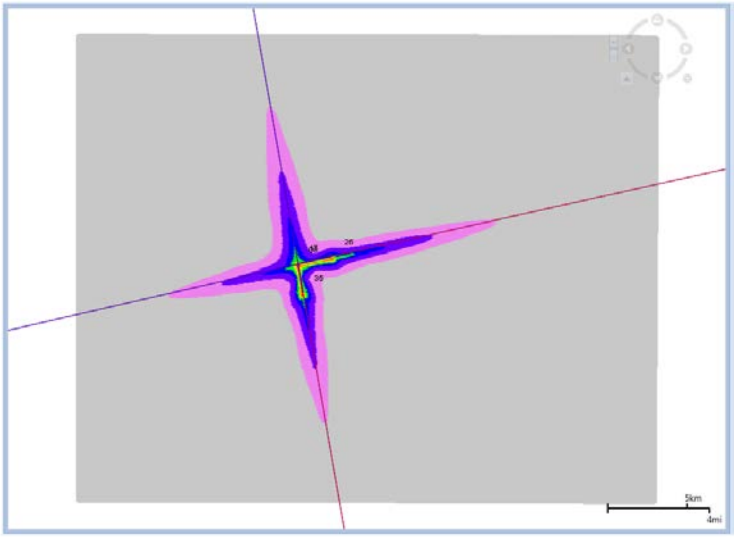

Figure 5-63. UCD-Com2-metrics – SEL AEDT 2b Contours

For UCD-Com2-metrics, the differences between the AEDT 2b and INM SEL contour area results were less than 7.6% for the contour areas of interest, with the higher contours with small areas having a larger difference. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

TALA, TALC and TAPNL

For UCD-Com2-metrics, TALA, TALC and TAPNL were tested against a fixed ambient threshold. Several issues were encountered with all three noise metrics. Although the studies imported fine, three bugs were identified. First, AEDT 2b does not produce valid receptor grid report results for these metrics. Instead, it sets all values to 0.0 in the report.

Second, the noise metrics are presented in dB in the AEDT 2b contours and reports. TALA, TALC and TAPNL metrics should be presented in minutes for a given day (maximum of 1,440 minutes).

Third, the contours displayed in AEDT 2b for TALA, TALC and TAPNL appear to be incorrect. The contours are drastically different from the equivalent contours generated by INM, and they seem to follow different trends. An example of the TALA contours is presented in Figure 5-64.

All three bugs will be resolved in the AEDT 2d release.

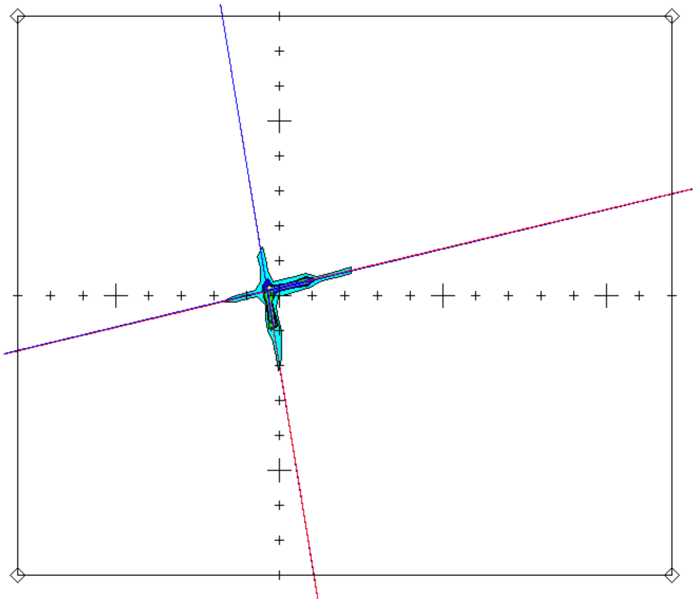

Figure 5-64. UCD-Com2-metrics - TALA, TALC and TAPNL INM Contours

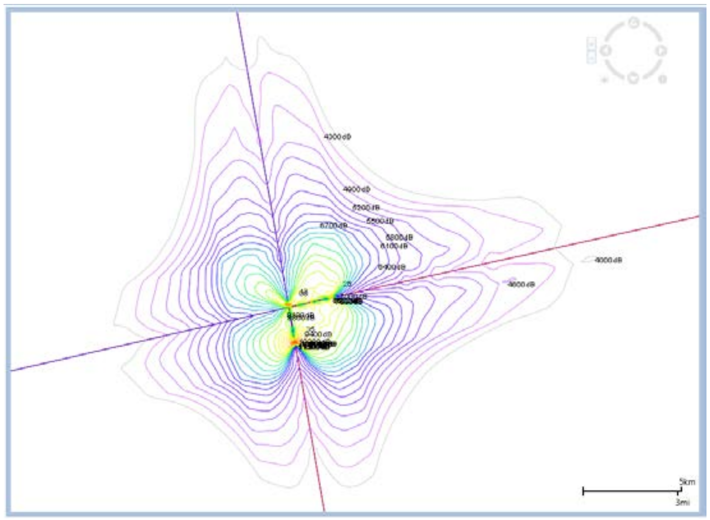

Figure 5-65. UCD-Com2-metrics - TALA, TALC and TAPNL AEDT 2b Contours

Table 5-48. UCD-Com2-metrics – WECPNL Phase 2 Testing Results

WECPNL Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
75	18.559	18.652	-0.093	0.5
80	6.882	6.941	-0.059	0.9
85	2.625	2.668	-0.043	1.6
90	1.091	1.145	-0.054	4.7
95	0.396	0.437	-0.041	9.4
100	0.092	0.047	0.045	N/A
105	0.012	0.000	0.012	N/A

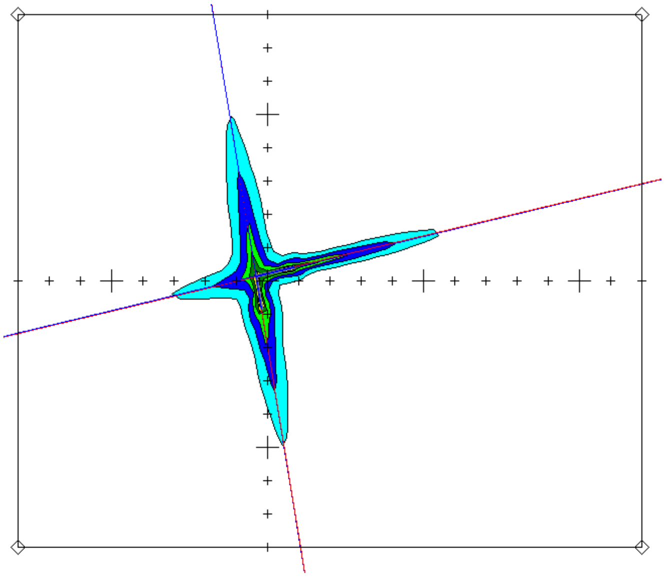

Figure 5-66. UCD-Com2-metrics – WECPNL INM Contours

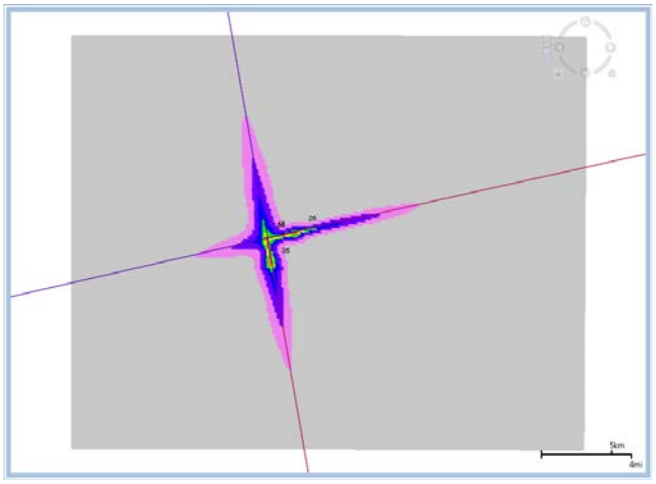

Figure 5-67. UCD-Com2-metrics – WECPNL AEDT 2b Contours

For UCD-Com2-metrics, the differences between the AEDT 2b and INM WECPNL contour area results were less than 9.4% for the contour areas of interest, with the higher contours with small areas having a larger difference. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

5.3.2.9 Phase 2 Testing Results - UCD-Com2-metrics-UD

User-defined noise metrics were tested with UCD-Com2-metrics-UD, which included commercial aircraft operations. The study was run in both INM 7.0d su1 and AEDT 2b with bank angle. It should be noted that user-defined metrics are not supported by the AEDT ASIF, so they cannot be imported from INM directly into AEDT. However, user-defined metrics can be defined as a new noise metric in AEDT, as was done for this analysis. The following user-defined CDNL (C-weighted DNL) and CCNEL (C-weighted CNEL) noise results for contours were generated:

Table 5-49. UCD-Com2-metrics-UD – CDNL with Bank Angle Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	313.751	315.711	-1.960	0.6
60	108.013	109.350	-1.337	1.2
65	31.439	31.731	-0.292	0.9
70	8.457	8.557	-0.100	1.2
75	2.732	2.787	-0.055	1.9
80	1.105	1.120	-0.015	1.3
85	0.355	0.363	-0.008	2.3

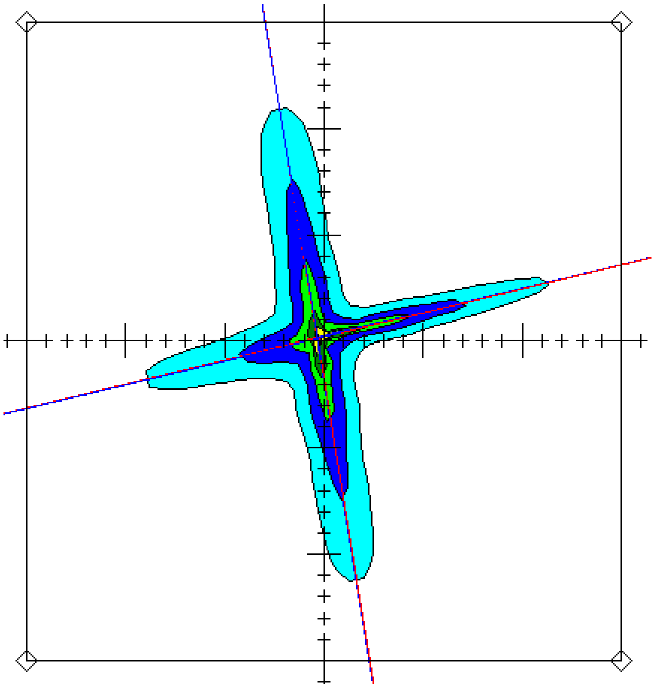

Figure 5-68. UCD-Com2-metrics-UD – CDNL with Bank Angle INM Contours

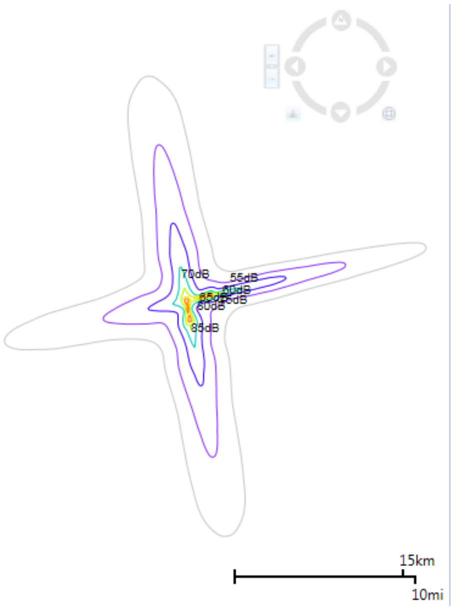

Figure 5-69. UCD-Com2-metrics-UD – CDNL with Bank Angle AEDT 2b Contours

For UCD-Com2-metrics-UD, the differences between the AEDT 2b and INM CDNL contour area results were less than 2.3% for the contour areas of interest, with the 65 dB CDNL contour results showed a difference of 0.92% between INM and AEDT 2b. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

It should be noted that although CDNL is a user-defined noise metric in INM, it is a standard noise metric in AEDT 2b, and is therefore not considered a true user-defined metric.

Table 5-50. UCD-Com2-metrics-UD – CCNEL with Bank Angle Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	329.152	331.031	-1.879	0.6
60	116.926	118.459	-1.533	1.3
65	34.200	34.519	-0.319	0.9
70	9.197	9.302	-0.105	1.1
75	2.933	2.989	-0.056	1.9
80	1.174	1.185	-0.011	0.9
85	0.388	0.203	0.185	N/A

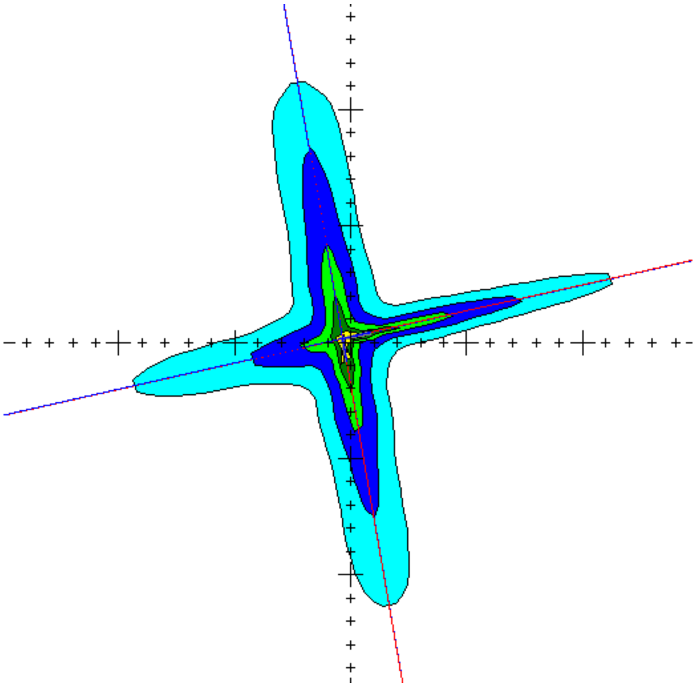

Figure 5-70. UCD-Com2-metrics-UD – CCNEL with Bank Angle INM Contours

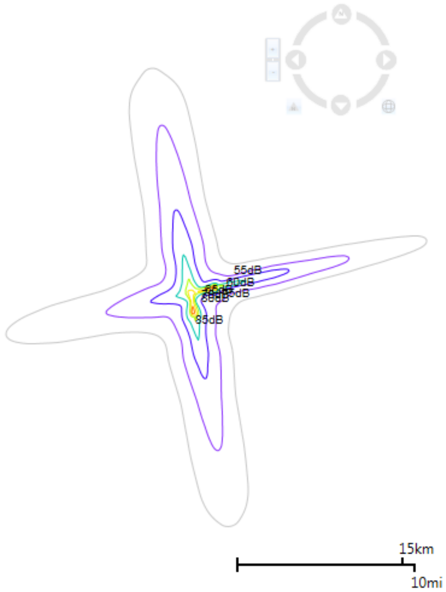

Figure 5-71. UCD-Com2-metrics-UD – CCNEL with Bank Angle AEDT 2b Contours

For UCD-Com2-metrics-UD, the differences between the AEDT 2b and INM user-defined CCNEL contour area results were less than 1.9% for the contour areas of interest, with the 65 dB CCNEL contour results showed a difference of 0.92% between INM and AEDT 2b. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

5.3.2.10 Phase 2 Testing Results - UCD-Com2-runups

UCD-Com2-runups is a simple airport study with commercial aircraft operations that include runup operations. The study was run in both INM 7.0d su1 and AEDT 2b with bank angle. The following DNL noise results for contours were generated:

Table 5-51. UCD-Com2-runups – DNL with Bank Angle Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	85.626	86.378	-0.752	0.9
60	32.760	33.027	-0.267	0.8
65	11.668	11.773	-0.105	0.9
70	4.344	4.360	-0.016	0.4
75	1.863	1.952	-0.089	4.5
80	0.697	0.735	-0.038	5.1
85	0.204	0.175	0.029	-16.3

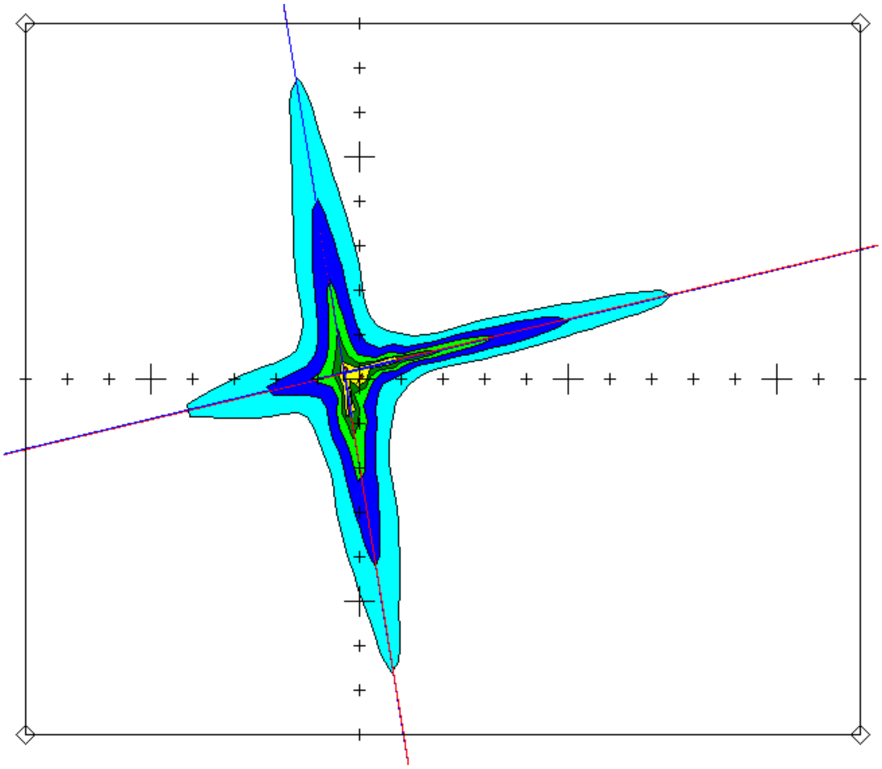

Figure 5-72. UCD-Com2-runups – DNL with Bank Angle INM Contours

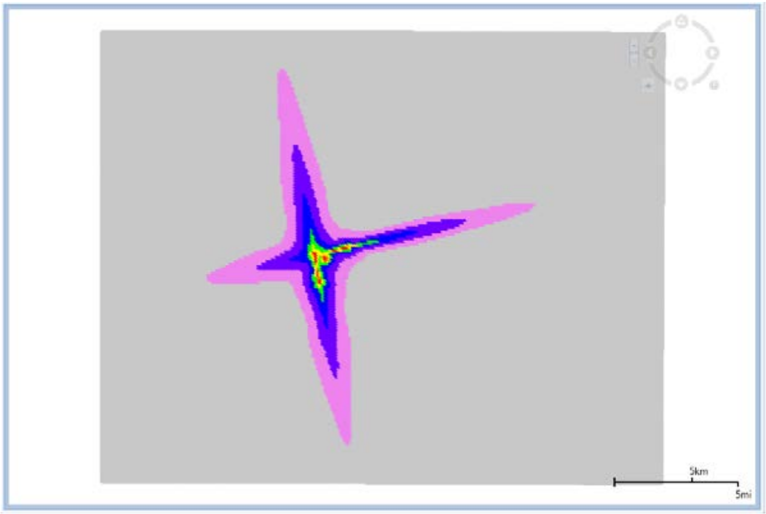

Figure 5-73. UCD-Com2-runups – DNL with Bank Angle AEDT 2b Contours

For UCD-Com2-runups, the differences between the AEDT 2b and INM DNL contour area results were less than 5.1% for the contour areas of interest, with the higher contours with areas smaller than 0.21 sq. km having a larger difference. The 65 dB DNL contour results showed a difference of 0.89% between INM and AEDT 2b. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

5.3.2.11 Phase 2 Testing Results - UCD-Helis

UCD-Helis is a simple airport study with helicopter operations that includes taxi operations. The study was run in both INM 7.0d su1 and AEDT 2b with bank angle.

It should be noted that although UCD-Helis focuses on modeling helicopter operations, not all helicopters nor all helicopter profiles in the AEDT Fleet database were included in this analysis. This analysis is meant to check the noise computation functionality related to helicopters in AEDT, and not specifically review the contents of the AEDT 2b databases.

The following DNL noise results for contours were generated:

Table 5-52. UCD-Helis – DNL with Bank Angle Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	175.579	176.575	-0.996	0.6
60	81.555	82.447	-0.892	1.1
65	4.278	5.008	-0.730	14.6
70	0.585	0.583	0.002	-0.3
75	0.237	0.237	0.000	-0.2
80	0.097	0.101	-0.004	4.0
85	0.036	0.033	0.003	-8.3

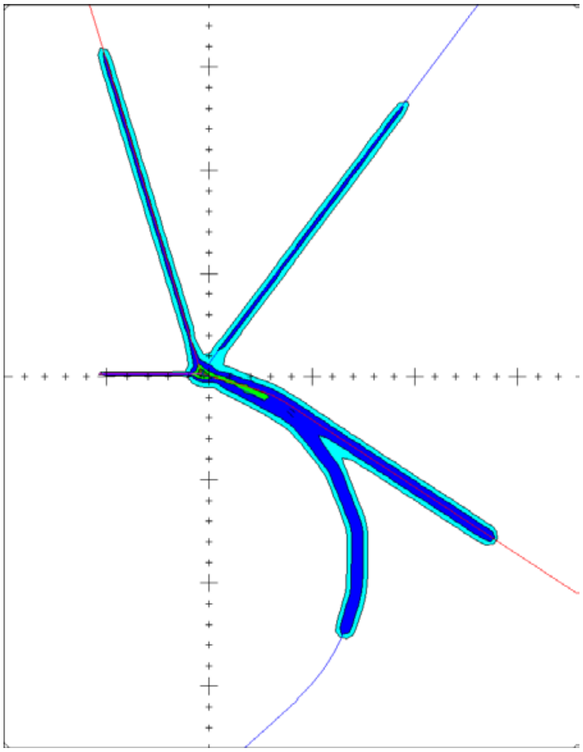

Figure 5-74. UCD-Helis – DNL with Bank Angle INM Contours

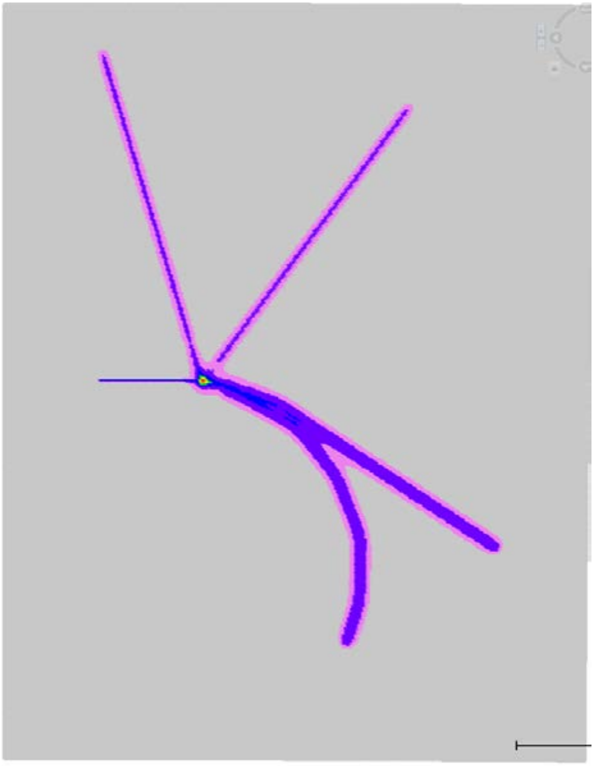

Figure 5-75. UCD-Helis – DNL with Bank Angle AEDT 2b Contours

For UCD-Helis, the differences between the AEDT 2b and INM DNL contour area results were less than 14.6% for the contour areas of interest. The 65 dB DNL contour results showed a difference of 14.6% between INM and AEDT 2b, and shows the largest contour area difference for this study. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes except for one small 65 dB DNL contour island.

After an investigation, a couple of reasons were identified to have caused the differences in the noise results. First, the update to the AEDT airport weather database cause differences in the results. While INM used the standard atmosphere, AEDT used the annual average weather at the Central Wisconsin airport. The annual average temperature at the Central Wisconsin airport was 43 degrees Fahrenheit. In addition, the differences in the noise grid locations combined with insufficient grid resolution have also contributed to the differences in the noise results. As mentioned in the beginning of Section 5.3, differences in noise grid location due to different grid map projection methods in INM and AEDT 2b do not necessarily cause differences in contour areas as long as the grid resolution is fine enough. The spacing of the grid points used in the initial analysis was 0.8 nm, which is sufficient for a typical airport noise study. However, since the UCD study had a small number of helicopter operations, a finer resolution was necessary. Therefore, the study was rerun after updating the airport weather in INM and decreasing the grid spacing to 0.2 nm from 0.8 nm. The updated results are presented in Table 5-53. The differences in contour areas decreased after rerunning the study except for 70 and 75 dB. Visual inspection of the updated contour plots showed that differences in the small westerly contour lobe caused these contour areas differences. Figure 5-76 shows comparisons of the westerly lobe between INM and AEDT. This westerly lobe is due to a taxi operation of a Bell 212 helicopter. INM correctly modeled this taxi operation using a taxi track and a taxi procedure. However, AEDT modeled this operation as a departure operation while using the same taxi track. Assigning an incorrect operation type in AEDT caused the Bell 212 to use the maximum takeoff thrust instead of the idle thrust for this taxi operation. This bug in AEDT caused greater DNL 70 and 75 dB areas. This issue was reported to the AEDT development team.

Table 5-53. UCD-Helis – DNL with Bank Angle Phase 2 Testing Results After Matching the Weather and Increasing Grid Resolution

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	176.509	176.264	0.245	-0.1
60	83.432	83.336	0.096	-0.1
65	5.959	5.889	0.07	-1.2
70	1.033	1.097	-0.064	5.8
75	0.248	0.449	-0.201	44.8
80	0.108	0.105	0.003	-2.9
85	0.047	0.045	0.002	-4.4

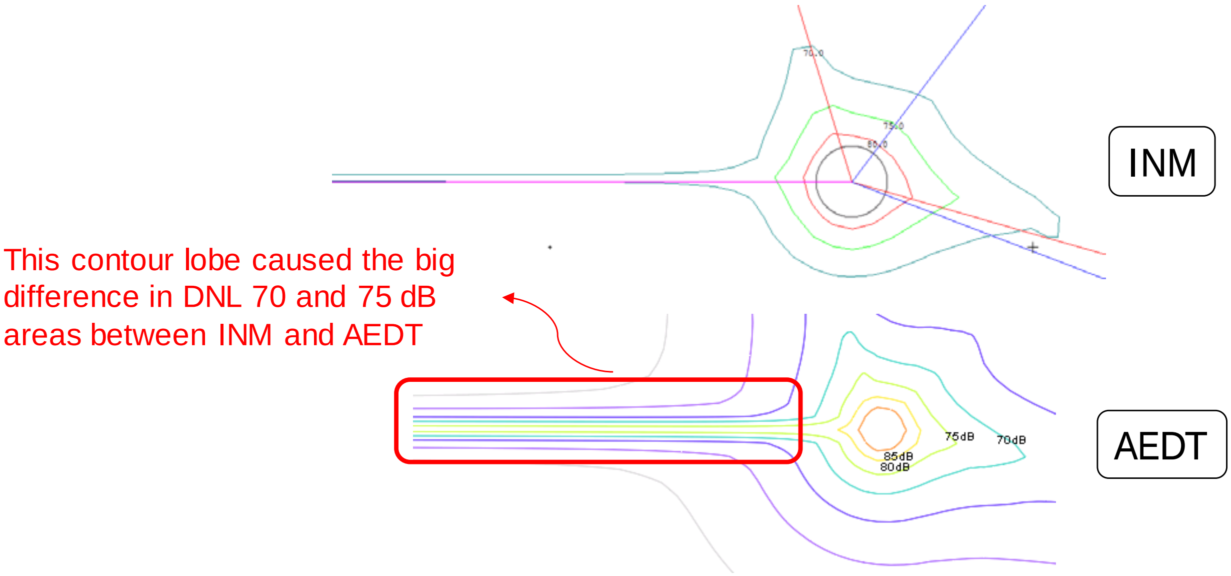

Figure 5-76. UCD-Helis – DNL with Bank Angle AEDT 2b Contours

5.3.2.12 Phase 2 Testing Results - UCD-Helis-user

User-defined helicopters were tested with UCD-Helis-user. User-defined helicopters in an INM study are not currently supported by the INM to ASIF Converter tool. This issue has been reported to the AEDT development team for further investigation. Although, user-defined helicopters can be created directly in AEDT 2b.

5.3.2.13 Phase 2 Testing Results - UCD-Mil

UCD-Mil is a simple airport study with military aircraft operations. The study was run in both INM 7.0d su1 and AEDT 2b with bank angle.

It should be noted that although UCD-Mil focuses on modeling military aircraft operations, not all military aircraft nor all aircraft profiles in the AEDT Fleet database were included in this analysis. This analysis is meant to check the noise computation functionality related to military aircraft in AEDT, and not specifically review the contents of the AEDT 2b databases.

The following DNL noise results for contours were generated:

Table 5-54. UCD-Mil – DNL with Bank Angle Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	74.413	75.083	-0.670	0.9
60	38.592	38.908	-0.316	0.8
65	19.146	19.307	-0.161	0.8
70	9.537	9.644	-0.107	1.1
75	4.776	4.804	-0.028	0.6
80	2.516	2.549	-0.033	1.3
85	1.258	1.270	-0.012	0.9

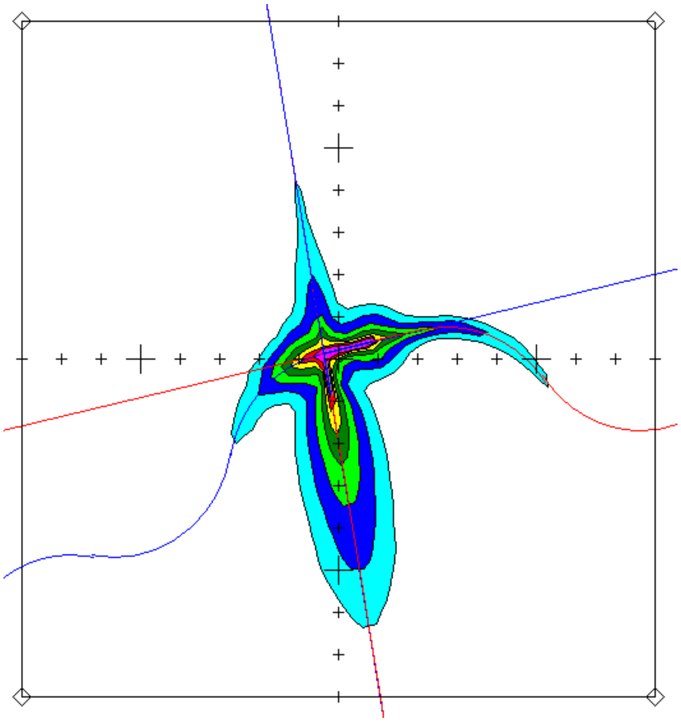

Figure 5-77. UCD-Mil – DNL with Bank Angle INM Contours

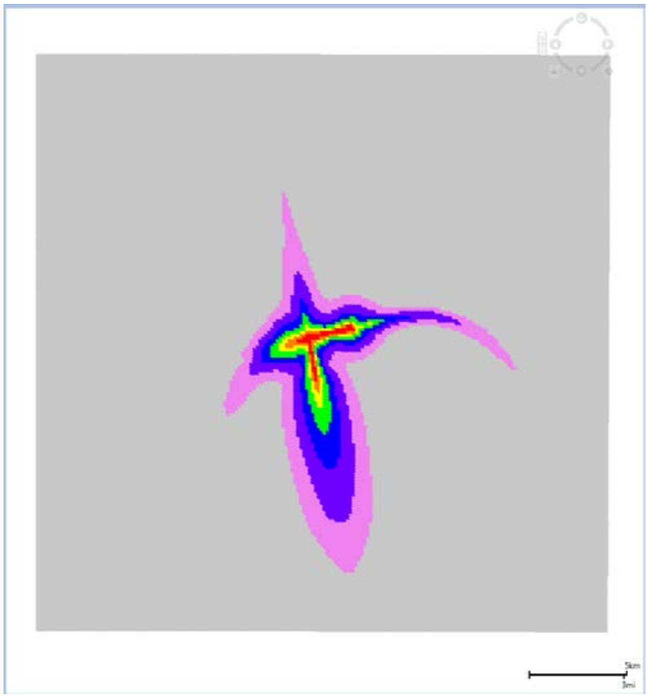

Figure 5-78. UCD-Mil – DNL with Bank Angle AEDT 2b Contours

For UCD-Mil, the differences between the AEDT 2b and INM DNL contour area results were less than 1.3% for the contour areas of interest. The 65 dB DNL contour results showed a difference of 0.84% between INM and AEDT 2b. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

5.3.2.14 Phase 2 Testing Results - UCD-Mil-user

User-defined military aircraft were tested with UCD-Mil. User-defined military aircraft in an INM study are currently not supported by the INM to ASIF Converter tool. This issue has been reported to the AEDT development team for further investigation. Although, user-defined military aircraft can be created directly in AEDT 2b.

5.3.2.15 Phase 2 Testing Results - UCD-Mil-runup

UCD-Mil-runup is a simple airport study with military aircraft operations that includes runup operations. The study was run in both INM 7.0d su1 and AEDT 2b with bank angle. The following DNL noise results for contours were generated:

Table 5-55. UCD-Mil-runup – DNL with Bank Angle Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	75.213	75.070	0.143	-0.2
60	39.214	38.901	0.313	-0.8
65	19.571	19.306	0.265	-1.4
70	9.797	9.643	0.154	-1.6
75	4.978	4.804	0.174	-3.6

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
80	2.645	2.549	0.096	-3.8
85	1.345	1.270	0.075	-5.9

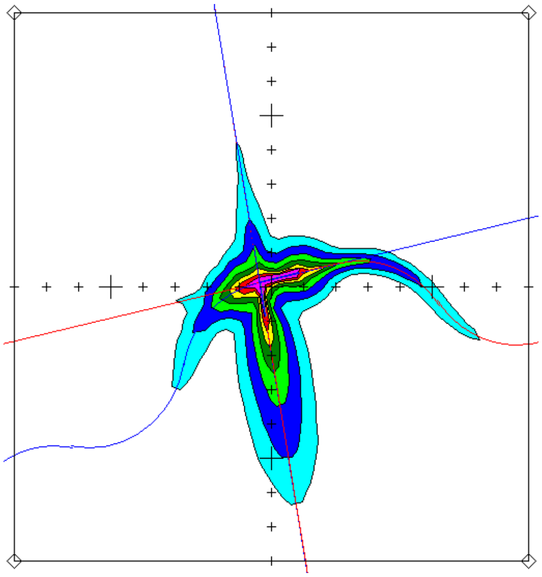

Figure 5-79. UCD-Mil-runup – DNL with Bank Angle INM Contours

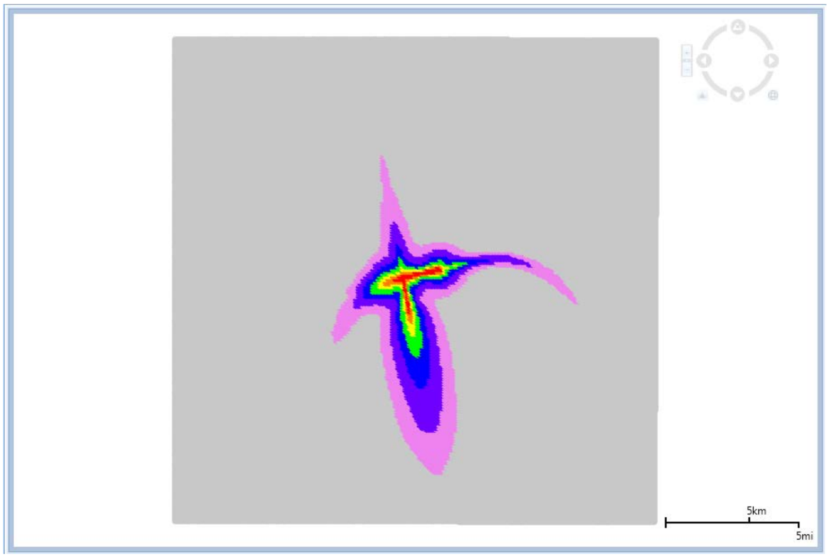

Figure 5-80. UCD-Mil-runup – DNL with Bank Angle AEDT 2b Contours

For UCD-Mil-runup, the differences between the AEDT 2b and INM DNL contour area results were less than 6.0% for the contour areas of interest. The 65 dB DNL contour results showed a difference of -1.4% between INM and AEDT 2b. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes, except for a few minor differences directly West of the runways. Since this is the area that should exhibit some of the noise effects due to runup operations, it was investigated further. This investigation revealed that the runup operations were not being imported by the AEDT ASIF. This issue is being investigated further.

5.3.2.16 Phase 2 Testing Results - UCD-DispTrack

UCD-DispTrack is a simple airport study with commercial aircraft operations that includes track dispersion of aircraft operations. The study was run in both INM 7.0d su1 and AEDT 2b with bank angle, using four different track dispersions. The following DNL noise results for contours were generated:

Table 5-56. UCD-DispTrack – DNL with Bank Angle Phase 2 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
50	119.480	120.733	-1.253	1.0
55	42.345	42.663	-0.318	0.7
60	13.902	14.015	-0.113	0.8
65	4.739	4.773	-0.034	0.7
70	1.834	1.840	-0.006	0.3
75	0.775	0.803	-0.028	3.5
80	0.227	0.234	-0.007	3.0
85	0.019	0.029	-0.010	34.4

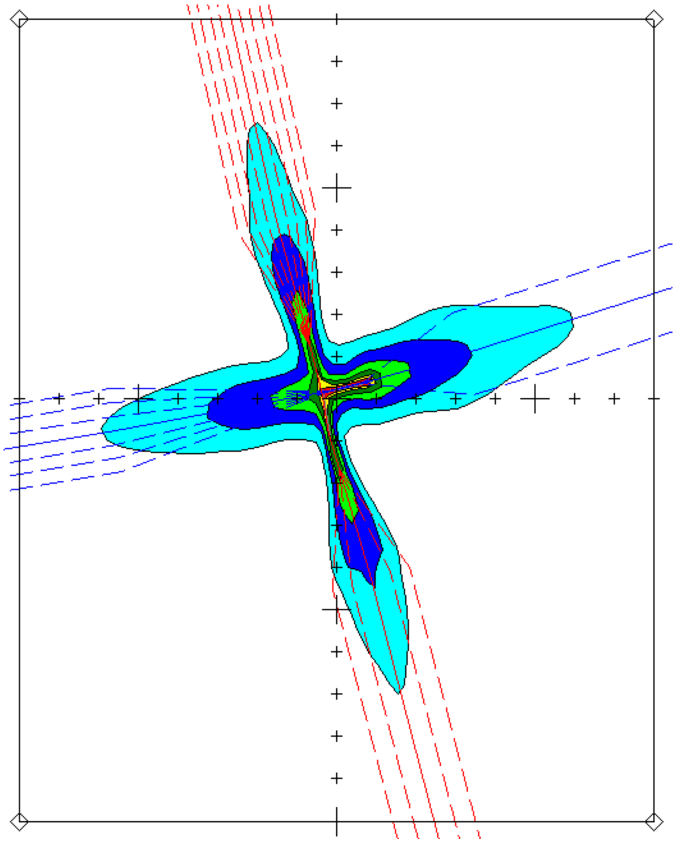

Figure 5-81. UCD-DispTrack – DNL with Bank Angle INM Contours

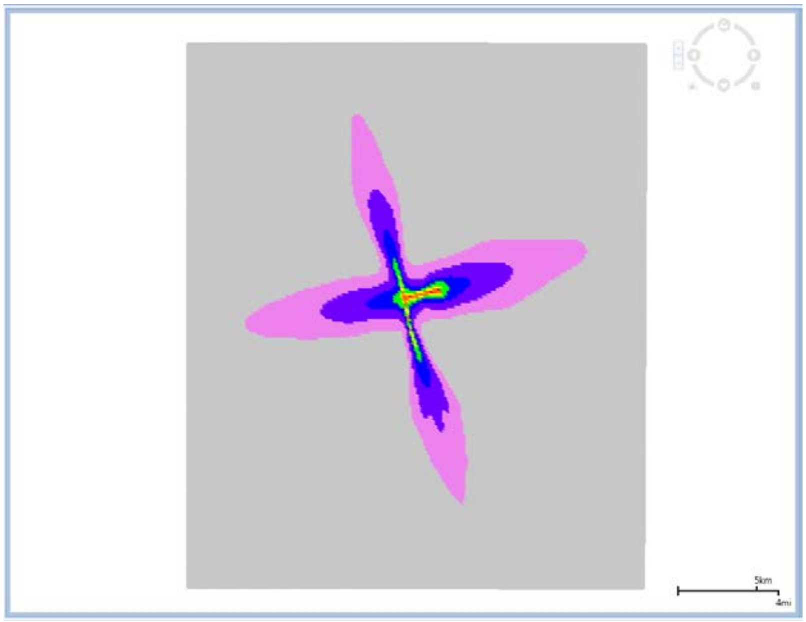

Figure 5-82. UCD-DispTrack – DNL with Bank Angle AEDT 2b Contours

For UCD-DispTrack, the differences between the AEDT 2b and INM DNL contour area results were less than 3.5% for the contour areas of interest. The 65 dB DNL contour results showed a difference of 0.7% between INM and AEDT 2b. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes.

5.3.2.17 Phase 2 Testing Results - UCD- Ambient

The UCD-Ambient test cases were designed to compare the TALA, TALC and TAPNL metrics referenced to a user-defined ambient noise file (ambient.txt) and various associated settings. However, test case UCD-Com2-metrics showed that these metrics were not being calculated and displayed properly in AEDT 2b. The same issue was observed in UCD-Ambient, when an ambient noise file was used.

5.3.3 Phase 3 Testing Results

The Phase 3 test cases were used to evaluate AEDT 2b noise computation functionality that involve terrain. Both of the test cases, PSP and SLC, were selected because significant terrain elevations within the vicinity of the airport provided good opportunities to focus on terrain-based noise adjustment effects in AEDT 2b. Like Phase 2, terrain-based noise adjustments are considered specialized functionality, because they are not often encountered in typical airport Part 150 analyses.

Through the course of the Use Case D testing in AEDT 2b, a bug was identified in the terrain-based adjustment code. This bug was resolved in AEDT 2b SP2. Therefore, the test cases were run in both INM 7.0dsu1 and AEDT 2b SP2 with bank angle in Phase 3.

The results are compared in the following tables and graphics, which include:

- Contour plots, and

- Contour area comparison tables.

Where appropriate, grid point difference plots and grid point difference statistic tables are also presented.

5.3.3.1 Phase 3 Testing Results

PSP is a simple airport study with commercial aircraft and helicopter operations. The study was run in both INM 7.0dsu1 and AEDT 2b SP2 with bank angle for three different scenarios:

- PSP-Flat: PSP with no terrain (baseline);
- PSP-Terrain: PSP with terrain; and
- PSP-LOS: PSP with terrain using the line-of-sight blockage adjustment and terrain fill.

The following DNL noise results for contours were generated:

Table 5-57. PSP-Flat – DNL with Bank Angle Phase 3 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	143.328	134.644	8.684	-6.5
60	53.606	54.393	-0.787	1.4
65	23.215	24.049	-0.834	3.5
70	11.204	11.663	-0.459	3.9
75	1.841	1.196	0.645	N/A

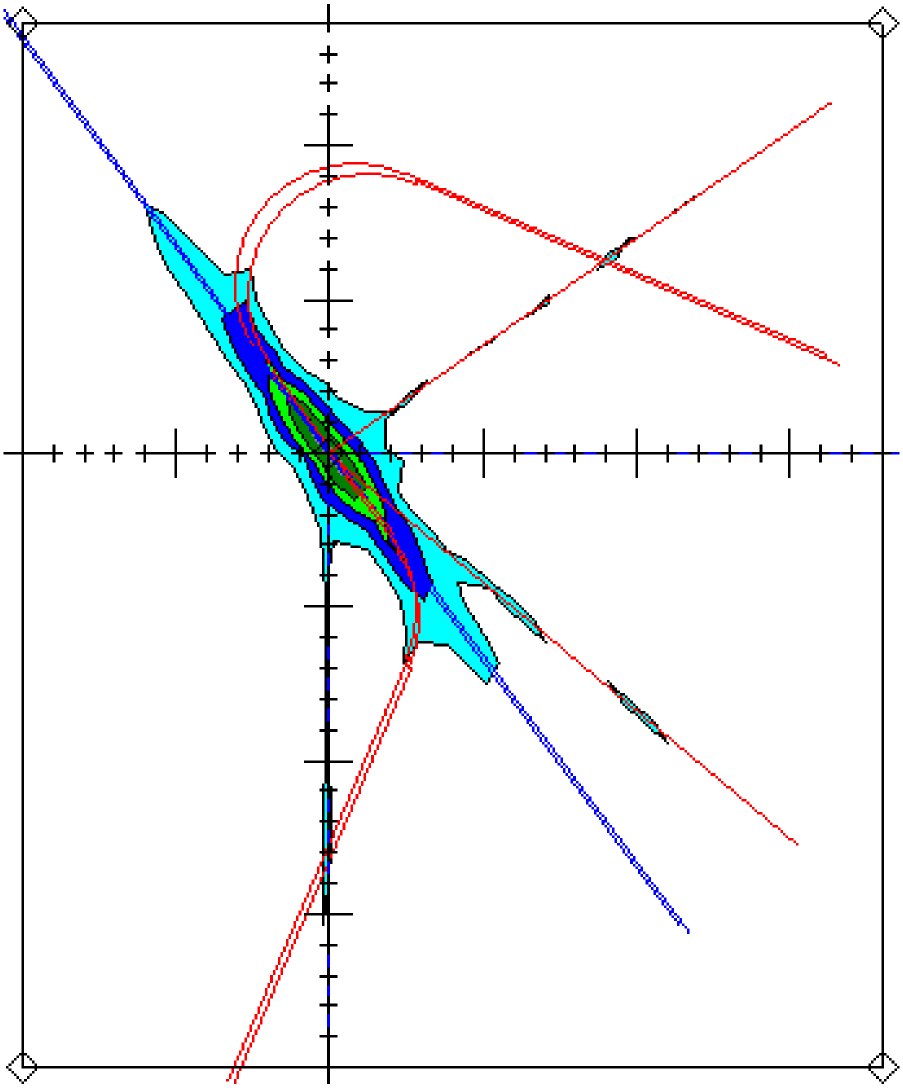

Figure 5-83. PSP-Flat – DNL with Bank Angle INM Contours

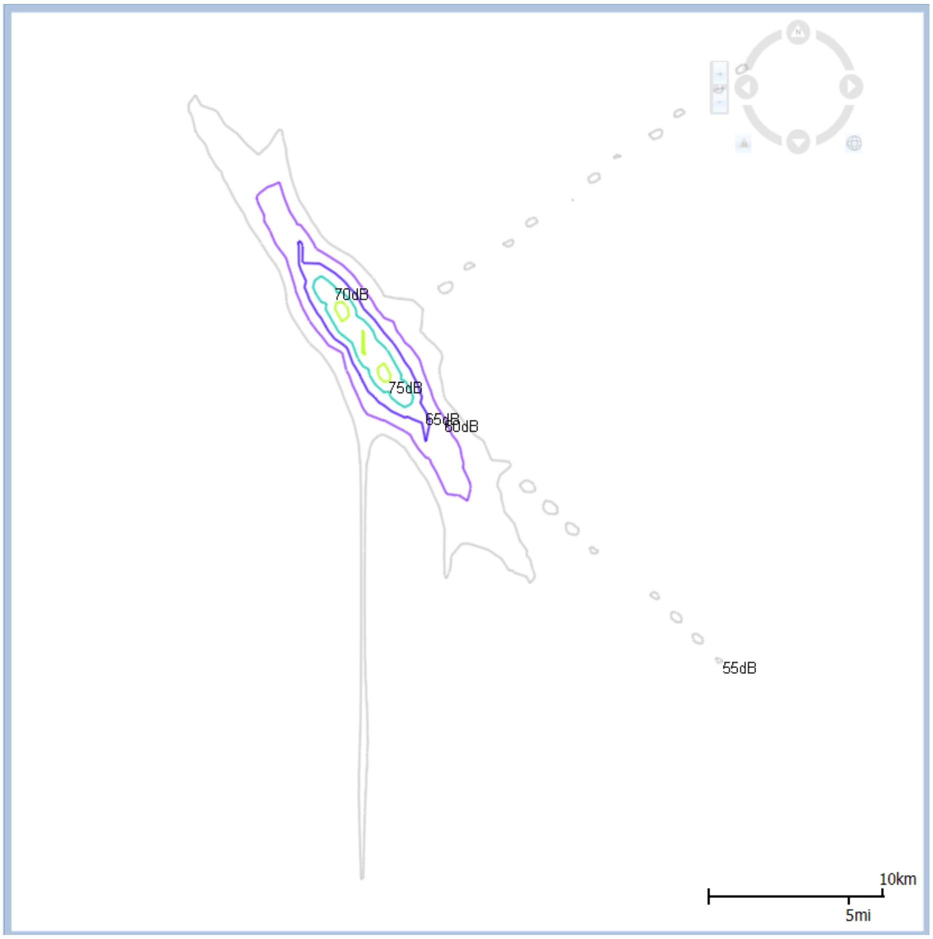

Figure 5-84. PSP-Flat – DNL with Bank Angle AEDT 2b Contours

For the PSP study with bank angle turned on and no terrain, the differences between the AEDT 2b and INM DNL contour area results were less than 6.5% for the contour areas of interest (with the difference for the 65 dB DNL contour being 3.5%). A visual comparison of the contour plots showed that the AEDT 2b and INM contours had similar shapes. Some contour islanding occurred in AEDT 2b in areas where there were no islanding occurred in INM. This is attributed to the differences between the AEDT 2b and INM contouring methods.

Table 5-58. PSP-Terrain – DNL with Bank Angle Phase 3 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	161.801	152.458	9.343	-6.1
60	57.228	57.821	-0.593	1.0
65	24.252	24.188	0.064	-0.3
70	11.212	11.578	-0.366	3.2
75	1.910	1.260	0.650	-51.6

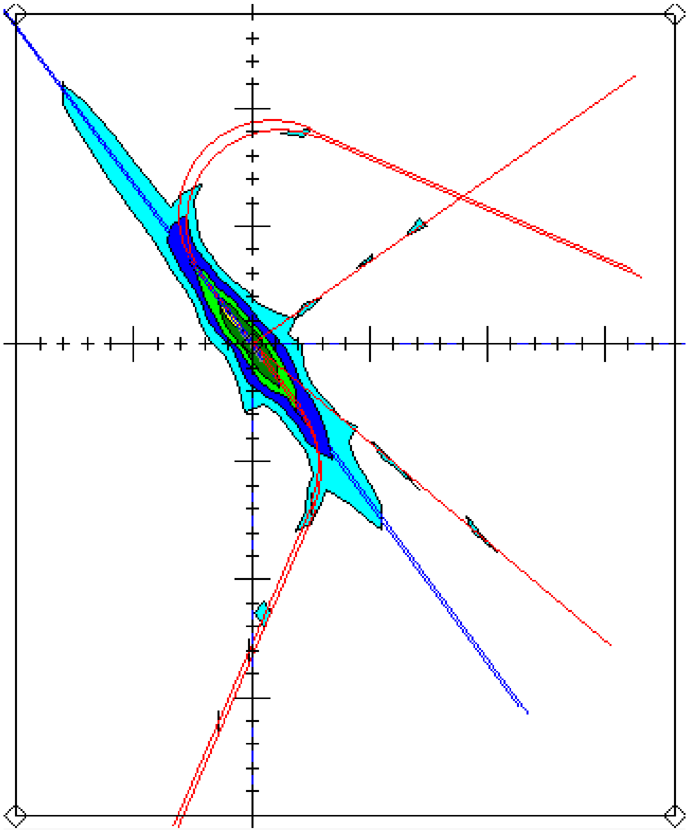

Figure 5-85. PSP-Terrain – DNL with Bank Angle INM Contours

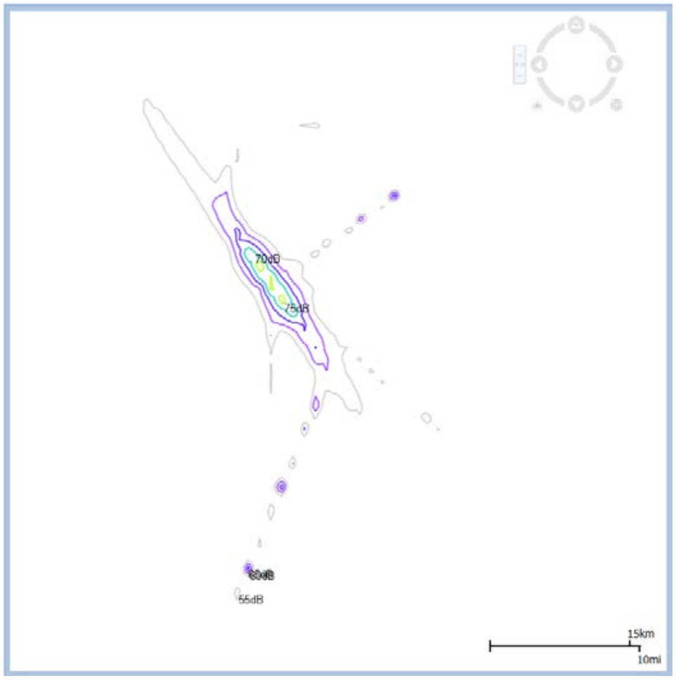

Figure 5-86. PSP-Terrain – DNL with Bank Angle AEDT 2b Contours

For the PSP study with bank angle and terrain turned on, the differences between the AEDT 2b and INM DNL contour area results were less than 6.1% for the contour areas of interest (with the difference for the 65 dB DNL contour being 0.3%). A visual comparison of the contour plots showed that the AEDT 2b and INM contours had similar shapes. Some contour islanding occurred in AEDT 2b in areas where there were no islanding occurred in INM. This is attributed to the differences between the AEDT 2b and INM contouring methods.

Table 5-59. PSP-LOS – DNL with Bank Angle Phase 3 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	154.918	146.677	8.241	-5.6
60	55.278	56.439	-1.161	2.1
65	23.081	23.821	-0.740	3.1
70	10.494	11.505	-1.011	8.8
75	1.015	1.225	-0.210	17.1

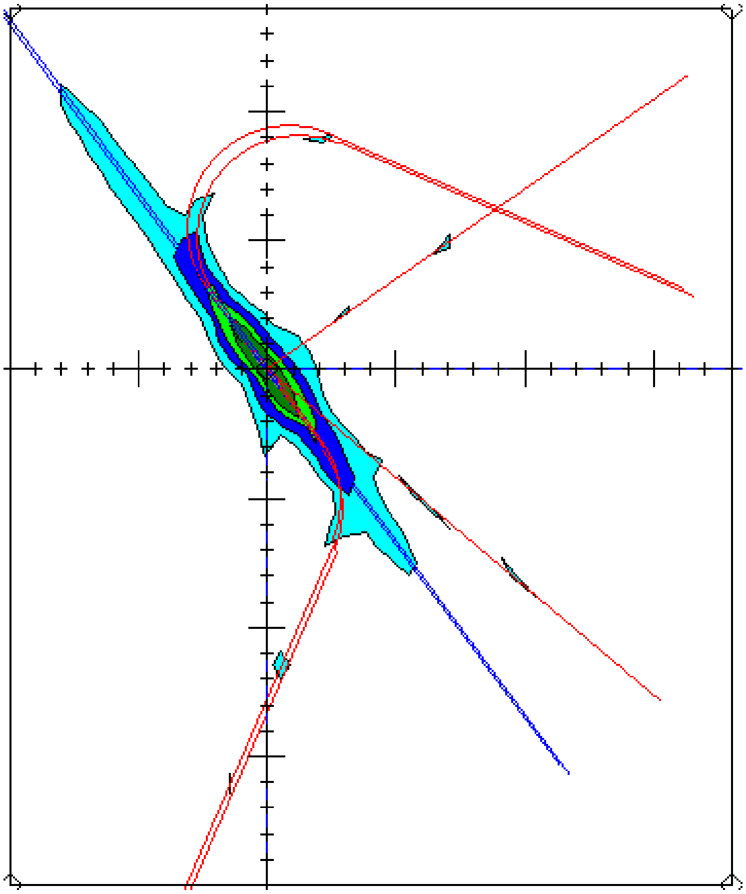

Figure 5-87. PSP-LOS – DNL with Bank Angle INM Contours

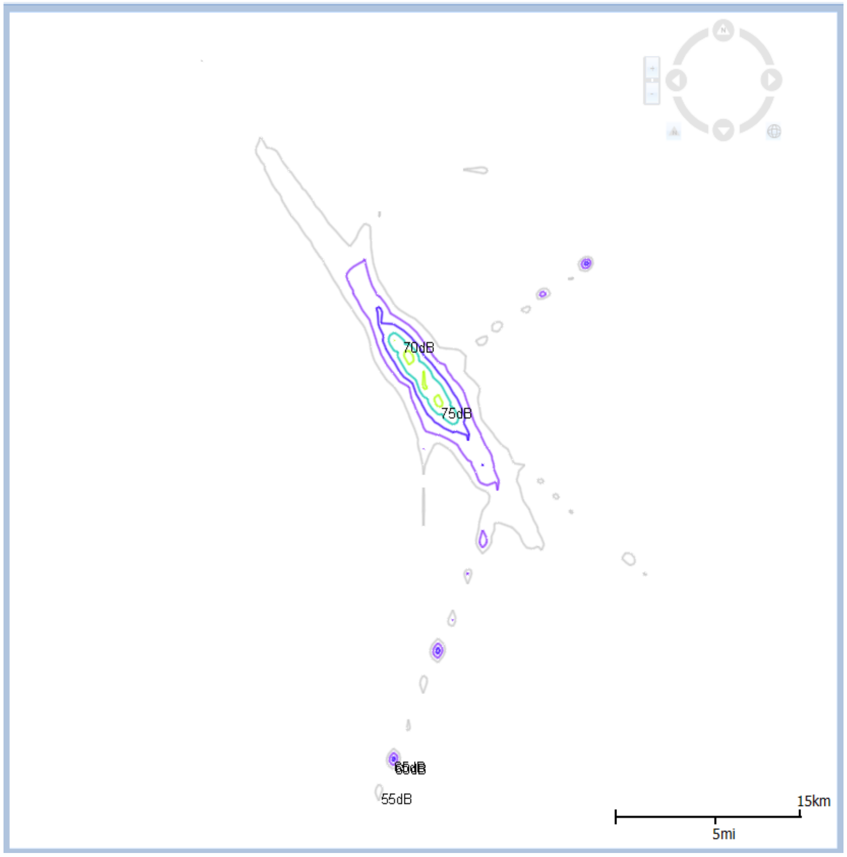

Figure 5-88. PSP-LOS – DNL with Bank Angle AEDT 2b Contours

For the PSP study with bank angle, terrain, line-of-sight blockage noise adjustment and terrain fill turned on, the differences between the AEDT 2b and INM DNL contour area results were less than 8.8% for the contour areas of interest (with the difference for the 65 dB DNL contour being 3.1%). A visual comparison of the contour plots showed that the AEDT 2b and INM contours had similar shapes. Some contour islanding occurred in AEDT 2b in areas where there were no islanding occurred in INM. This is attributed to the differences between the AEDT 2b and INM contouring methods.

5.3.3.2 Phase 3 Testing Results – SLC

SLC is a simple airport study with commercial aircraft and helicopter operations. The study was run in both INM 7.0dsu1 and AEDT 2b SP2 with bank angle for three different scenarios:

- SLC-Flat: SLC with no terrain (baseline);
- SLC-Terrain: SLC with terrain; and
- SLC-LOS: SLC with terrain using the line-of-sight blockage adjustment and terrain fill.

The following DNL noise results for contours were generated:

Table 5-60. SLC-Flat – DNL with Bank Angle Phase 3 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	299.696	0.029	299.667	N/A
60	139.604	0.000	139.604	N/A
65	53.282	54.542	-1.260	2.3
70	31.257	31.812	-0.555	1.7
75	11.282	11.057	0.225	-2.0
80	5.112	3.602	1.510	-41.9
85	1.988	1.422	0.566	-39.8

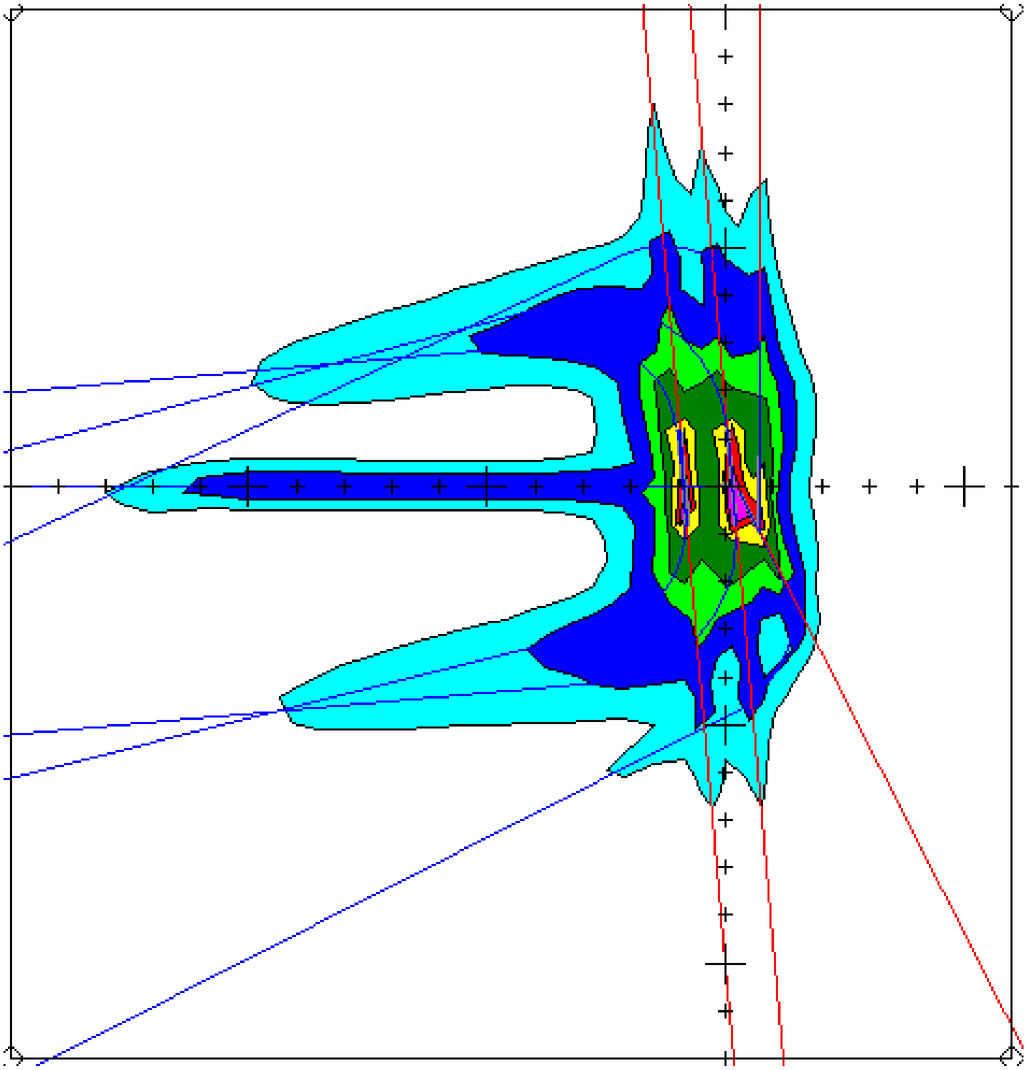

Figure 5-89. SLC-Flat – DNL with Bank Angle INM Contours

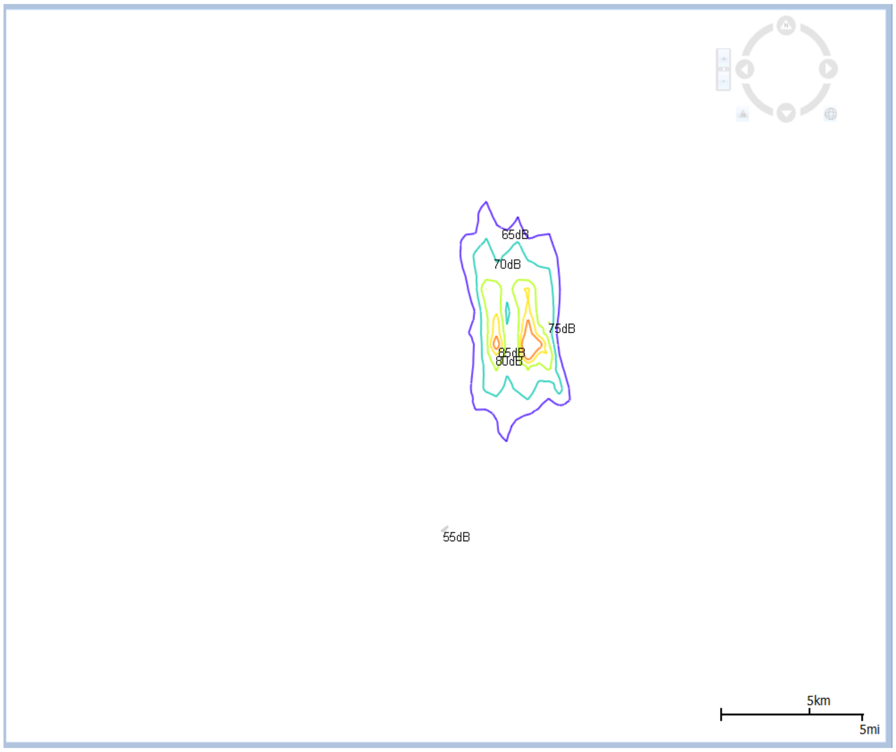

Figure 5-90. SLC-Flat – DNL with Bank Angle AEDT 2b Contours

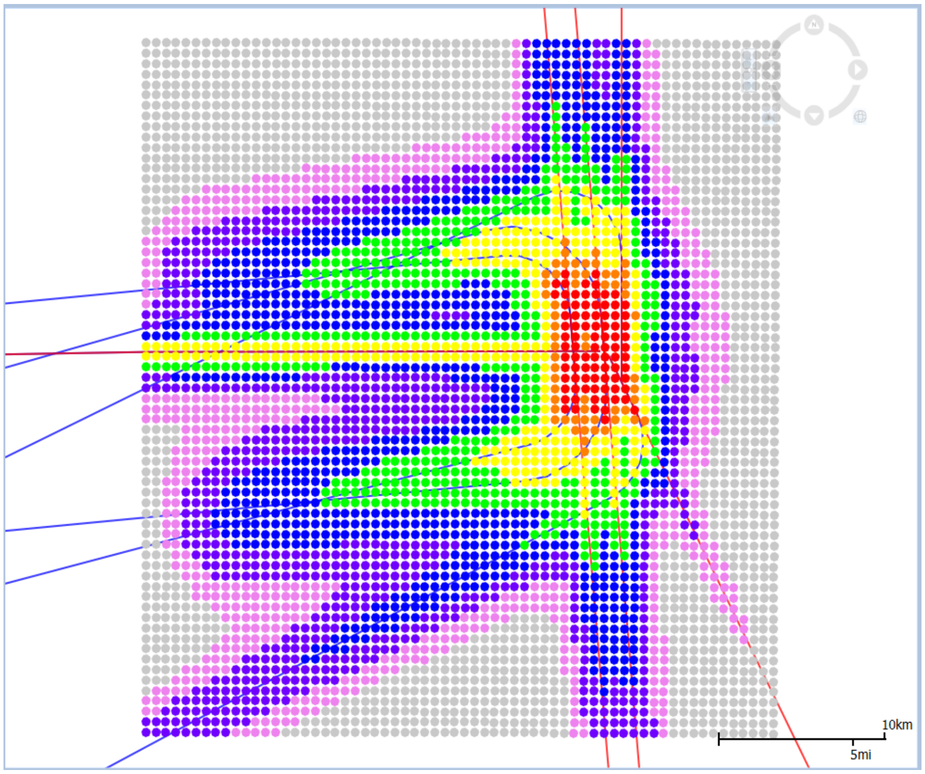

Figure 5-91. SLC-Flat – DNL with Bank Angle AEDT 2b Receptor Grid

For the SLC study with bank angle turned on and no terrain, the differences between the AEDT 2b and INM DNL contour area results were less than 2.3% for the contour areas of interest (with the difference for the 65 dB DNL contour being 2.3%). However, several contours (55 and 60 dB DNL) in AEDT 2b were significantly different from the corresponding INM contours, as can be seen with a visual comparison of the contour plots. It should be noted that AEDT 2b does not plot those contours nor generates areas for comparison, if those contours extend outside of the domain of the receptor grid. In the case of the SLC study, several contours extended outside of the analysis grid in AEDT 2b, as can be confirmed by the receptor grid plot. Therefore, the large differences in contour levels for the 55 and 60 dB DNL contours can be attributed, in part, to the differences between the AEDT 2b and INM contouring methods.

Table 5-61. SLC-Terrain – DNL with Bank Angle Phase 3 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	323.818	7.452	316.366	N/A
60	139.813	0.647	139.166	N/A
65	53.187	50.345	2.842	-5.6
70	31.269	28.325	2.944	-10.4
75	11.330	9.904	1.426	-14.4
80	5.147	3.088	2.059	-66.7
85	2.041	1.252	0.789	-63.1

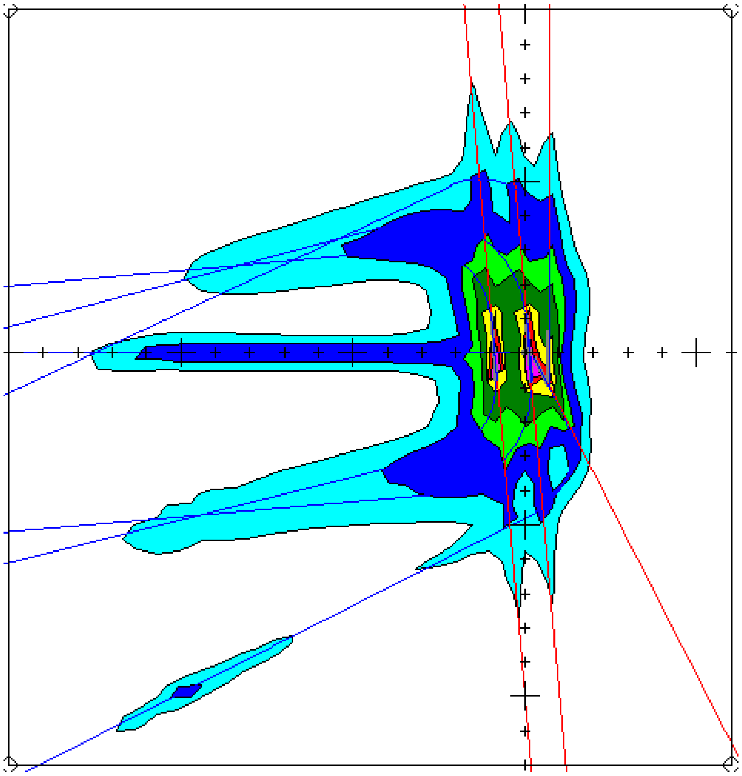

Figure 5-92. SLC-Terrain – DNL with Bank Angle INM Contours

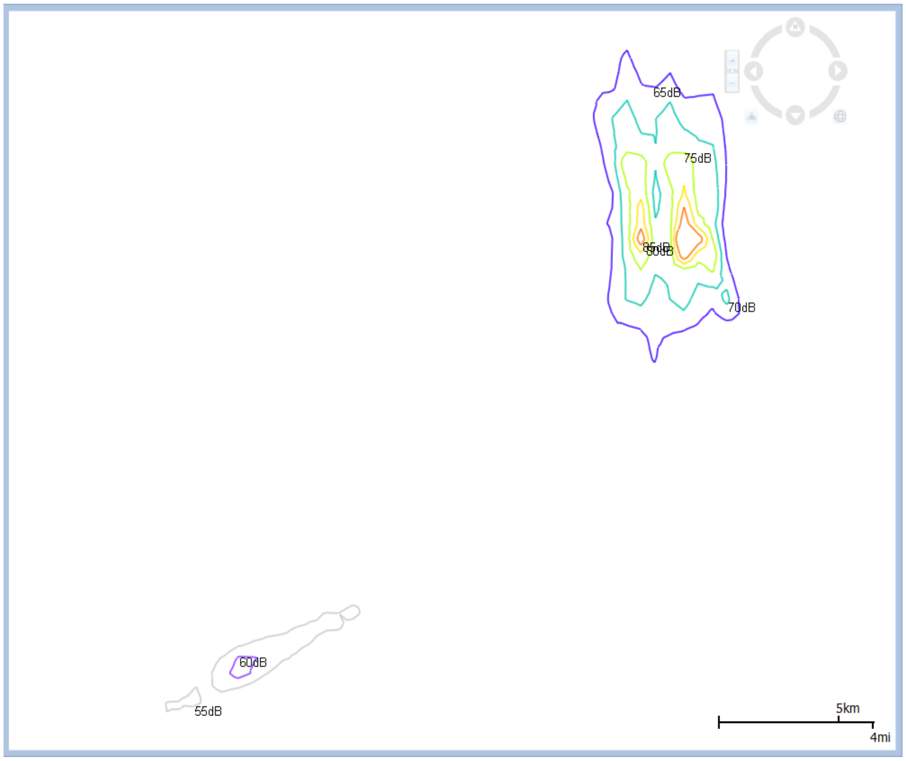

Figure 5-93. SLC-Terrain – DNL with Bank Angle AEDT 2b Contours

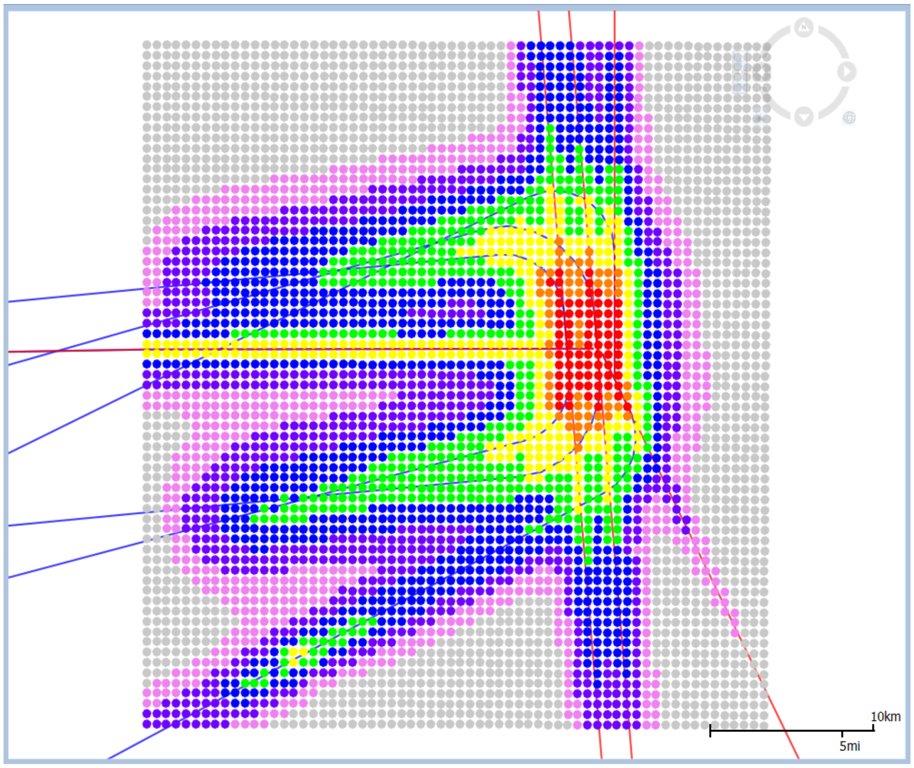

Figure 5-94. SLC-Terrain – DNL with Bank Angle AEDT 2b Receptor Grid

For the SLC study with bank angle and terrain turned on, the differences between the AEDT 2b and INM DNL contour area results were less than 14.4% for the contour areas of interest (with the difference for the 65 dB DNL contour being 5.6%). As seen in the no terrain case, several contours (55 and 60 dB DNL) in AEDT 2b were significantly different from the corresponding INM contours, due to those contours extending outside of the analysis grid in AEDT 2b, which caused the contours to be dropped from the AEDT 2b display due to the differences between the AEDT 2b and INM contouring methods.

Table 5-62. SLC-LOS – DNL with Bank Angle Phase 3 Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	318.213	7.588	310.625	-4093.7
60	136.971	0.645	136.326	N/A
65	52.649	49.812	2.837	-5.7
70	30.453	27.697	2.756	-10.0
75	10.585	9.718	0.867	-8.9
80	4.126	2.932	1.194	-40.7
85	1.083	1.104	-0.021	1.9

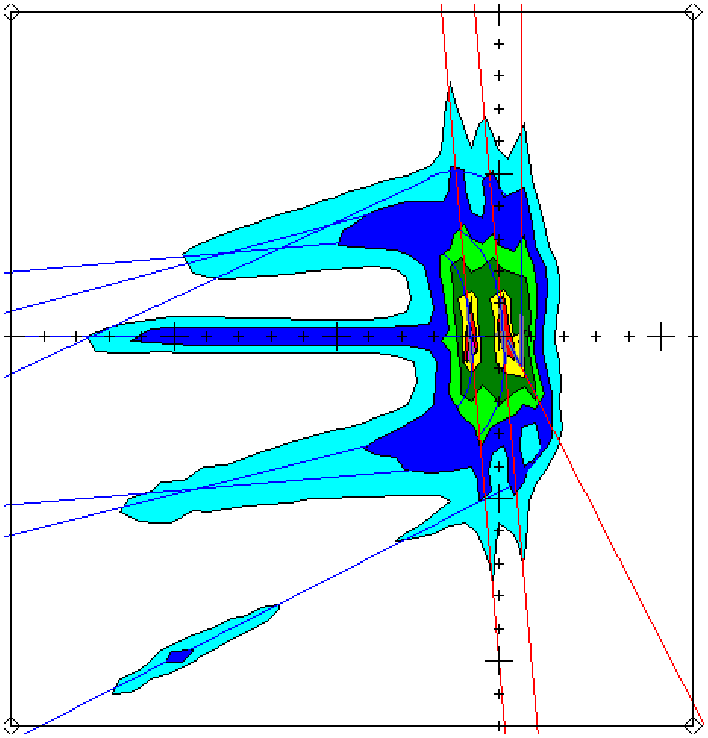

Figure 5-95. SLC-LOS – DNL with Bank Angle INM Contours

Figure 5-96. SLC-LOS – DNL with Bank Angle AEDT 2b Contours

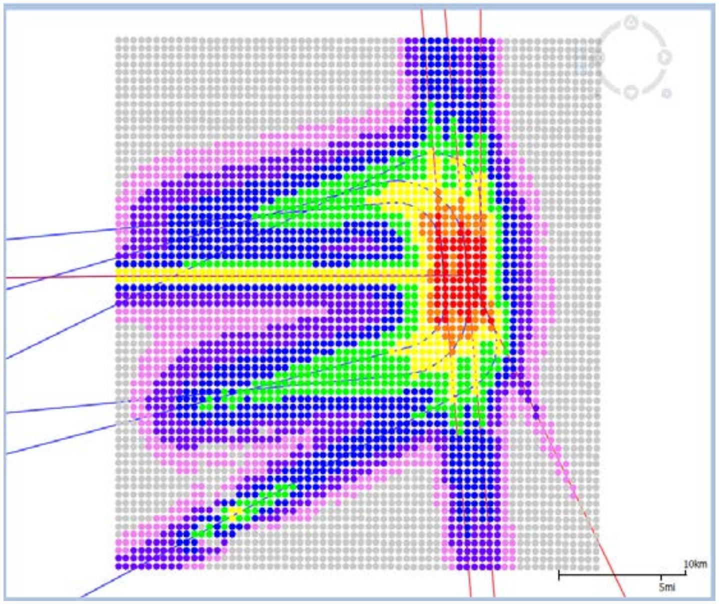

Figure 5-97. SLC-LOS – DNL with Bank Angle AEDT 2b Receptor Grid

For the SLC study with bank angle, terrain, line-of-sight blockage adjustment and terrain fill turned on, the differences between the AEDT 2b and INM DNL contour area results were less than 10.0% for the contour areas of interest (with the difference for the 65 dB DNL contour being 5.7%). As seen in the no terrain case, several contours (55 and 60 dB DNL) in AEDT 2b were significantly different from the corresponding INM contours, due to those contours extending outside of the analysis grid in AEDT 2b, which caused the contours to be dropped from the AEDT 2b display due to differences between the AEDT 2b and INM contouring methods.

5.4 Noise Impact Due to Changes in Engine Installation Locations

As mentioned earlier in this chapter, a change in the AEDT 2b database was mainly responsible for the differences in noise results for the tests conducted in Use Case D along with a bug in that noise contouring algorithm that was discussed with the JFK study. In INM, the engine installation location determines which engine installation directivity adjustment is applied to the lateral attenuation adjustment for the aircraft, and those location values are associated with the spectral class database. The different engine installation directivity adjustments are presented in Figure 5-98. Since separate spectral classes were used for approach and departure operations for any given aircraft, there existed the possibility that an aircraft could (incorrectly) have different engine installation directivity adjustments for approach and departure operations. If the incorrect engine installation location was assigned to an aircraft, the result could be a noise level difference of up to 1.9 dB, depending on the elevation angle.

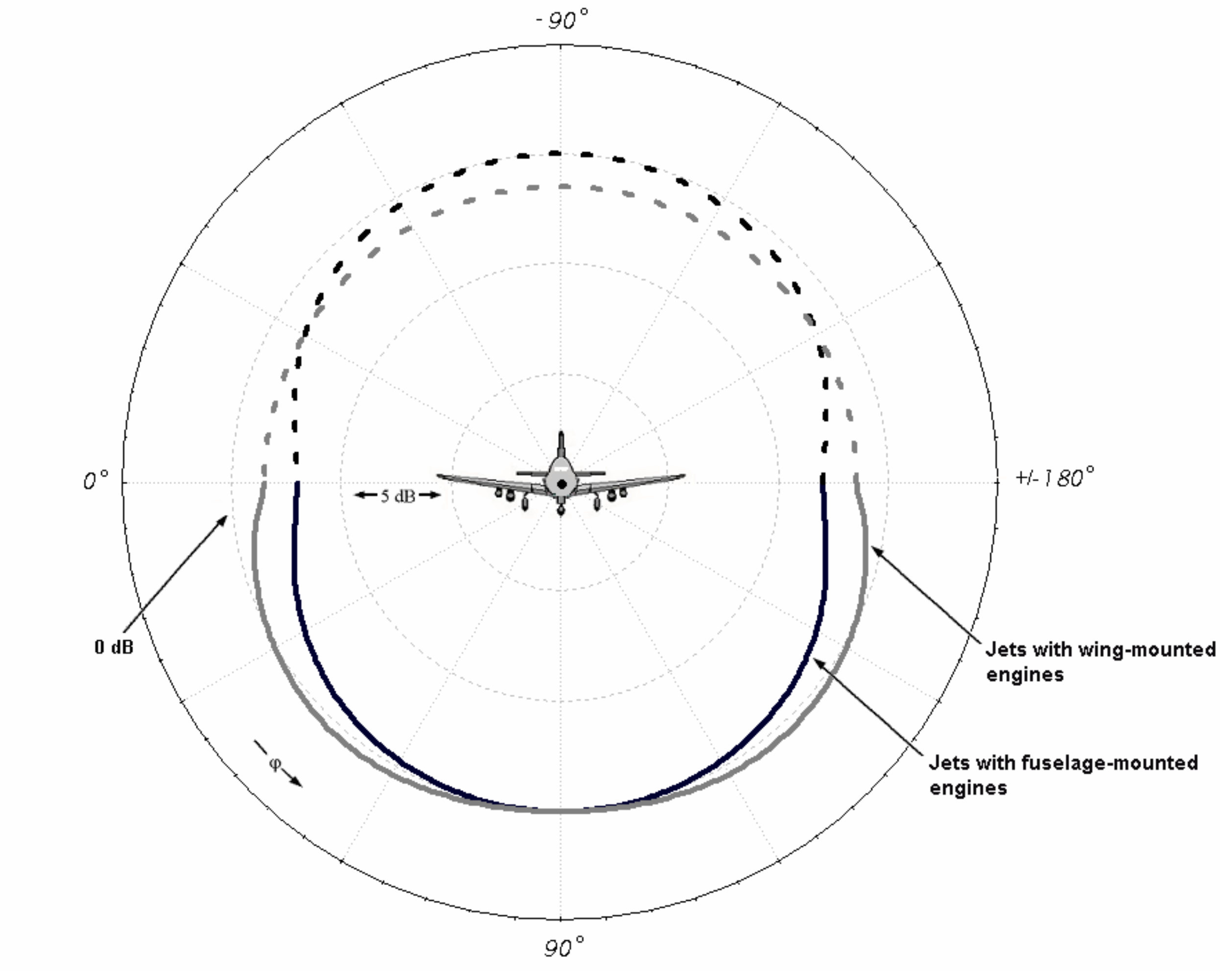

Figure 5-98. Illustration of Engine-Installation Effects for Jet-Powered Airplanes[11]

This issue was resolved in AEDT with the decoupling of engine installation location and spectral class. Therefore, only a single engine installation location is referenced for each aircraft, and therefore the same engine installation directivity adjustment is guaranteed to be used for approach and departure operations in AEDT 2b. However, this means that several aircraft in the test cases used for AEDT UQ Use Case D do exhibit this issue. Those aircraft are listed in Table 5-63. As listed in the table, 26 INM aircraft types had different engine locations from the corresponding AEDT aircraft for either or both departures and arrivals. While AEDT corrected the inconsistent engine installation locations of the INM aircraft, the process also introduced errors in AEDT engine installation locations for some aircraft. INM aircraft 727100, 727EM1, 727Q15, 727Q7, and 727QF are Boeing 727-100 and 727-200 with various engine models. In INM, the engine locations of all of the Boeing 727s are correctly assigned as fuselage mounted. However, in AEDT, the engines of the corresponding aircraft types are incorrectly assigned as wing mounted.

Table 5-63. Aircraft with Engine Installation Location Differences in INM vs. AEDT

INM AIRCRAFT ID	AIRCRAFT DESCRIPTION	INM Eng. Location for Arrivals	INM Eng. Location for Departures	AEDT Eng. Location	Is AEDT Correct?
737	Boeing 737/JT8D-9	Fuselage	Wing	Wing	YES
717200	Boeing 717-200/BR 715	Wing	Fuselage	Fuselage	YES
727100	Boeing 727-100/JT8D-7	Fuselage	Fuselage	Wing	NO
727EM1	FEDX 727-100/JT8D-7	Fuselage	Fuselage	Wing	NO
727Q15	Boeing 727-200/JT8D-15QN	Fuselage	Fuselage	Wing	NO
727Q7	Boeing 727-100/JT8D-7QN	Fuselage	Fuselage	Wing	NO
727QF	UPS 727100 22C 25C	Fuselage	Fuselage	Wing	NO
737D17	Boeing 737-200/JT8D-17	Fuselage	Wing	Wing	YES
737QN	Boeing 737/JT8D-9QN	Fuselage	Wing	Wing	YES
CNA510	Cessna Mustang Model 510 / PW615F	Wing	Fuselage	Fuselage	YES
CNA55B	Cessna 550 Citation Bravo / PW530A	Wing	Fuselage	Fuselage	YES
CNA750	Citation X / Rolls Royce Allison AE3007C	Wing	Fuselage	Fuselage	YES
ECLIPSE500	Eclipse 500 / PW610F	Fuselage	Wing	Fuselage	YES
EMB170	ERJ170-100	Fuselage	Fuselage	Wing	YES
EMB175	ERJ170-200	Fuselage	Fuselage	Wing	YES
FAL20	FALCON 20/CF700-2D-2	Wing	Fuselage	Fuselage	YES
GIV	Gulfstream GIV-SP/TAY 611-8	Wing	Fuselage	Fuselage	YES
GV	Gulfstream GV/BR 710	Wing	Fuselage	Fuselage	YES
LEAR25	LEAR 25/CJ610-8	Wing	Fuselage	Fuselage	YES
MD81	MD-81/JT8D-217	Wing	Fuselage	Fuselage	YES
MD82	MD-82/JT8D-217A	Wing	Fuselage	Fuselage	YES
MD83	MD-83/JT8D-219	Wing	Fuselage	Fuselage	YES
MD9025	MD-90/V2525-D5	Wing	Fuselage	Fuselage	YES
MD9028	MD-90/V2528-D5	Wing	Fuselage	Fuselage	YES
MU3001	MU300-10/JT15D-5	Wing	Fuselage	Fuselage	YES
SABR80	NA SABRELINER 80	Wing	Fuselage	Fuselage	YES

In order to assess the noise impacts due to the changes in engine installation locations from INM to AEDT, SEL contour areas from single flight operations of a couple of aircraft types were compared. Five aircraft types of 737QN, MD81, SABR80, 727Q15, and 727Q7 were flown individually at the SFO airport in both INM and AEDT. For 737QN, MD81, and SABR80, the engine locations for the arrivals were incorrectly assigned in INM and were fixed in AEDT. Table 5-64, Table 5-65, and Table 5-66 provide comparisons of SEL contour areas of these three aircraft types between INM and AEDT. For 737QN, MD81, and SABR80, the differences in SEL contour areas were small for most dB levels. The tests showed that changes in engine installation locations for these three aircraft did not have a significant impact on noise results.

Table 5-64. SEL Contour Areas at SFO from a Single 737QN Arrival Flight

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
75	25.869	25.805	0.064	0.25
80	11.859	11.793	0.066	0.56
85	4.335	4.253	0.082	1.93
90	1.141	1.051	0.09	8.56

Table 5-65. SEL Contour Areas at SFO from a Single MD81 Arrival Flight

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
75	14.593	14.461	0.132	0.91
80	4.092	4.005	0.087	2.17
85	0.87	0.911	-0.041	-4.50
90	0.326	0.296	0.03	10.14

Table 5-66. SEL Contour Areas at SFO from a Single SABR80 Arrival Flight

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
75	18.095	18.062	0.033	0.18
80	8.886	9.02	-0.134	-1.49
85	4.276	4.291	-0.015	-0.35
90	1.63	1.604	0.026	1.62

On the other hand, the test results for 727Q15 in Table 5-67 for an arrival and in Table 5-68 for a departure flight showed from 12% up to 20% differences in SEL contour areas. For both the departure and arrival cases, AEDT showed greater contour areas for all dB levels. Table 5-69 and Table 5-70 provide the LAMAX contour areas from a 727Q15 arrival and a departure flight at SFO. Similar to the SEL results, AEDT had about 13% greater contour areas for all dB levels. As mentioned in Section 5.3.1, the differences in the SEL and LAMAX noise results for 727Q15 between INM and AEDT were the main causes of the differences in DNL and LAMAX levels at SFO and PHL. Figure 5-99 shows the SEL noise contours from a 727Q15 arrival at SFO calculated from INM and AEDT. Visual inspection of the contours from 70 to 95 dB reveals that the contours from AEDT (red) are larger than the contours from INM (blue), while the general shapes are very similar.

Table 5-67. SEL Contour Areas at SFO from a Single 727Q15 Arrival Flight

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
75	34.33	40.59	-6.26	-15.42
80	16.15	19.14	-2.99	-15.62
85	7.08	8.59	-1.51	-17.58
90	2.86	3.57	-0.71	-19.89

Table 5-68. SEL Contour Areas at SFO from a Single 727Q15 Departure Flight

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
75	304.91	346.36	-41.45	-11.97
80	194.32	223.75	-29.42	-13.15
85	96.81	114.96	-18.15	-15.79
90	39.44	46.99	-7.55	-16.07

Table 5-69. LAMAX Contour Areas at SFO from a Single 727Q15 Arrival Flight

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
75	8.4	9.71	-6.26	-13.49
80	4.36	5.06	-2.99	-13.83
85	2.06	2.4	-1.51	-14.17
90	0.92	1.07	-0.71	-14.02
95	0.4	0.46	-0.21	-13.04

Table 5-70. LAMAX Contour Areas at SFO from a Single 727Q15 Departure Flight

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
75	74.41	85.6	-6.26	-13.07
80	36.16	41.86	-2.99	-13.62
85	17.32	20.03	-1.51	-13.53
90	9.41	10.85	-0.71	-13.27
95	5.76	6.64	-0.21	-13.25

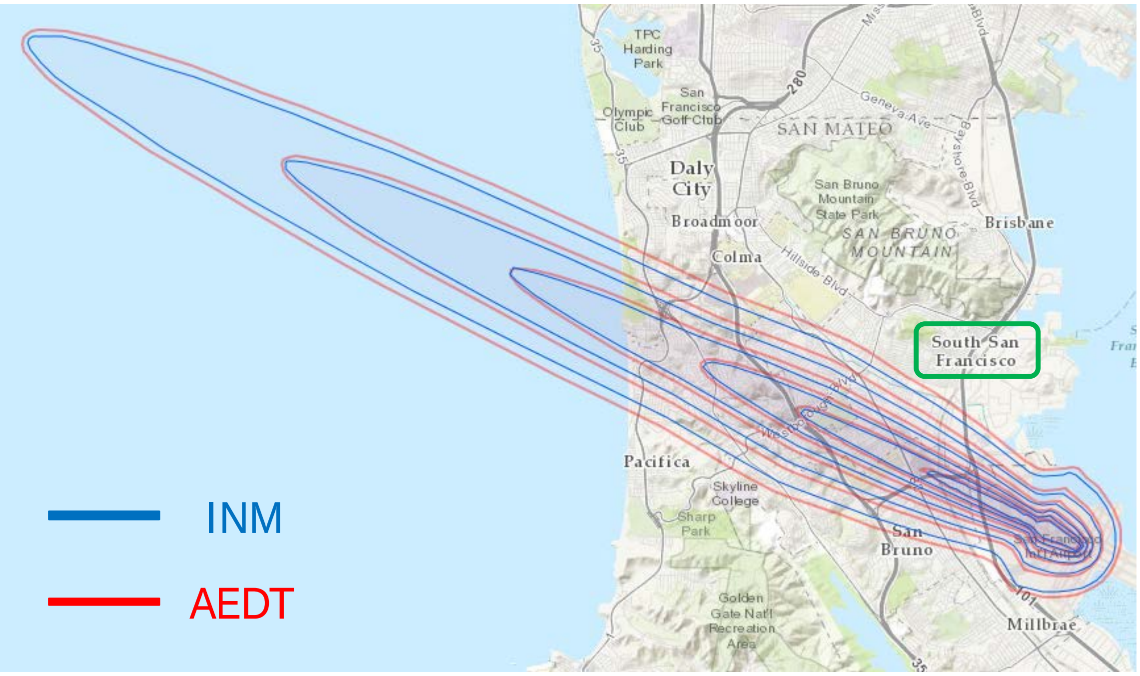

Figure 5-99. SEL Contour Comparisons for a 727Q15 Single Arrival Flight

To confirm that the differences in noise results are due to the different engine installation locations, a series of investigations was conducted. First, all the ANP coefficients of 727Q15 including aircraft performance characteristics, departure procedures, and NPD curves were compared and confirmed that they were all exactly the same. The INM and AEDT studies were set up at the SFO airport using the same airport weather, runway, flight track, and noise grid definitions. To see if differences in the APM were responsible for differences in the noise results, flight tracks from INM and AEDT were compared as well. Figure 5-100 shows comparisons of flight trajectories and thrust profiles from INM and AEDT. Both the altitudes and thrust against ground distances profiles from INM and AEDT show very close match between each other. The AEDT flight path had slightly more segments than the flight path from INM, which can improve accuracy of noise calculations. However, the differences in noise results due to increased number of flight segments are less than 1%. Finally, the engine installation location of 727Q15 was temporarily corrected in AEDT's fleet database to accurately model the installation effect. After changing the engine location from wing to fuselage for 727Q15 in AEDT, the arrival and departure SEL 70 to 90 dB contour areas matched the INM results with less than 0.5% differences for all dB levels. This series of tests confirmed that the differences in noise results between 727Q15 between INM and AEDT were driven by the different engine installation locations.

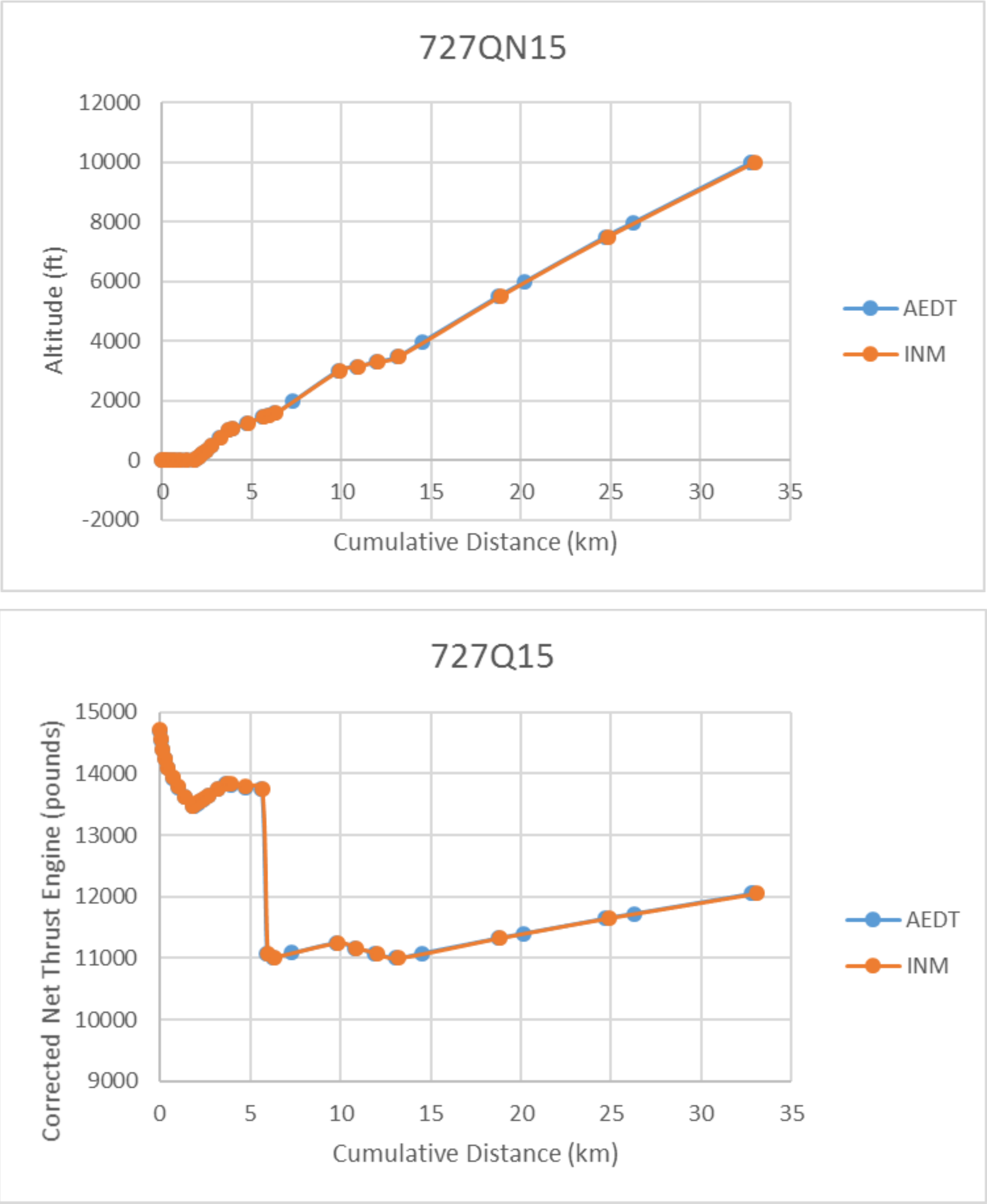

Figure 5-100. Comparison of Flight Trajectories and Thrust Profiles of a 727Q15 Departure from INM and AEDT

An additional test result is provided here to show the differences in the noise results when the engine locations between INM and AEDT are the same. 727D17 and 727Q9 are other Boeing 727 aircraft with different engine models than the 727Q15. For these two ANP aircraft, the engine locations are correctly assigned as fuselage in both INM and AEDT. Figure 5-101 depicts the SEL 70 to 95 dB contours for a 727D17 arrival from INM and AEDT. Table 5-71 compares the contour areas for the corresponding contours. The test results show that a model of 727-200 with consistent engine location can produce very similar noise results between INM and AEDT with less than 1% difference for all the SEL levels compared.

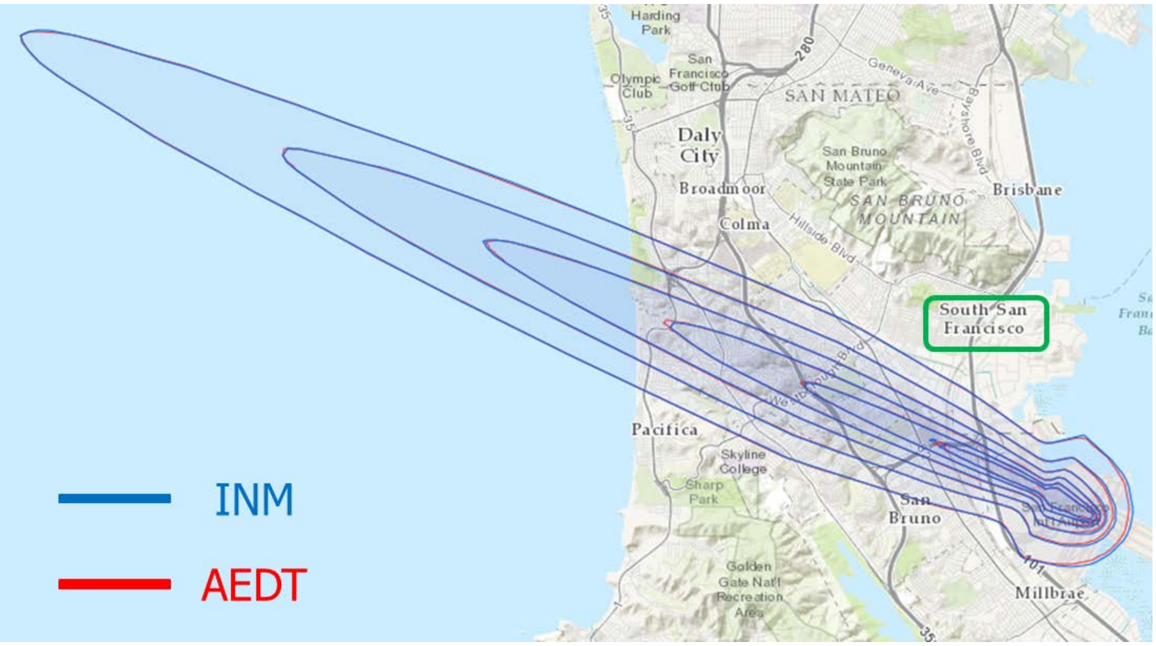

Figure 5-101. SEL Contour Comparisons for a 727D17 Single Arrival Flight

Table 5-71. SEL Contour Comparisons for a 727D17 Single Arrival Flight

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
70	71.387	70.972	0.415	0.58
75	36.644	36.431	0.213	0.58
80	18.023	17.905	0.118	0.66
85	7.881	7.882	-0.001	-0.01
90	2.983	2.957	0.026	0.88
95	0.87	0.862	0.008	0.93

5.5 Upgrades/Changes to Functionality and Issues

The Phase 1 testing began using AEDT 2b Beta version (Sprint 59), and it was repeated using the AEDT 2b release (version 62.0.42218.1). Several bugs identified in the Phase 1 testing with AEDT 2b Beta version were addressed in the AEDT 2b release.

The Phase 1, Phase 2, and Phase 3 test cases were run in the AEDT 2b release (version 62.0.42218.1). The following bugs were identified in AEDT 2b release during this testing:

- Importing ambient file is not supported in AEDT 2b
- User-defined helicopters in INM are not converted by the INM to ASIF Converter
- User-defined military aircraft in INM are not converted by the INM to ASIF Converter
- Military aircraft runup operations are not supported in AEDT 2b
- Terrain data unit conversion error in AEDT 2b

- Terrain error related to helipad reference coordinates for helicopter operations when terrain is used
- AEDT incorrectly defines a taxi operation of a helicopter as a departure

The bank angle error, terrain unit conversion error, and terrain error related to helipad reference coordinates for helicopter operations were resolved in the AEDT 2b SP2 release (version 62.3.43407.1). Since the two terrain errors prevented the Phase 3 terrain cases from being run in AEDT 2b, they were retested with the AEDT 2b SP2. The following bugs were identified in AEDT 2b SP2 during Phase 3 testing:

- Terrain file caching issue, especially when modeling line-of-sight blockage
- Time Above results (TALA, TALC, TAPNL) are not correctly displayed in minutes
- Time Above results are not getting written to the receptor reports
- Time Above results may be incorrectly calculated or displayed
- Identified a potential grid point coordinate difference between AEDT INM (maybe be related to ASIF conversion or a residual issue related to different methods for converting INM relative coordinates in x, y to latitude and longitude)

The contouring difference encountered in Phase 3, where AEDT 2b did not plot contours that extended outside of the analysis error, was not actually a bug, but a design choice in AEDT 2b. Therefore, it may be useful to identify this difference from the legacy tool in the AEDT 2b documentation, in order to share this information with the AEDT 2b user base.

The remaining open bugs have been submitted to the AEDT development team for further investigation. These issues are either included in the development plans for future versions of AEDT or have already been resolved. Table 5-72 lists the issues and bugs that were identified in AEDT 2b during the Use Case D analyses and their current status.

Table 5-72. List of AEDT 2b Issues and Bugs Identified in Use Case D

Issue or Bug in AEDT 2b	Status
Importing ambient file is not supported in AEDT 2b	Resolved in the AEDT 2b SP3 release
User-defined aircraft in INM are not converted by the INM to ASIF Converter	AEDT currently does not support importing user-defined aircraft from INM. This is a known issue and AEDT does not support this feature at this time.
Military aircraft runup operations are not supported in AEDT 2b	Resolved in the AEDT 2c SP1 release
Terrain data unit conversion error in AEDT 2b	Resolved in the AEDT 2b SP2 release
Terrain error related to helipad reference coordinates for helicopter operations when terrain is used	Resolved in the AEDT 2b SP2 release

Issue or Bug in AEDT 2b	Status
Incorrect assignment of a helicopter taxi as a departure	Will be resolved in the AEDT 2d release
Terrain file caching issue, especially when modeling line-of-sight blockage	Resolved in the AEDT 2b SP3 release
Time Above results (TALA, TALC, TAPNL) are not correctly displayed in minutes	Will be resolved in the AEDT 2d release
Time Above results are not getting written to the receptor reports	Will be resolved in the AEDT 2d release
Time Above results may be incorrectly calculated or displayed	Will be resolved in the AEDT 2d release
Contouring algorithm fails to account for contour holes and islands leading to erroneous contour areas and populations	Resolved in the AEDT 2c release
Incorrect assignment of engine locations in the fleet database leading to incorrect lateral attenuation adjustments	Will be resolved in the AEDT 2d release
AEDT adjusts later attenuation for different engine locations for military aircraft when it is not supposed to	Under investigation

5.6 Conclusions

Capability Demonstration and Functionality Evaluation

The results of Use Cases D show that AEDT 2b is capable of executing an airport Part 150 analysis. Three phases of testing were covered that included full airport studies (typical of Part 150 analyses), functionality not included in the previous studies, and a specific focus on terrain modeling. The majority of the AEDT 2b functionality was confirmed in Use Case D.

During the modeling of Use Case D, there were a number of issues and bugs that were identified and addressed in order to complete the analysis. The majority of these bugs have been rectified in subsequent versions of AEDT 2b. This resulted in the repeat of the Use Case D Phase 1 testing, and then later the Phase 3 testing. The results from those repeated analyses are presented in this report. The remaining issues are included in development plans for future versions of AEDT.

Verification and Validation

A comparison of the AEDT 2b and INM 7.0d showed that the models have comparable noise results in most cases, although some differences were noted. Some differences seen in this analysis highlighted differences in APM versions, flight path segmentation methods and contouring methods between the two models, as well as database updates/improvements in AEDT. Overall, the noise contour and receptor grid results are within a reasonable range, indicating that the noise functionality is operating as intended in AEDT 2b. For some test cases, the INM and AEDT results showed unreasonably large differences. Further investigations found that the differences were attributed to either or combinations of 1) a bug in AEDT's contouring algorithm and 2) differences in engine installation locations for some aircraft between INM and

AEDT. The bug in AEDT's contouring algorithm was fixed for the AEDT 2c release. The updated Fleet DB in AEDT 2c SP3 also addressed the incorrect engine installation locations.

Next Steps

Once the issues in AEDT 2b SP2 identified in Section 5.5 are resolved, Use Case D Phase 1, Phase 2, and Phase 3 testing should be repeated and compared to the original results. This may be conducted in a piecewise basis, as AEDT issues are resolved, if necessary.

In addition, the suite of AEDT test cases should be expanded to include additional airport (Part 150) studies. For example, the legacy DEN study (which tests user-defined profiles, location points, different noise metrics and study-specific weather, as well as provides the opportunity to compare measured and modeled results) may also be used for Phase 1 and Phase 3 testing, as time and resources allow. Furthermore, a recent MSP study was submitted to AEDT tech support (which tests helicopter operations, user-defined profiles and terrain), and permission was given by the study developer to utilize their MSP study for future AEDT UQ efforts (potentially Phase 1 and Phase 3 testing), if necessary. Finally, FAA's DISCOVER-AQ data set (which also provides the opportunity to compare measured and modeled results, as well as test user-defined profiles, location points and study-specific weather) could also be developed as AEDT and INM studies, and added to the Phase 2 test suite.

As additional noise functionality is added to AEDT, more phases of AEDT UQ Use Case D testing (and the corresponding test cases) should be developed. This could include additional testing for noise metrics that utilize ambient data. Existing National Parks studies could be used for this purpose.

6 Use Case E – Part 1: Air Traffic Airspace and Procedure Analysis

This section illustrates AEDT 2b SP2's capability for performing noise impact, fuel consumption, CO_2 production, and emissions calculations to support a NEPA study for an applicable[6] airspace redesign study. This type of NEPA study was conducted as part of this uncertainty quantification effort in order to validate that AEDT 2b SP2 has the necessary functionality and capability to perform this type of applicable analysis.

Section 6.1 briefly demonstrates that AEDT 2b has all the functionality needed to complete the required steps to fulfill the requirements under NEPA.

Section 6.2 shows the results of conducting a demonstration applicable NEPA study for the Cleveland/Detroit area airspace with both AEDT 2b SP2 and AEDT 2a SP2. The intent of these two analyses was to show that, excluding any intentional differences, AEDT 2b SP2 will compute noise impact results that are comparable to AEDT 2a SP2 for this type of applicable analysis.

6.1 Functionality Assessment

This section provides an overview of the results of the functionality evaluation. This consists of descriptions of the high-level data and steps involved in conducting this type of applicable airspace analysis.

The user's first step is to establish the necessary input data for this scope of study. These inputs are described in this section. This is followed by a description of the study setup in AEDT 2b SP2. After the user validates that the operations that have been set up in the tool can be modeled for flight performance a job is created to run the scenario. Upon examining metric results, impact evaluation analysis may be performed. The resulting data can then be exported for NEPA reporting.

6.1.1 Applicable Study Inputs

During the capability demonstration, AEDT 2b SP2 was able to handle all necessary inputs needed to complete an applicable airspace analysis. For this capability demonstration, this included the following inputs:

- Set of study airport layouts consisting of airport code and user-defined runways (imported via AEDT Standard Input File [ASIF])
- Study boundary (imported via ASIF)
- Average annual day traffic (imported via ASIF)

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[6] As stated in Section 1 of this report, the applicable analyses for which AEDT 2a was designed are air traffic airspace and procedure actions where the study area is larger than the immediate vicinity of the airport, incorporates more than one airport, and/or includes actions above 3,000 feet AGL.

- Baseline tracks and accompanying aircraft operations (pair of a flight path and a set of aircraft operations)
- Alternative tracks and accompanying aircraft operations
- Receptors for areas of interest (imported via ASIF)
- Population centroids (pop_2011 receptor, imported via ASIF)
- Sensitive areas – e.g., residences, churches, national parks, schools, hospitals, etc. (4f6f receptor set, imported via ASIF)
- Annualization weights for the scenario cases/groups (imported via ASIF)
- Terrain (3CD)

6.1.2 Setting up a Study (i.e., Populating an AEDT 2b SP2 Study Database)

AEDT 2b SP2 was able to complete all the steps necessary to set up the applicable airspace study. Two main tasks were completed to achieve this: defining the study and creating the baseline and alternative scenarios. The following information was input into AEDT 2b SP2 to define the study:

- Study area
- Airport layouts
- Weather information
- Impact receptors
- User-defined aircraft and profiles (as needed)
- Study altitude cut-off (altitude above which noise would stop being computed)
- Terrain data

In addition, metric results were created in AEDT 2b SP2 to represent the baseline and the alternative scenarios that were examined in the study.

To help facilitate the analysis, AEDT 2b SP2, like its predecessor, supports organizing aircraft operations into groups. Operation groups (known as "case" in AEDT 2a) allow for flexibility in the development of studies and metric results and help facilitate the analysis. For example, the studies can be built one airport at a time or even one traffic flow at a time.

6.1.2.1 Create Annualization for Scenario

Once the study was set up in AEDT 2b SP2, the operation groups were annualized according to the provided annualization weights imported via ASIF. AEDT 2b SP2 was able to utilize the operation groups in the baseline and alternative scenarios and annualize them to represent the imported annualization scaling factors.

6.1.2.2 Track, Fleet, and Operation Information

AEDT 2b SP2 was able to import the track, fleet, and operational level information needed to complete the airspace redesign capability demonstration. In this assessment, the tracks were the same flight tracks used in the AEDT 2a SP2 study that AEDT 2b SP2 was emulating. The fleet and operational levels that are used were checked to be identical to those used in the AEDT 2a SP2 study.

6.1.2.3 Additional Input Data

AEDT 2b SP2 was able to read the provided terrain data and use it during modeling calculations. In addition, AEDT 2b SP2 was able to create receptor points and receptor sets (previously called grid points) from the imported ASIF files. The receptor points are locations on the ground that are used as part of the noise calculation. Figure 6-1 shows a sample receptor set in AEDT 2b SP2. Finally, AEDT 2b SP2 was able to import and visualize geographic/landmarks via U.S. Census Bureau Geography Division Topologically Integrated Geographic Encoding and Referencing system (TIGER) data and provide aerial imagery base map information.

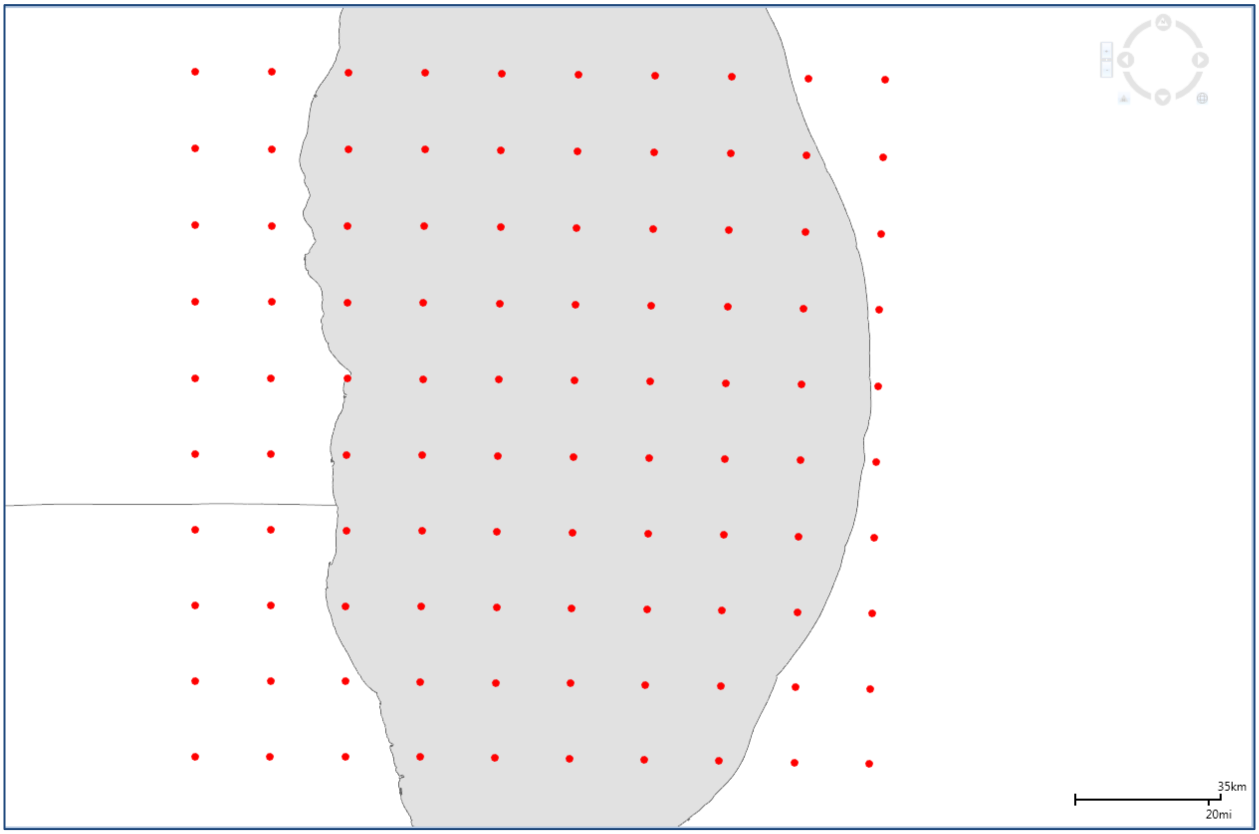


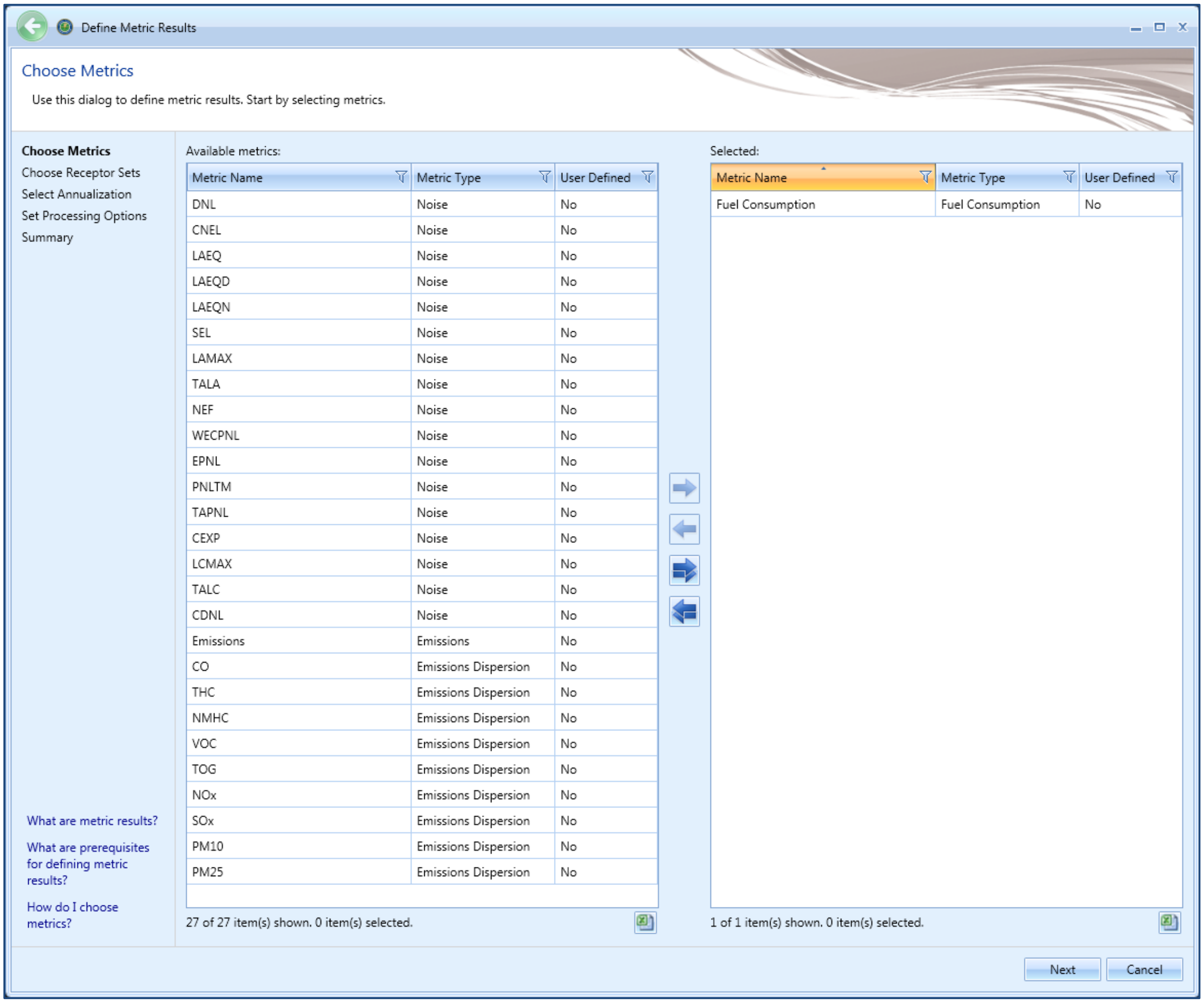
Figure 6-1. Grid Receptor Set in AEDT 2b SP2

6.1.3 Validate Operation Flyability

An important part of this type of airspace analysis is the capability to validate the ability of each aircraft operation to be successfully modeled on its assigned operational track. AEDT 2b SP2 provides the user with the option to only run the flight performance module of the model (via fuel burn metric), allowing for the flight performance modeling validation to occur prior to running the full study and calculating noise exposure and impacts. Typically, a noise analyst will run the study using flight performance only to assess the number of failed flights and determine which of those flights need adjustment to adequately model the scenario.

6.1.3.1 Create a Metric Result for Baseline Scenario to Run Flight Performance Only

AEDT 2b SP2 was able to compute seventeen noise metrics in this capability demonstration. Most importantly, the tool was able to compute the Day Night Average Sound Level (DNL) metric, which is the metric required for NEPA analysis. Figure 6-2 illustrates the noise metrics and emissions metrics available to the user. Figure 6-3 illustrates the modeling options available in AEDT 2b SP2.



Choose Metrics

Use this dialog to define metric results. Start by selecting metrics.

Available metrics:

Metric Name	Metric Type	User Defined
DNL	Noise	No
CNEL	Noise	No
LAEQ	Noise	No
LAEQD	Noise	No
LAEQN	Noise	No
SEL	Noise	No
LAMAX	Noise	No
TALA	Noise	No
NEF	Noise	No
WECPNL	Noise	No
EPNL	Noise	No
PNLTM	Noise	No
TAPNL	Noise	No
CEXP	Noise	No
LCMAX	Noise	No
TALC	Noise	No
CDNL	Noise	No
Emissions	Emissions	No
CO	Emissions Dispersion	No
THC	Emissions Dispersion	No
NMHC	Emissions Dispersion	No
VOC	Emissions Dispersion	No
TOG	Emissions Dispersion	No
NOx	Emissions Dispersion	No
SOx	Emissions Dispersion	No
PM10	Emissions Dispersion	No
PM25	Emissions Dispersion	No

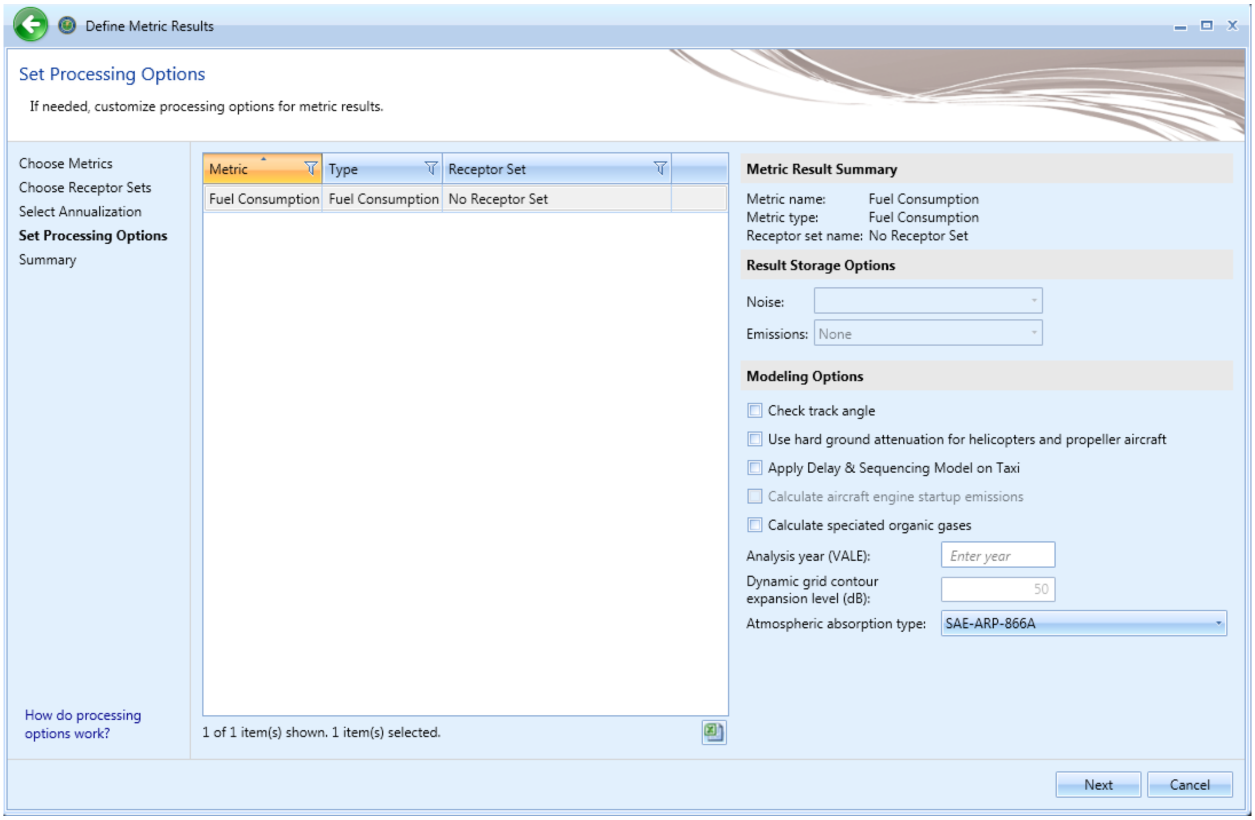
27 of 27 item(s) shown. 0 item(s) selected.

Selected:

Metric Name	Metric Type	User Defined
Fuel Consumption	Fuel Consumption	No

1 of 1 item(s) shown. 0 item(s) selected.

Figure 6-2. AEDT 2b SP2 Available Noise and Emissions Metrics



Set Processing Options

If needed, customize processing options for metric results.

Metric	Type	Receptor Set
Fuel Consumption	Fuel Consumption	No Receptor Set

1 of 1 item(s) shown. 1 item(s) selected.

Metric Result Summary

Metric name: Fuel Consumption
Metric type: Fuel Consumption
Receptor set name: No Receptor Set

Result Storage Options

Noise:
Emissions: None

Modeling Options

☐ Check track angle
☐ Use hard ground attenuation for helicopters and propeller aircraft
☐ Apply Delay & Sequencing Model on Taxi
☐ Calculate aircraft engine startup emissions
☐ Calculate speciated organic gases

Analysis year (VALE): Enter year
Dynamic grid contour expansion level (dB): 50
Atmospheric absorption type: SAE-ARP-866A

Figure 6-3. AEDT 2b SP2 Modeling Options

6.1.4 Create a Metric Result

The capability demonstration showed that AEDT 2b SP2 has the functionality that is required to run an applicable airspace analysis. The user is able to specify user terrain if needed, choose the correct metric, apply line-of-sight blockage, and compute fuel consumption, CO_2 production, and additional emissions. In addition, the user can choose the correct receptor set with which to perform the analysis. Finally, the user can annualize the job results based on an annualization created during the study set up or import previously generated annualization imported via ASIF.

6.1.4.1 Capture Fuel Consumption and CO_2 Values

AEDT 2b SP2 was able to compute fuel consumption and CO_2 and is available in the Emissions Report. These results are with different levels of fidelity and can be computed for the full study area and under the mixing height for the airport (or 3,000 feet AFE if the mixing height is not available for the airport).

6.1.4.2 Noise Impact Analysis

For the demonstration applicable to NEPA analysis, AEDT 2b SP2 was able to compute noise results at internal population points and at receptor points as shown in Figure 6-4. AEDT 2b SP2 was able to complete an impact analysis resulting in the generation of noise exposure, noise exposure change, and noise impact areas on a map. Figure 6-5 shows an impact set graph, one of the outputs of an impact analysis. This graph and its significance are discussed in further detail in examples in Section 6.2.2. Unlike AEDT 2a, AEDT 2b SP2 does not offer a streamlined Change

Analysis workflow that can be used to provide information to the user regarding which case is contributing most to the noise at a receptor point.

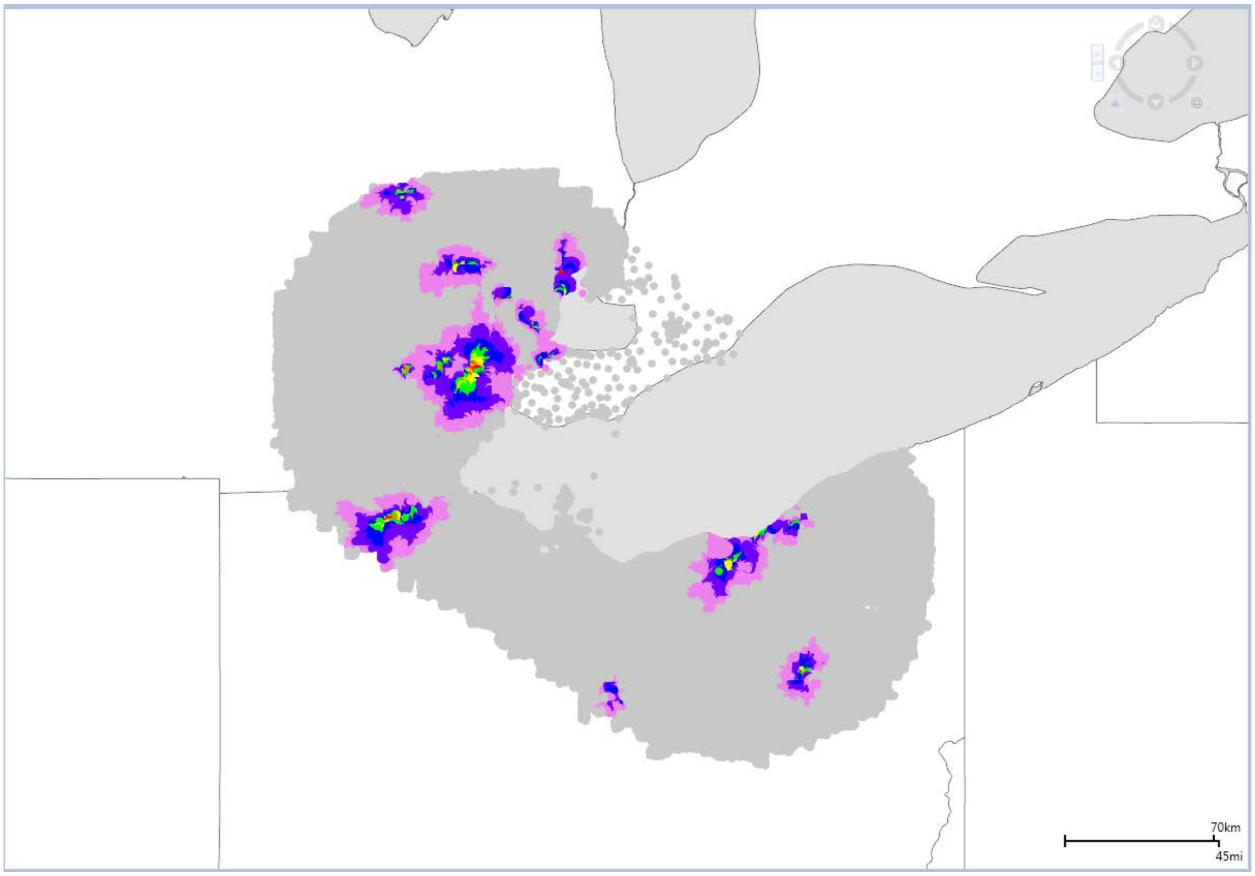
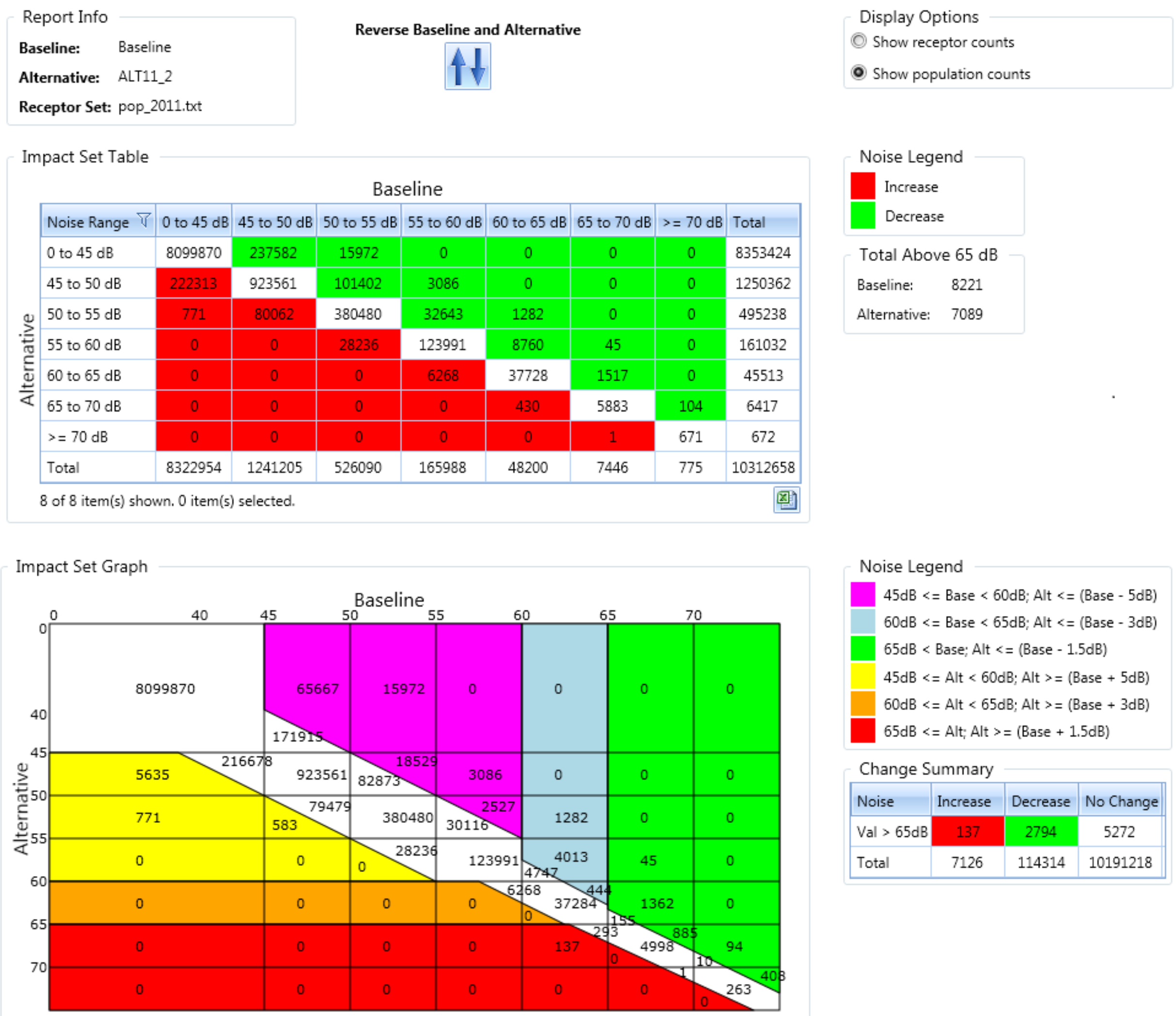


Figure 6-4. AEDT 2b SP2 Receptor Set and Noise Exposure Results



Report Info

Baseline: Baseline

Alternative: ALT11_2

Receptor Set: pop_2011.txt

Display Options

○ Show receptor counts

● Show population counts

Impact Set Table

Baseline

Alternative

Noise Range	0 to 45 dB	45 to 50 dB	50 to 55 dB	55 to 60 dB	60 to 65 dB	65 to 70 dB	>= 70 dB	Total
0 to 45 dB	8099870	237582	15972	0	0	0	0	8353424
45 to 50 dB	222313	923561	101402	3086	0	0	0	1250362
50 to 55 dB	771	80062	380480	32643	1282	0	0	495238
55 to 60 dB	0	0	28236	123991	8760	45	0	161032
60 to 65 dB	0	0	0	6268	37728	1517	0	45513
65 to 70 dB	0	0	0	0	430	5883	104	6417
>= 70 dB	0	0	0	0	0	1	671	672
Total	8322954	1241205	526090	165988	48200	7446	775	10312658

8 of 8 item(s) shown. 0 item(s) selected.

Noise Legend

🟥 Increase

🟩 Decrease

Total Above 65 dB

Baseline: 8221

Alternative: 7089

Noise Legend

- 45dB <= Base < 60dB; Alt <= (Base - 5dB)
- 60dB <= Base < 65dB; Alt <= (Base - 3dB)
- 65dB < Base; Alt <= (Base - 1.5dB)
- 45dB <= Alt < 60dB; Alt >= (Base + 5dB)
- 60dB <= Alt < 65dB; Alt >= (Base + 3dB)
- 65dB <= Alt; Alt >= (Base + 1.5dB)

Change Summary

Noise	Increase	Decrease	No Change
Val > 65dB	137	2794	5272
Total	7126	114314	10191218

Figure 6-5. Impact Set Table and Graph

6.1.5 Export Data for NEPA Report

There are several specific reports provided by AEDT 2b SP2 that support NEPA study reports. The core data needed are provided by the following AEDT components:

- Impact set table and graph
- Impact maps
- Generate Administrative File function in the Study Maintenance screen

6.1.6 Conclusions on Functionality

AEDT 2b SP2 was able to successfully complete a capability demonstration using an applicable NEPA analysis for an airspace redesign project and was able to complete the required steps to fulfill the requirements under NEPA.

6.2 AEDT 2b SP2 and AEDT 2a SP2 Compatibility Demonstration

As part of the AEDT 2b SP2 uncertainty quantification effort, an analysis derived from an applicable legacy airspace study was run in both AEDT 2a SP2 and AEDT 2b SP2. The legacy study that served as a basis for the comparative analyses was the Cleveland and Detroit Environmental Assessment which is part of an applicable airspace analysis known as the Midwest Airspace Enhancement (MASE) project. The goal was to demonstrate that AEDT 2b SP2 is capable of successfully running large-scale applicable noise studies in a similar manner to the workflow in AEDT 2a SP2. Changes in algorithmic methods and data between the two tools did show differences in the results that are presented in this section.

It should be noted that the legacy studies were modified to remove sources of error to ensure that they could be compared in an "apples-to-apples" manner in both AEDT 2b SP2 and AEDT 2a SP2. Descriptions of the necessary study data modifications are presented in the sections below. As a result, the outputs generated by the two tools and presented here are different from the results that would be obtained if both analyses were conducted from the ground up as designed for that particular tool alone. Consequently, the results presented here will be different from the results obtained in the original legacy studies.

6.2.1 Methodology

Step 1: Create a common reference study

First a common reference study was created for use in both AEDT 2b SP2and AEDT 2a SP2. The data set was reduced to those flights that passed flight performance modeling in both AEDT 2a SP2 and AEDT 2b SP2, thereby ensuring a common reference study and enabling an error-free comparison of results from the two tools. This was achieved as follows:

1. All flights for the legacy study from previous demonstrations were first imported via ASIF and run for flight performance only in AEDT 2a SP2 to identify all the flight failures in AEDT 2a SP2 by examination of the log file.

2. The same ASIF was then imported into AEDT 2b SP2 and run for flight performance only. All the flights that failed in this run were similarly identified using the AEDT log file.

3. The union of all failed flights were removed from the reference ASIF file to create a new common reference file that will pass flight performance modeling in both AEDT 2a SP2 and AEDT 2b SP2 without any errors. This common reference file was subsequently reimported into both tools to create new "error free" versions of the study as a 2a SP2 study and as a 2b SP2 study.

Below is a summary of the total number of failed flights in AEDT 2b FP1 and the common flight performance errors that were encountered:

- Total flight performance errors: 3,144
- Not enough thrust to meet target altitude error: 2,915
- Insufficient thrust available to satisfy altitude control: 215
- Impossible to satisfy the given landing constraints using the given weather conditions: 14

Step 2: Run the common reference study in both AEDT 2b SP2 and AEDT 2a SP2 and compare results.

The common reference version of the study was loaded and run in both AEDT 2b SP2 and AEDT 2a SP2, and the results were compared. Both terrain and single airport weather were used in the modeling runs in order to demonstrate typical environmental modeling options employed in real-world studies. Finally, annualized weighted noise levels and noise impacts for results generated by AEDT 2b SP2 and AEDT 2a SP2 were compared.

6.2.2 Overview of an Impact Graph

Before proceeding to the presentation of the results of the studies and comparisons, it is important to understand the impact graph which is used when comparing scenarios in this type of analysis. Figure 6-6 is an example of an impact graph output. The graph shows change in noise between a Baseline and Alternative scenario. DNL noise levels in the baseline scenario are noted on the x-axis. DNL noise levels in the alternative scenario are noted on the y-axis. The numbers in a given location indicate the number of population centroids that have the corresponding noise values in the baseline and alternative scenarios. The following annotations appear in Figure 6-6:

- Total population receiving “no change” in noise – All population that falls in the central diagonal zone defined by the scoring criteria; shown in white
- Total population receiving a decrease in noise – All population above and to the right of the “no change” zone; shaded in purple, blue, and green
- Total population receiving an increase in noise – All population below and to the left of the “no change” zone; shaded in yellow, orange, and red
- Total population above DNL 65 dB (baseline) – All population to the right of the vertical line denoting baseline exposure of 65 dB
- Total population above DNL 65 dB (baseline) receiving a decrease in noise – All population in the green area
- Total population above DNL 65 dB (baseline) receiving an increase in noise – All population in the triangular red area to the right of the vertical baseline exposure 65 dB line and below the “no change” zone;
- Total population above DNL 65 dB (alternative) – All population below the horizontal line denoting alternative exposure of DNL 65 dB
- Total population above DNL 65 dB (alternative) receiving an increase in noise – All population in the red area

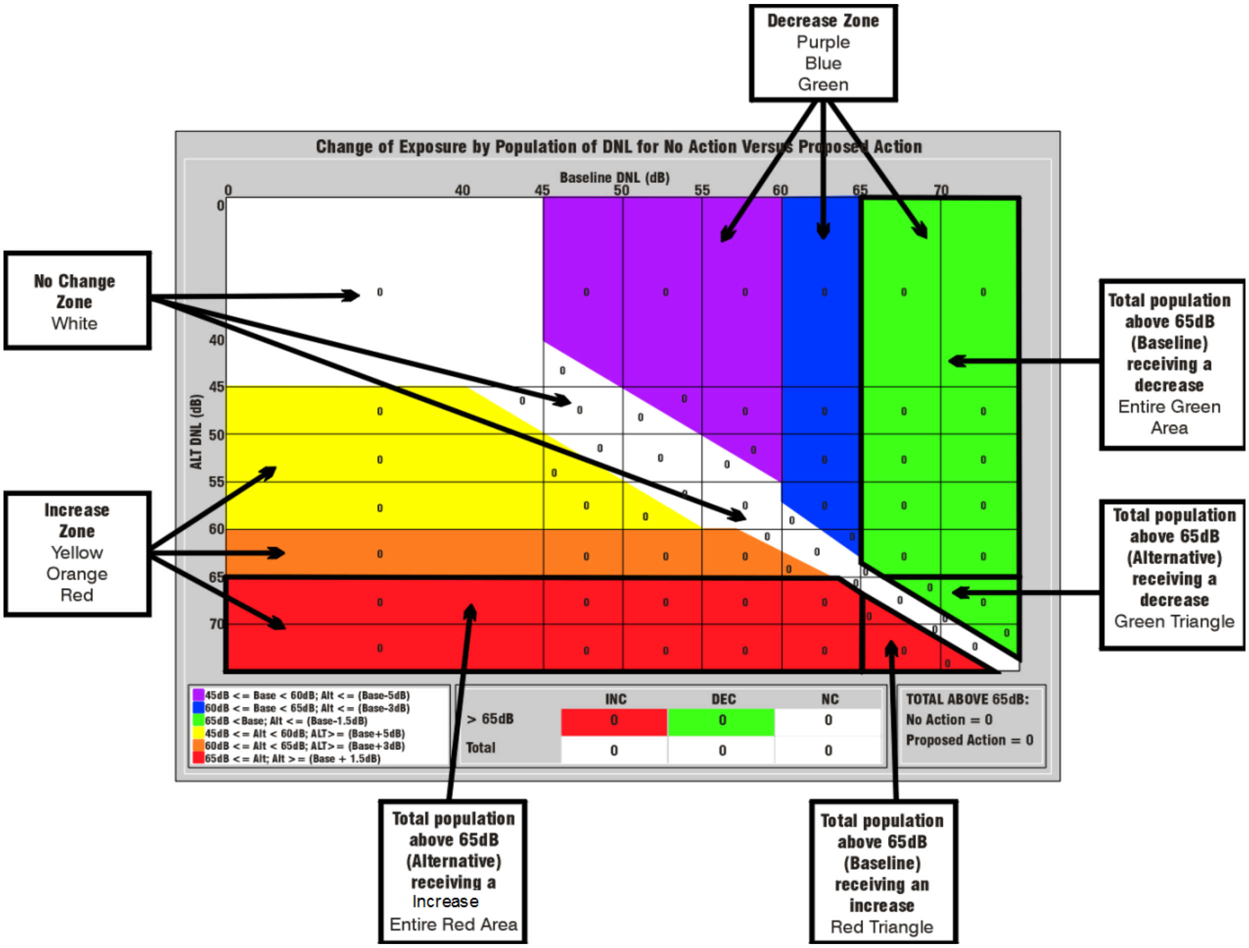


Figure 6-6. Example Impact Graph

6.2.3 Results

6.2.3.1 Background for the Cleveland/Detroit Study

The Cleveland/Detroit comparison, CLE/DTW, is based on the noise analysis of the MASE Environmental Assessment, with some modifications. As mentioned previously, due to modifications of the original study for consistency of comparison, the results generated by the two tools and presented here are different from the results that would occur if both analyses were conducted from the ground up, designed for that particular tool alone. Consequently, the results presented here are not representative of the results from the original legacy studies.

The purpose of the original project was to implement new routes and procedures to increase efficiency, enhance safety, manage throughput to other facilities, make better use of existing airport capabilities, and to take advantage of new navigation technologies. Key characteristics were as follows:

- 15 airports modeled across two U.S. states and Canada.

- For the baseline and ALT11 (alternative) scenarios, there were a total of 50,371 tracks, with 1,107,883 fractionalized aircraft events and a cumulative average annual day operations weight of 5,798.

- The Population 2011 (pop_2011) receptor set was used, which included 173,242 population centroid receptors.

- Two alternatives used across two out years in this study.

Additional background information for the original CLE/DTW study on which this analysis was based is available on the FAA website for the project[15].

The baseline and an alternative scenario (ALT11) were chosen for this demonstration.

Figure 6-7 provides a view of the airports in the study region. Canada's land mass is not shown in this image. Figure 6-8 shows the traffic flows for the CLE/DTW region in the study, providing context for the complexity of the study.

Figure 6-7. CLE/DTW Area Airport Map

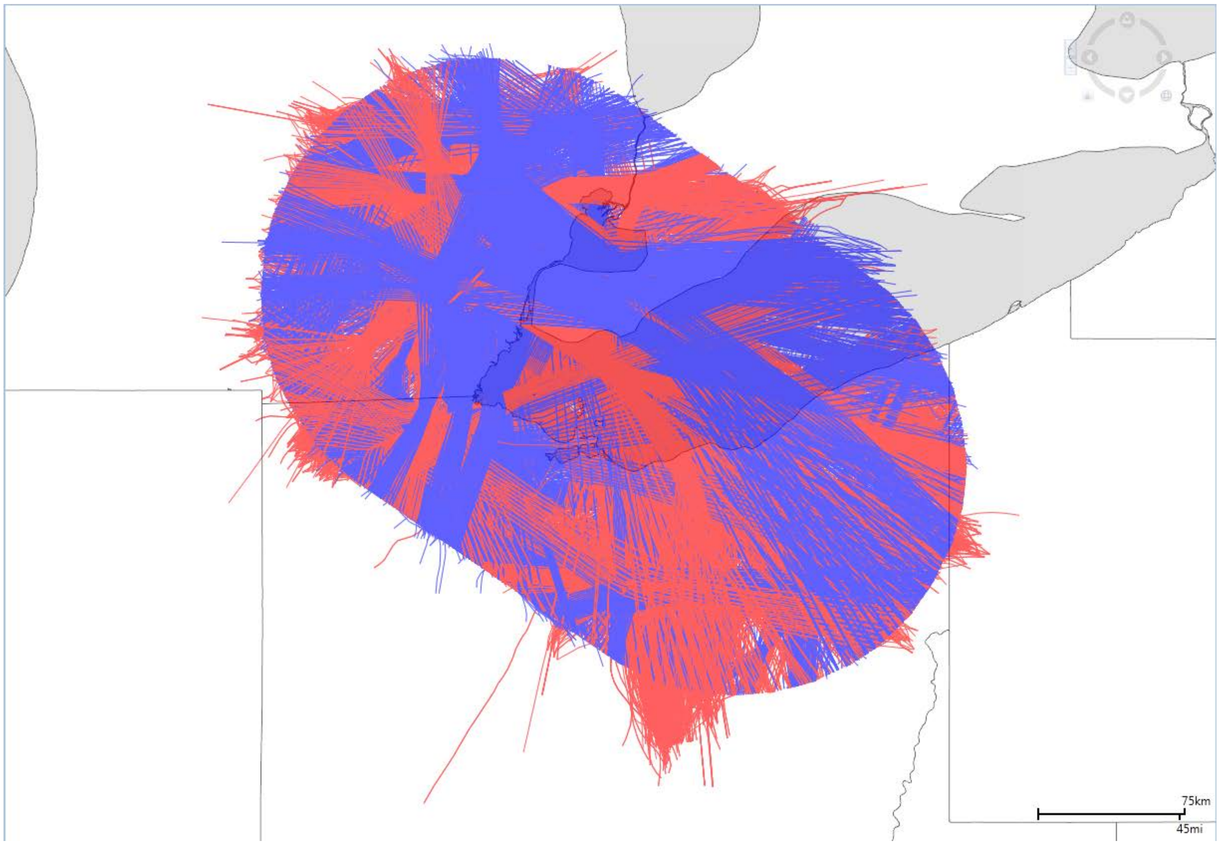
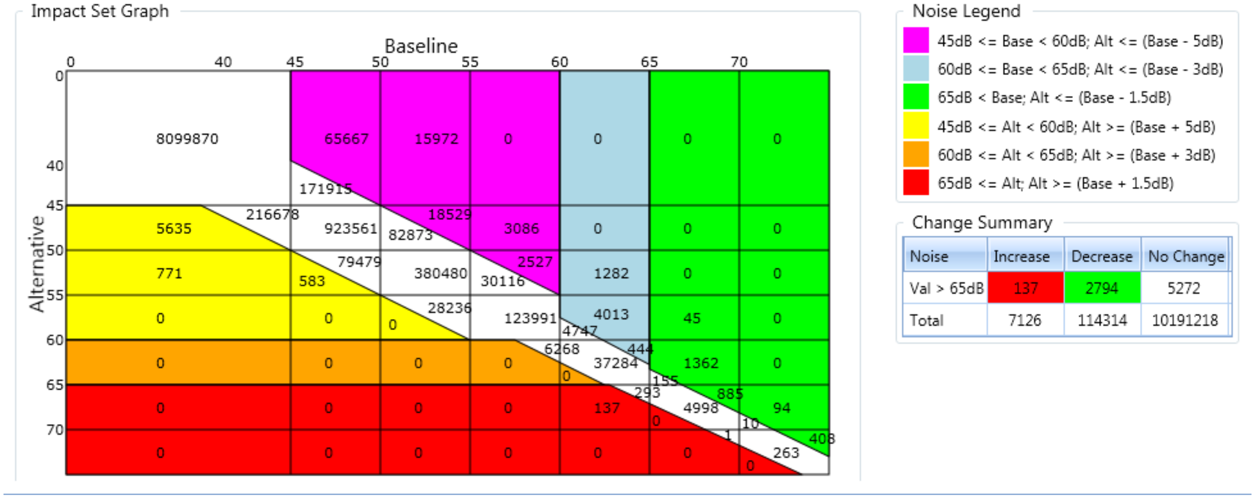


Figure 6-8. CLE/DTW Traffic (red tracks for arrivals, blue tracks for departures)

6.2.3.2 AEDT 2b SP2/AEDT 2a SP2 Comparison for All CLE/DTW Traffic

For the complete study, including both CLE and DTW with the population 2011 receptor set, AEDT 2b SP2 and AEDT 2a SP2 showed small differences across all change zones, as shown in Figure 6-9 and Figure 6-10. As previously described, due to changes in flight performance, noise modules, terrain interpolation and weather modeling, it is expected that a comparison of the studies would show some differences in noise exposure and impacts. In the key areas of adverse noise impact the comparison shows that AEDT 2b SP2 results in slight decreases. For example, in the > 65 dB impact area the number of people decreases by about 6% and in the 60-65 impact zone AEDT 2aSP2 showed that the 115 persons (represented by 2-3 centroids) shifted to be less than 60 dB in AEDT 2b SP2.



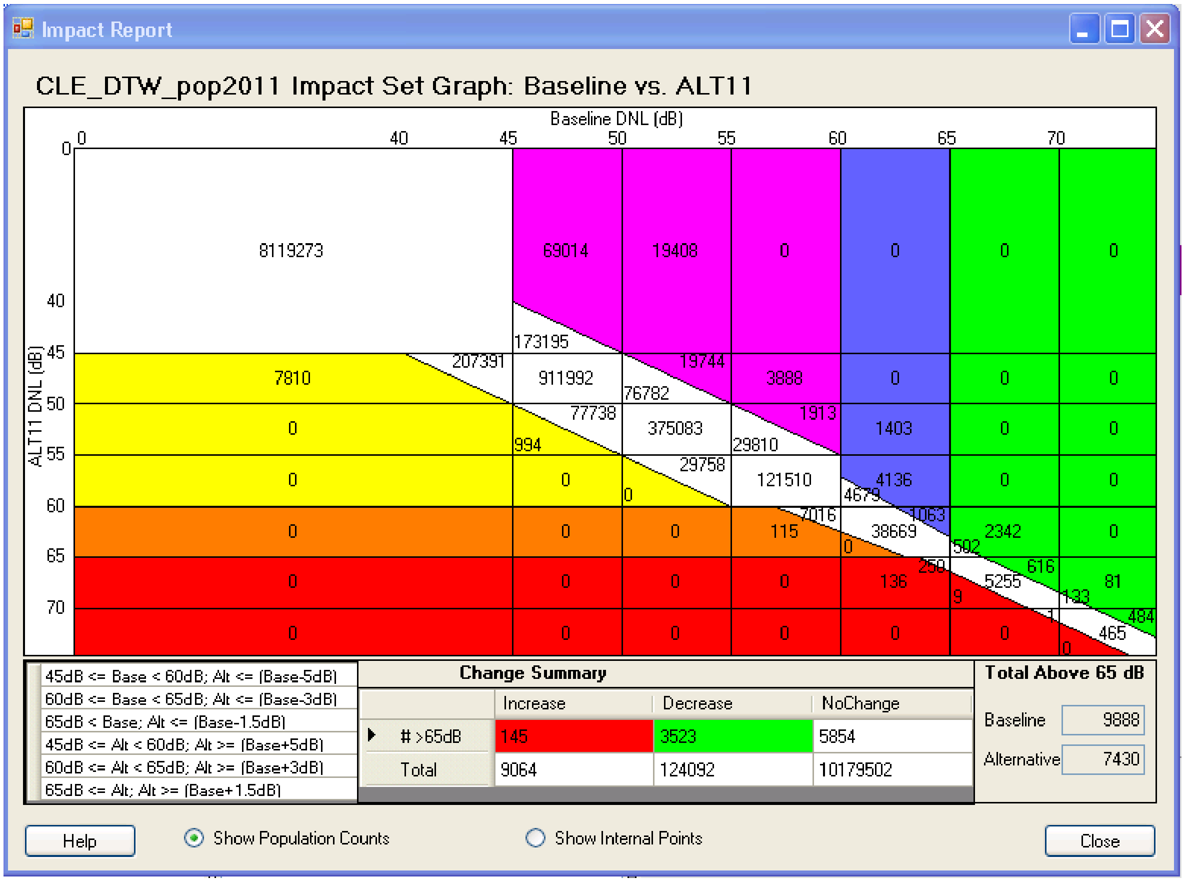
Noise Legend

- 🟪 45dB <= Base < 60dB; Alt <= (Base - 5dB)
- 🟦 60dB <= Base < 65dB; Alt <= (Base - 3dB)
- 🟩 65dB < Base; Alt <= (Base - 1.5dB)
- 🟨 45dB <= Alt < 60dB; Alt >= (Base + 5dB)
- 🟧 60dB <= Alt < 65dB; Alt >= (Base + 3dB)
- 🟥 65dB <= Alt; Alt >= (Base + 1.5dB)

Change Summary

Noise	Increase	Decrease	No Change
Val > 65dB	137	2794	5272
Total	7126	114314	10191218

Figure 6-9. AEDT 2b SP2 Impact Graph for All CLE/DTW Traffic



CLE_DTW_pop2011 Impact Set Graph: Baseline vs. ALT11

45dB <= Base < 60dB; Alt <= (Base-5dB)
60dB <= Base < 65dB; Alt <= (Base-3dB)
65dB < Base; Alt <= (Base-1.5dB)
45dB <= Alt < 60dB; Alt >= (Base+5dB)
60dB <= Alt < 65dB; Alt >= (Base+3dB)
65dB <= Alt; Alt >= (Base+1.5dB)

Change Summary

	Increase	Decrease	NoChange
# >65dB	145	3523	5854
Total	9064	124092	10179502

Total Above 65 dB

Baseline	9888
Alternative	7430

● Show Population Counts   ○ Show Internal Points

Figure 6-10. AEDT 2a SP2 Impact Graph for All CLE/DTW Traffic

Despite the identical study input data, given the advances in the state-of-the-art in AEDT 2b SP2 and the various updates to the underlying static data a reasonable expectation could be that the overall noise impacts would differ between the two tools. However, the large study analysis shows that the final noise impacts are remarkably similar between the two tools. In other words, an analyst conducting a study using AEDT 2a SP2 can expect that noise impacts calculated using AEDT 2b SP2 will be very similar.

In order to ensure that the resulting differences are accurate reflections of the core computational modules, the following parameters were validated to be identical between the two tools:

- Number of flights that passed flight performance
- Total weight count of operations
- Total number of tracks
- Receptor locations (pop_2011)
- Annualization

The impact maps for each study (Figure 6-11 and Figure 6-12) show similarity between AEDT 2a SP2 and AEDT 2b SP2, with an apparent decrease in the amount of noise around both DTW and CLE in AEDT 2b SP2 relative to the amount of noise in AEDT 2a SP2.

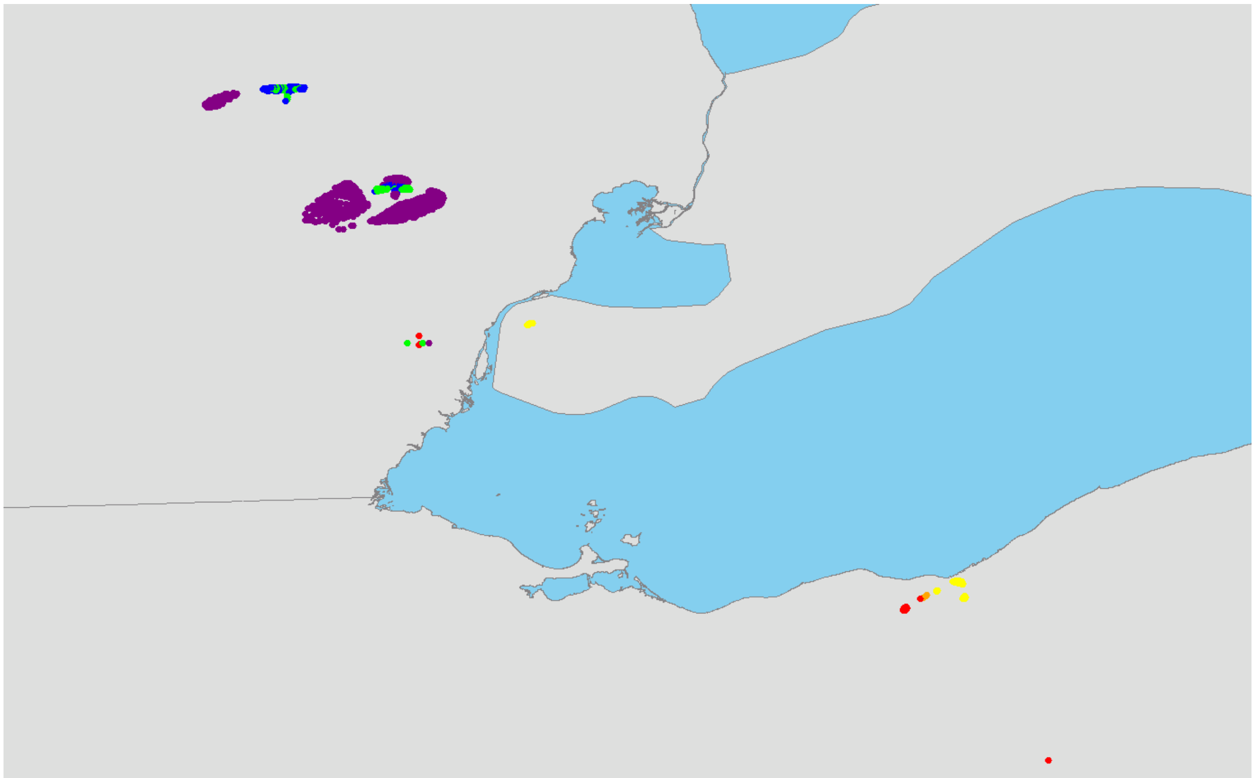


Figure 6-11. AEDT 2A SP2 CLE/DTW Full Study Impact Map

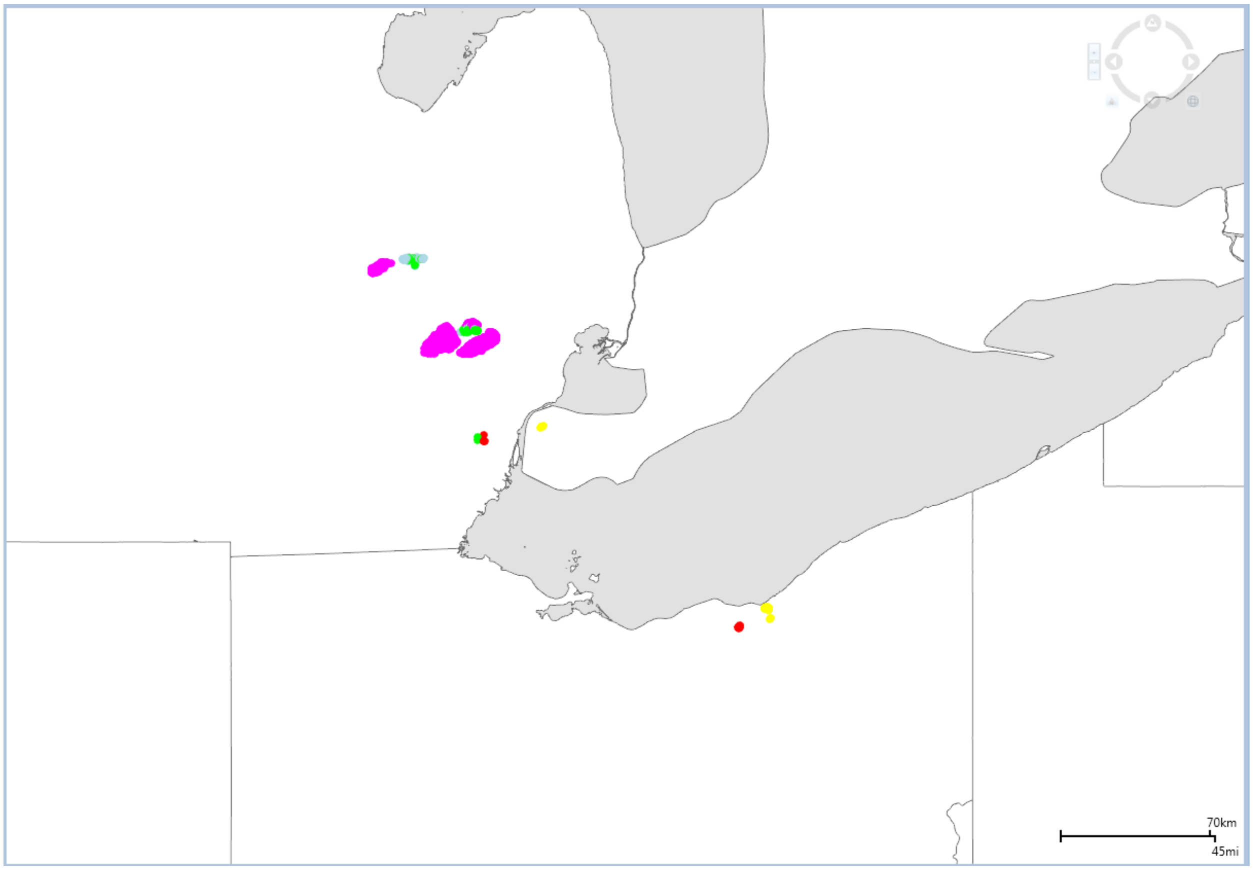


Figure 6-12. AEDT 2b SP2 CLE/DTW Full Impact Map

Overall, the results from the two tools demonstrated an acceptable degree of concurrence, and most importantly, AEDT 2b SP2 successfully completed the applicable airspace analysis requirements for the CLE/DTW study.

6.2.4 Compatibility Demonstration Conclusions

This report details the noise impact results of two large applicable airspace analyses that were run in both AEDT 2a SP2 and AEDT 2b SP2 for purposes of comparison. These analyses were based on real-world legacy studies, with modifications made to both studies in order to ensure an “apples-to-apples” comparison between AEDT 2a SP2 and AEDT 2b SP2. The objective was to verify that the noise impacts from the use of these two tools on these existing studies were comparable and most importantly that AEDT 2b SP2 has the ability to perform comparable airspace environmental studies.

Some expected differences occurred in the comparison – notably the magnitude of noise impacts. This is not an unexpected result because AEDT 2b SP2 incorporates more accurate modeling of aircraft flight performance and noise modeling as well as updated system data for flight performance and noise modeling.

7 Use Case E – Part 2: Airspace Redesign Environmental Analyses

7.1 *Definition and Purpose*

As part of the AEDT 2b SP2 uncertainty quantification effort, an AEDT study based on one originally generated for an airspace re-design environmental analysis was run in both AEDT 2a SP2 and AEDT 2b SP2. The legacy study that served as a basis for the analysis was from the DC Metroplex Project (part of the FAA NextGen Metroplex initiative). The goal was to demonstrate that AEDT 2b SP2 is suitable for this use case. Intentional differences between AEDT 2a SP2 and AEDT 2b SP2, especially in the area of aircraft performance, resulted in noise and aircraft performance differences. These differences are deemed acceptable and expected.

It should be understood that the original DC Metroplex study was modified, by necessity, to ensure that it could be executed in a comparable manner in both tools, AEDT 2b SP2 and AEDT 2a SP2. Descriptions of the necessary analysis modifications are presented in the sections below. As a result, the outputs generated by the two tools are presented here are different from the results that would occur if both analyses were conducted without modification to either version of the study. Consequently, the results presented here would not compare directly with results from the original study.

7.1.1 Deriving a Common Reference Study

The intent of performing uncertainty quantification using Use Case E is to ensure that AEDT 2b SP2 has the necessary infrastructure to compute the results and outputs required by Use Case E and that these results and outputs are suitable for this use case. The primary mechanism for determining suitability is comparing against the current regulatory tool for this use case, AEDT 2a SP2. The goal is to show that AEDT 2b SP2 output is consistent with that of AEDT 2a SP2 where desired, and that any deviations in output from AEDT 2a SP2 are as designed. A common reference study was created for use by both AEDT 2b SP2 and AEDT 2a SP2. The starting point for building the study was a legacy Noise Integrated Routing System (NIRS) study. The study was originally built to be run in NIRS. Due to differences in processing between NIRS and AEDT 2a SP2 (described in the AEDT 2a Uncertainty Quantification Report[16]), not all flight operations from the original NIRS study could be successfully processed in AEDT 2a SP2. Similarly, not all flight operations that were successfully processed in AEDT 2a SP2 could be successfully processed in AEDT 2b SP2. The intent of the uncertainty quantification analysis is not to actually perform a full regulatory environmental analysis in AEDT 2b SP2. Therefore, air operations from the original NIRS study which could not pass flight performance modeling in either AEDT 2a SP2 or AEDT 2b SP2 were removed in order to provide an apples-to-apples comparison between the two AEDT versions using a common set of flight operations. Additionally, to reduce the number of failing flights, some altitude control codes were modified to ensure that the resultant study contained a number of flight operations commensurate with typical Metroplex environmental studies to ensure that this analysis also serves as a good test of AEDT’s capacity and computational performance.

A summary of the number of fight operations used in the Use Case E analysis is presented in Table 7-1.

Table 7-1. Air Operation Count for each scenario

	Baseline Scenario	Proposed Action Scenario
Operation Count	132,530	549,454

7.1.2 Running the Common Reference Study

The common reference version of the DC Metroplex study was run in both AEDT 2a SP2 and AEDT 2b SP2. Day Night Average Sound Level (DNL) noise values were compared at population points for each of the scenarios between both versions of the tool.

The common reference study contains 14 study airports. The study is divided into two scenarios (Baseline and Proposed Action) each consisting of 28 cases (arrivals and departures for the 14 airports).The study used a single population receptor set which consisted of 339,327 points. These points were derived from the United States Census data, historically noise-sensitive areas (e.g., historic sites, national parks), and evenly spaced (population-less) population points.

The “Use Single Airport Weather” run option was enabled for all runs. Since Baltimore-Washington International Airport (KBWI) was associated with the greatest number of individual air operations, this airport was selected as the airport whose average weather would be used in flight performance and noise calculations.

United States Geologic Survey (USGS) National Elevation Dataset (NED) GridFloat terrain data files were used to specify the elevation of each population point in the study. The terrain data set consisted of 32 individual 1°x1° latitude-longitude terrain files at a resolution of 1/3 arc-seconds. The altitude cutoff specified in the common reference study was 18,726.2 feet MSL.

7.1.3 Flight Performance Failure Classifications

The source study for this analysis was originally created for NIRS. This study which was imported into AEDT 2a SP2, run, and all operations that failed to calculate were removed. This “clean” AEDT 2a SP2 study was then imported into AEDT 2b SP2 and run. Due to differences between flight performance calculations between AEDT 2a SP2 and AEDT 2b SP2, some flights that were successfully processed in AEDT 2a SP2 failed to process in AEDT 2b SP2. The following three types of flight failures were observed when the AEDT 2a SP2 version of the DC Metroplex study was first run in AEDT 2b SP2:

1. Insufficient thrust to support an “At” altitude control during ANP-driven calculations.
2. Insufficient thrust to support the specified acceleration when attempting to meet an “At-or-Below” altitude control at altitudes below 10,000 ft AFE (during ANP-driven calculations).
3. Insufficient thrust to support an altitude control at altitudes above 10,000 ft AFE (during BADA-driven calculations).

Failures of type 1 and 2 come as a result of the thrust checks that are included in the AEDT 2b SP2 ANP-driven track control algorithm which were not present in the AEDT 2a SP2 version of that algorithm. Operations with calculated flight paths that were unsupported by the available thrust of their respective ANP airplanes no longer pass in AEDT 2b as they did in AEDT 2a SP2 and NIRS. Flap selection improvements that were implemented for AEDT 2b SP2 are expected to cause slight flight performance differences between AEDT 2a SP2 and AEDT 2b SP2 at altitudes below 10,000 ft AFE and may also contribute to flight failures.

Type 1 failures occur when an air operation cannot meet the altitude prescribed by an associated "At" altitude control within thrust constraints and at the speed and flap setting specified by the air operation's STANDARD ANP procedure. These failures are an intended consequence of AEDT 2b SP2 enforcing more realistic thrust constraints during altitude processing than was done in AEDT 2a SP2 and NIRS.

Type 2 failures occur for "At-or-Below" altitude controls and can occur due to the specified acceleration associated with the segment that prompts the failure. Target speeds are determined by a speed schedule taken from the applicable STANDARD ANP procedure. No attempt is made to reduce target speeds from those set in the speed schedule, even when the altitude target is lowered in an attempt to stay below an "At-or-Below" control point altitude value when there is not sufficient thrust to match it. Therefore, "At-or-Below" altitude control segments can fail when an unachievable acceleration is specified within the segment.

Type 3 failures occur because of the changes to the iterative procedure used to calculate accelerating climb segments in the BADA-driven portion of altitude controls. AEDT uses one of two different iterative procedures when resolving BADA accelerating climb segments, a preferred procedure and a backup approximation. The preferred iterative procedure was improved to be more stable in AEDT 2b SP2. The AEDT 2a SP2 version of the preferred iterative procedure occasionally calculated negative altitudes while converging to a solution which led to erroneous interpolated weather parameters being used in flight performance calculations. When the flight performance algorithm detects such circumstances, it abandons the use of the preferred iterative solver when resolving BADA accelerating-climb segments and it instead resolves the segment using a backup approximation. Type 3 failures are instances of the (improved) AEDT 2b SP2 preferred iterative solver of BADA accelerating-climb segments stably converging to a solution whereas the AEDT 2a SP2 version does not. The more accurate segment calculated in the AEDT 2b SP2 case can fail to meet altitude control requirements while the segment calculated in AEDT 2a SP2 using the backup approximation does not.

The total amount of flight failures observed in AEDT 2b SP2, classified by operation type and scenario, are presented in Table 7-2.

Table 7-2. Flight Performance Failures in AEDT 2b SP2

Scenario – Operation Type	Type 1	Type 2	Type 3
Baseline – Departure	13,243	242	773
Baseline – Arrival	26,114	4	0
Proposed Action – Departure	23,230	0	2,035
Proposed Action – Arrival	98,108	0	0

The failed flights were removed from the final data set to ensure that the same flight operations were compared between studies.

7.2 Comparison to AEDT 2a SP2

7.2.1 Flight Performance Differences

Several improvements in the way flight performance calculations are performed were made for AEDT 2b SP2. This section provides a brief overview differences in the flight performance calculations conducted by AEDT 2a SP2 and AEDT 2b SP2, along with specific examples of flight operations from the DC Metroplex study that demonstrate those differences.

7.2.1.1 Study-wide Flight Performance Comparison

In order to quantify trends in the differences in flight performance output, the full study was analyzed separately for the flight regimes below 10,000 feet AFE and above 10,000 feet AFE. Data for comparison were created by establishing analysis points at 1 NM intervals along each operation's ground track. Altitude, speed, and thrust values were captured at each of these analysis points from both AEDT 2a SP2 and AEDT 2b SP2 flight performance output, and the differences between them were calculated for subsequent averaging and comparison.

The values presented in Table 7-3 represent the average and maximum percent difference below 10,000 feet AFE for altitude, speed and thrust.

Table 7-3. DC Metroplex Study Comparison – Altitudes Below 10,000 feet AFE

		Average % Difference			Maximum % Difference		
Operation Type	Operation Count	Altitude	Speed	Thrust	Altitude	Speed	Thrust
Arrival	482,080	0.74%	2.42%	24.18%	5.22%	7.38%	94.33%
Departure	199,900	1.49%	0.61%	14.53%	6.15%	2.18%	44.64%

Table 4 shows average and maximum percent differences for altitude, speed and thrust in the flight regime above 10,000 feet AFE.

Table 7-4. DC Metroplex Study Comparison – Altitudes Above 10,000 feet AFE

		Average % Difference			Maximum % Difference		
Operation Type	Operation Count	Altitude	Speed	Thrust	Altitude	Speed	Thrust
Arrival	451,809	0.02%	1.87%	15.62%	0.16%	5.75%	44.38%
Departure	98,173	0.98%	0.54%	6.62%	2.15%	1.53%	17.08%

The operation counts in Table 4 are less than the study total because some flights do not go above 10,000 feet AFE in both AEDT 2a SP2 and AEDT 2b SP2. Additionally, some flight performance output in AEDT 2b SP2 surpasses 10,000 feet AFE while the same flight does not reach 10,000 feet AFE when modeled in AEDT 2a SP2 and vice versa. This is because of differences in thrust calculations between the two models and how they affect flights using "At-or-below" altitude controls.

The values in the table are consistent with expectations due to the flight performance algorithm improvements in AEDT 2b SP2. Individual flight performance results which support the study-wide data are examined in detail in the following sections.

7.2.1.2 Detailed Flight Performance Comparisons

Departure and arrival operations of the type exercised in the DC Metroplex study feature tracks with altitude controls both above and below 10,000 feet AFE at their associated airport. Therefore, analysis of any operation may span up to three distinct flight performance calculation regimes:

- Uncontrolled portion below 10,000 feet AFE
- Altitude-controlled portion below 10,000 feet AFE
- Altitude-controlled portion above 10,000 feet AFE

7.2.1.2.1 Uncontrolled Portion Below 10,000 Feet AFE

Flight performance for the uncontrolled portion of an operation is based on evaluation of the assigned STANDARD ANP procedural profile without regard to altitude controls on the track. Procedures are assigned based on operation type (i.e., departure or arrival) and stage length. The uncontrolled portion is bound at one end by grounded content (takeoff or landing). At the opposite end, the uncontrolled portion is bound by either the point along the track (moving away from the runway) at which the STANDARD procedure reaches the initial/final state of the procedure, reaches 10,000 feet AFE, or becomes incompatible with local altitude controls. The two main differences in the processing of uncontrolled flight portions below 10,000 ft AFE in altitude are:

- Determination of the break-away point from the defined STANDARD ANP procedure
- Thrust transition smoothing

7.2.1.2.1.1 Determination of the Break-Away Point from the Defined STANDARD ANP Procedure

The point at which flight calculations stop following the defined STANDARD flight procedure in order to meet altitude control constraints is determined by different rules in each AEDT version. In AEDT 2a SP2, it occurs where a standard procedure step would violate a control's altitude restriction; whereas in AEDT 2b SP2 it occurs where the next point in the STANDARD procedure's flight path is either above or beyond the first altitude control defined on the ground track. This change was made for AEDT 2b to improve its ability to realistically satisfy altitude control constraints. With this change there will be differences between AEDT 2a SP2 and AEDT 2b SP2 with regards to the exact extent that the STANDARD procedural profile is flown before transitioning to the altitude-controlled portions of the flight.

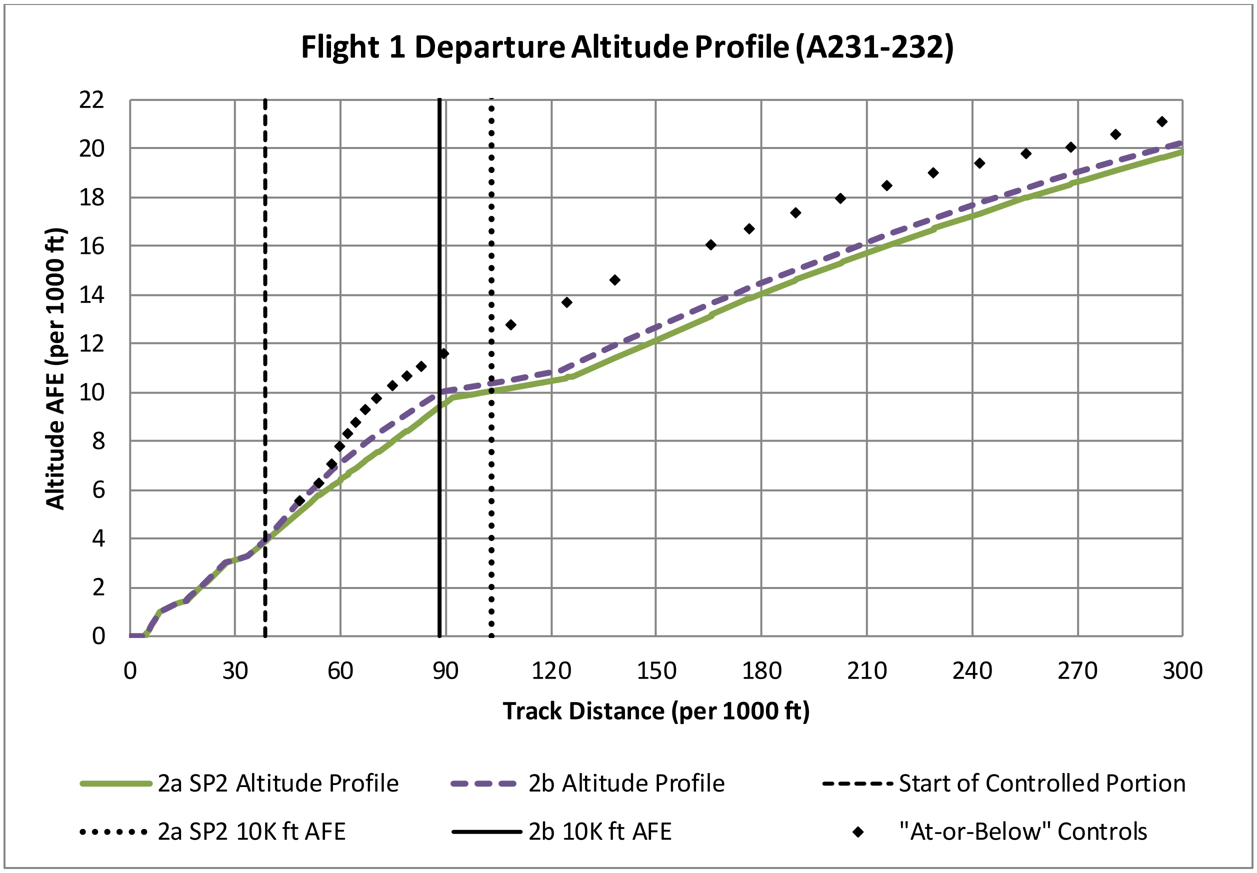


Figure 7-1. Flight 1 Altitude Profile

Flight 1, a departure on a ground track defined with "At-or-Below" altitude controls, flew several hundred feet lower in AEDT 2a SP2 compared to AEDT 2b SP2. This behavior was observed throughout the altitude-controlled portion of the flight both below and above the 10,000-foot threshold (AFE). Figure 7-1 plots the altitude profiles and locations of altitude control targets for Flight 1.

The STANDARD ANP procedure meets the "At-or-Below" constraint for all of the defined altitude controls. AEDT 2a SP2 therefore does not break away but simply follows that procedure throughout the terminal area. Even though the constraints are met, AEDT 2b SP2 does break away from the STANDARD ANP procedure and tries to get as close as possible to the specified altitude values of "At-or-Below" points. By doing so it is able to match the altitude values of the first two control points, however the aircraft does not have enough thrust to match the later control points. The resultant altitude offset from AEDT 2a SP2 is maintained throughout the rest of the calculated flight path as AEDT 2b SP2 continues to try to match the altitude controls as closely as possible with the available thrust.

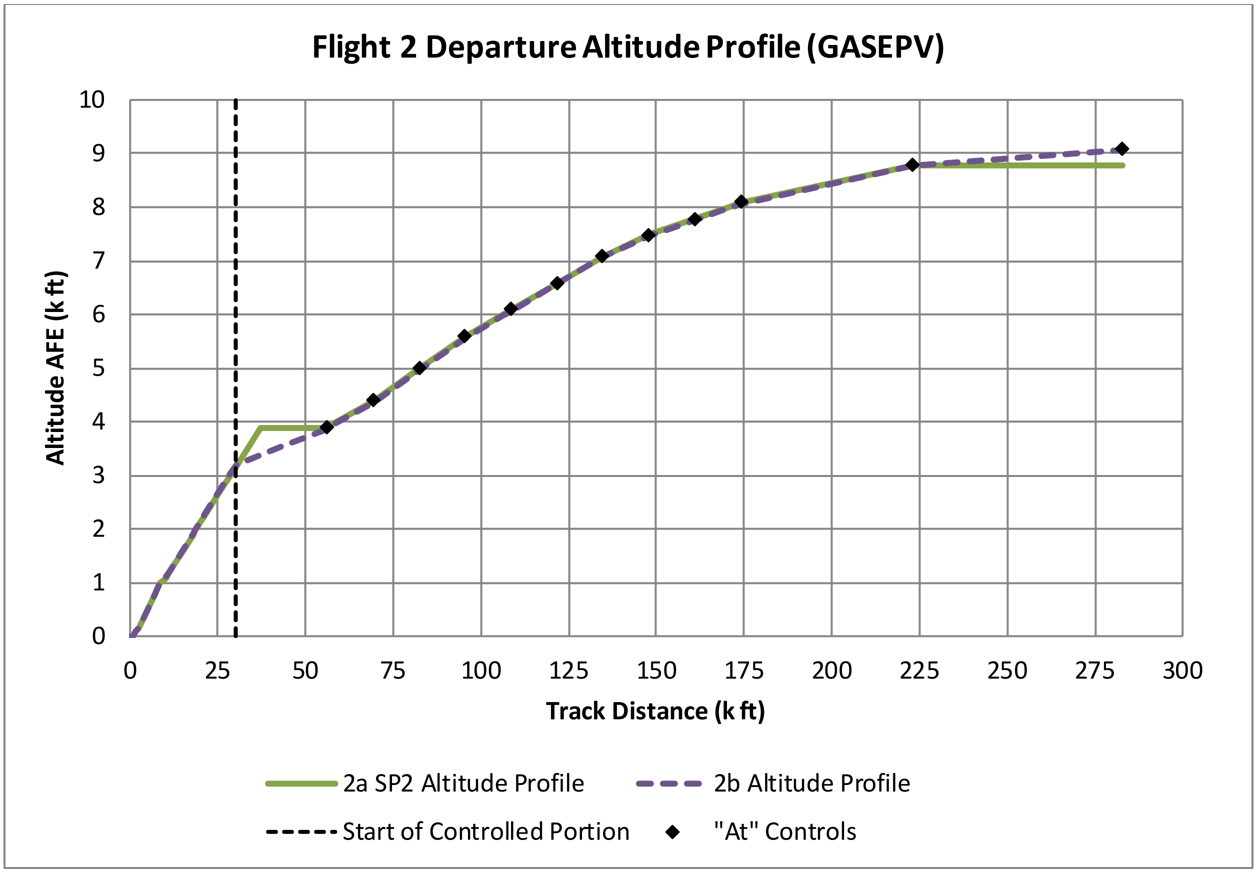


Figure 7-2. Flight 2 Altitude Profile

The altitude profile for a propeller aircraft (Flight 2: ANP ID: GASEPV, BADA ID: P28A) using "At" controls is shown in Figure 7-2. This figure demonstrates a common difference observed in the shapes of the altitude profiles calculated by AEDT 2a SP2 and AEDT 2b SP2, which occurs in the vicinity of the start of the altitude-controlled portion of a flight. At the start of the altitude-controlled portion, the AEDT 2a SP2 version of Flight 2 climbs more steeply than the AEDT 2b SP2 version and then levels off to reach the first altitude control. The AEDT 2b SP2 instance of the flight performs a direct climb at a shallower angle in order to reach the first altitude control.

The cause of this difference relates to the manner in which the AEDT 2a SP2 algorithm switches from the uncontrolled (standard ANP procedure steps) to controlled (custom ANP-based procedure steps) flight performance calculations. As mentioned above, the AEDT 2a SP2 algorithm flies the standard procedure steps of a flight operation's ANP aircraft until it has flown a procedure step that puts the aircraft either above (altitude-wise) or beyond (distance-wise) the first altitude control. For Flight 2, a procedure step was flown which put the aircraft above the first altitude control. In such a situation, the AEDT 2a SP2 flight performance algorithm clips the result from that procedure step at the altitude of the first control and adds a level step directly to that control.

The AEDT 2b SP2 flight performance algorithm flies all of the standard procedural profile steps but then only keeps those that are both below (altitude-wise) and before (distance-wise) the first altitude control. AEDT 2b SP2 completely discards flight performance content from the standard procedure step that would have put the aircraft above and beyond the first altitude control and, instead, it climbs from the end point of preceding step to the first altitude control.

Another difference in the altitude profiles can be seen at the end of the flight. The AEDT 2a SP2 algorithm uses a tolerance of ± 300 feet when deciding whether an altitude control has been met. The flight path at the second to last altitude control is exactly 300 feet below the final altitude control. In constructing the final custom procedure step, the algorithm determines that aircraft is already within 300 feet (inclusive) of the final control altitude, and therefore maintains altitude to the control (using a level procedure step) instead of constructing a climb to the final control altitude as was done in AEDT 2b SP2.

7.2.1.2.1.2 Thrust Transition Smoothing

AEDT 2b SP2 use a modified process of filtering out flight path points with the same geographic location than the one in implemented in AEDT 2a SP2. In AEDT 2a SP2 when two points with the same geographic location are detected, such as the end point of a given segment and the start point of the following segment, the second point is deleted and not included in the output flight path. In AEDT 2b SP2, the second co-located point is only deleted if all flight performance values are very similar across the two points. In instances where there are significant differences, which typically only occur for thrust values, the second point is not deleted but instead relocated 1,000 ft further along the ground track. This creates a thrust transition segment similar to those created when changing power states during departures, i.e. switching from takeoff thrust to climb thrust.

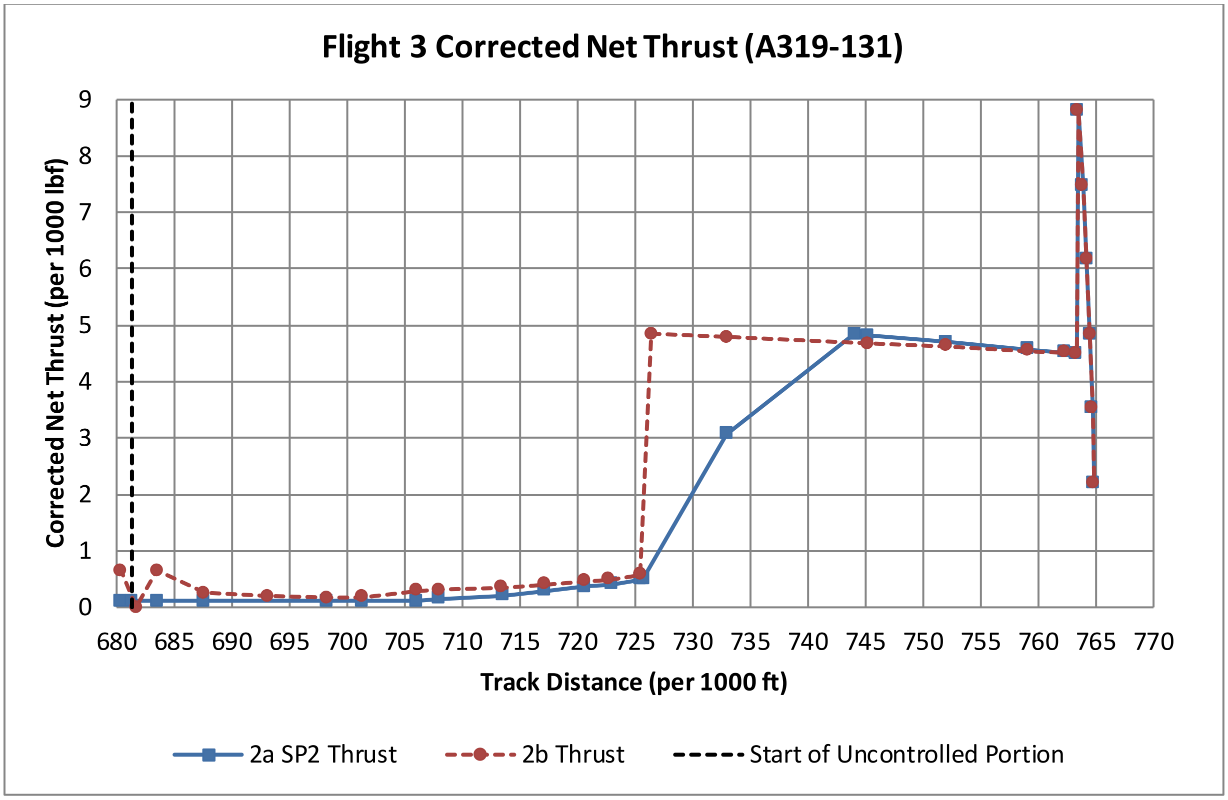


Figure 7-3. Flight 3 Corrected Net Thrust

An example of the affect this difference can have on flight performance output is shown in Figure 7-3, which shows thrust vs. distance for the uncontrolled portion of an A319-131 arrival. AEDT 2b SP2 transitions from idle to a higher thrust value over a 1,000 ft long segment while the AEDT 2a SP2 thrust changes more gradually over the entire length of the segment with the higher thrust value. The intermediate point at track distance of approximately 733,000 ft is the location of a ground track point. It has been inserted into the flight path after the two-dimensional flight profile calculations were performed and was not part of the original higher-thrust segment.

7.2.1.2.2 Altitude-Controlled Portion Below 10,000 Feet AFE

The most noteworthy differences between flight performance calculations in AEDT 2a SP2 and AEDT 2b SP2 occur in the altitude-controlled portion below 10,000 feet AFE. Both versions model flight with the aid of ANP data, but they use two distinct methodologies. The two main differences in those methodologies are:

- Thrust calculations
- Bank angle effects

7.2.1.2.2.1 Thrust Calculation Differences

Once they have broken away from the STANDARD ANP procedure in order to meet altitude control constraints, and are still at altitudes below 10,000 ft AFE, AEDT 2a SP2 and AEDT 2b SP2 use different methods to compute thrust. AEDT 2a SP2 computes the thrust for each segment using ANP thrust coefficients for climbing segments, a simplified force balance for level segments, and either ANP idle thrust coefficients or a simplified force balance for descending segments depending on corresponding ANP procedure steps. AEDT 2b SP2 computes thrust using an ECAC Doc. 29 force balance for all segments.

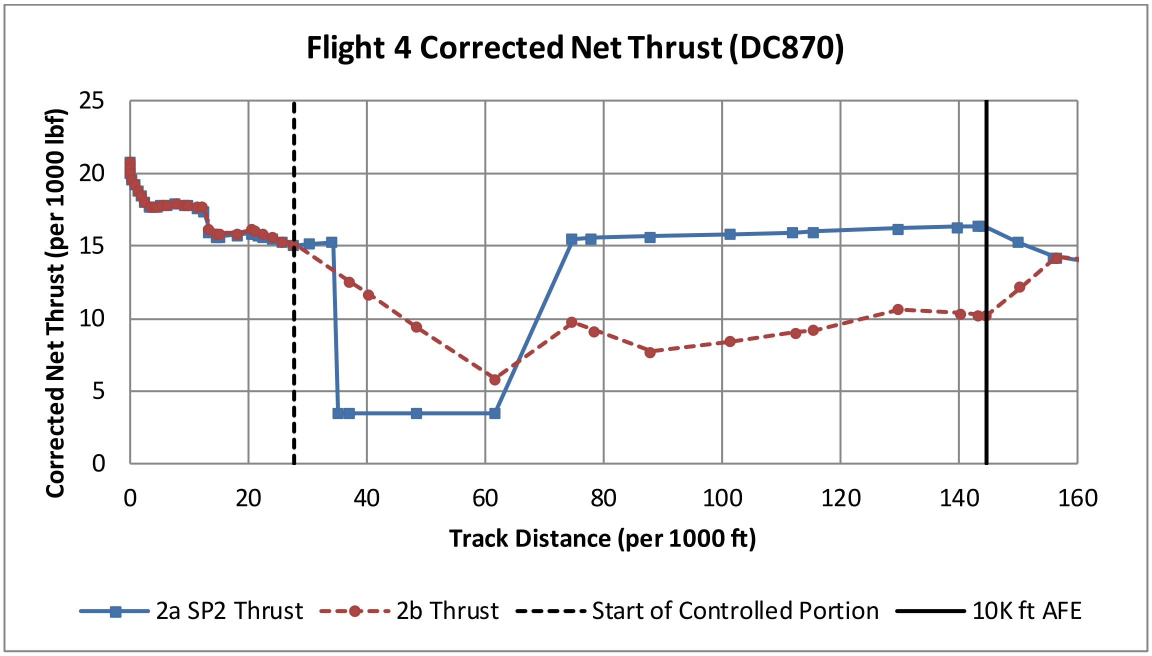


Figure 7-4. Flight 4 Corrected Net Thrust

Flight 4 shows differing amounts of calculated thrust in the below 10,000 feet AFE altitude-controlled portion of a departure flight in AEDT 2b SP2 when compared to AEDT 2a SP2. This flight has a level segment between approximately 35,000 ft and 75,000 ft in track distance. For this segment AEDT 2a SP2 is using a simple force balance that neglects banking and acceleration effects, while AEDT 2b SP2 accounts for acceleration and bank angle in its force balance. Accounting for those effects causes AEDT 2b SP2 to calculate higher, more realistic thrust values than AEDT 2a SP2 for level segments.

Between approximately 75,000 ft and 145,000 ft in track distance the flight is climbing to reach an altitude of 10,000 ft AFE. In this portion of the flight AEDT 2a SP2's calculated thrust is simply the aircraft's maximum climb thrust as defined by the corresponding ANP thrust coefficients. AEDT 2b SP2 calculates the thrust required to achieve a flight path that honors the altitude control values and outputs those directly as long as they are below the available maximum climb thrust as defined by ANP. In this case the required thrust is lower than the ANP maximum climb thrust, therefore AEDT 2b SP2's thrust output is lower than that of AEDT 2a SP2.

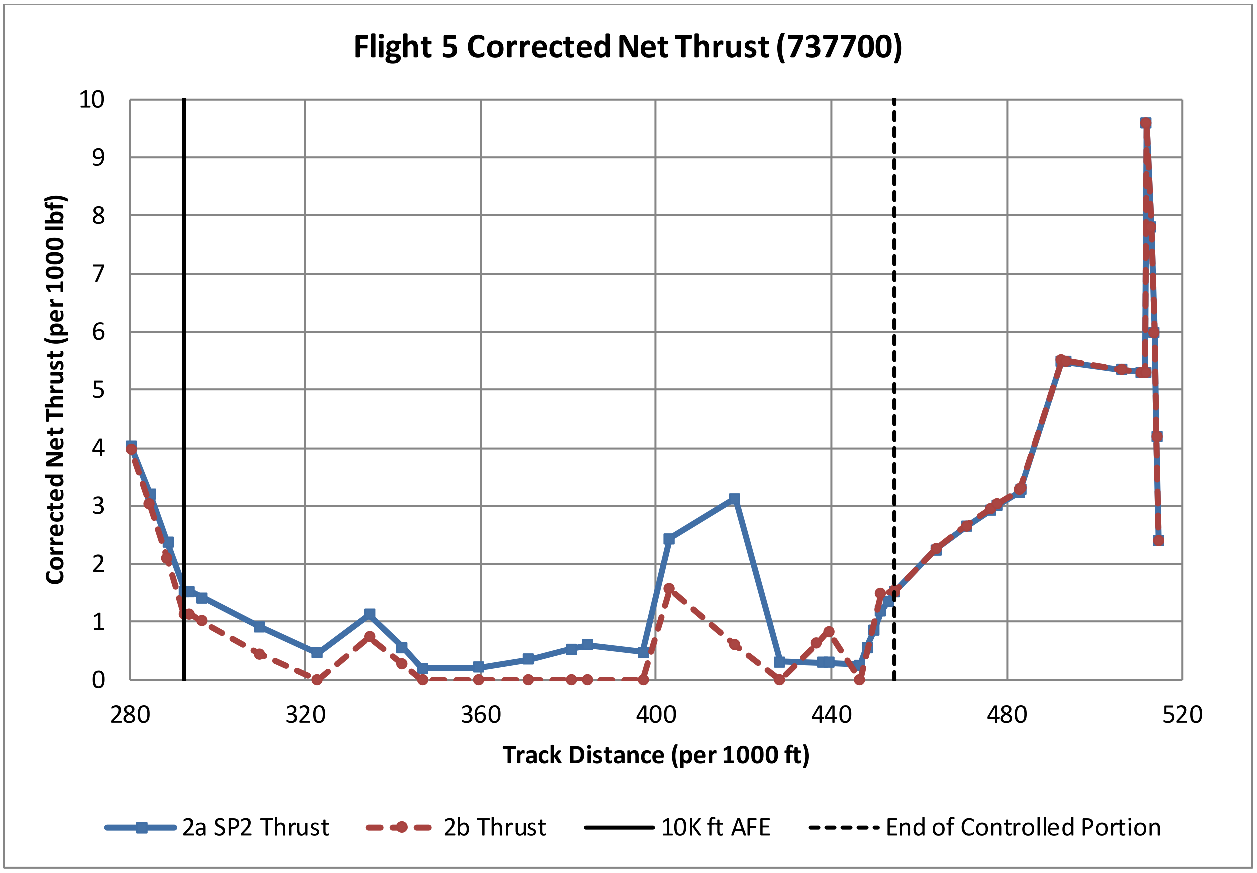


Figure 7-5. Flight 5 Corrected Net Thrust

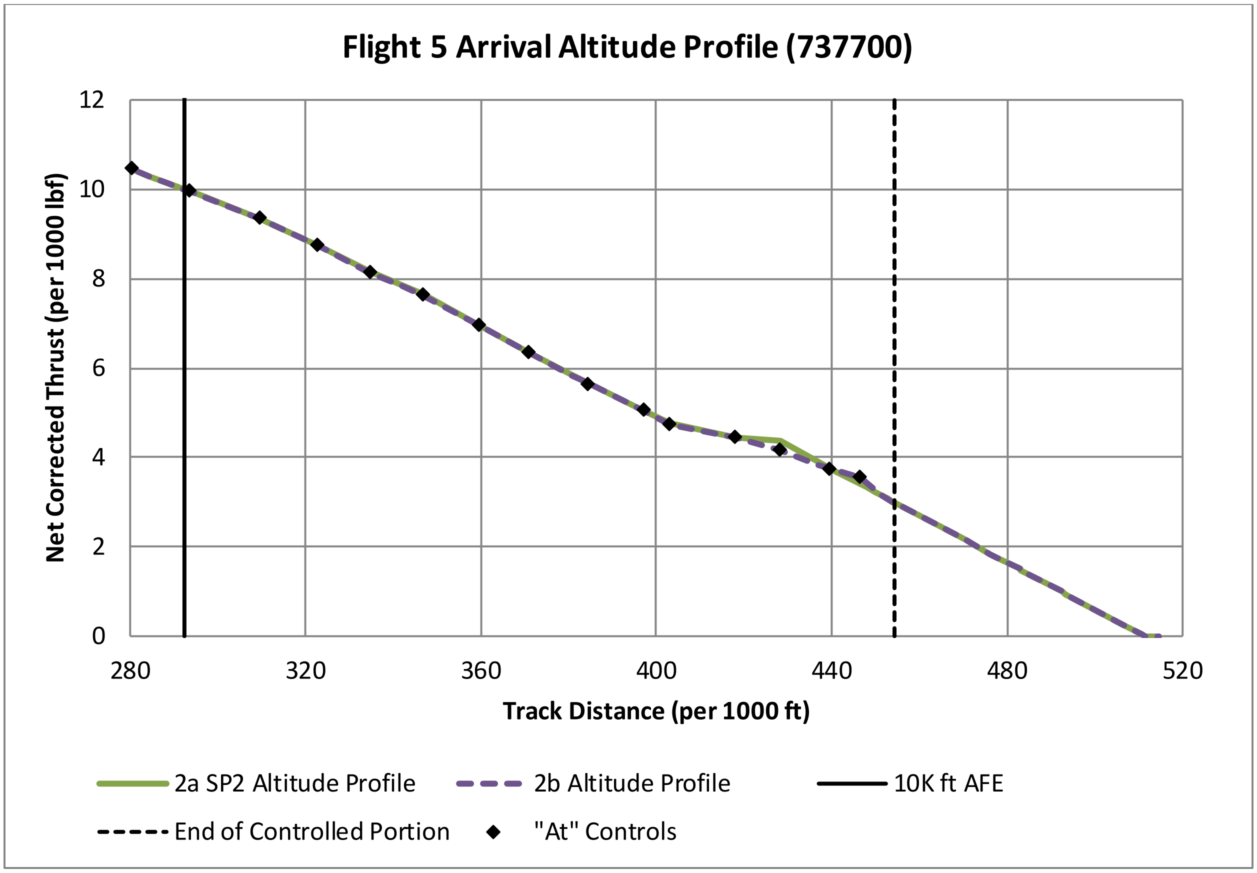


Figure 7-6. Flight 5 Altitude Profile

Flight 5, an arrival with "At" altitude controls, results in higher calculated thrust in AEDT 2a SP2 in the below 10,000 feet AFE altitude-controlled portion of the flight. Figure 7-5 and Figure 7-6 present the corrected net thrust and altitude profiles of Flight 5.

The differences in thrust seen toward the end of the controlled portion of flight 5 are due to the differing force balances used to calculate thrust for descent segments in AEDT 2a SP2 and AEDT 2b SP2. When calculating thrust for descent segments, AEDT 2a SP2 does not account for bank angle, nor does it explicitly account for the actual acceleration/deceleration experienced during the segment (the coefficients are instead calibrated for the acceleration expected at reference conditions). AEDT 2b SP2 accounts for these affects, and therefore calculates lower thrust values than AEDT 2a SP2 in this portion of the flight.

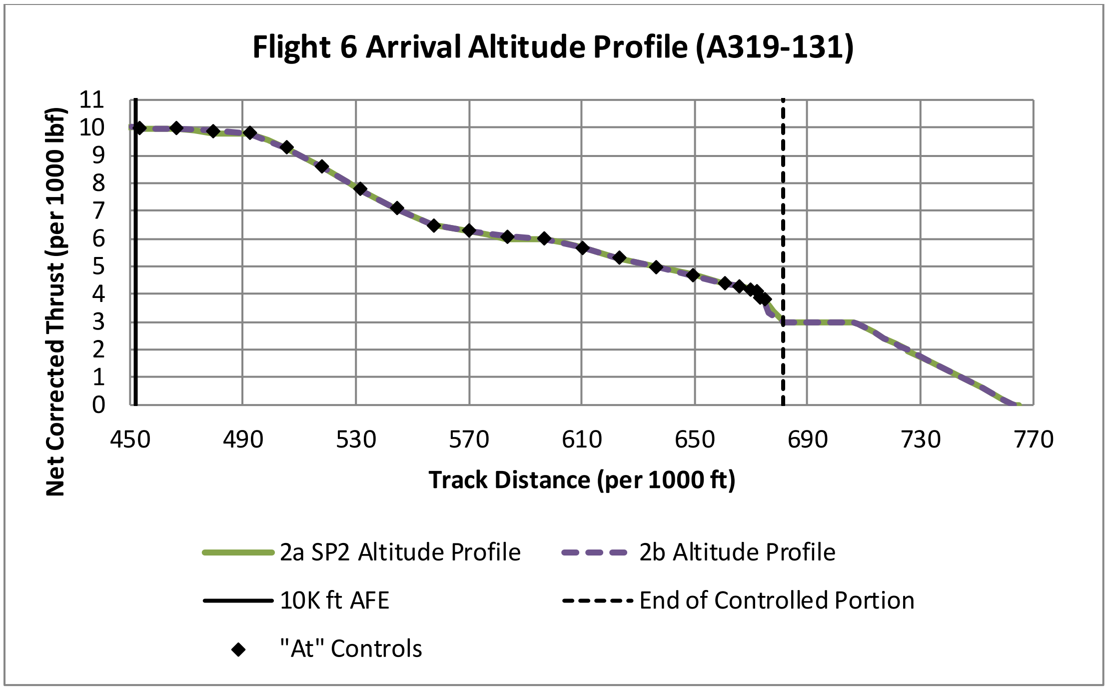


Figure 7-7. Flight 6 Altitude Profile

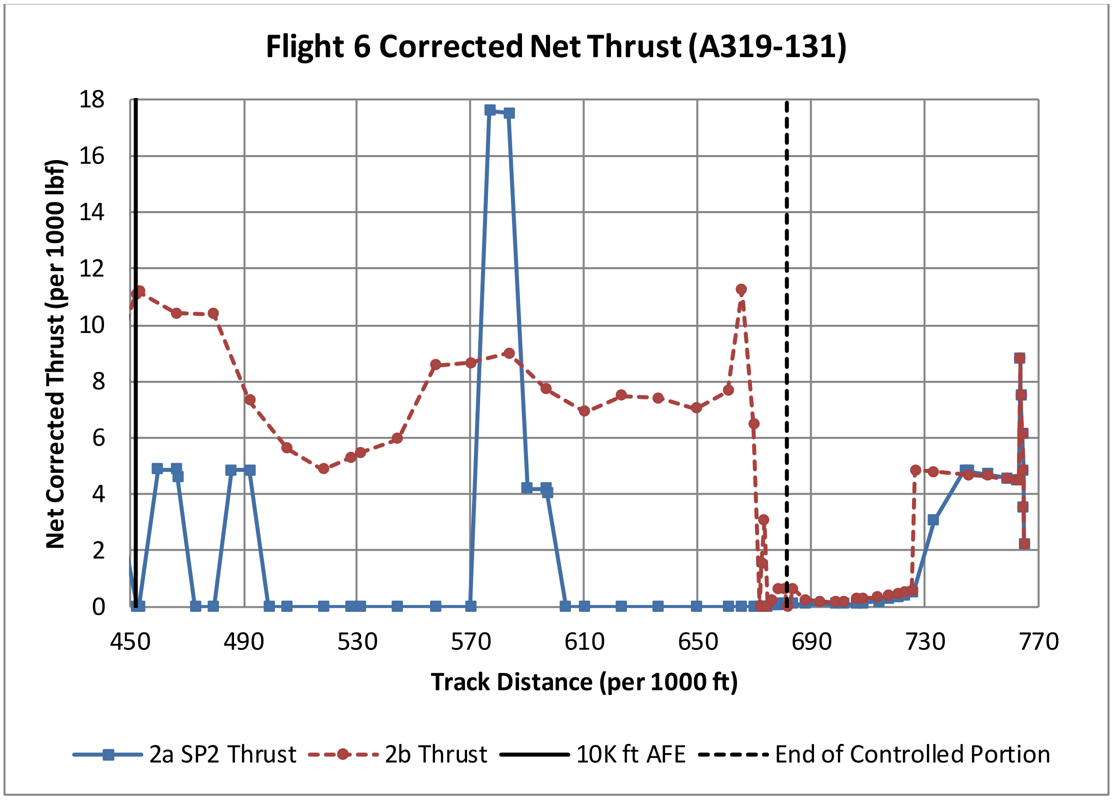


Figure 7-8. Flight 6 Corrected Net Thrust

Flight 6, an arrival with “At” altitude controls, produced higher amounts of thrust in AEDT 2b SP2 than AEDT 2a SP2. AEDT 2a SP2 uses descend-idle and level procedure steps when calculating the altitude-controlled portion of the flight (Figure 7-7). In this case the ANP idle thrust coefficients used for the descending segments result in negative thrust values, and AEDT 2a SP2 sets them to a minimum value of 1 pound of corrected net thrust. The force balance used by AEDT 2b SP2 calculates higher thrust values for these descending segments. For the level segments, the more-inclusive force balance used by AEDT 2b SP2 also calculates higher thrust values than the simpler force balance used by AEDT 2a SP2.

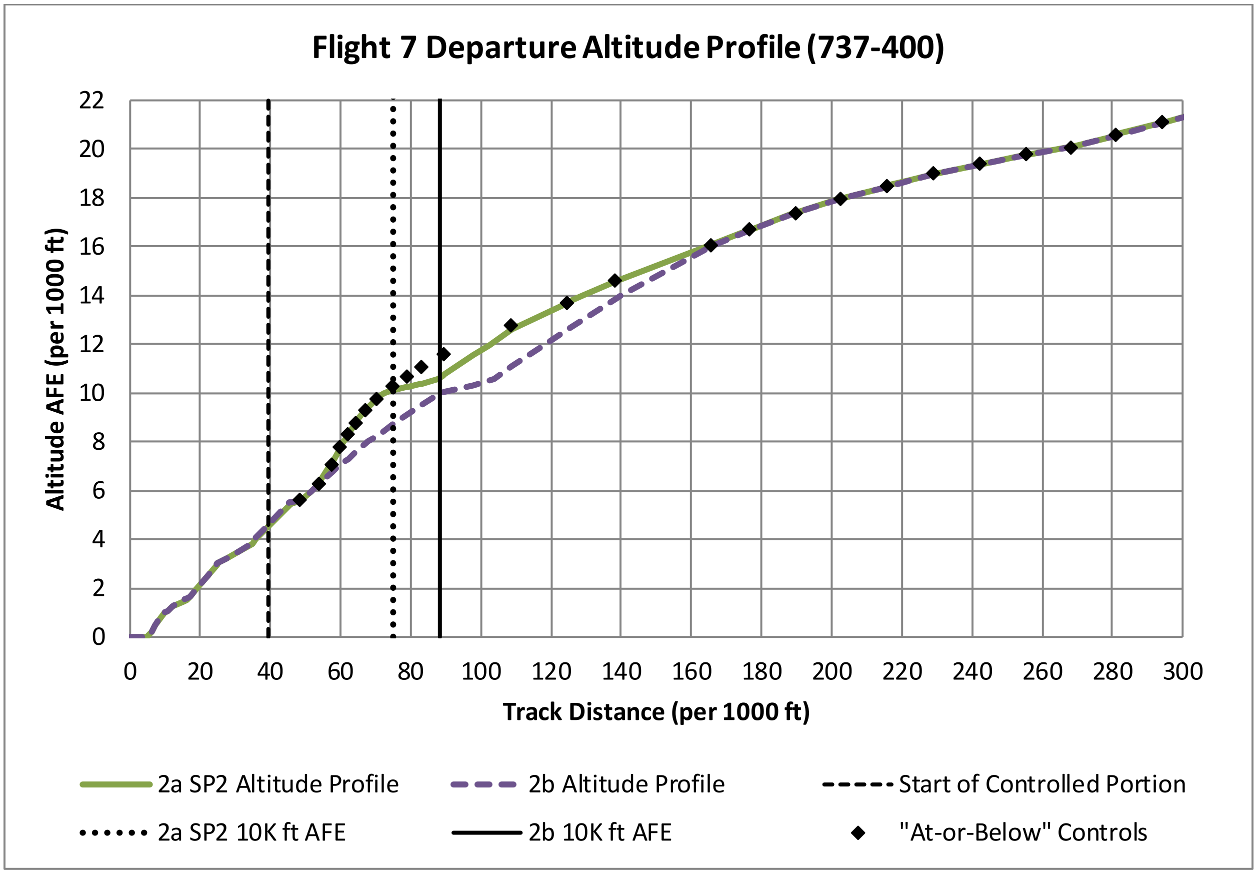


Figure 7-9. Flight 7 Altitude Profile

Flight 7, a departure operation with a track that exclusively contains “At-or-Below” altitude controls, flew several hundred feet lower in AEDT 2b SP2 as compared to AEDT 2a SP2. Figure 7-9 presents the altitude profile of Flight 7.

AEDT 2a SP2 used a STANDARD ANP procedural profile which would have flown above the first altitude control. The flown altitude was lowered to the control altitude, marking the beginning of the below-10,000 feet AFE controlled regime. None of the control targets on the way to 10,000 feet AFE required climb angles exceeding 30 degrees, which is the limit applied by AEDT 2a SP2 when determining whether a given segment is achievable. AEDT 2a SP2 therefore produced a flight path that matches all of the altitude control values below 10,000 ft AFE. AEDT 2b applies a more restrictive limit based on the aircraft’s available thrust, which resulted in a lower climb rate as compared to AEDT 2a SP2. The two AEDT versions show similar behavior above 10,000 ft AFE as is expected, with the only difference being the ground track distance at which each version reaches the 10,000 ft AFE altitude and subsequent offset until the aircraft's available thrust allows the two flight paths to converge and meet all of the altitude control values above 16,000 ft.

7.2.1.2.2.2 Bank Angle Effect Differences

A specific subset of the thrust calculation differences between AEDT 2a SP2 and AEDT 2b SP2 is the accounting for bank angle effects during thrust calculations for segments in the altitude-controlled portions of flights. As noted above, AEDT 2a SP2 uses ANP thrust coefficients when calculating thrust for climbing departure segments, and therefore does not consider bank effects. AEDT 2b SP2 uses a force balance that does account for bank angle effects to calculate thrust for these segments.

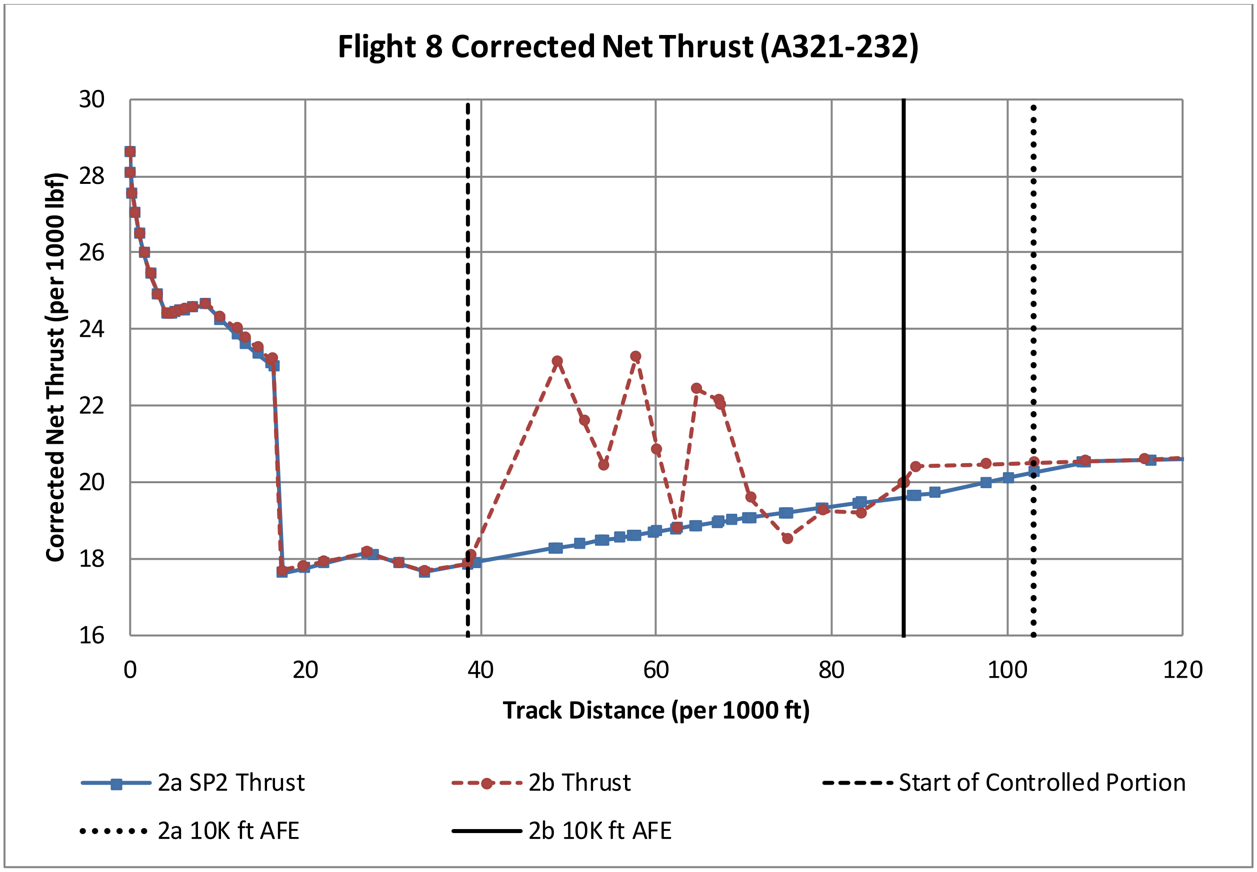


Figure 7-10. Flight 8 Corrected Net Thrust

Flight 8 produces higher amounts of thrust in AEDT 2b SP2 during the altitude-controlled portion of the flight below 10,000 feet AFE. A plot of corrected net thrust focusing on the section of the flight below 10,000 feet AFE is presented in Figure 7-10.

The main reason for the higher thrust calculated by AEDT 2b SP2 for Flight 8 becomes apparent when the ground track of this track is visualized, as in Figure 7-11. The red portion corresponds to portions of the track before altitude controls are specified. The blue portion corresponds to the portion of the track that obeys altitude controls and is below 10,000 feet AFE. The beige portion corresponds to the controlled portion of the flight that is above 10,000 feet AFE.

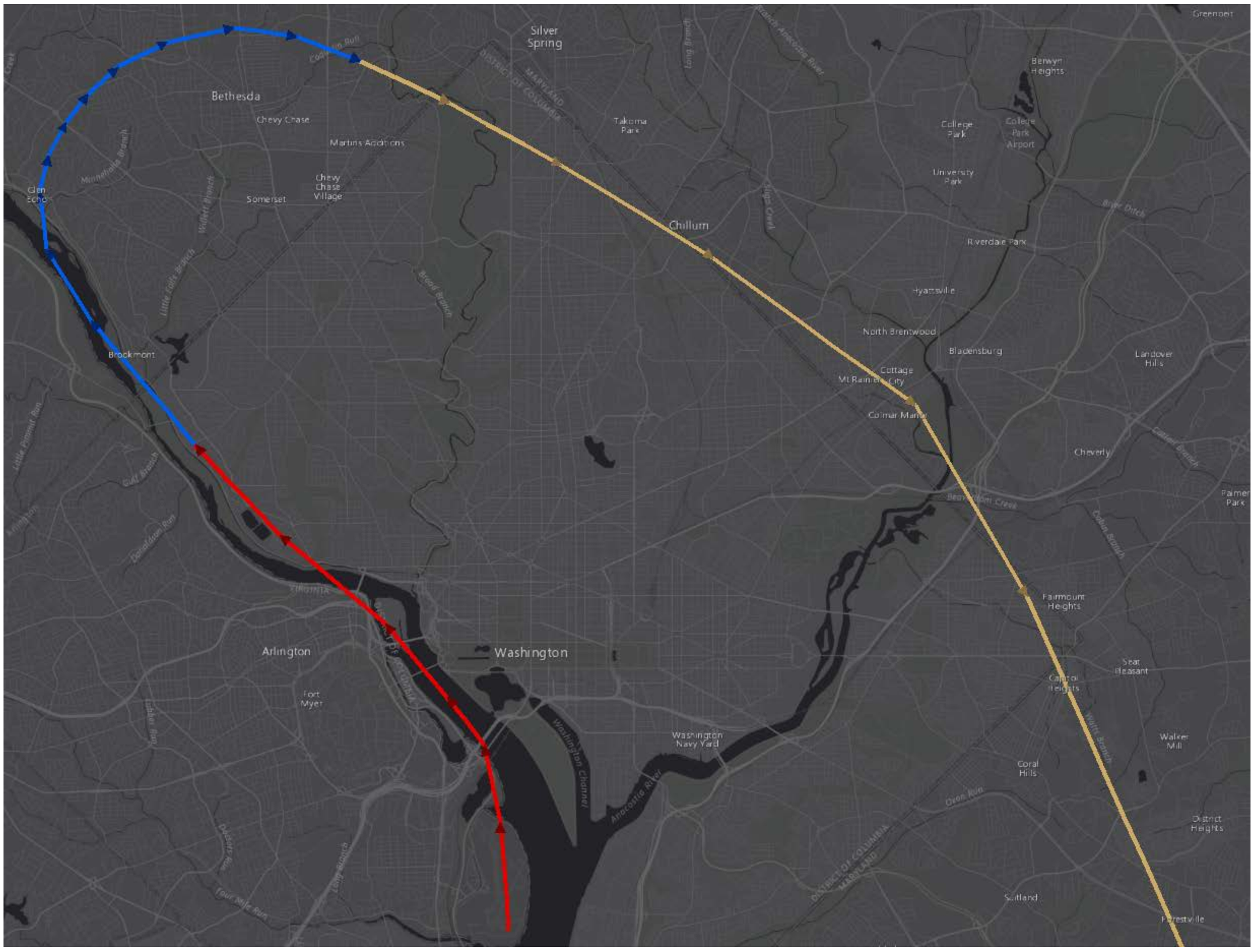


Figure 7-11. Ground Track of Flight 8

Figure 7-11 shows that, after an initial vectoring to the northwest, Flight 8 begins a sharp turn in order to head to the southeast, thereby undergoing significant banking. The values of bank and climb angles of the eleven segments which were below 10,000 feet AFE in AEDT 2b SP2 for Flight 8 are presented in Table 5. The altitudes shown in the table correspond to the altitude (in feet AFE) of the endpoint of the segment.

Table 7-5. The Bank and Climb Angle Values of the Eleven Segments Fully Below 10,000 feet AFE

Altitude AFE (ft)	5,585	6,285	6,845	7,127	7,359	7,644
Bank Angle (°)	-8.32	-1.52	-6.2	-33.84	-36.29	-33.24
Climb Angle (°)	9.28	7.52	8.73	6.78	5.55	7.37
Altitude AFE (ft)	7,972	8,335	8,725	9,117	9,510	
Bank Angle (°)	-28.95	-26.9	-28.57	-24.89	-28.65	
Climb Angle (°)	7.23	5.92	5.23	5.54	5.26	

AEDT 2a SP2 does not take into account the bank angle values calculated for Flight 8 in its thrust calculations while AEDT 2b SP2 does, resulting in higher thrust values being calculated.

7.2.1.2.3 Altitude-Controlled Portion Above 10,000 Feet AFE

AEDT 2a SP2 and AEDT 2b SP2 use very similar methods which rely on aircraft performance data from EUROCONTROL's BADA performance database (version 3) to model aircraft movements above 10,000 feet AFE. The difference between the two tools lies in the details of how these methods are implemented. AEDT 2b SP2 includes a collection of enhancements and bug fixes that combine to improve the accuracy of its output. The three main flight calculation differences in this flight regime are:

- Speed calculations
- Interpolation method
- Propagation of differences originating at altitudes below 10,000 ft AFE

7.2.1.2.3.1 Speed Calculations

AEDT 2b SP2 corrects some speed calculation errors present in AEDT 2a SP2. The most significant example is the calculation of the speed-dependent Mach transition altitude.

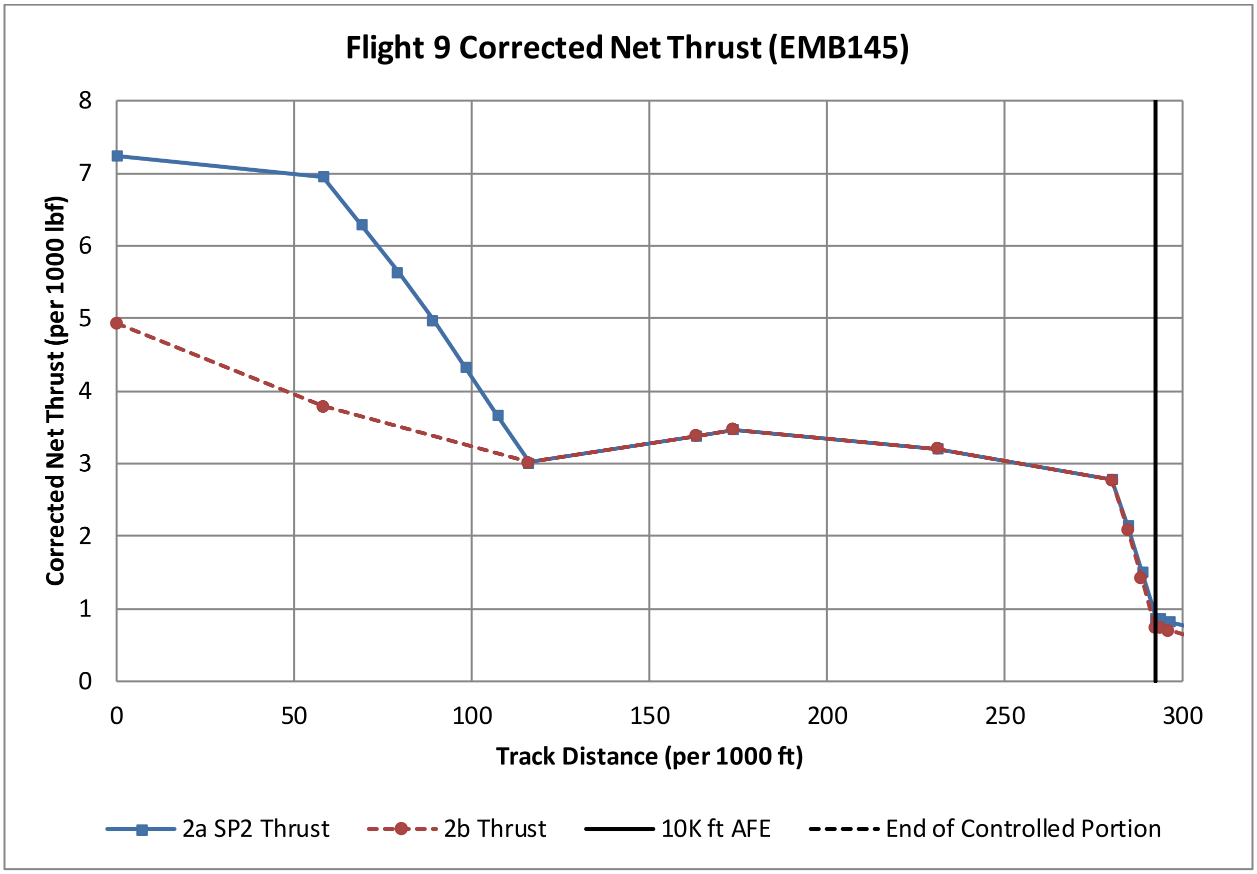


Figure 7-12. Flight 9 Corrected Net Thrust

Flight 9, an arrival with "At" altitude controls, experienced higher amounts of thrust at the beginning of the flight in AEDT 2a SP2 compared to AEDT 2b SP2. Figure 7-12, Figure 7-13, and Figure 7-14 present the thrust curves, altitude profiles (above 10,000 feet AFE) and Mach transition altitudes of Flight 9. The thrust differences for Flight 9 are due to speed differences. Above 10,000 feet AFE, a BADA-based procedure is used to calculate flight performance characteristics, where an increase in speed leads to an increase in required thrust (if all other variables are similar).

Figure 7-13 shows a difference in the Mach transition altitude calculated by the two models. The difference is due to an inaccurate calculation in AEDT 2a SP2, which calculated the altitude using the BADA climb Mach number instead of the BADA descent Mach number. The incorrect calculation in AEDT 2a SP2 caused the flight to begin its descent at the descent Mach number, which is faster than the BADA descent calibrated airspeed (CAS) for the altitude range flown. In AEDT 2b SP2, the descent began below its calculated Mach transition altitude and therefore started at the nominally lower BADA descent CAS.

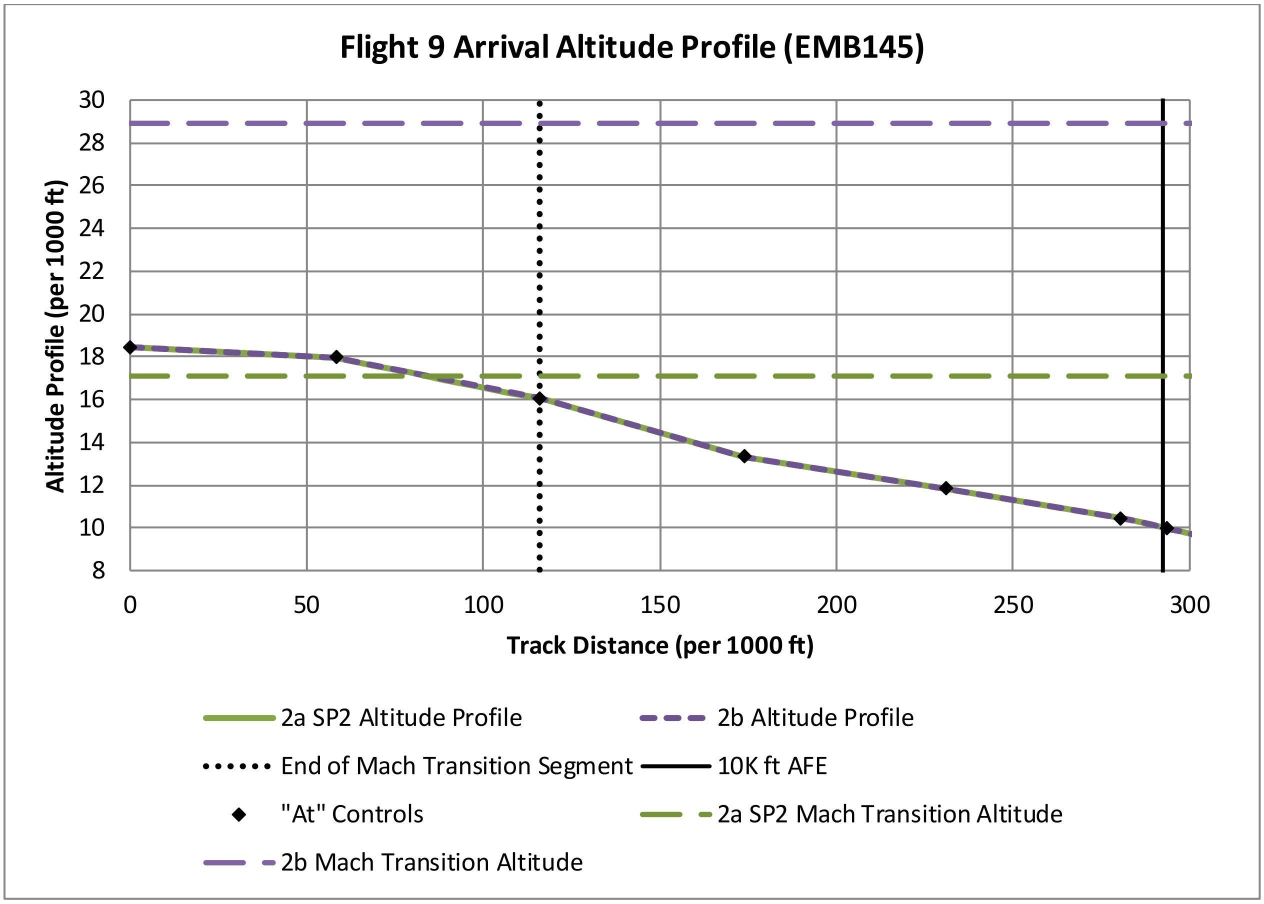


Figure 7-13. Flight 9 Altitude Profile

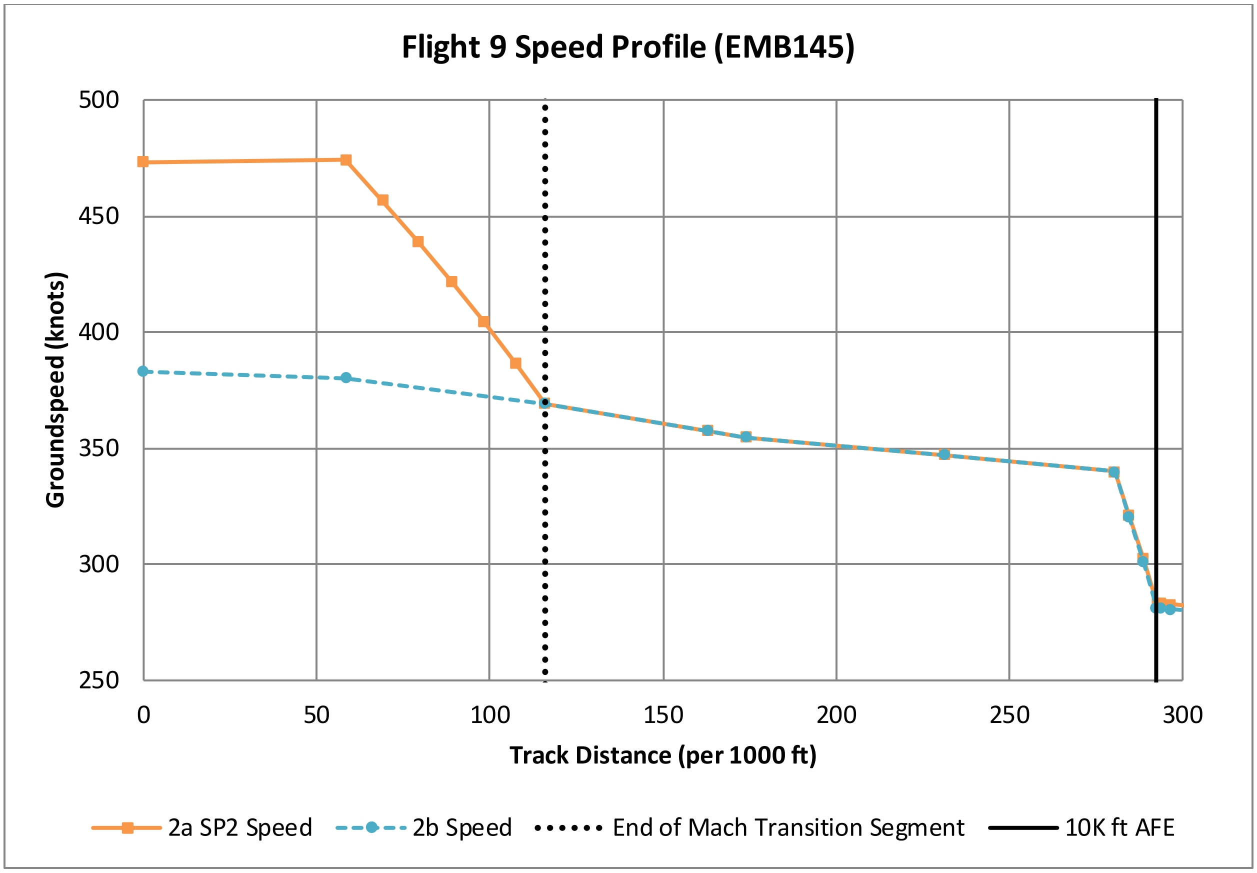


Figure 7-14. Flight 9 Speed Profile

Figure 7-14 shows the speed profile above 10,000 feet AFE which demonstrates that the higher thrust in AEDT 2a SP2 coincides with portions of Flight 9 which experienced higher speeds in AEDT 2a SP2 relative to AEDT 2b SP2.

7.2.1.2.3.2 Interpolation Method

AEDT 2a SP2 and AEDT 2b SP2 use different interpolation algorithms that can result in thrust calculation differences at uncontrolled track points within the controlled regime. In both AEDT versions, flight performance is first calculated at all the controlled track points, then the results at controlled points are interpolated to determine flight performance at uncontrolled points between them. The difference between the two methodologies is the manner in which these interpolations are performed for speed and thrust. AEDT 2a SP2 interpolates these values using a square interpolation methodology while AEDT 2b SP2 does so using a linear interpolation methodology. AEDT 2a SP2 can output higher thrust values due to these algorithmic differences.

Flight 10, an arrival operation with “At” altitude controls, exhibited higher amounts of thrust throughout the altitude-controlled portion of the flight above 10,000 feet AFE. The plot of AEDT 2a SP2 and AEDT 2b SP2 thrust for this flight operation is presented in Figure 7-15.

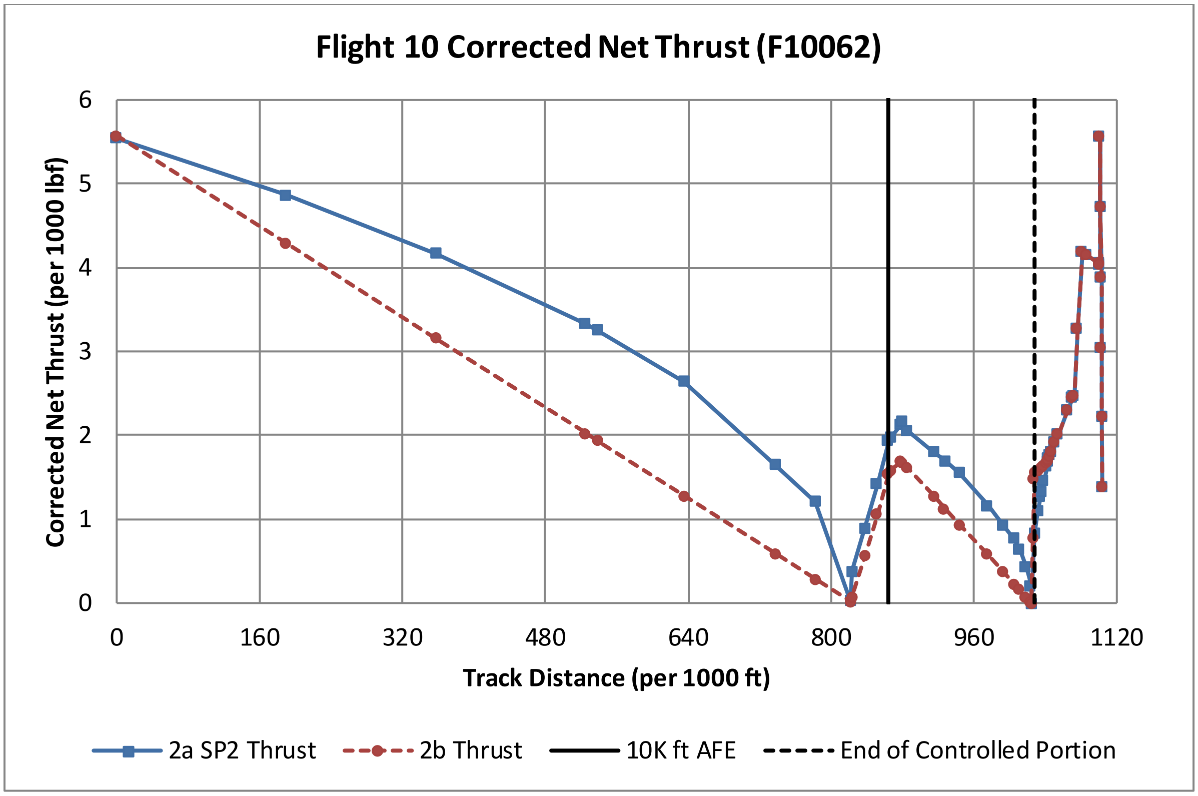


Figure 7-15. Flight 10 Corrected Net Thrust

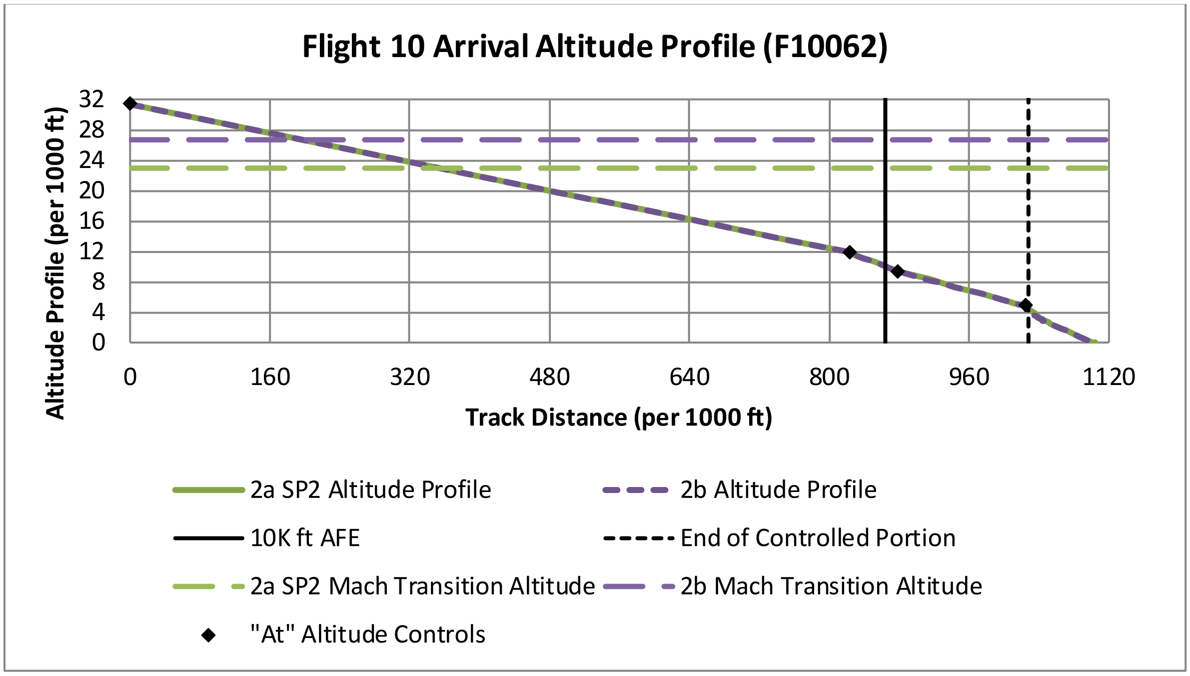


Figure 7-16. Flight 10 Altitude Profile

Figure 7-16 shows a plot of the altitude profile and altitude controls for Flight 10. The first altitude-controlled segment of Flight 10 descends past the Mach transition altitude and is not expected to exhibit speed dissimilarities between AEDT 2a SP2 and AEDT 2b SP2 due to the speed calculation changes described above.

The Mach transition altitudes calculated for Flight 10 were much closer in magnitude (23,091 feet MSL for AEDT 2a SP2 and 26,825 feet MSL for AEDT 2b SP2). Figure 7-17 confirms that this minor difference has no effect on the speed profile of Flight 10.

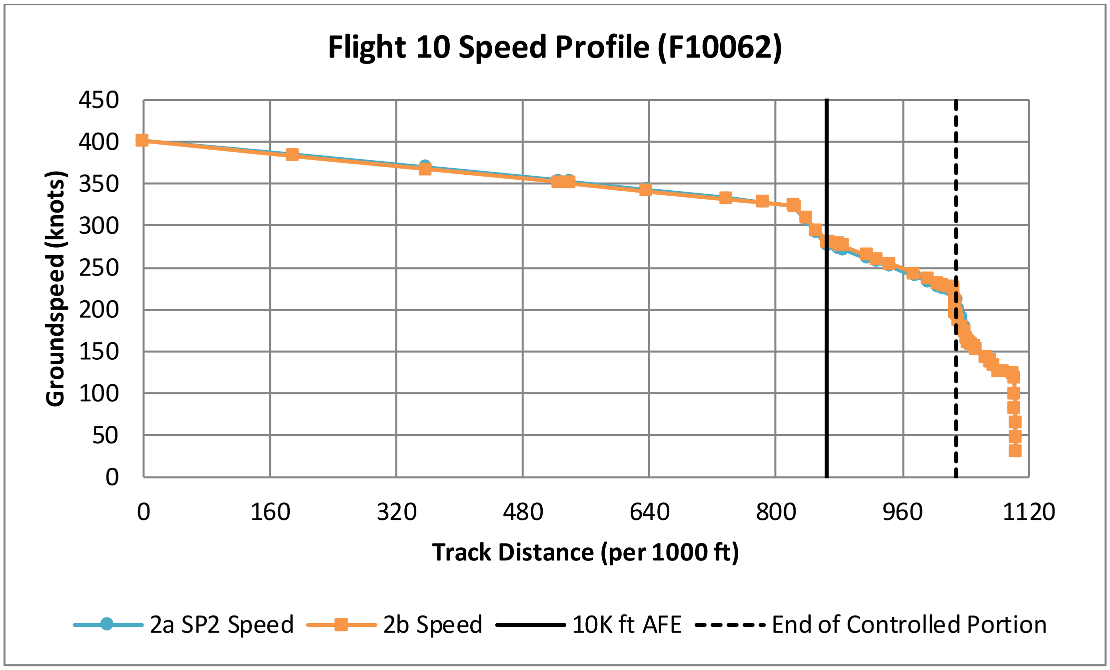


Figure 7-17. Flight 10 Speed Profile

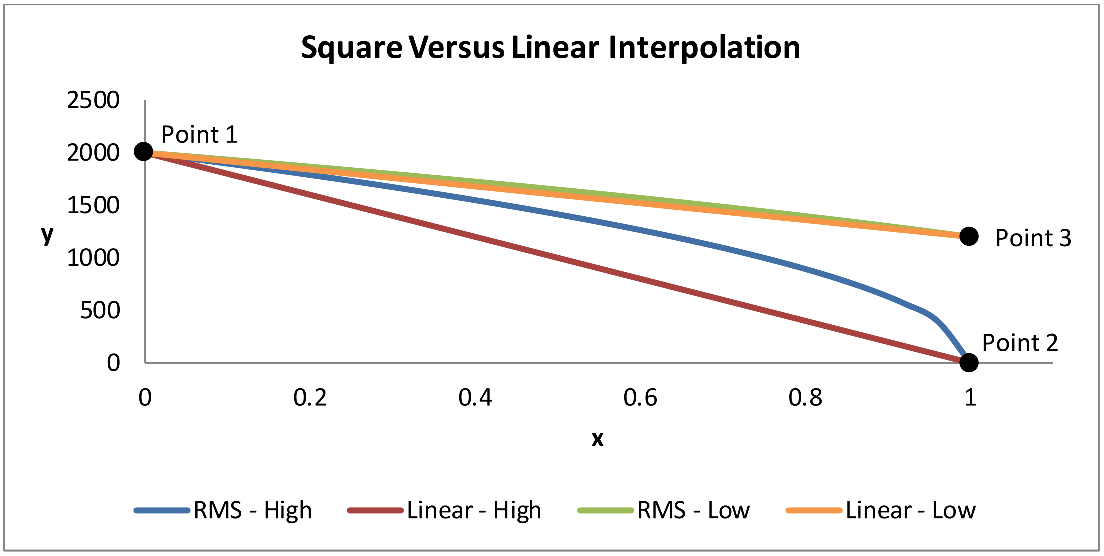


Figure 7-18. Difference between a Square and a Linear Interpolation

The thrust differences between AEDT 2a SP2 and AEDT 2b SP2 are not due to altitude or speed differences but rather the interpolation method used to assign thrust values at uncontrolled track points. AEDT 2a SP2 uses a square interpolation method while AEDT 2b SP2 uses a linear method. The qualitative difference between a linear interpolation and a square interpolation is presented in Figure 7-18. For an example set of computed points, Point 1 = (x_1, y_1) = (0, 2000) and Point 2 = (x2, y2) = (1, 1), the blue line in Figure 7-18 shows the curve formed by a square interpolation of two values that are significantly different in terms of magnitude. For two points whose computed values (y-axis) are closer in magnitude, Point 1 and Point 3 = (x3, y3) = (1, 1200), the curve of the square interpolation is not as pronounced.

Square interpolations produce a curved interpolation shape compared with the straight-line linear interpolation. The bowed shaped of the square curve becomes more noticeable as the magnitude between the computed values (represented by the y-axis in the figure) of the points between which the interpolation occurs increases.

It can be concluded that the higher AEDT 2a SP2 thrust above 10,000 feet AFE (but also below that altitude) is attributable to AEDT 2a SP2 utilizing a square interpolation where AEDT 2b uses a linear interpolation.

7.2.1.2.3.3 Propagation of Differences Originating at Altitudes Below 10,000 ft AFE

The flight performance calculation differences between AEDT 2a SP2 and AEDT 2b SP2 described above for altitudes below 10,000 ft AFE can cause differences at altitudes below 10,000 ft, because they affect the aircraft's position relative to any remaining altitude controls above 10,000 ft AFE.

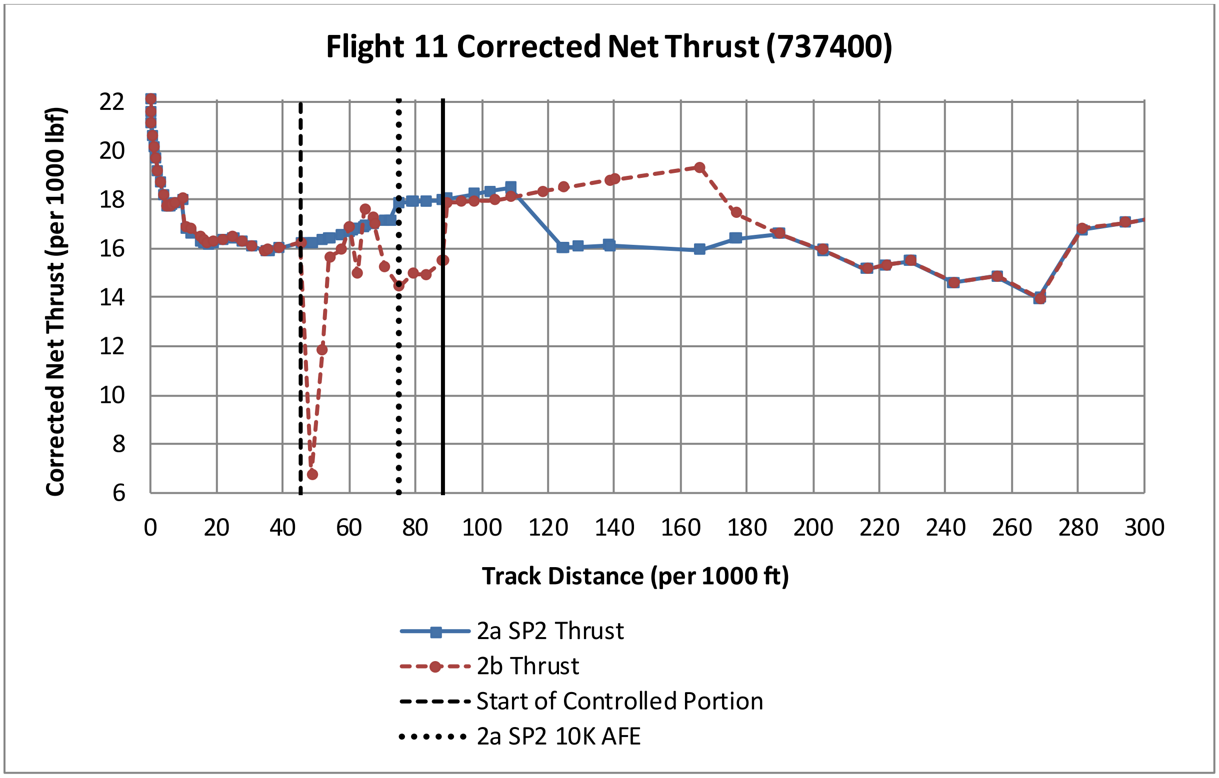


Figure 7-19. Flight 11 Corrected Net Thrust

Flight 11, a departure operation, exhibited higher thrust along a significant portion of its track in AEDT 2b SP2 relative to AEDT 2a SP2. Figure 7-19 shows the thrust plot of Flight 11. In AEDT 2a SP2, Flight 11 reaches an altitude of 10,000 ft AFE much sooner than the AEDT 2b SP2 instance and accelerates from the 10,000 ft AFE ANP CAS to the BADA climb-out CAS much sooner than in AEDT 2b SP2. By the time the AEDT 2a SP2 flight finishes the acceleration (with its corresponding high thrust values), Flight 11 in AEDT 2b SP2 is still in the initial stages. Once the AEDT 2a SP2 flight overcomes its altitude deficit with respect to the altitude control targets and reduces thrust, the AEDT 2b SP2 flight has only just finished accelerating to the speed schedule, and is still climbing at full power to overcome its remaining altitude deficit. Additionally, since the AEDT 2b version of Flight 11 accumulated a greater altitude deficit than the AEDT 2a SP2 instance (on account of the latter's disregard for limitations in aircraft climb capability below 10,000 ft AFE), it spent a longer portion of its flight time overcoming this altitude deviation. The AEDT 2a SP2 instance experiences elevated thrust levels of thrust from about 75,000 to 110,000 feet along its track length (a total of approximately 35,000 feet), while the AEDT 2b undergoes this same condition from about 90,000 to 165,000 feet along the track (a total of approximately 70,000 feet).

7.2.2 Noise Differences

The following subsections present differences in DNL noise values at each of the population receptor set points defined in the study.

Baseline Scenario

Figure 7-20 plots the DNL noise differences between AEDT 2a SP2 and AEDT 2b SP2 for the Baseline scenario. This plot includes only the population points whose DNL noise values equal or exceed 40 dB in AEDT 2b SP2.

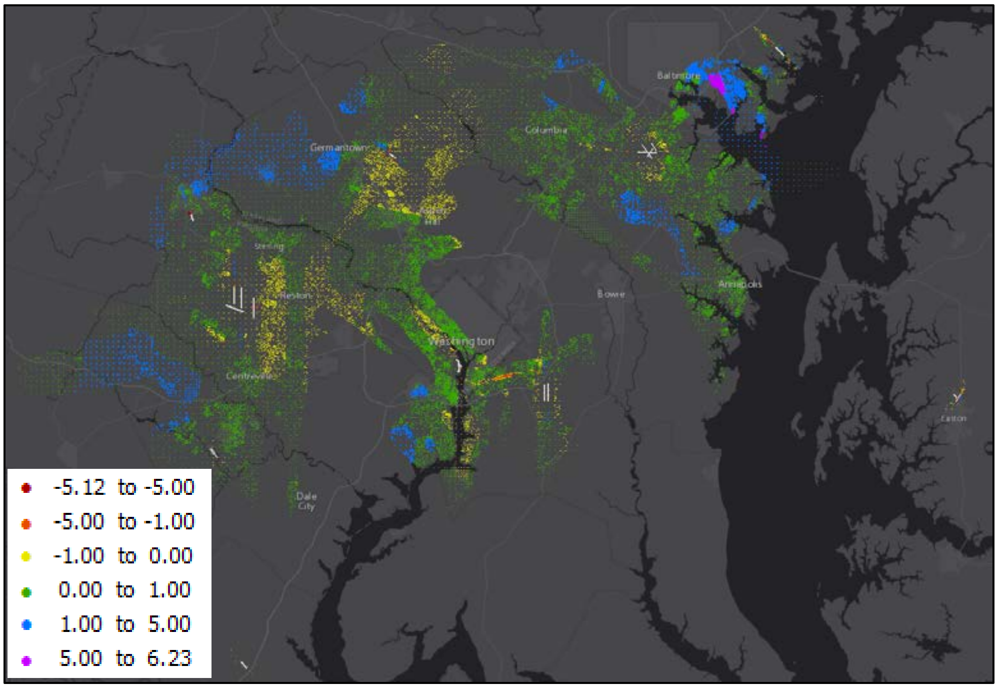


Figure 7-20. Noise Differences between AEDT 2a SP2 and AEDT 2b SP2 for the Baseline Scenario

For the noise comparison tables below, the AEDT 2a SP2 DNL noise values are the baseline for comparison. An increase in noise means that AEDT 2b produces more noise than AEDT 2a SP2 while a decrease in noise means AEDT 2b is producing less noise than AEDT 2a SP2. The change in DNL noise (in dB) observed between AEDT 2b SP2 and AEDT 2a SP2 is described below and summarized in Table 7-6:

- Approximately 83% of population receptor points in the Baseline scenario (whose noise values equaled or exceeded 40 dB) reported an increase in noise in the 2b version of the study compared to the 2a SP2 version while 17% reported a decrease.
- About 88% of the changes were less than 1 dB in magnitude.
- About 99.99% of the changes were less than 5 dB in magnitude.
- The largest decrease for a receptor was 5.12 dB in magnitude.
- The largest increase for a receptor was 6.23 dB in magnitude.

Table 7-6. Noise Changes Observed in the AEDT 2b SP2 Baseline Scenario Compared to AEDT 2a SP2

DNL Change (dB)			Number of Receptors (above 40 dB DNL)	Percent of Total Receptors (above 40 dB DNL)
-5.12	< Δ ⩽	-5	1	0.00
-5	< Δ ⩽	-1	81	0.20
-1	< Δ ⩽	0	6,807	16.91
0	< Δ ⩽	1	28,737	71.37
1	< Δ ⩽	5	4,352	10.81
5	< Δ ⩽	6.23	287	0.71

Proposed Action Scenario

Figure 7-21 plots the DNL noise differences between AEDT 2a SP2 and AEDT 2b SP2 for the Proposed Action scenario. This plot includes only the population points whose DNL noise values equal or exceed 40 dB in AEDT 2b SP2.

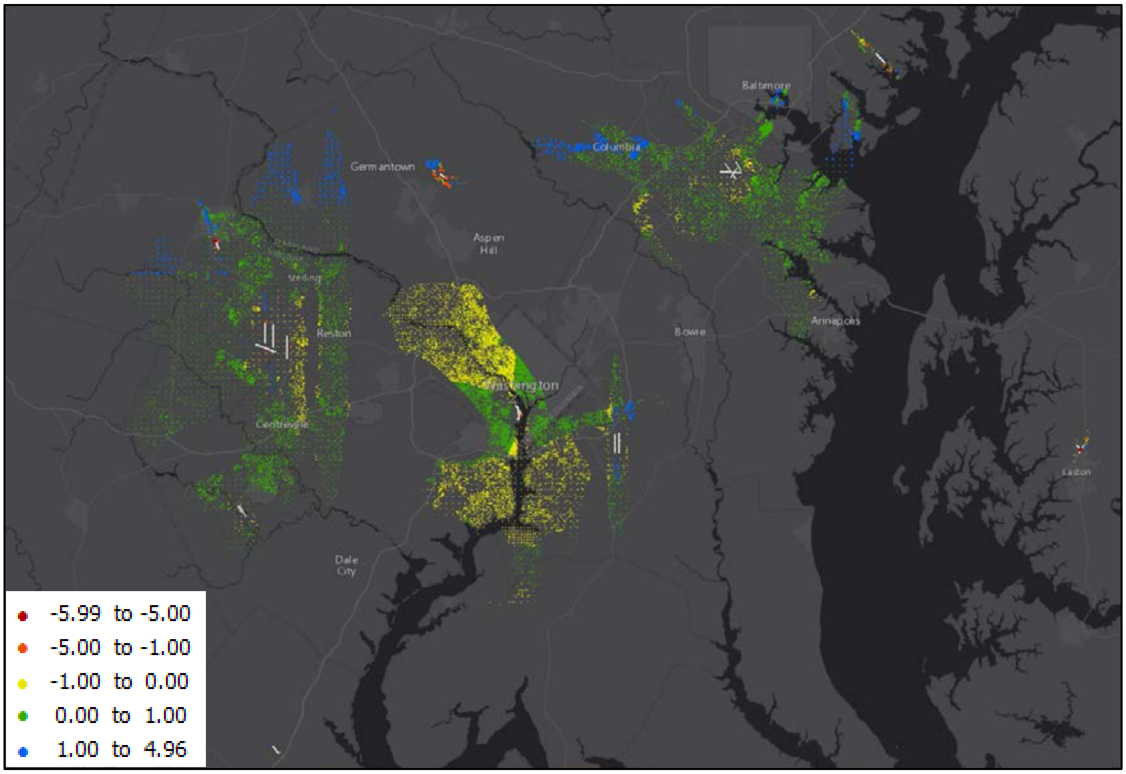


Figure 7-21. Noise Differences between AEDT 2a SP2 and AEDT 2b SP2 for the Proposed Action Scenario

The change in DNL noise (dB) observed between AEDT 2b SP2 and AEDT 2a SP2 is described below and summarized in Table 7:

- Approximately 65% of population receptor points in the Proposed Action scenario (whose noise values equaled or exceeded 40 dB) reported an increase in noise in the 2b version of the study compared to the 2aSP2 version while 35% reported a decrease.
- About 96.9% of the changes were less than 1 dB in magnitude.
- About 99.9% of the changes were less than 5 dB in magnitude.
- The largest decrease for a receptor was 5.99 dB in magnitude.
- The largest increase for a receptor was 4.96 dB in magnitude.

Table 7-7. Noise Changes Observed in AEDT 2b SP2 Proposed Action Scenario Compared to AEDT 2a SP2

DNL Change (dB)			Number of Receptors (above 40 dB DNL)	Percent of Total Receptors (above 40 dB DNL)
-5.99	< Δ ⩽	-5	2	0.01
-5	< Δ ⩽	-1	47	0.18
-1	< Δ ⩽	0	9,033	35.29
0	< Δ ⩽	1	15,776	61.63
1	< Δ ⩽	4.96	742	2.90

7.2.3 Fuel-Burn and CO2 Emissions Results

Significant differences were observed in the amounts of fuel-burn and carbon dioxide produced between the AEDT 2a SP2 and the AEDT 2b SP2 versions of the DC Metroplex study.

Each of the following four tables presents a percentage comparison of AEDT 2a SP2 and AEDT 2b SP2 emissions. Emissions produced in AEDT 2a SP2 are taken as the reference: a positive percentage indicates that AEDT 2b SP2 produced larger amounts of emissions compared with AEDT 2a SP2 while a negative percentage implies the opposite.

Table 7-8. Percentage Differences in Fuel-burn and CO_2 Emissions (Baseline Departures)

Baseline Departures		
Mode	**Fuel (%)**	**CO_2 (%)**
Below 10,000 feet AFE	-6.24	-6.24
Above 10,000 feet AFE	-0.23	-0.23
Full Flight	-1.95	-1.95

Table 7-9. Percentage Differences in Fuel-burn and CO_2 Emissions (Baseline Arrivals)

Baseline Arrivals		
Mode	**Fuel (%)**	**CO_2 (%)**
Above 10,000 feet AFE	174.97	174.97
Below 10,000 feet AFE	4.51	4.51
Full Flight	72.35	72.35

Table 7-10. Percentage Differences in Fuel-burn and CO_2 Emissions (Proposed Action Departures)

Proposed Action Departures		
Mode	**Fuel (%)**	**CO_2 (%)**
Below 10,000 feet AFE	-0.70	-0.70
Above 10,000 feet AFE	-3.90	-3.90
Full Flight	-1.86	-1.86

Table 7-11. Percentage Differences in Fuel-burn and CO_2 Emissions (Proposed Action Arrivals)

Proposed Action Arrivals		
Mode	**Fuel (%)**	**CO_2 (%)**
Above 10,000 feet AFE	224.98	224.98
Below 10,000 feet AFE	5.54	5.54
Full Flight	91.62	91.62

Values for the “Full Flight” modes indicate that AEDT 2b SP2 departures saw a slight reduction in fuel consumption and CO_2 production, but AEDT 2b SP2 arrivals experienced a significant rise in both of these quantities.

Differences in the “Above 10,000 feet AFE” flight mode are due to differences in the fuel-burn models for segments above 10,000 feet AFE.

7.2.3.1 Fuel-Burn Model Above 10,000 Feet AFE

Fuel flow rate calculations are computed on a segment-by-segment basis. When calculating the rate of fuel flow for a particular segment, AEDT 2a SP2 first determines the idle/descent fuel flow rate, which varies by BADA aircraft and engine type.

If the segment is descending at a rate greater than 20 ft/min, the segment fuel flow rate is automatically set to the idle/descent fuel flow rate. If the segment is not descending, then the segment fuel flow rate is computed using thrust specific fuel coefficients. If the segment fuel flow rate is less than the idle/descent fuel flow rate, the fuel flow is capped at the idle/descent value.

AEDT 2b SP2 computes segment fuel flow rates in the same manner as AEDT 2a SP2, except that fuel flow rates for segments which descend at greater than 20 ft/min will not automatically use the idle/descent fuel flow. Fuel flow will be calculated using the thrust specific coefficients and the final segment fuel flow rate will be the greater of the thrust specific fuel flow as compared to the idle/descent fuel flow.

Under typical operating conditions, idle/descent fuel flow rates are substantially lower than fuel flow rates computed using thrust specific coefficients. Therefore, it is expected that flight operation segments that descend at greater than 20 ft/min will produce significantly less thrust in AEDT 2a SP2 as compared with their AEDT 2b SP2 analogs.

7.2.3.2 Fuel-Burn Results Above 10,000 Feet AFE

Examining the fuel burn results from a Boeing 737-700 arrival and an Embraer ERJ145 arrival, we see significantly higher fuel flow rates above 10,000 feet AFE in AEDT 2b SP2. Figures 22 and 23 present the fuel flow rate (per engine) and corrected net thrust for the 737-700. These figures demonstrate that even with identical amounts of thrust, AEDT 2b SP2 produces significantly higher fuel flow due to the changes in the fuel flow algorithm when thrust is similar.

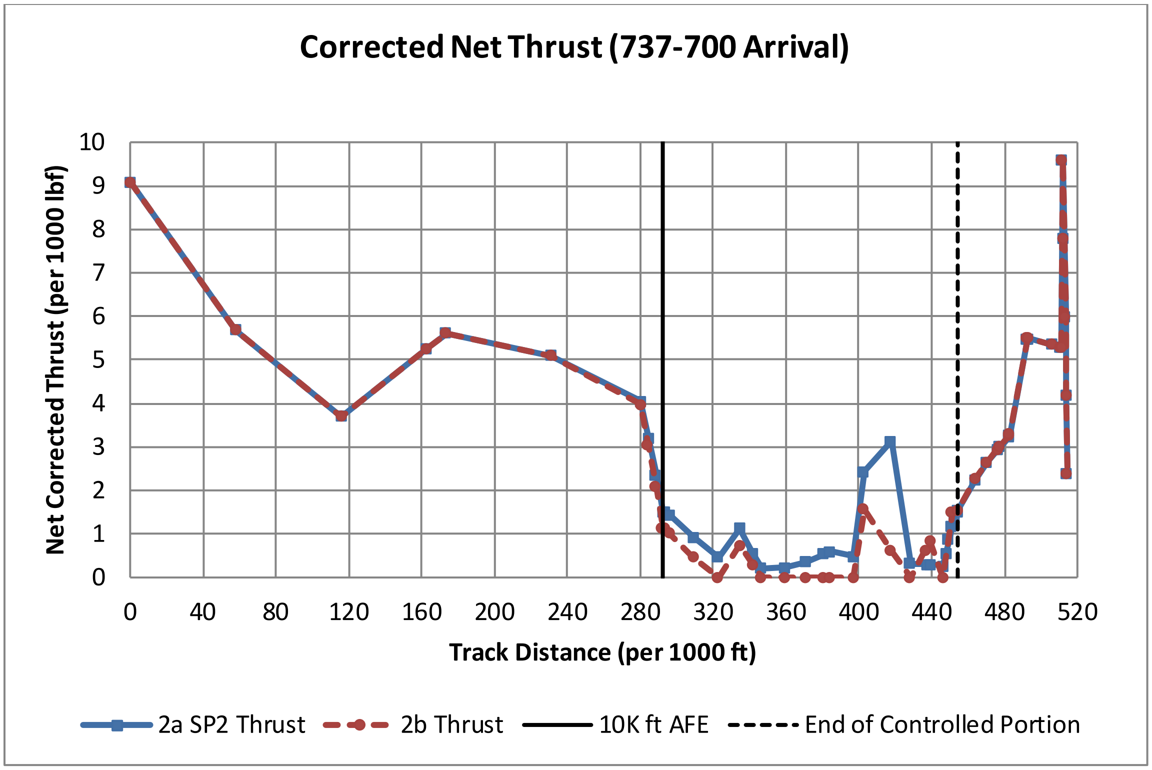


Figure 7-22. Corrected Net Thrust

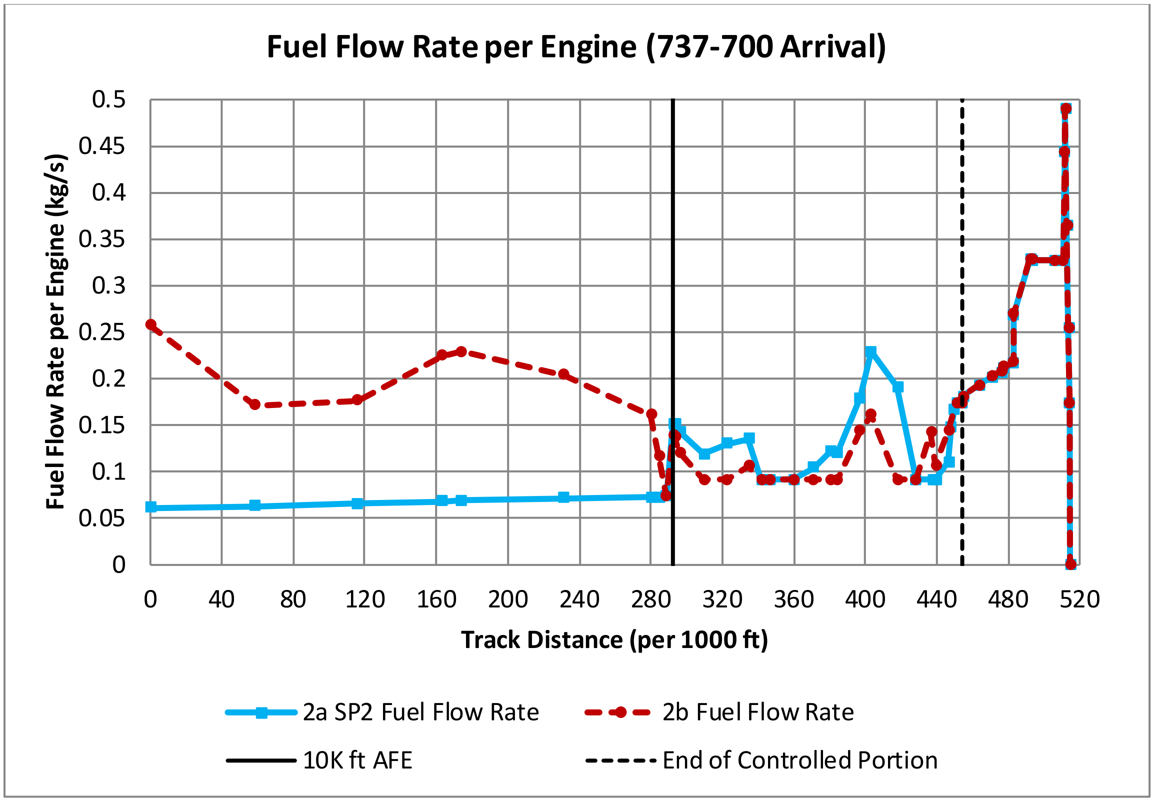


Figure 7-23. Arrival Fuel Flow Rate per Engine

Figure 7-24 and Figure 7-25 present the corrected net thrust and the fuel flow rate (per engine) for the Embraer ERJ145 arrival. These demonstrate that in the high-altitude regime above 10,000 feet AFE, AEDT 2b SP2 produces higher fuel flow rates even when AEDT 2a SP2 produces higher amounts of thrust.

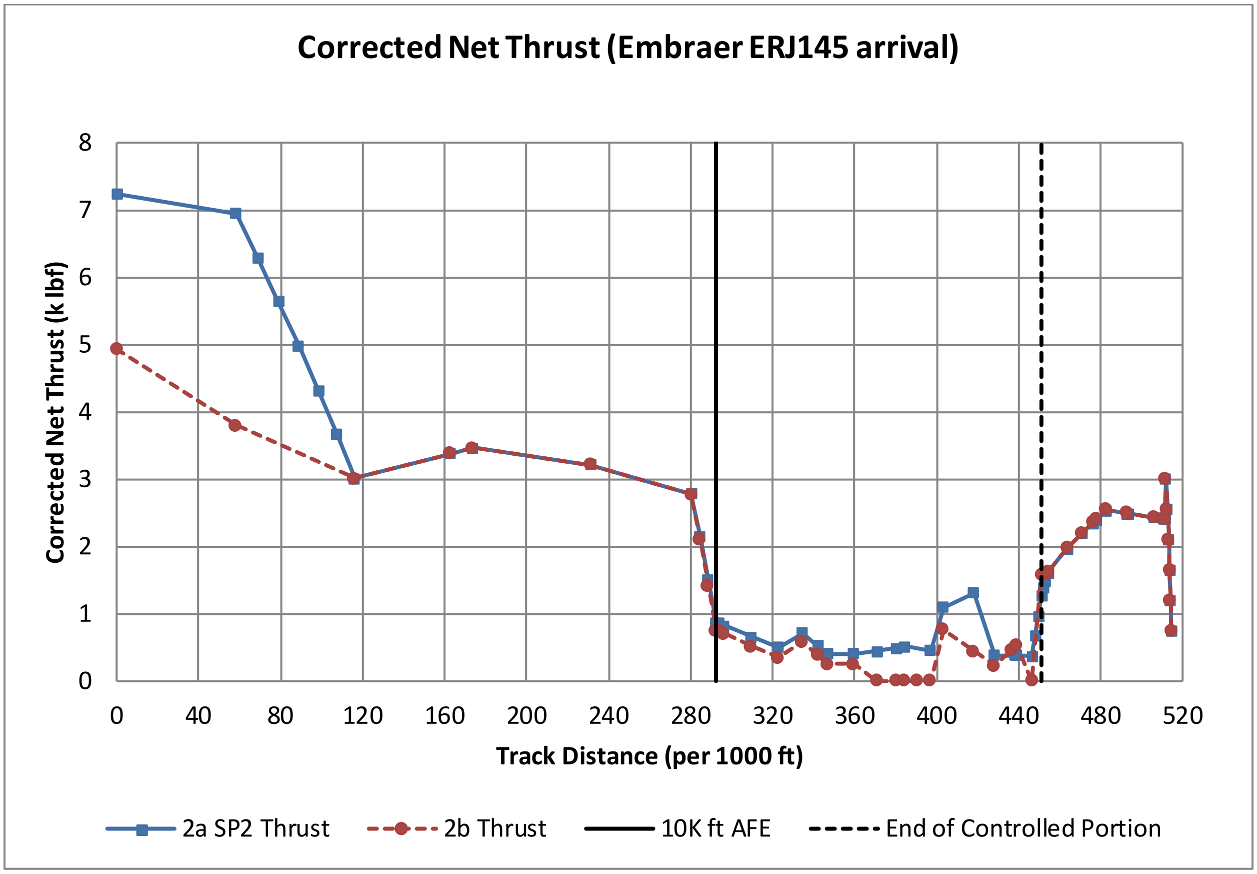


Figure 7-24. Corrected Net Thrust

Throughout the entire flight, fuel flow rates in AEDT 2b SP2 closely track with computed values for thrust. On the other hand, fuel flow rates only track with computed thrust values below 10,000 feet AFE in AEDT 2a SP2. During the controlled portion below 10,000 feet AFE, AEDT 2a SP2 produces higher amounts of thrust for both arrivals, which leads to higher fuel flow rates in that particular flight regime.

These combined results reveal that AEDT 2a SP2 has a built-in stipulation which only serves to lower fuel flow rates for arrivals above 10,000 feet AFE. Since this rule was removed in AEDT 2b SP2, it is expected for arrivals to produce higher amounts of fuel-burn and emissions in AEDT 2b SP2 above 10,000 feet AFE.

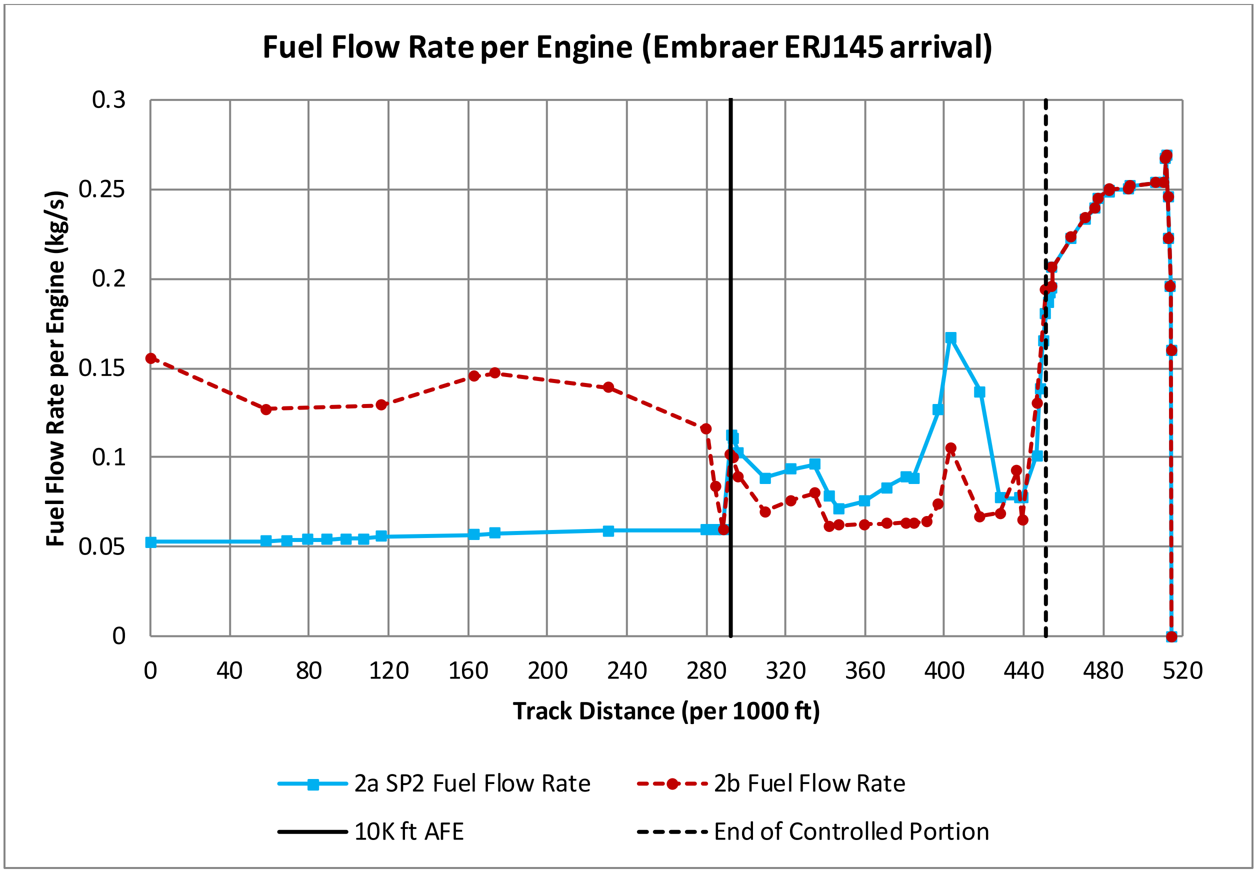


Figure 7-25. Arrival Fuel Flow Rate per Engine

7.2.4 Conclusions

The preceding sections detailed a comparison of a common reference version of the DC Metroplex study in order to assess the ability of AEDT 2b SP2 to produce an analysis based on Use Case E guidelines. The purpose of the comparison was to corroborate the results produced by the AEDT 2b SP2 analysis against those of AEDT 2a SP2.

An analysis of the acoustic results revealed that perceived levels of noise at population point receptors was very similar in both versions of the tool, with the majority of population receptors reporting a decibel or less of a difference between the two versions of the tool. As a whole, a larger number of receptors reported a decrease in noise in AEDT 2b SP2 rather than an increase. There were a few, localized sets of population points that reported non-negligible differences (both decreases and increases in AEDT 2b SP2). An in-depth comparison of aircraft performance was conducted in order to reveal differences that would explain noise differences. This analysis of aircraft performance revealed specific instances of flights whose dissimilar flight performance parameters (i.e., thrust, speed, position) in the two versions of the tool, would contribute to the few, non-negligible differences in noise.

An examination of emissions results pertinent to Use Case E (i.e., fuel-burn and CO_2) showed that most flight modes experienced only slight variances in computed emissions values. Only the “Above 10,000 feet AFE” flight mode experienced a significant difference in emissions.

However, it was concluded that this difference is entirely expected based on aircraft performance improvements introduced into AEDT 2b SP2.

In conclusion, AEDT 2b SP2 is capable of conducting a Use Case E analysis and the results produced from such an analysis are compatible and comparable with the analogous results produced by AEDT 2a SP2.

8 Use Case F – Full Functionality Single Study

8.1 Definition and Purpose

AEDT 2b SP2 has been enhanced from previous versions of AEDT in order to support multiple analysis types, including the ability to run emissions dispersion and the Voluntary Airport Low Emission (VALE) reports. Use Case F is designed to exercise as much AEDT 2b SP2 functionality as possible within a single study. Study KIAD (Dulles International Airport) was designed to utilize all of the available aircraft types, operations, and track definitions in order to generate the full list of available noise, fuel burn and emissions results and their associated reports. As this study does not represent real world operations, and since previous use cases have validated results from AEDT 2b SP2 against AEDT 2a SP2, validation and verification was not performed on study KIAD.

8.2 Study Definition

Study KIAD models airport operations at KIAD for an example day in the month of January. Four distinct January days are modeled through four scenarios. These scenarios vary the amount of airport operations (i.e., light-usage and heavy-usage) for two separate years (2010 and 2015).

8.2.1 Scenarios and Airport Layouts

Study KIAD has a total of four airport layouts: two for each of the analysis years (2010 and 2015) for Dulles International Airport and the nearby Roanoke Regional Airport (KROA). Figure 8-1 shows the 2010 airport layout for KIAD.

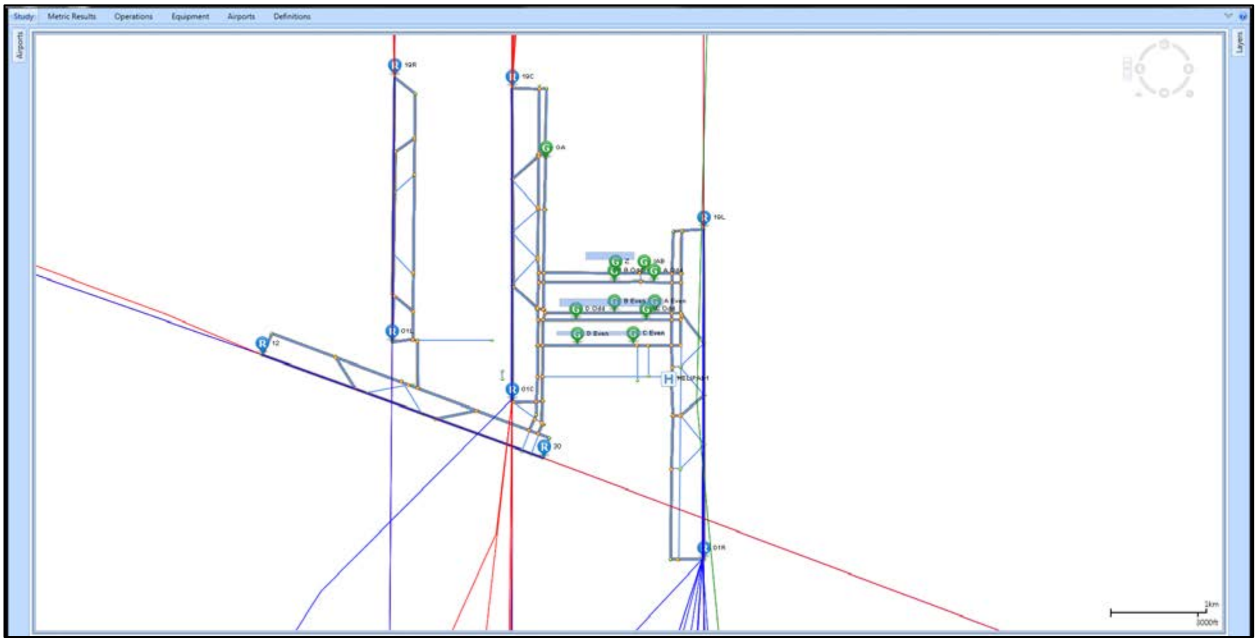


Figure 8-1. KIAD 2010 Airport Layout

Each airport layout has the following characteristics:

- 4 Runways
- 1 Helipad
- 11 Gates
- 44 Taxiways
- 170 Taxipaths
- 5 Airport Configurations
- 10 Activity Profiles (defined as triplets of one each of following three profile types)
    - 2 Monthly Profiles
    - 4 Daily Profiles
    - 10 Quarterly-Hour Profiles
- 43 Airport Layout Tracks
    - 8 Fixed-Wing Departure Tracks
    - 8 Fixed-Wing Arrival Tracks
    - 8 Rotary-Wing Departure Tracks
    - 8 Rotary-Wing Arrival Tracks
    - 10 Touch-and-Go Tracks
    - 1 Heli-Taxi Track
- 3 Stationary Sources
- 8 Parking Facilities
- 3 Buildings

8.2.2 User-Defined Fleet Data

Study KIAD contains the following user defined data:

- 8 APUs composed of user defined default durations as well as user defined emissions values for each APU
- 1 jet aircraft airframe
- 1 jet engine
- 4 GSEs which are composed of user defined default usage and emissions values

8.2.3 Cases/Airport Operations

Airport operations are grouped into seven cases. Each case is utilized across all scenarios (except non-aircraft sources, which do not contribute to noise results) and contains a different set of operations which are described in the following sections.

8.2.3.1 Non-Aircraft Ground Operations

The non-aircraft ground operations case contains operations for stationary sources and ground support equipment. The total number of operations from non-aircraft sources is specified through either an explicit number of operations (annual ops) or through a peak quarter hour (PQH) value which interacts with the operation's activity profile triplet to specify a total number of operations. Table 8-1 shows the PQH operation breakdown for the stationary sources.

Table 8-1. Stationary Sources

Scenario-Year Peak Quarter-Hour Ops	Natural Gas Boiler 1	Natural Gas Boiler 2	Diesel Generator
Light-Usage 2010	0.29	0.31	0.100
Heavy-Usage 2010	0.30	0.32	0.120
Light-Usage 2015	0.28	0.32	0.096
Heavy-Usage 2015	0.29	0.33	0.110

Table 8-2 shows the operational breakdown of the ground support equipment.

Table 8-2. Ground Support Equipment

Scenario-Year	Diesel Air Conditioner	Gasoline Aircraft Tractor	Diesel Lavatory Truck
Light-Usage 2010	3.00	2.00	0.050
Heavy-Usage 2010	3.00	2.00	0.055
Light-Usage 2015	3.30	2.20	0.045
Heavy-Usage 2015	3.32	2.21	0.052

8.2.3.2 Terminal-Area Track Operations

The operation counts for each of the terminal-area track operation cases are displayed by operation type (Table 8-3) and aircraft type (

Table 8-4).

Table 8-3. Operation Counts for Terminal Area Cases by Operation Type

Scenario-Year	Arrivals	Departures
Light-Usage 2010	342	344
Heavy-Usage 2010	506	486
Light-Usage 2015	325	281
Heavy-Usage 2015	469	489

Table 8-4. Operation Counts for Terminal Area Cases by Aircraft Type

Scenario-Year	Jets	Turbo-props	Pistons	Helicopters
Light-Usage 2010	613	69	4	0

Scenario-Year	Jets	Turbo-props	Pistons	Helicopters
Heavy-Usage 2010	865	105	20	2
Light-Usage 2015	544	50	12	0
Heavy-Usage 2015	819	107	29	3

8.2.3.3 Sensor Path Operations

The Sensor Path case contains six sensor path operations consisting of one set of jet, turbo-prop, and piston airplane operations. Each set has a runway to runway operation departing from KIAD and arriving at KROA and one departing from KROA and arriving at KIAD.

8.2.3.4 Terminal-Area Altitude-Controlled Track Operations

The Altitude-Controlled case contains 46 airplane operations (18 jets, nine turbo-props, and 19 pistons) exercising tracks containing "At" and "At-or-Below" altitude controls. There are 31 arrival and 15 departure operations.

8.2.3.5 Activity Profile Terminal-Area Track Operations

The Activity Profile Terminal-Area Track case contains 10 operations: Six jet airplane operations (3 arrivals, 3 departures), two piston airplane operations (1 arrival, 1 departure), and two helicopter operations (one arrival, one departure).

8.2.3.6 Non-Arrival/Departure Track Operations

The "special" track operations case contains 11 operations. These consist of a touch and go, circuit, and overflight operation for each of the three airplane types (jet, turbo-prop, and piston). There are two helicopter Heli-taxi operations (one wheeled and one non-wheeled).

8.2.3.7 Aircraft Runup Operations

The runup operation case contains three runup operations (one jet, one turbo-prop, and one piston aircraft).

8.2.4 Grid Definitions

The following grids are defined in study KIAD:

Cartesian Individual Receptor Set

- 5 Individual Receptors (Site_C, Site_K, Site_M, Site_X, Stonehouse)

Cartesian Network Grid Receptor Set

- 50x50 Grid (2,500 Total Receptors)
- Lower Left Corner Location (Latitude, Longitude, Altitude): (-77.645148, 38.802233, 95.4024 m)
- X-spacing: 0.4 Nautical Miles
- Y-spacing: 0.4 Nautical Miles

Population Receptor Set

- 4,094 Total Receptors
- 566,799 Total Population

Dynamic Grid Receptor Set

- Defined around KIAD
- Lower Left Corner Location (Latitude, Longitude, Altitude): (-77.507122, 38.916720, 0 m)
- X-spacing: 0.5 Nautical Miles
- Y-spacing: 0.5 Nautical Miles

8.2.5 Additional Input Data

8.2.5.1 Terrain

A set of three Grid-Float 1/3 arc-second terrain files totaling 1.3 GB provide terrain coverage for acoustics results produced by the study.

8.2.5.2 Surface and Upper Air (EDMS) Weather

Surface Weather

- Obtained from the National Oceanic and Atmospheric Administration (NOAA) Integrated Surface Database (ISD) at: https://www.ncdc.noaa.gov/isd
- Weather coverage for the 2009, 2010, 2011, 2014, 2015, and 2016.

Upper Air Weather

- Obtained from the NOAA/ Earth Systems Research Laboratory (ESRL) Radiosonde Database at: http://esrl.noaa.gov/raobs/
- Hourly-weather coverage for all of 2010 and 2015 as well as 12/31/2009, 1/1/2011, 12/31/2014, and 1/1/16.

8.2.5.3 Census data

2010 Census data for the Washington, DC, area was obtained from the US 2010 Census data web page at: http://www.census.gov/2010census/data/.

8.3 Results

The following section outlines the metric result definitions of the results required to satisfy the Use Case F requirements. Sample graphics, tables and reports, where applicable, are included for each type of result. Terrain and weather data were utilized as applicable.

8.3.1 Noise

8.3.1.1 System Noise Metrics

Metric results exercising all 17 system noise metrics (DNL, CNEL, LAEQ, LAEQN, LAEQD, SEL, LAMAX, TALA, NEF, WECPNL, EPNL, PNLTM, TAPNL, CEXP, LCMAX, TALC, CDNL) were run for both the light and heavy usage scenarios for the 2010 and 2015 analysis years. Sample noise contours and noise reports for select noise metrics are shown in Figure 8-2 through Figure 8-5.

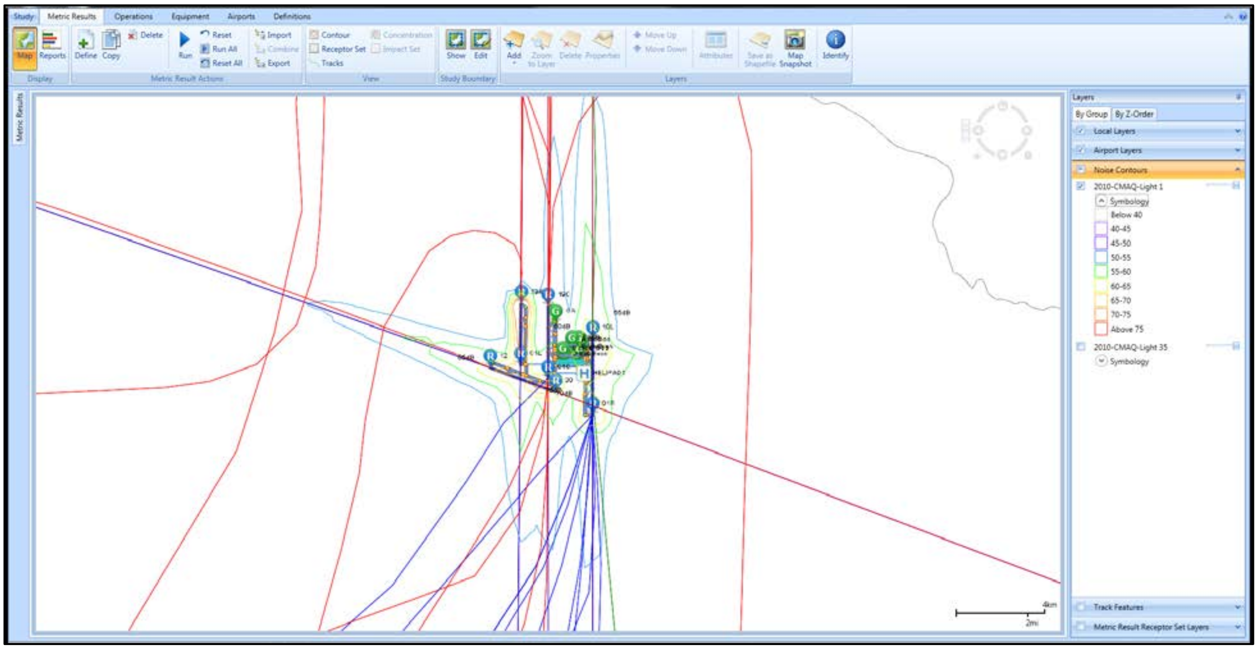
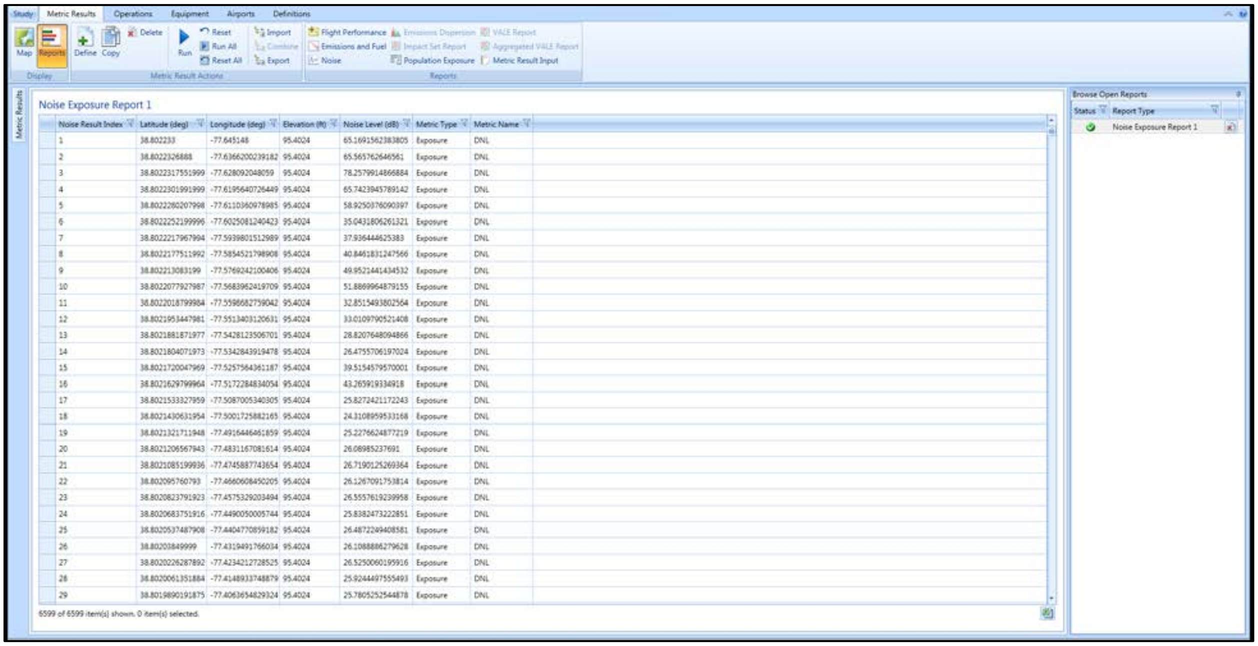


Figure 8-2. DNL Noise Contours – 2010 Light-usage Scenario



Noise Exposure Report 1

Noise Result Index	Latitude (deg)	Longitude (deg)	Elevation (ft)	Noise Level (dB)	Metric Type	Metric Name
1	38.802233	-77.645148	95.4024	65.1691562383805	Exposure	DNL
2	38.8022326888	-77.6366200239182	95.4024	65.565762646561	Exposure	DNL
3	38.8022317551999	-77.628092048059	95.4024	78.2579914866884	Exposure	DNL
4	38.8022301991999	-77.6195640726449	95.4024	65.7423945789142	Exposure	DNL
5	38.8022280207998	-77.6110360978985	95.4024	58.9250376090397	Exposure	DNL
6	38.8022252199996	-77.6025081240423	95.4024	35.0431806261321	Exposure	DNL
7	38.8022217967994	-77.5939801512989	95.4024	37.936444625383	Exposure	DNL
8	38.8022177511992	-77.5854521798908	95.4024	40.8461831247566	Exposure	DNL
9	38.802213083199	-77.5769242100406	95.4024	49.9521441434532	Exposure	DNL
10	38.8022077927987	-77.5683962419709	95.4024	51.8869964879155	Exposure	DNL
11	38.8022018799984	-77.5598682759042	95.4024	32.8515493802564	Exposure	DNL
12	38.8021953447981	-77.5513403120631	95.4024	33.0109790521408	Exposure	DNL
13	38.8021881871977	-77.5428123506701	95.4024	28.8207648094866	Exposure	DNL
14	38.8021804071973	-77.5342843919478	95.4024	26.4755706197024	Exposure	DNL
15	38.8021720047969	-77.5257564361187	95.4024	39.5154579570001	Exposure	DNL
16	38.8021629799964	-77.5172284834054	95.4024	43.265919334918	Exposure	DNL
17	38.8021533327959	-77.5087005340305	95.4024	25.8272421172243	Exposure	DNL
18	38.8021430631954	-77.5001725882165	95.4024	24.3108959533168	Exposure	DNL
19	38.8021321711948	-77.4916446461859	95.4024	25.2276624877219	Exposure	DNL
20	38.8021206567943	-77.4831167081614	95.4024	26.08985237691	Exposure	DNL
21	38.8021085199936	-77.4745887743654	95.4024	26.7190125269364	Exposure	DNL
22	38.802095760793	-77.4660608450205	95.4024	26.1267091753814	Exposure	DNL
23	38.8020823791923	-77.4575329203494	95.4024	26.5557619239958	Exposure	DNL
24	38.8020683751916	-77.4490050005744	95.4024	25.8382473222851	Exposure	DNL
25	38.8020537487908	-77.4404770859182	95.4024	26.4872249408581	Exposure	DNL
26	38.80203849999	-77.4319491766034	95.4024	26.1088886279628	Exposure	DNL
27	38.8020226287892	-77.4234212728525	95.4024	26.5250060195916	Exposure	DNL
28	38.8020061351884	-77.4148933748879	95.4024	25.9244497555493	Exposure	DNL
29	38.8019890191875	-77.4063654829324	95.4024	25.7805252544878	Exposure	DNL

6599 of 6599 item(s) shown. 0 item(s) selected.

Figure 8-3. DNL Noise Report – 2010 Light-usage Scenario

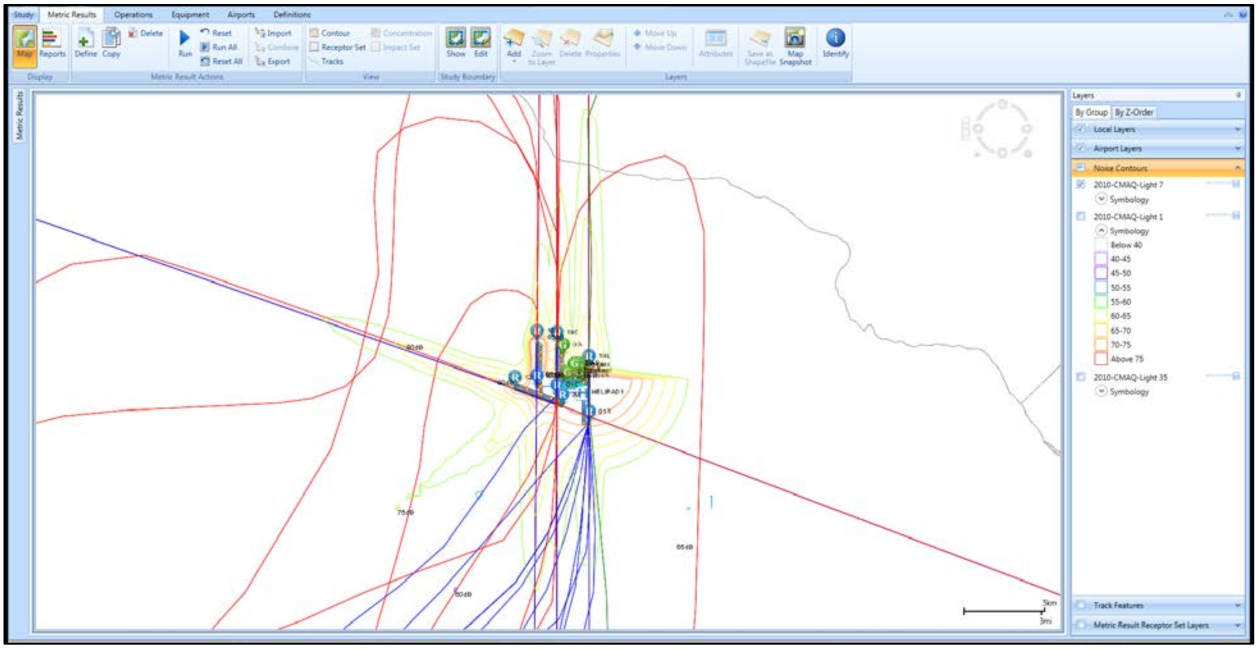


Figure 8-4. LAMAX Noise Contours – 2010 Light-usage Scenario

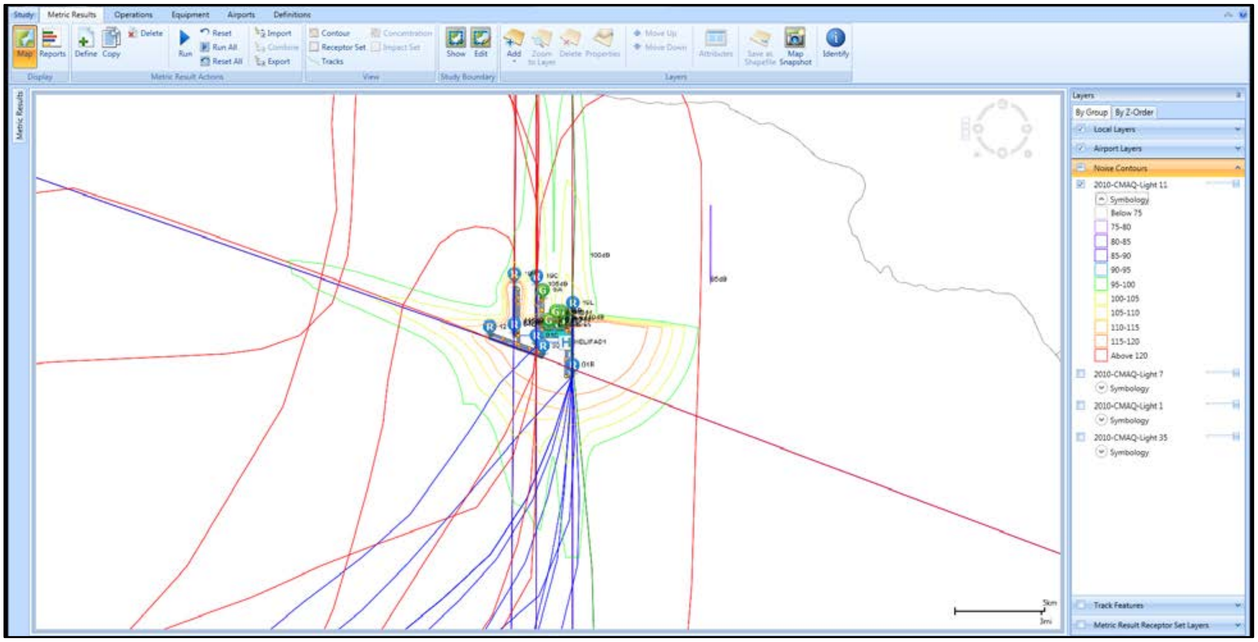


Figure 8-5. EPNL Noise Contours – 2010 Light-usage Scenario

8.3.1.2 Noise Impact Set

An impact set is used to show changes between two DNL metric results with different annualization values. Study KIAD contains two metric results for the 2010 light usage scenario whose annualization scale factors differ (Baseline = 2, Alternative = 1). Figure 8-6 and Figure 8-7 show the Impact Set and Impact Set Report for these metric results.

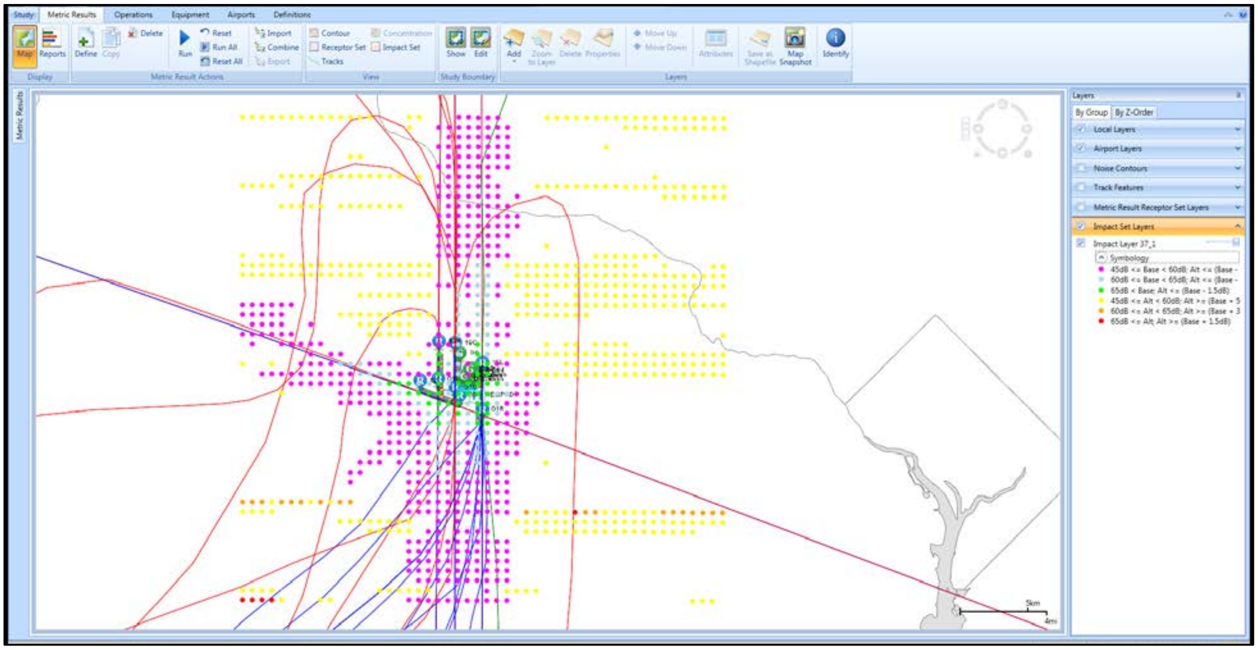
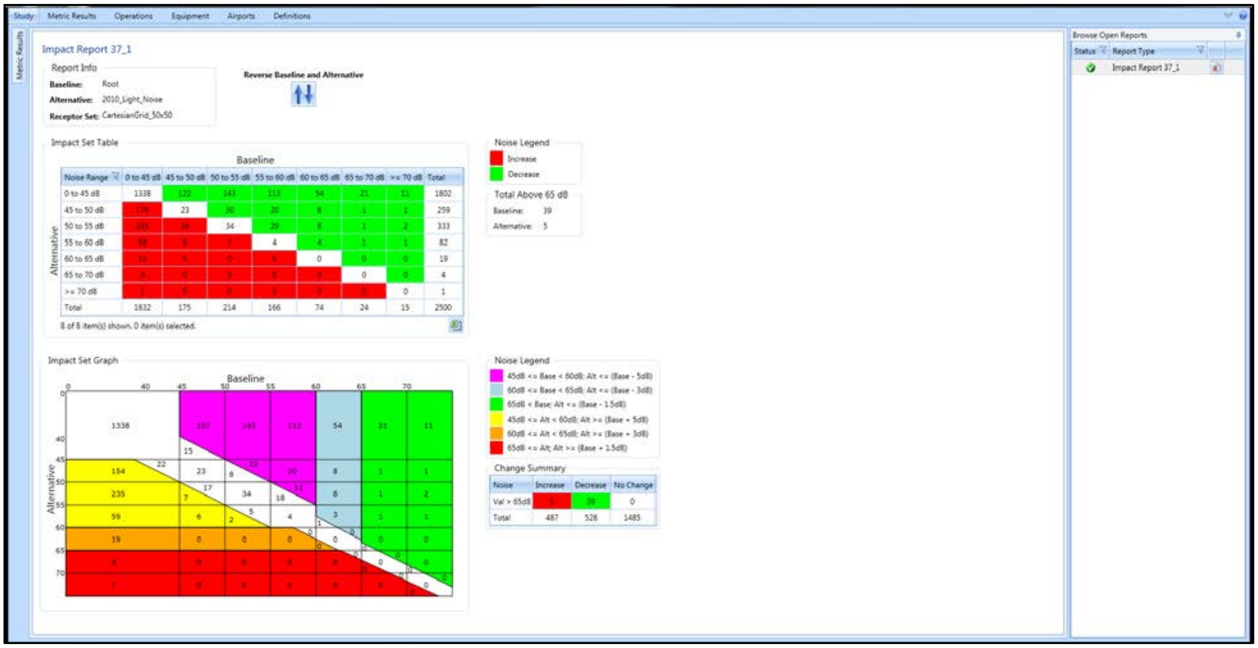


Figure 8-6. DNL Impact Set



Impact Report 37_1

Report Info

Baseline: Root
Alternative: 2010_Light_Noise
Receptor Set: CartesianGrid_50x50

Impact Set Table

Noise Range	0 to 45 dB	45 to 50 dB	50 to 55 dB	55 to 60 dB	60 to 65 dB	65 to 70 dB	>= 70 dB	Total
0 to 45 dB	1338	122	143	113	54	21	11	1802
45 to 50 dB	176	23	30	20	8	1	1	259
50 to 55 dB	235	24	34	29	8	1	2	333
55 to 60 dB	59	6	7	4	4	1	1	82
60 to 65 dB	19	0	0	0	0	0	0	19
65 to 70 dB	4	0	0	0	0	0	0	4
>= 70 dB	1	0	0	0	0	0	0	1
Total	1832	175	214	166	74	24	15	2500

8 of 8 item(s) shown. 0 item(s) selected.

Noise Legend
- 🟥 Increase
- 🟩 Decrease

Total Above 65 dB
Baseline: 39
Alternative: 5

Noise Legend
- 🟪 45dB <= Base < 60dB; Alt <= (Base - 5dB)
- ■ 60dB <= Base < 65dB; Alt <= (Base - 3dB)
- 🟩 65dB < Base; Alt <= (Base - 1.5dB)
- 🟨 45dB <= Alt < 60dB; Alt >= (Base + 5dB)
- 🟧 60dB <= Alt < 65dB; Alt >= (Base + 3dB)
- 🟥 65dB <= Alt; Alt >= (Base + 1.5dB)

Change Summary

Noise	Increase	Decrease	No Change
Val > 65dB	1	39	0
Total	487	528	1485

Figure 8-7. DNL Impact Set Report

8.3.1.3 Population Noise

Census data for Washington Dulles was exercised in conjunction with a Cartesian grid receptor set (required to generate a Population Exposure Report) in order to show the number of people affected by the specified noise levels. Figure 8-8 shows the Receptor Set layer for this metric result. Figure 8-9 shows the Population Exposure Report.

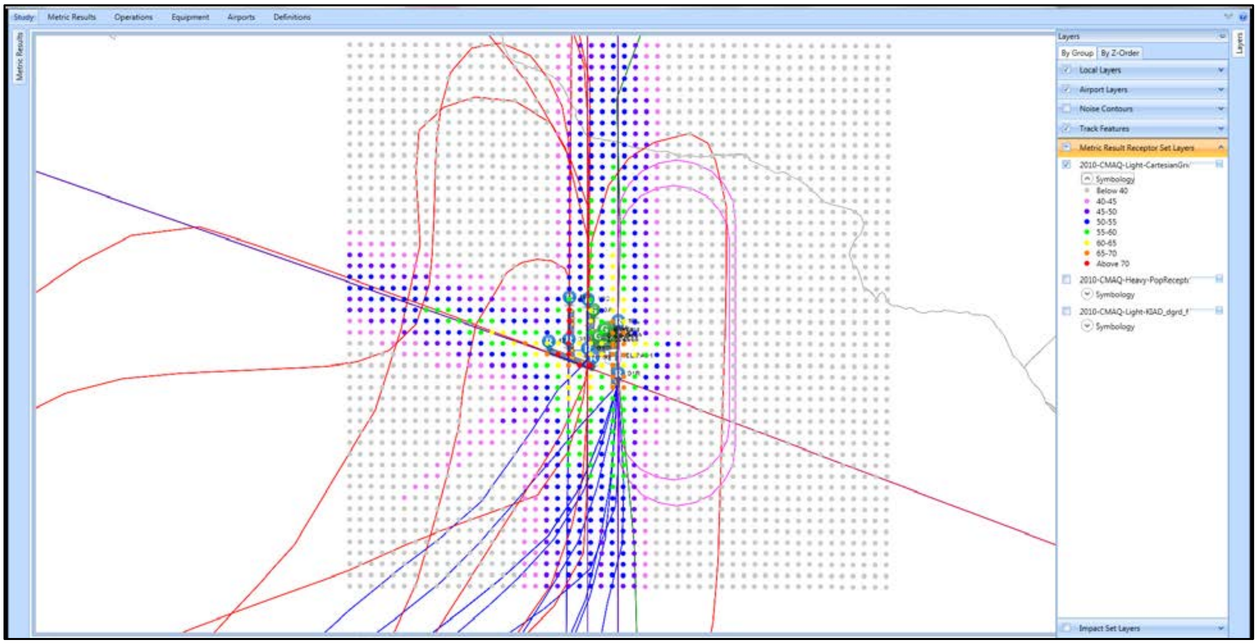
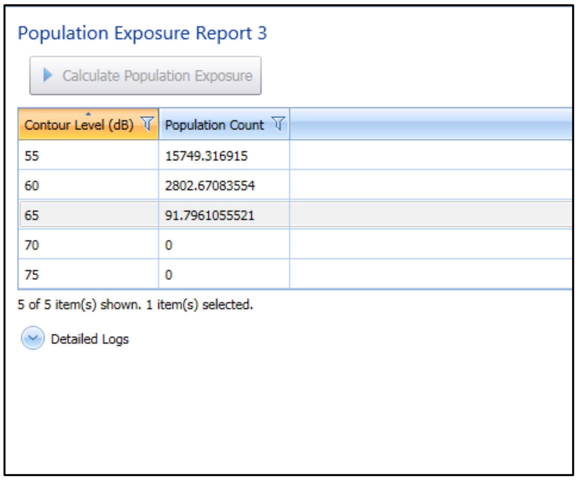


Figure 8-8. Grid Receptor Set – 2010 Light-usage Scenario



Contour Level (dB)	Population Count
55	15749.316915
60	2802.67083554
65	91.7961055521
70	0
75	0

5 of 5 item(s) shown. 1 item(s) selected.

Figure 8-9. Population Exposure Report – 2010 Light-usage Scenario

8.3.1.4 Dynamic Grid Results

Study KIAD contains a DNL metric result that utilizes a dynamic grid. Dynamic grid functionality improves run time by generating only the receptor points necessary to process the contour levels as defined in the study settings. Figure 8-10 shows the dynamic grid contour output.

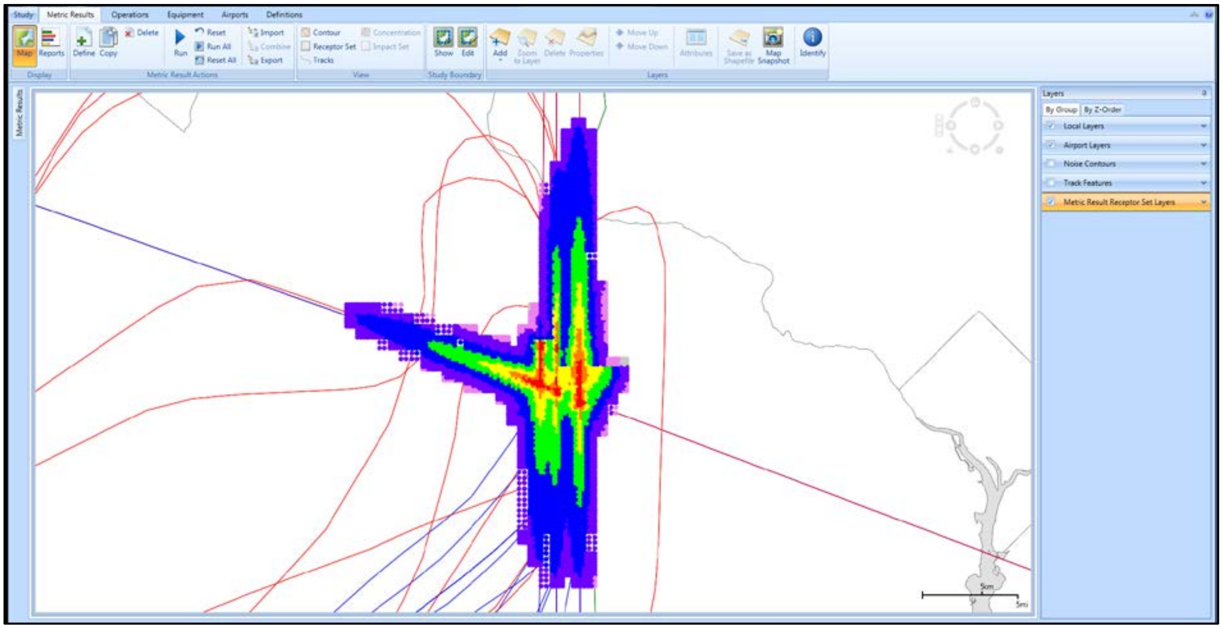
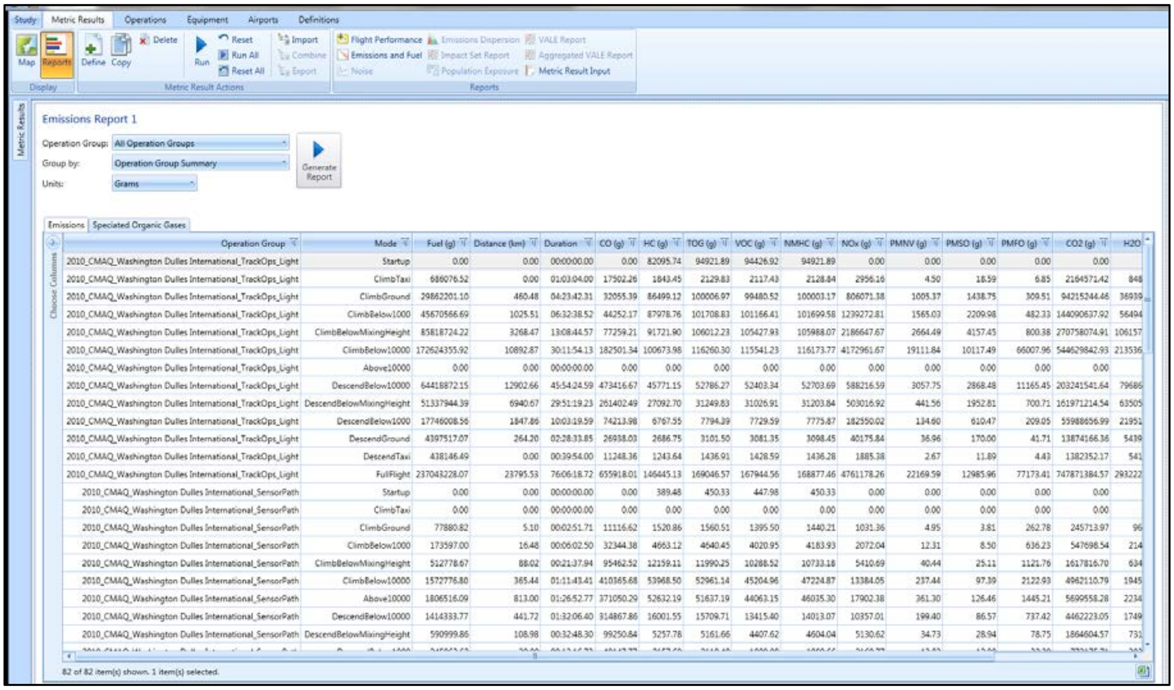


Figure 8-10. DNL Dynamic Grid Noise Contours

8.3.2 Fuel Consumption and Emissions Inventory

Emissions metric results were created for both the 2010 and 2015 analysis years for each scenario, light-usage and heavy-usage.

Figure 8-11 shows the fuel burn and emissions results for the 2010 light-usage analysis year, summarized by operation group. Results for speciated organic gases are shown in Figure 8-12.



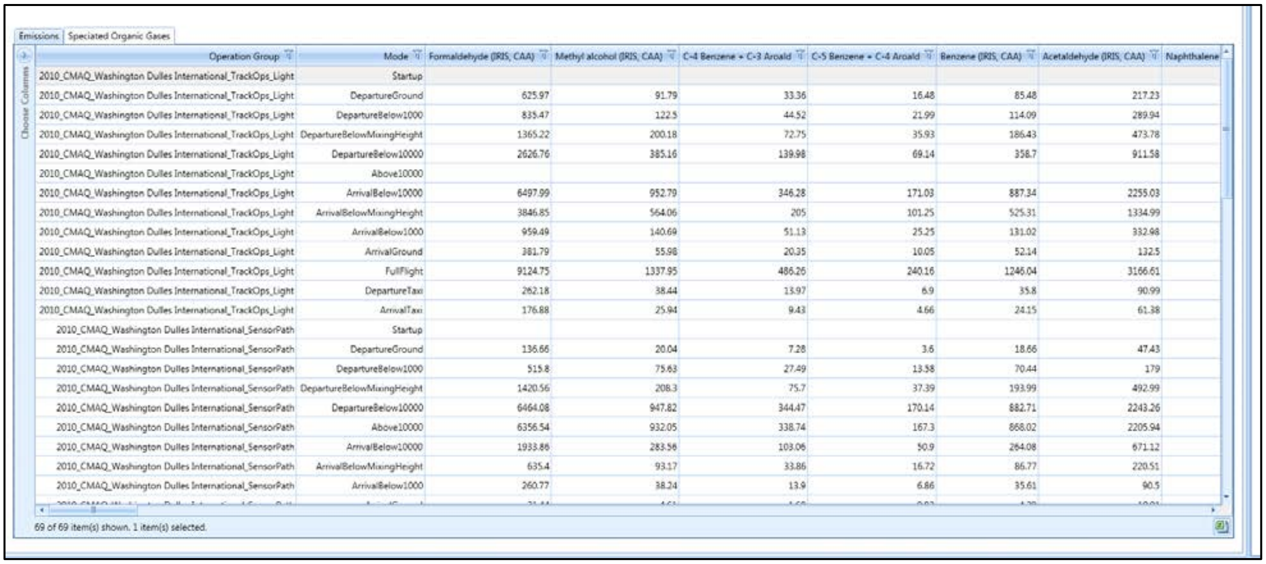
Emissions Report 1

Operation Group: All Operation Groups
Group by: Operation Group Summary
Units: Grams

Operation Group	Mode	Fuel (g)	Distance (km)	Duration	CO (g)	HC (g)	TOG (g)	VOC (g)	NMHC (g)	NOx (g)	PMNV (g)	PMSO (g)	PMFO (g)	CO2 (g)	H2O
2010_CMAQ_Washington Dulles International_TrackOps_Light	Startup	0.00	0.00	00:00:00.00	0.00	82095.74	94921.89	94426.92	94921.89	0.00	0.00	0.00	0.00	0.00	
2010_CMAQ_Washington Dulles International_TrackOps_Light	ClimbTaxi	686076.52	0.00	01:03:04.00	17502.26	1843.45	2129.83	2117.43	2128.84	2956.16	4.50	18.59	6.85	2164571.42	848
2010_CMAQ_Washington Dulles International_TrackOps_Light	ClimbGround	29862201.10	460.48	04:23:42.31	32055.39	86499.12	100006.97	99480.52	100003.17	806071.38	1005.37	1438.75	309.51	94215244.46	36939
2010_CMAQ_Washington Dulles International_TrackOps_Light	ClimbBelow1000	45670566.69	1025.51	06:32:38.52	44252.17	87978.76	101708.83	101166.41	101699.58	1239272.81	1565.03	2209.98	482.33	144090637.92	56494
2010_CMAQ_Washington Dulles International_TrackOps_Light	ClimbBelowMixingHeight	85818724.22	3268.47	13:08:44.57	77259.21	91721.90	106012.23	105427.93	105988.07	2186647.67	2664.49	4157.45	800.38	270758074.91	106157
2010_CMAQ_Washington Dulles International_TrackOps_Light	ClimbBelow10000	172624355.92	10892.87	30:11:54.13	182501.34	100673.98	116260.30	115541.23	116173.77	4172961.67	19111.84	10117.49	66007.96	544629842.93	213536
2010_CMAQ_Washington Dulles International_TrackOps_Light	Above10000	0.00	0.00	00:00:00.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
2010_CMAQ_Washington Dulles International_TrackOps_Light	DescendBelow10000	64418872.15	12902.66	45:54:24.59	473416.67	45771.15	52786.27	52403.34	52703.69	588216.59	3057.75	2868.48	11165.45	203241541.64	79686
2010_CMAQ_Washington Dulles International_TrackOps_Light	DescendBelowMixingHeight	51337944.39	6940.67	29:51:19.23	261402.49	27092.70	31249.83	31026.91	31203.84	503016.92	441.56	1952.81	700.71	161971214.54	63505
2010_CMAQ_Washington Dulles International_TrackOps_Light	DescendBelow1000	17746008.56	1847.86	10:03:19.59	74213.98	6767.55	7794.39	7729.59	7775.87	182550.02	134.60	610.47	209.05	55988656.99	21951
2010_CMAQ_Washington Dulles International_TrackOps_Light	DescendGround	4397517.07	264.20	02:28:33.85	26938.03	2686.75	3101.50	3081.35	3098.45	40175.84	36.96	170.00	41.71	13874166.36	5439
2010_CMAQ_Washington Dulles International_TrackOps_Light	DescendTaxi	438146.49	0.00	00:39:54.00	11248.36	1243.64	1436.91	1428.59	1436.28	1885.38	2.67	11.89	4.43	1382352.17	541
2010_CMAQ_Washington Dulles International_TrackOps_Light	FullFlight	237043228.07	23795.53	76:06:18.72	655918.01	146445.13	169046.57	167944.56	168877.46	4761178.26	22169.59	12985.96	77173.41	747871384.57	293222
2010_CMAQ_Washington Dulles International_SensorPath	Startup	0.00	0.00	00:00:00.00	0.00	389.48	450.33	447.98	450.33	0.00	0.00	0.00	0.00	0.00	
2010_CMAQ_Washington Dulles International_SensorPath	ClimbTaxi	0.00	0.00	00:00:00.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
2010_CMAQ_Washington Dulles International_SensorPath	ClimbGround	77880.82	5.10	00:02:51.71	11116.62	1520.86	1560.51	1395.50	1440.21	1031.36	4.95	3.81	262.78	245713.97	96
2010_CMAQ_Washington Dulles International_SensorPath	ClimbBelow1000	173597.00	16.48	00:06:02.50	32344.38	4663.12	4640.45	4020.95	4183.93	2072.04	12.31	8.50	636.23	547698.54	214
2010_CMAQ_Washington Dulles International_SensorPath	ClimbBelowMixingHeight	512778.67	88.02	00:21:37.94	95462.52	12159.11	11990.25	10288.52	10733.18	5410.69	40.44	25.11	1121.76	1617816.70	634
2010_CMAQ_Washington Dulles International_SensorPath	ClimbBelow10000	1572776.80	365.44	01:11:43.41	410365.68	53968.50	52961.14	45204.96	47224.87	13384.05	237.44	97.39	2122.93	4962110.79	1945
2010_CMAQ_Washington Dulles International_SensorPath	Above10000	1806516.09	813.00	01:26:52.77	371050.29	52632.19	51637.19	44063.15	46035.30	17902.38	361.30	126.46	1445.21	5699558.28	2234
2010_CMAQ_Washington Dulles International_SensorPath	DescendBelow10000	1414333.77	441.72	01:32:06.40	314867.86	16001.55	15709.71	13415.40	14013.07	10357.01	199.40	86.57	737.42	4462223.05	1749
2010_CMAQ_Washington Dulles International_SensorPath	DescendBelowMixingHeight	590999.86	108.98	00:32:48.30	99250.84	5257.78	5161.66	4407.62	4604.04	5130.62	34.73	28.94	78.75	1864604.57	731

82 of 82 item(s) shown. 1 item(s) selected.

Figure 8-11. Fuel Consumption and Emissions Report – 2010 Heavy-usage Scenario



Operation Group	Mode	Formaldehyde (IRIS, CAA)	Methyl alcohol (IRIS, CAA)	C-4 Benzene + C-3 Aroald	C-5 Benzene + C-4 Aroald	Benzene (IRIS, CAA)	Acetaldehyde (IRIS, CAA)	Naphthalene
2010_CMAQ_Washington Dulles International_TrackOps_Light	Startup							
2010_CMAQ_Washington Dulles International_TrackOps_Light	DepartureGround	625.97	91.79	33.36	16.48	85.48	217.23	
2010_CMAQ_Washington Dulles International_TrackOps_Light	DepartureBelow1000	835.47	122.5	44.52	21.99	114.09	289.94	
2010_CMAQ_Washington Dulles International_TrackOps_Light	DepartureBelowMixingHeight	1365.22	200.18	72.75	35.93	186.43	473.78	
2010_CMAQ_Washington Dulles International_TrackOps_Light	DepartureBelow10000	2626.76	385.16	139.98	69.14	358.7	911.58	
2010_CMAQ_Washington Dulles International_TrackOps_Light	Above10000							
2010_CMAQ_Washington Dulles International_TrackOps_Light	ArrivalBelow10000	6497.99	952.79	346.28	171.03	887.34	2255.03	
2010_CMAQ_Washington Dulles International_TrackOps_Light	ArrivalBelowMixingHeight	3846.85	564.06	205	101.25	525.31	1334.99	
2010_CMAQ_Washington Dulles International_TrackOps_Light	ArrivalBelow1000	959.49	140.69	51.13	25.25	131.02	332.98	
2010_CMAQ_Washington Dulles International_TrackOps_Light	ArrivalGround	381.79	55.98	20.35	10.05	52.14	132.5	
2010_CMAQ_Washington Dulles International_TrackOps_Light	FullFlight	9124.75	1337.95	486.26	240.16	1246.04	3166.61	
2010_CMAQ_Washington Dulles International_TrackOps_Light	DepartureTaxi	262.18	38.44	13.97	6.9	35.8	90.99	
2010_CMAQ_Washington Dulles International_TrackOps_Light	ArrivalTaxi	176.88	25.94	9.43	4.66	24.15	61.38	
2010_CMAQ_Washington Dulles International_SensorPath	Startup							
2010_CMAQ_Washington Dulles International_SensorPath	DepartureGround	136.66	20.04	7.28	3.6	18.66	47.43	
2010_CMAQ_Washington Dulles International_SensorPath	DepartureBelow1000	515.8	75.63	27.49	13.58	70.44	179	
2010_CMAQ_Washington Dulles International_SensorPath	DepartureBelowMixingHeight	1420.56	208.3	75.7	37.39	193.99	492.99	
2010_CMAQ_Washington Dulles International_SensorPath	DepartureBelow10000	6464.08	947.82	344.47	170.14	882.71	2243.26	
2010_CMAQ_Washington Dulles International_SensorPath	Above10000	6356.54	932.05	338.74	167.3	868.02	2205.94	
2010_CMAQ_Washington Dulles International_SensorPath	ArrivalBelow10000	1933.86	283.56	103.06	50.9	264.08	671.12	
2010_CMAQ_Washington Dulles International_SensorPath	ArrivalBelowMixingHeight	635.4	93.17	33.86	16.72	86.77	220.51	
2010_CMAQ_Washington Dulles International_SensorPath	ArrivalBelow1000	260.77	38.24	13.9	6.86	35.61	90.5	

69 of 69 item(s) shown. 1 item(s) selected.

Figure 8-12. Speciated Organic Gases Report – 2010 Heavy-usage Scenario

8.3.3 Emissions Concentrations

Study KIAD emissions dispersion metric results generated emissions concentrations for the data required by the National Ambient Air Quality Standards (NAAQS) for the selected pollutants. A sample emissions concentration layer for nitrogen oxides (NOx) and the corresponding Emissions Dispersion Report are displayed in Figure 8-13 and Figure 8-14.

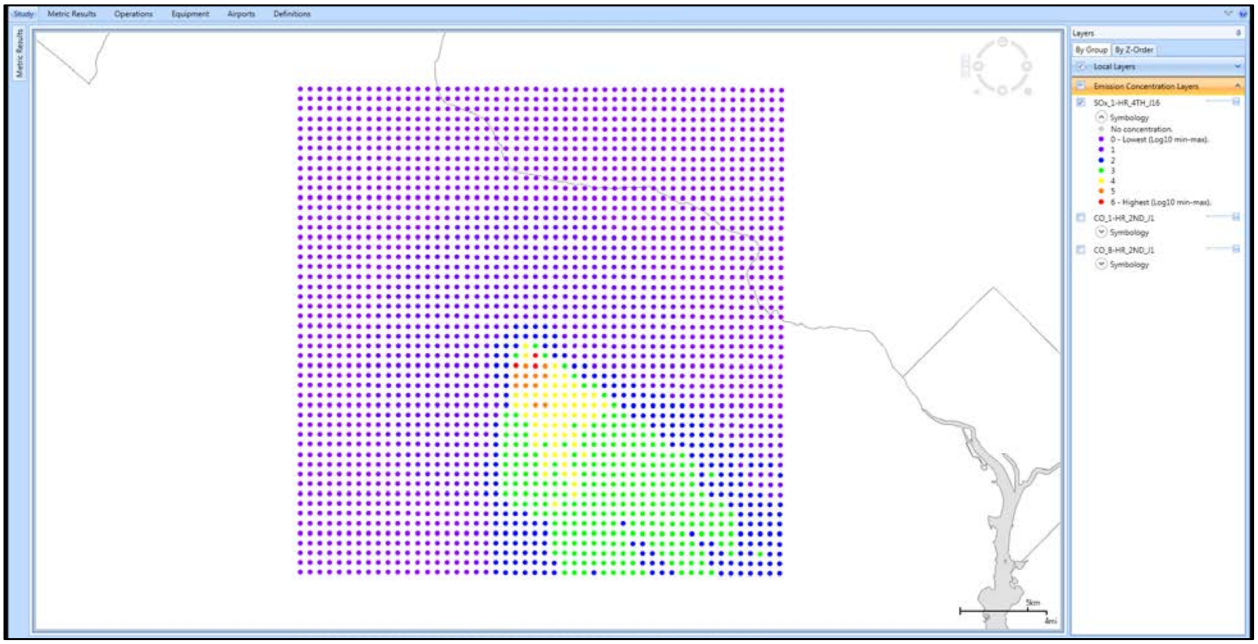


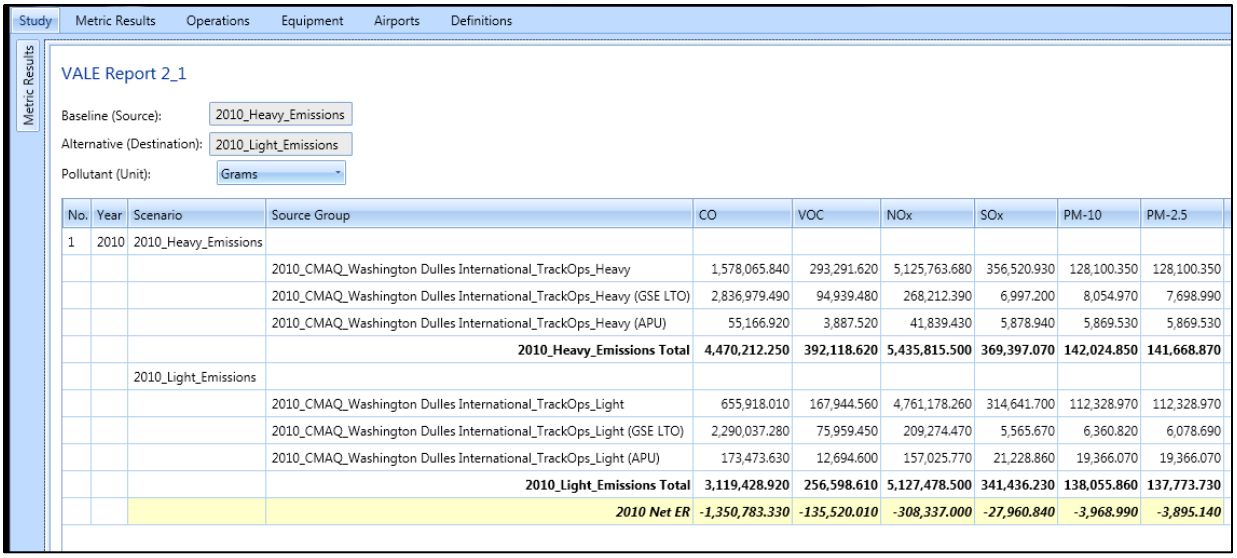
Figure 8-13. Emissions Concentration Layer (NOx)

Figure 8-14. Emissions Dispersion Report (NOx)

8.3.4 Voluntary Airport Low Emissions Report (VALE)

8.3.4.1 VALE Report

The VALE reduction report shows net change in emissions between two emissions metric results in a single year. A sample VALE report for the 2010 light-usage and heavy-usage scenarios is shown in Figure 8-15.



VALE Report 2_1

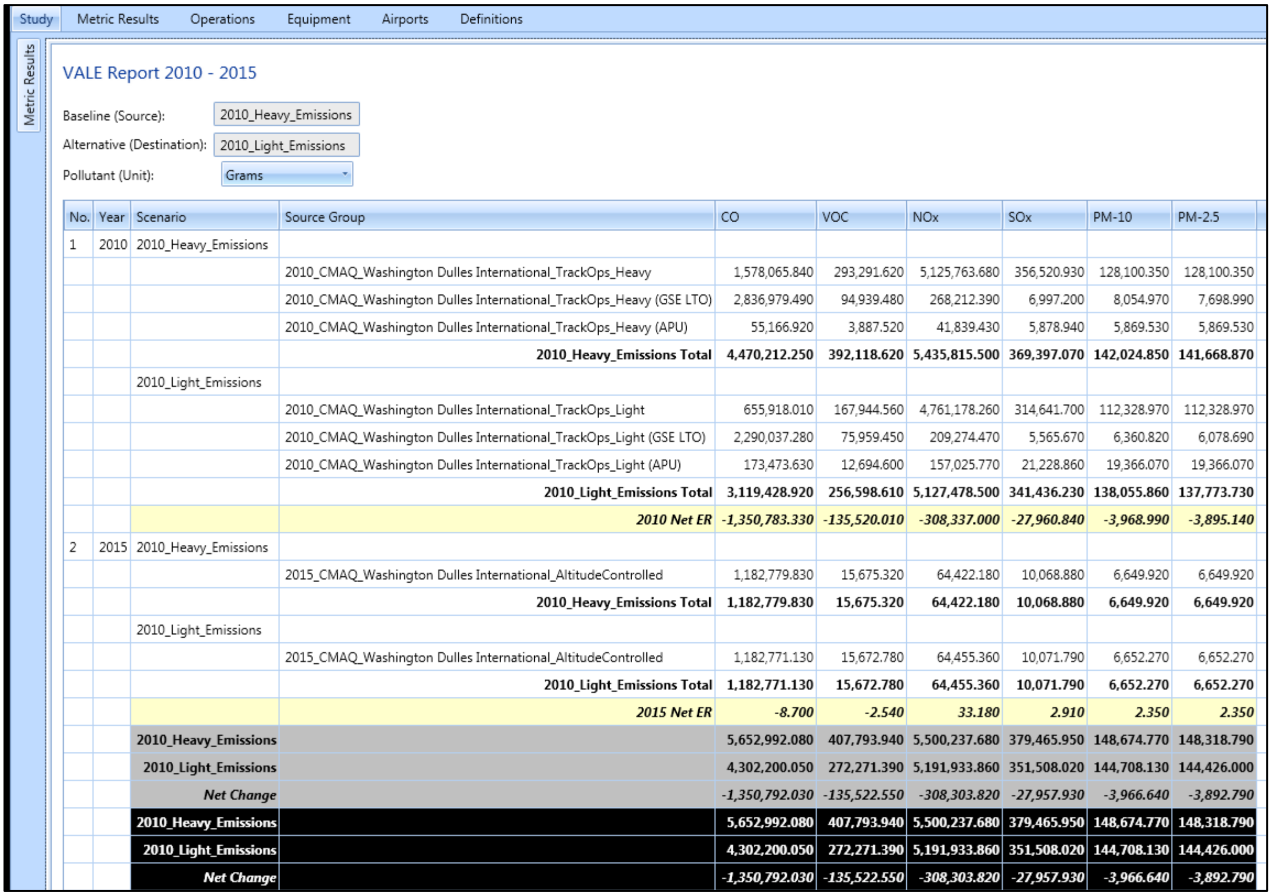
Baseline (Source): 2010_Heavy_Emissions
Alternative (Destination): 2010_Light_Emissions
Pollutant (Unit): Grams

No.	Year	Scenario	Source Group	CO	VOC	NOx	SOx	PM-10	PM-2.5
1	2010	2010_Heavy_Emissions							
			2010_CMAQ_Washington Dulles International_TrackOps_Heavy	1,578,065.840	293,291.620	5,125,763.680	356,520.930	128,100.350	128,100.350
			2010_CMAQ_Washington Dulles International_TrackOps_Heavy (GSE LTO)	2,836,979.490	94,939.480	268,212.390	6,997.200	8,054.970	7,698.990
			2010_CMAQ_Washington Dulles International_TrackOps_Heavy (APU)	55,166.920	3,887.520	41,839.430	5,878.940	5,869.530	5,869.530
			2010_Heavy_Emissions Total	**4,470,212.250**	**392,118.620**	**5,435,815.500**	**369,397.070**	**142,024.850**	**141,668.870**
		2010_Light_Emissions							
			2010_CMAQ_Washington Dulles International_TrackOps_Light	655,918.010	167,944.560	4,761,178.260	314,641.700	112,328.970	112,328.970
			2010_CMAQ_Washington Dulles International_TrackOps_Light (GSE LTO)	2,290,037.280	75,959.450	209,274.470	5,565.670	6,360.820	6,078.690
			2010_CMAQ_Washington Dulles International_TrackOps_Light (APU)	173,473.630	12,694.600	157,025.770	21,228.860	19,366.070	19,366.070
			2010_Light_Emissions Total	**3,119,428.920**	**256,598.610**	**5,127,478.500**	**341,436.230**	**138,055.860**	**137,773.730**
			2010 Net ER	***-1,350,783.330***	***-135,520.010***	***-308,337.000***	***-27,960.840***	***-3,968.990***	***-3,895.140***

Figure 8-15. VALE Report – 2010 Light-usage vs Heavy-usage

8.3.4.2 Aggregated VALE Report

The aggregated VALE report for the analysis years 2010 and 2015 is shown in Figure 8-16.



VALE Report 2010 - 2015

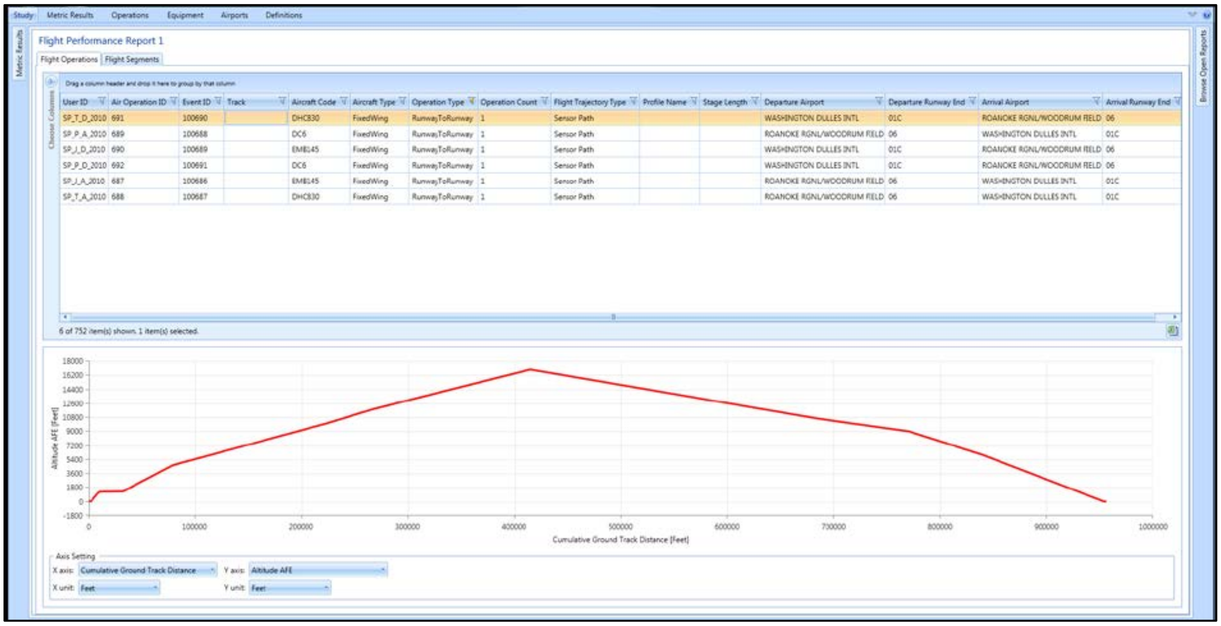
Baseline (Source): 2010_Heavy_Emissions
Alternative (Destination): 2010_Light_Emissions
Pollutant (Unit): Grams

No.	Year	Scenario	Source Group	CO	VOC	NOx	SOx	PM-10	PM-2.5
1	2010	2010_Heavy_Emissions							
			2010_CMAQ_Washington Dulles International_TrackOps_Heavy	1,578,065.840	293,291.620	5,125,763.680	356,520.930	128,100.350	128,100.350
			2010_CMAQ_Washington Dulles International_TrackOps_Heavy (GSE LTO)	2,836,979.490	94,939.480	268,212.390	6,997.200	8,054.970	7,698.990
			2010_CMAQ_Washington Dulles International_TrackOps_Heavy (APU)	55,166.920	3,887.520	41,839.430	5,878.940	5,869.530	5,869.530
			2010_Heavy_Emissions Total	**4,470,212.250**	**392,118.620**	**5,435,815.500**	**369,397.070**	**142,024.850**	**141,668.870**
		2010_Light_Emissions							
			2010_CMAQ_Washington Dulles International_TrackOps_Light	655,918.010	167,944.560	4,761,178.260	314,641.700	112,328.970	112,328.970
			2010_CMAQ_Washington Dulles International_TrackOps_Light (GSE LTO)	2,290,037.280	75,959.450	209,274.470	5,565.670	6,360.820	6,078.690
			2010_CMAQ_Washington Dulles International_TrackOps_Light (APU)	173,473.630	12,694.600	157,025.770	21,228.860	19,366.070	19,366.070
			2010_Light_Emissions Total	**3,119,428.920**	**256,598.610**	**5,127,478.500**	**341,436.230**	**138,055.860**	**137,773.730**
			2010 Net ER	***-1,350,783.330***	***-135,520.010***	***-308,337.000***	***-27,960.840***	***-3,968.990***	***-3,895.140***
2	2015	2010_Heavy_Emissions							
			2015_CMAQ_Washington Dulles International_AltitudeControlled	1,182,779.830	15,675.320	64,422.180	10,068.880	6,649.920	6,649.920
			2010_Heavy_Emissions Total	**1,182,779.830**	**15,675.320**	**64,422.180**	**10,068.880**	**6,649.920**	**6,649.920**
		2010_Light_Emissions							
			2015_CMAQ_Washington Dulles International_AltitudeControlled	1,182,771.130	15,672.780	64,455.360	10,071.790	6,652.270	6,652.270
			2010_Light_Emissions Total	**1,182,771.130**	**15,672.780**	**64,455.360**	**10,071.790**	**6,652.270**	**6,652.270**
			2015 Net ER	***-8.700***	***-2.540***	***33.180***	***2.910***	***2.350***	***2.350***
		2010_Heavy_Emissions		**5,652,992.080**	**407,793.940**	**5,500,237.680**	**379,465.950**	**148,674.770**	**148,318.790**
		2010_Light_Emissions		**4,302,200.050**	**272,271.390**	**5,191,933.860**	**351,508.020**	**144,708.130**	**144,426.000**
		Net Change		***-1,350,792.030***	***-135,522.550***	***-308,303.820***	***-27,957.930***	***-3,966.640***	***-3,892.790***
		2010_Heavy_Emissions		**5,652,992.080**	**407,793.940**	**5,500,237.680**	**379,465.950**	**148,674.770**	**148,318.790**
		2010_Light_Emissions		**4,302,200.050**	**272,271.390**	**5,191,933.860**	**351,508.020**	**144,708.130**	**144,426.000**
		Net Change		***-1,350,792.030***	***-135,522.550***	***-308,303.820***	***-27,957.930***	***-3,966.640***	***-3,892.790***

Figure 8-16. Aggregated VALE Report for Analysis Years 2010 and 2015

8.3.5 Sensor Path Runway-to-Runway Flight Performance

Sensor Path (runway to runway) flight operations are included in the study KIAD noise results. Flight performance results for sensor path flights are available in the Flight Performance report as shown in Figure 8-17 (results are filtered by operation type).



User ID	Air Operation ID	Event ID	Track	Aircraft Code	Aircraft Type	Operation Type	Operation Count	Flight Trajectory Type	Profile Name	Stage Length	Departure Airport	Departure Runway End	Arrival Airport	Arrival Runway End
SP_T_D_2010	691	100690		DHC830	FixedWing	RunwayToRunway	1	Sensor Path			WASHINGTON DULLES INTL	01C	ROANOKE RGNL/WOODRUM FIELD	06
SP_P_A_2010	689	100688		DC6	FixedWing	RunwayToRunway	1	Sensor Path			ROANOKE RGNL/WOODRUM FIELD	06	WASHINGTON DULLES INTL	01C
SP_J_D_2010	690	100689		EMB145	FixedWing	RunwayToRunway	1	Sensor Path			WASHINGTON DULLES INTL	01C	ROANOKE RGNL/WOODRUM FIELD	06
SP_P_D_2010	692	100691		DC6	FixedWing	RunwayToRunway	1	Sensor Path			WASHINGTON DULLES INTL	01C	ROANOKE RGNL/WOODRUM FIELD	06
SP_J_A_2010	687	100686		EMB145	FixedWing	RunwayToRunway	1	Sensor Path			ROANOKE RGNL/WOODRUM FIELD	06	WASHINGTON DULLES INTL	01C
SP_T_A_2010	688	100687		DHC830	FixedWing	RunwayToRunway	1	Sensor Path			ROANOKE RGNL/WOODRUM FIELD	06	WASHINGTON DULLES INTL	01C

6 of 752 item(s) shown. 1 item(s) selected.

X axis: Cumulative Ground Track Distance
Y axis: Altitude AFE
X unit: Feet
Y unit: Feet

Figure 8-17. Flight Performance Report – Sensor Path Operations

8.3.6 Study Input Report

The Study Input report summarizes all of the data inputs in a study (Figure 8-18).

Figure 8-18. Study Input Report – KIAD

8.4 Full Functionality Single Study Limitations

AEDT 2b SP2 is capable of running nearly all combinations of operation types and noise and emissions metrics. The exceptions listed below were outside of the scope of AEDT 2b SP2 development and were not exercised in study KIAD:

- Non-aircraft ground operations (i.e., Stationary Sources and GSEs) do not produce acoustics results and cannot be included in an annualization that is meant to annualize noise. Therefore, emissions for these operations cannot be analyzed when run with noise.
- Sensor Path flight operations and runup operations are not processed in Emissions-Dispersion metric results.
- When sequencing is enabled, the following operations cannot be processed:
  1. Overflights
  2. Circuit flights
  3. Runup operations
  4. Sensor path operations
- Activity profile air operations can only be exercised when sequencing is enabled.

8.5 Conclusion

Use Case F successfully demonstrated that AEDT 2b SP2 was able to exercise nearly all available input data in a single study, providing broad flexibility to conduct multiple types of noise and emissions analyses.

9 Parametric Uncertainty and Sensitivity Analysis

9.1 Overview

The objective of this research is to perform a meaningful system level parametric uncertainty analysis on AEDT 2b. This investigation requires expertise in aircraft design and mathematical formulations, especially with respect to uncertainty and sensitivity analysis, in addition to properly modeling the relationships of the input parameters in AEDT 2b. The outcome of this research will be used for a multitude of items, specifically to: 1) identify gaps in the tools functionality and areas for further development, 2) contribute to the development of external understanding of the FAA tools suite capabilities, 3) provide a sensitivity analysis of the output response to uncertainties in input parameters and assumptions, and 4) establish a new approach for future UQ efforts.

In order to achieve these objectives, the following tasks were proposed and conducted:

1) A review of prior works regarding AEDT UQ in order to properly define the problem and the analysis scope;
2) An uncertainty characterization to identify the source of the uncertainties among AEDT 2b input parameters, their variability, and the correlation among them; and
3) A sensitivity analysis and uncertainty propagation to quantify how individual and combined changes in AEDT input parameters impact AEDT outputs.

9.2 Analysis Scope

As discussed in section 9.1, the objective of this research is to conduct a system level parametric uncertainty analysis on AEDT 2b. In order to define the scope of this analysis, previous AEDT UQ studies were reviewed first. During the development of AEDT, two major research efforts have been undertaken in the past related to parametric uncertainty quantification of AEDT. The most recent work was conducted on AEDT 2a in 2014, and two reports were developed from this research: the AEDT 2a UQ Report[16] and the AEDT 2a SP2 UQ Supplemental Report[17]. Another major effort was made on parametric uncertainty quantification of AEDT Alpha in 2010[18,19,20,21]. Based on the understanding of the approaches taken, datasets used, and the results observed for those two efforts, the scope and approach for the AEDT 2b UQ research was defined as summarized in Table 9-1.

Table 9-1. Summary of Previous Studies and Comparison to Current Approach

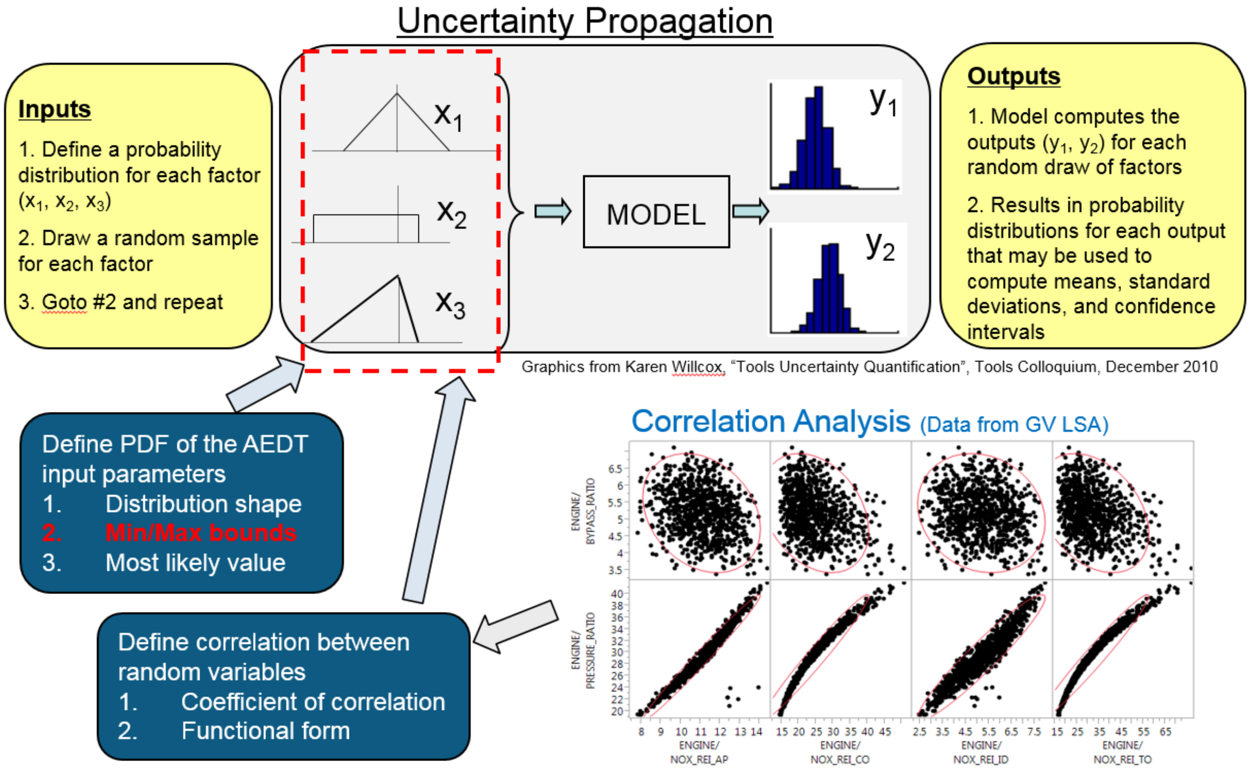
	AEDT 2a and AEDT Alpha Parametric UQ	AEDT 2b Parametric UQ
Analysis Scope	• One-day of departures and arrivals at an airport	• **Single flight from an airport to an airport by an aircraft**
Approach	• Combined impacts of inputs varying together	• **Impacts of individual input changes** to outputs • Combined impacts of inputs varying together
Output Parameters	• LTO fuel burn and emissions • Noise	• **Full gate-to-gate fuel burn and emissions** • LTO fuel burn and emissions • Noise
Input Parameters	• Airport Atmosphere • Aircraft Performance (BADA and ANP) • Emissions • Aircraft Noise	• Airport Atmosphere • Aircraft Performance (BADA and ANP) • Emissions • Aircraft Noise
Dependencies among Inputs	• Vary input parameters independently	• **Capture physical relationship among input parameters**

While previous efforts focused on the airport level, in this research, the parametric uncertainty analysis was conducted at the vehicle level for an aircraft performing a single flight, per Table 9-1. The previous airport level studies analyzed uncertainty on aggregated fuel burn, emission, and noise exposure from hundreds to thousands of departures and arrivals by a number of different aircraft types performed at a given airport. This aircraft level study focused on the isolated outputs of fuel burn, emission, and noise exposure from a single flight. To better understand the uncertainty propagation, both the individual and combined impacts of the inputs on the AEDT 2b outputs were assessed through separate analyses. In addition, in this research the uncertainty analysis was performed on both the full gate-to-gate fuel burn and emissions and the landing-takeoff cycle fuel burn and emissions. The input parameters that were varied include those defining airport atmospheric conditions, aircraft performance coefficients, engine emissions indices and aircraft noise representations. Moreover, the parametric uncertainty analysis captured the physical relationships among input parameters to study the impact of their correlations on the AEDT 2b outputs, whereas previous research assumed these parameters could be treated as independent.

9.3 Technical Approach

The overall parametric uncertainty assessment process illustrated in Figure 9-1 consists of three main steps: 1) define the probability distribution of the AEDT input parameters, 2) run the AEDT model for the cases sampled from the distributions, and 3) collect and analyze the results. Once the key AEDT input parameters are identified, the (joint) probability distributions of these parameters can be defined for assessing the uncertainty propagation to the AEDT outputs of interest. Then sampling techniques can be used to define cases based on the distributions and the AEDT model can be executed to generate the output results of interest. The AEDT model used in this study is a tool called the "AEDT Tester" which is a batch mode version of AEDT core logic[22]. The fuel burn, NOx and noise results in this study were generated using the AEDT Tester, and statistical analysis was conducted on these results.

With the results generated from this uncertainty propagation process, the probability distribution of each AEDT output can be developed, and their variation and mean can be studied. The statistical analysis can also calculate the total sensitivity index for each input parameter which evaluates how the input parameters impact the AEDT outputs. In addition, surrogate models can be generated that can be used to further investigate the uncertainty propagation of input parameters on the AEDT outputs.



Graphics from Karen Willcox, "Tools Uncertainty Quantification", Tools Colloquium, December 2010

Figure 9-1. Parametric Uncertainty Assessment Process for AEDT 2b

9.3.1 Global Sensitivity Analysis (GSA)

One of the objectives of this research is to understand how important each input parameter is in contributing to the variation of the AEDT outputs. This can be investigated through the Global Sensitivity Analysis (GSA). The GSA assesses the impact of the input parameters on the outputs and determines how much each input parameter affects the output uncertainty. Additionally, the correlation among the input parameters can be taken into account when the GSA is conducted. The GSA can calculate the Total Sensitivity Index (TSI)[23] and use it to measure the relative impact attributed to each of the input parameters. Statistical analysis methods, including Monte Carlo Simulations (MCS), were employed to compute the TSI for each input parameter.

A single aircraft simulation through the AEDT Tester takes approximately 5 seconds for gate-to-gate fuel burn and emissions calculations, but the terminal area noise calculations increase simulation by about 2 minutes due to the fine grid resolutions necessary for proper contour detail. To conduct enough Monte Carlo samples and rapidly run the analysis, a surrogate model is required. There are various methods that can be used to create a surrogate model. In this research, the Artificial Neural Network (ANN) and Response Surface Methodology (RSM) were used to generate the surrogate models, as explained in the next section.

9.3.2 Design of Experiment and Surrogate Modeling Techniques

The surrogate modeling techniques employed in this study include RSM[24] and ANN. The RSM approximates the complicated physical behavior of the model into 2nd order polynomials sometimes referred to as Response Surface Equations (RSEs), which allow an instantaneous evaluation of aircraft performance characteristics. ANN-based surrogate models are inspired by the structure of the human brain and are constructed by complex connections between the neurons. These ANN based models' origin can be traced back to a 1943 article by neurophysiologist Warren McCulloch and mathematician Walter Pitts entitled "A Logical Calculus of Ideas Immanent in Nervous Activity"[25].

Surrogate modeling is further facilitated by systematically creating samples using Design-of-Experiment (DoE) techniques. Many types of DoE have been invented and successfully applied to various engineering problems. Among them, Box-Behnken designs[26] and Central Composite Design (CCD) have been widely adopted in the domain of aerospace design along with RSM[27]. ANNs are known to work better with space-filling sampling techniques, such as Latin-Hypercube Sampling (LHS), developed by the Sandia Laboratory in 1981[28].

For this study, these surrogate models were generated using a software toolkit called JMP®. One of the most valuable features of JMP® is its ability to instantaneously visualize how the variables affect one another. Through the Prediction Profiler feature, one may change a key input parameter and instantaneously see the effect on the outputs. An example Prediction Profiler is shown in Figure 9-2 and depicts the prediction traces for each independent X variable. The prediction trace is defined as the predicted response in which one variable is changed while the others are held at their current values. This effectively shows the sensitivity of the response to the input variables. Moving the dotted line with the mouse varies the X variable, and JMP® re-computes the underlying surrogate model and updates the prediction traces and values in real time. Effects of the parameters in the prediction profiler are evaluated based on the magnitude and direction of the slope, where the "-1" and "1" values, shown above X_1 and X_2, are normalized values with respect to the original dimensional ranges. The larger the slope, the greater the influence of a given parameter. If a parameter, listed on the abscissa, does not contribute significantly to the response listed on the ordinate, as "Y", the slope is approximately zero. The sign of the slope, either positive or negative, depicts the direction of influence of the parameter. Furthermore, the limits of the metrics can be readily obtained by the upper and lower value of "Y", shown as 50 and 100.

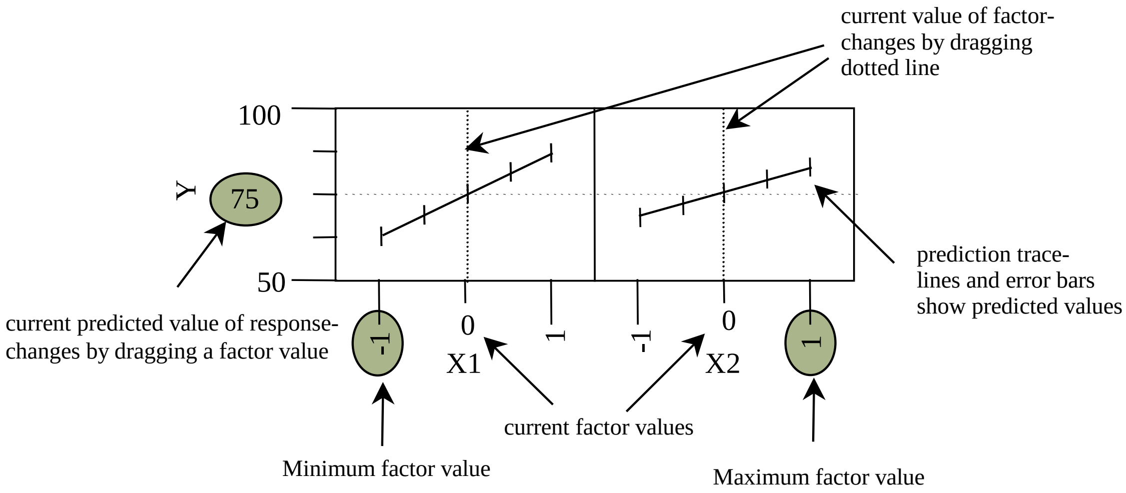


Figure 9-2. Example of a JMP® Prediction Profiler

9.3.3 Propagating Uncertainties and Capturing Correlation among AEDT Input Parameters

To facilitate the parametric uncertainty analysis for AEDT 2b, prior research conducted and coefficient data generated under PARTNER Projects 14 and 36 were leveraged. Under these projects, a number of engine/airframe combinations were developed and validated directly to the AEDT definitions and performance. As such, a consistent approach was developed to quantify changes at the vehicle level to changes in the outputs of the AEDT modeling environment. This full definition includes all aspects of BADA and SAE AIR-1845, including detailed takeoff and landing procedures, noise, etc., which is consistent with the output results of the AEDT Fleet DB representation as documented in numerous PARTNER annual reports since 2007. This aspect is imperative for the current research, since changes in the aircraft or engine design are parametrically linked to Fleet DB coefficients, thereby changing the performance in AEDT. This process is the fundamental driver of the uncertainty analysis.

In prior analyses, a comprehensive approach was developed translating a vehicle definition in Environmental Design Space (EDS) to a representation in the AEDT Fleet DB and also testing the vehicle on representative missions in the previously discussed AEDT Tester, which mimics the way aircraft are flown in AEDT. The AEDT Tester only requires definition of the requisite AEDT Fleet DB coefficients, and thus can be used in conjunction with AEDT Fleet DB aircraft definitions as well as EDS-generated aircraft. As surrogate models for the Global and Regional Environmental Aviation Tradeoff (GREAT) tool and/or the generic fleet were developed over the years, a plethora of aircraft models with AEDT Fleet DB coefficient definitions were generated and linked to their corresponding output results from the AEDT Tester. These data, and the models from which they were created, serve as the basis to understand the uncertainty associated with variations in aircraft design to the changes in the coefficients and sequentially to the changes in the AEDT output results.

As an example, the geometry and technology level of a 150 passenger aircraft were varied and the calculated coefficients are depicted in Figure 9-1. The scatterplot shows the physical correlations for a very small subset of the coefficients needed within the Fleet DB. Each dot on the right represents a specific definition of an aircraft. When a clear trend exists in a panel between two variables (i.e., COEFF_CF1 and COEFF_CF2 are positively correlated), this implies a physical correlation between the two which must be accounted for during the uncertainty propagation. In the previous AEDT UQ studies, these distributions on the left were sampled independently and usually as either a triangular or uniform distribution. When strong correlations among input parameters are ignored, a sampled set of inputs can create a physically infeasible case. For this reason the collation of prior analysis conducted was leveraged to properly define the input distributions and the physical correlation between them and to establish the proper uncertainty representations of the inputs to AEDT.

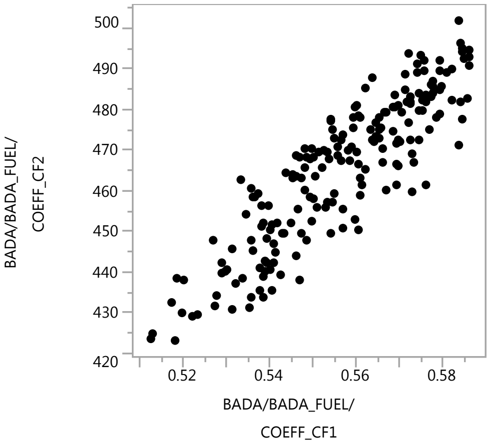


Figure 9-3. BADA Fuel Flow Coefficients from EDS LSA Aircraft

To capture the correlation between the input parameters of AEDT 2b, copulas theory is utilized. Copulas can allow one to easily model and estimate the distribution of random vectors by estimating marginal distributions and copulas separately. It provides systems analysts with the ability to quantify complex relationships, even if that relationship is only qualitatively or notionally understood. Copulas allow systems analysts to capture educated qualitative judgments on the relationships between random variables while preserving the uncertain nature of the problem[29].The copula function represents a joint distribution that specifies a particular dependence structure between the marginal distributions that it links together.

9.4 Uncertainty Characterization

The first step of the parametric uncertainty assessment study was to characterize the sources of uncertainties. The outcome of this task was a list of AEDT input parameters that may have significant impacts on each of the environmental metrics of mission fuel burn, mission NOx, terminal area fuel burn and NOx, and noise. The impacts of the AEDT input parameters identified in this step on the AEDT outputs were quantified in the sensitivity studies and Monte Carlo Simulations. This task was completed by performing the following three subtasks:

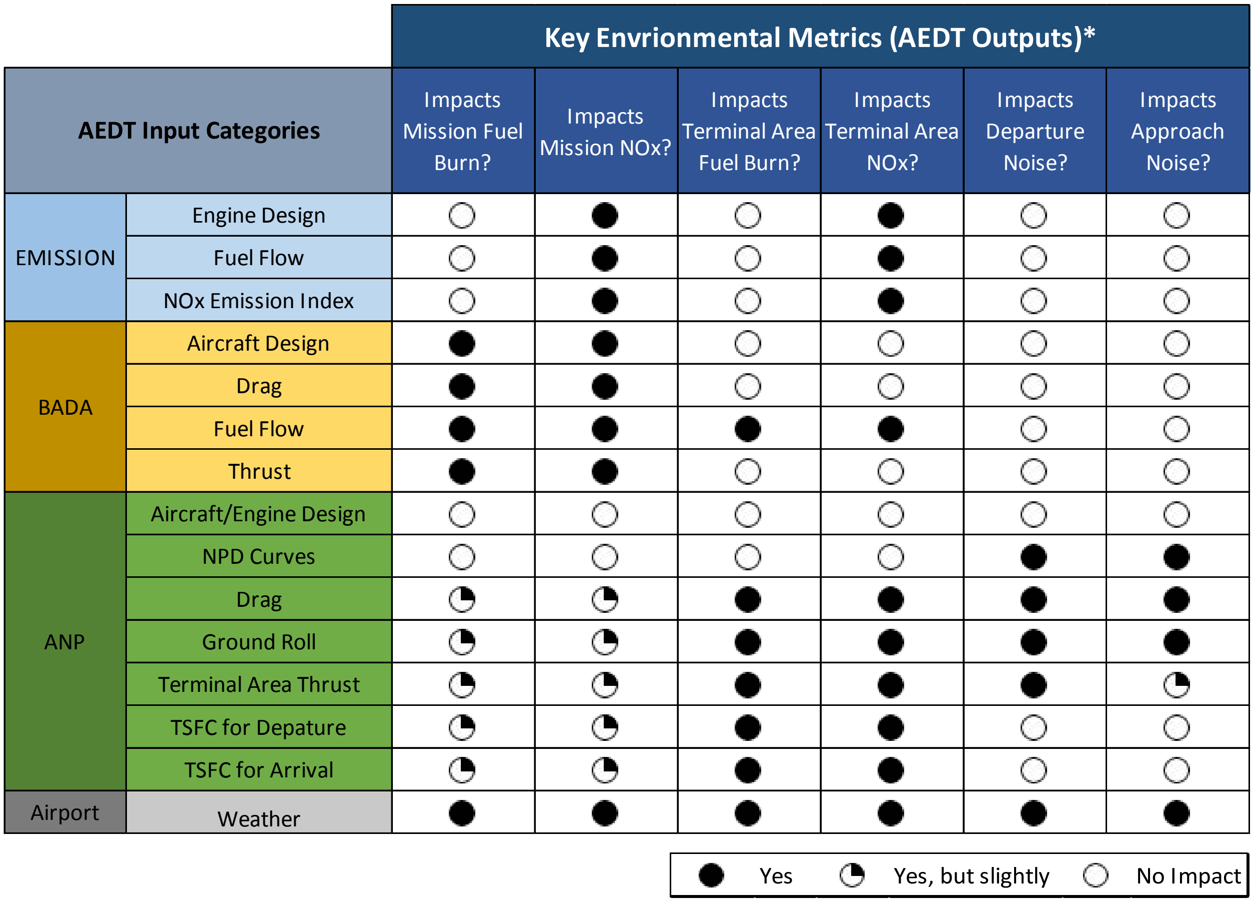
- Identify mapping of key AEDT inputs to key environmental metrics based on literature review and expert knowledge;
- Analyze AEDT Fleet DB to quantify the variability in AEDT input parameters among aircraft in similar technology level and size; and

- Perform a correlation analysis of AEDT input parameters.

9.4.1 Identification of Key AEDT Inputs to Environmental Metrics

In order to characterize the sources of uncertainties that contribute to uncertainties in AEDT outputs, it is important to understand how AEDT calculates each of the environmental metrics and what the sources of the data to perform such calculations are. The algorithms for aircraft fuel burn, NOx emissions, and airport noise assessments, along with all the input parameters and their units, are described in the AEDT 2a Technical Manual[30]. Aircraft and engine performance and aircraft noise data are provided in the AEDT Fleet DB. Airport atmospheric conditions are included in the Airport DB. Only a subset of the Fleet DB coefficients are used for the calculation of a particular environmental metric. The AEDT algorithm uses BADA and ANP coefficients for aircraft performance calculations, ICAO's engine emissions databank for NOx calculations, and aircraft NPD curves for airport noise calculations.

As the first step of defining the list of input parameters and their associated probability distributions and correlations, a mapping between the key AEDT input parameters and the environmental metrics was created. An exhaustive list of AEDT input parameters in BADA, ANP, and Engine Emissions DBs was assembled. The list of the parameters along with their descriptions and units are provided in Appendix AEDT Input Parameters. These parameters were grouped into subcategories of drag, fuel flow, thrust, etc. Figure 9-4 provides a qualitative mapping between the AEDT input groups to mission fuel burn, mission NOx, terminal area fuel burn and NOx, departure noise, and approach noise. Filled circles are used to indicate direct impacts between the input and the metric. Partially filled circles suggest a minor relationship between the input and the metric. An open circle implies that input has no impact on the metric. For example, the mapping shows that engine emissions, BADA, and ANP thrust specific fuel consumption (TSFC) have no impacts on departure and approach noise. Since noise assessment is a time consuming process, it is important to limit the number of input parameters that are included in the uncertainty analysis to improve the resolution of a space filling design of experiments per a given number of simulations. This information is used in next steps to manage the number of input parameters that are varied.



		Key Envrionmental Metrics (AEDT Outputs)*					
AEDT Input Categories		Impacts Mission Fuel Burn?	Impacts Mission NOx?	Impacts Terminal Area Fuel Burn?	Impacts Terminal Area NOx?	Impacts Departure Noise?	Impacts Approach Noise?
EMISSION	Engine Design	○	●	○	●	○	○
	Fuel Flow	○	●	○	●	○	○
	NOx Emission Index	○	●	○	●	○	○
BADA	Aircraft Design	●	●	○	○	○	○
	Drag	●	●	○	○	○	○
	Fuel Flow	●	●	●	●	○	○
	Thrust	●	●	○	○	○	○
ANP	Aircraft/Engine Design	○	○	○	○	○	○
	NPD Curves	○	○	○	○	●	●
	Drag	◔	◔	●	●	●	●
	Ground Roll	◔	◔	●	●	●	●
	Terminal Area Thrust	◔	◔	●	●	●	◔
	TSFC for Depature	◔	◔	●	●	○	○
	TSFC for Arrival	◔	◔	●	●	○	○
Airport	Weather	●	●	●	●	●	●

● Yes ◔ Yes, but slightly ○ No Impact

*This qualitative mapping is based on AEDT Technical Manual. Specific mappings can be different depending on the aircraft model in the AEDT Fleet DB. Detailed quantitative mapping are provided for four different aircraft models in the report.

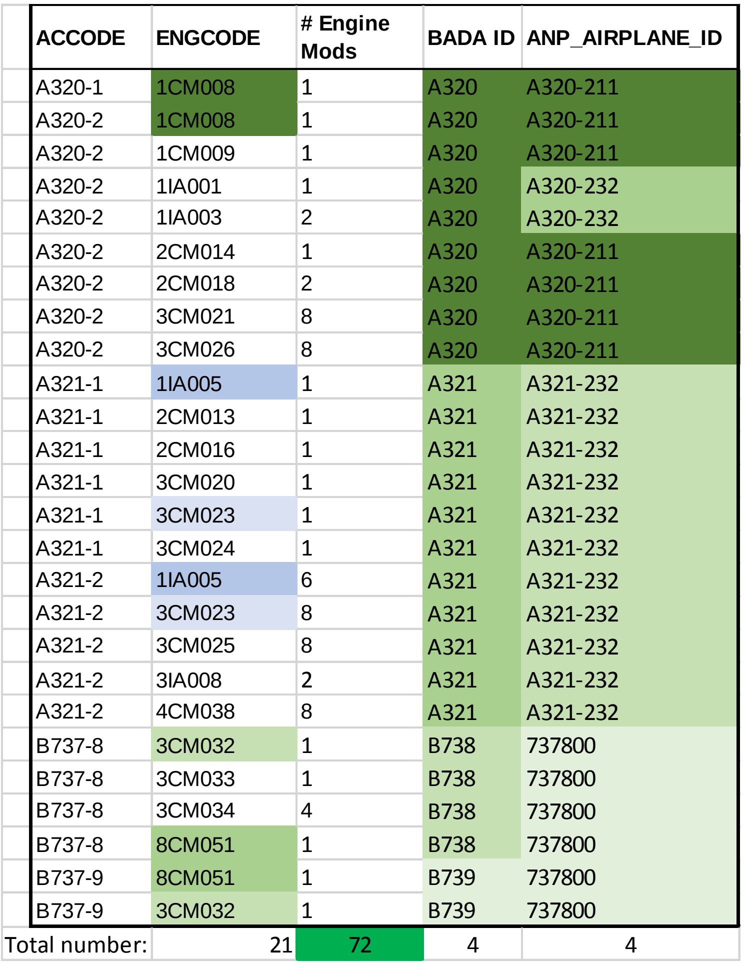
Figure 9-4. Impact of AEDT Input to Environmental Metrics

9.4.2 AEDT Fleet Database Analysis

As show in Figure 9-1, in the parametric uncertainty assessment process, to define the probability distribution for an AEDT input parameter, the distribution shape for the parameter must be determined first. In this study, the triangular distribution was chosen to define the distributions of the AEDT input parameters due to simpler implementation. The triangular distribution is typically used as a subjective description of a population for which there is only limited sample data, which applies to the problem under consideration. Furthermore, the triangular distribution is easily defined using just three parameters: the minimum, most likely, and maximum values. Since the B737 was used as the baseline aircraft for the parametric analysis, the baseline values were assigned as the most likely value for the triangular distribution for each AEDT input parameter.

In order to obtain the minimum and maximum value of each AEDT input parameter for defining their probability distributions, coefficients from the AEDT Fleet DB aircraft in the Large Single Aisle (LSA) class were analyzed to gain some insights on the degree of variations in the AEDT input parameters. AEDT Fleet DB is a comprehensive and consistent source of the real world aircraft data, and consists of data tables that can be used to populate the BADA, ANP, and ICAO emissions parameters. Thus, by studying these data one can understand the range of each parameter for the LSA class aircraft. The LSA aircraft include the A320, A321, B737-800, and B373-900 families which have similar technology and design characteristics. In reality, a number of derivative models of those four aircraft types exist. Correspondingly, the AEDT Fleet DB stores each of these different models with a unique combination of airframe, engine and engine modification data. SQL scripts were developed to collect the data for these LSA aircraft. Table 9-2 shows the mapping between the unique aircraft model and the BADA/ANP aircraft. As can be seen from Table 9-2, there are 72 unique aircraft models; however, these models are mapped to only four BADA and ANP aircraft, that is, the different aircraft models are represented by the same BADA/ANP aircraft in AEDT, which is an additional source of uncertainty.

Table 9-2. Mapping between BADA/ANP Aircraft and Unique Aircraft Model



ACCODE	ENGCODE	# Engine Mods	BADA ID	ANP_AIRPLANE_ID
A320-1	1CM008	1	A320	A320-211
A320-2	1CM008	1	A320	A320-211
A320-2	1CM009	1	A320	A320-211
A320-2	1IA001	1	A320	A320-232
A320-2	1IA003	2	A320	A320-232
A320-2	2CM014	1	A320	A320-211
A320-2	2CM018	2	A320	A320-211
A320-2	3CM021	8	A320	A320-211
A320-2	3CM026	8	A320	A320-211
A321-1	1IA005	1	A321	A321-232
A321-1	2CM013	1	A321	A321-232
A321-1	2CM016	1	A321	A321-232
A321-1	3CM020	1	A321	A321-232
A321-1	3CM023	1	A321	A321-232
A321-1	3CM024	1	A321	A321-232
A321-2	1IA005	6	A321	A321-232
A321-2	3CM023	8	A321	A321-232
A321-2	3CM025	8	A321	A321-232
A321-2	3IA008	2	A321	A321-232
A321-2	4CM038	8	A321	A321-232
B737-8	3CM032	1	B738	737800
B737-8	3CM033	1	B738	737800
B737-8	3CM034	4	B738	737800
B737-8	8CM051	1	B738	737800
B737-9	8CM051	1	B739	737800
B737-9	3CM032	1	B739	737800
Total number:	21	72	4	4

It also can be seen that in Table 9-2 the same engine emission model (represented by ENGCODE) is used for different engine versions which may have different weight, drag, fuel burn, emission and noise properties (as shown in Table 9-3), which is another potential source of uncertainty that may require further analysis.

Table 9-3. Engine Modification for the Same Aircraft

ACCODE	ENGCODE	BADA ID	ANP_AIRPLANE_ID	EQUIP_ID	ENGINE_MOD_ID	DESCRIPTION
A321-2	1IA005	A321	A321-232	1021	140	No engine modification.
				3393	145	G_AND_R Weight Variation
				3397	184	Select One package
				3394	188	G_AND_R Weight Variation
				3395	220	G_AND_R Weight Variation
				3396	261	G_AND_R Weight Variation
A321-2	3CM023	A321	A321-232	1028	140	No engine modification.
				3405	177	/P enhanced performance, Enhanced acoustic thrust reverser
				3406	178	/P enhanced performance, Improved fan frame forward panels, Enhanced acoustic thrust reverser
				3407	214	/P enhanced performance, Improved fan frame forward panels, Core chevron nozzle
				3408	238	/P enhanced performance, Improved fan frame forward panels
				3409	255	/P enhanced performance
				3410	257	/P enhanced performance, Improved fan frame forward panels, Basic NIP (Enhanced acoustic thrust reverser, Core chevron nozzle)
				3411	285	/P enhanced performance, Core chevron nozzle

The SQL queries were run to retrieve coefficient values for the BADA, ANP, and ICAO emissions parameters, which are show in Table 9-4, Table 9-5, and Table 9-6.

Table 9-4. BADA Coefficients for LSA Aircraft

(a) BADA Thrust Coefficients

BADA_ID	COEFF_TC1	COEFF_TC2	COEFF_TC3	COEFF_TC4	COEFF_TC5	COEFF_TDL	COEFF_TDH
A320	142310	51680	5.68E-11	10.138	0.008871	0.10847	0.13603
A321	158520	45206	1.18E-10	9.8789	0.0089517	0.042086	0.02219
B738	146590	53872	3.05E-11	9.6177	0.0085132	0.075573	0.087412
B739	145920	55371	1.84E-11	9.4957	0.0084278	0.081951	-0.04567
Low Bound (%)	**-5%**	**-10%**	**-73%**	**-3%**	**-3%**	**-44%**	**-201%**
Upper Bound (%)	**5%**	**10%**	**73%**	**3%**	**3%**	**44%**	**201%**

(b) BADA Drag Coefficients

BADA_ID	COEFF_CF1	COEFF_CF2	COEFF_CFCR
A320	0.75882	2938.5	0.96358
A321	0.72987	1236.9	1
B738	0.70057	1068.1	0.92958
B739	0.70675	1135.2	0.93511
Low Bound (%)	**-4%**	**-47%**	**-4%**
Upper Bound (%)	**4%**	**47%**	**4%**

(c) BADA Fuel Flow Coefficients

	FLIGHT PHASE									
	Approach		Cruise		Initial Climb		Landing		Takeoff	
BADA_ID	COEFF_CD0	COEFF_CD2	COEFF_CD0	COEFF_CD2	COEFF_CD0	COEFF_CD2	COEFF_CD0	COEFF_CD2	COEFF_CD0	COEFF_CD2
A320	0.038	0.0419	0.026659	0.038726	0.023	0.044	0.096	0.0371	0.033	0.041
A321	0.047354	0.040818	0.026984	0.035074	0.029161	0.045714	0.07959	0.037708	0.037609	0.041415
B738	0.0492	0.0424	0.025452	0.035815	0.0262	0.0448	0.0689	0.0404	0.0357	0.0423
B739	0.046859	0.037823	0.025734	0.033615	0.029603	0.039659	0.080202	0.034566	0.036274	0.038513
Low Bound (%)	**-13%**	**-6%**	**-3%**	**-7%**	**-13%**	**-7%**	**-16%**	**-8%**	**-7%**	**-5%**
Upper Bound (%)	**13%**	**6%**	**3%**	**7%**	**13%**	**7%**	**16%**	**8%**	**7%**	**5%**

In Table 9-4, the lower bound and upper bound were calculated for each parameter based on the data for the four BADA aircraft. The lower bound is calculated as the difference between the minimum value and the midpoint of the parameter in percentage form. Similarly, the upper bound is the difference between the maximum value and the midpoint of the parameter in percentage form. One can see that the degree of variation of the similar aircraft type varies significantly for different AEDT coefficients. For example, COEF_TC1 varies from -5% to 5%, while COEFF_TDH varies from -201% to 201%. This gives more insights about how to define the probability distribution for these parameters using the triangular distribution.

Table 9-5. ANP Coefficients

(a) ANP Thrust Coefficients

	Takeoff Thrust				Climb Thrust			
ACFT_ID	**COEFF_E**	**COEFF_F**	**COEFF_GA**	**COEFF_GB**	**COEFF_E**	**COEFF_F**	**COEFF_GA**	**COEFF_GB**
737800	26089.1	-29.10981	0.143559	0	22403.5	-27.26452	0.305603	0
A320-211	23652.9	-22.93379	2.96E-01	-5.46E-06	16859.1	-4.3786	1.84E-01	2.99E-06
A320-232	24746.2	-25.24732	3.04E-01	9.25E-06	15539.2	-4.08932	4.38E-01	-1.44E-05
A321-232	28636.4	-26.7318	2.50E-01	-3.92E-06	21870.8	-21.48672	3.81E-01	-5.56E-06
Low Bound (%)	**-10%**	**12%**	**-36%**	**-389%**	**-18%**	**74%**	**-41%**	**152%**
Upper Bound (%)	**10%**	**-12%**	**36%**	**389%**	**18%**	**-74%**	**41%**	**-152%**

(b) ANP TSFC Coefficients

	Depature TSFC				Arrival TSFC			
ACFT_ID	**K1**	**K2**	**K3**	**K4**	**BETA1**	**BETA2**	**BETA3**	**ALPHA**
737800	0.5798	7.64E-01	1.01E-06	2.66E-06	1.353	2.02E+00	1.87E+01	5.36E-01
A320-211	0.667	5.41E-01	-1.84E-06	6.34E-06	0.4761	1.65E+00	8.73E+00	7.90E-01
A320-232	0.667	5.41E-01	-1.84E-06	6.34E-06	0.4761	1.65E+00	8.73E+00	7.90E-01
A321-232	0.6108	5.26E-01	-2.19E-06	8.56E-06	0.4661	1.62E+00	1.04E+01	7.57E-01
Low Bound (%)	**-7%**	**-18%**	**270%**	**-53%**	**-49%**	**-11%**	**-36%**	**-19%**
Upper Bound (%)	**7%**	**18%**	**-270%**	**53%**	**49%**	**11%**	**36%**	**19%**

(c) ANP Design Coefficients

ACFT_ID	MX_GW_TKO	MX_GW_LND	THR_STATIC
737800	174200	146300	26300
A320-211	169756	142198	25000
A320-232	169756	145505	26500
A321-232	196211	166449	30000
Low Bound (%)	**-7%**	**-8%**	**-9%**
Upper Bound (%)	**7%**	**8%**	**9%**

Table 9-6. Emission Coefficients

ENGINE_ID	ENGINE_CODE	RATED_OUT	UA_RWF_TO	UA_RWF_CO	UA_RWF_AP	UA_RWF_ID	NOX_REI_TO	NOX_REI_CO	NOX_REI_AP	NOX_REI_ID	BYPASS_RATIO	PRESSURE_RATIO	# Engine Mods
1213	1CM008	111.2	1.051	0.862	0.291	0.1011	24.6	19.6	8	4	6	26.6	1
1214	1CM009	117.88	1.131	0.925	0.307	0.1044	26.4	21.1	8.3	4.1	6	27.9	1
1248	1IA001	111.2	1.113	0.924	0.334	0.124	37.13	30.82	13.45	5.91	5.3	29.8	1
1250	1IA003	111.2	1.053	0.88	0.319	0.128	26.5	22.3	8.9	4.7	4.82	27.2	2
1252	1IA005	133.4	1.331	1.077	0.377	0.138	33.8	27.1	10.1	5	4.54	32.1	1
1341	2CM013	137.9	1.426	1.158	0.376	0.119	37.8	28.5	11	4.7	5.6	31.3	1
1342	2CM014	117.9	1.166	0.961	0.326	0.107	28.7	23.3	10	4.3	5.9	27.1	1
1344	2CM016	133.45	1.345	1.104	0.369	0.129	27.75	14.91	7.02	4.73	5.7	30.2	1
1346	2CM018	117.9	1.18	0.975	0.335	0.121	16.61	12.58	6.13	4.49	5.7	27.1	2
1378	3CM020	133.5	1.32	1.07	0.37	0.12	23.3	16.4	7.3	4.1	5.7	30.5	1
1379	3CM021	120.1	1.14	0.95	0.34	0.12	18.4	13.6	6.5	3.9	5.9	27.7	8
1381	3CM023	133.45	1.295	1.058	0.345	0.11	33	26.2	10.7	4.5	5.7	30.47	1
1382	3CM024	137.9	1.361	1.099	0.356	0.113	35.1	27.4	10.9	4.6	5.6	31.57	1
1383	3CM025	142.35	1.43	1.141	0.366	0.115	37.3	28.5	11.2	4.7	5.6	32.78	8
1384	3CM026	120.11	1.132	0.935	0.312	0.104	28	23.2	10	4.3	5.9	27.69	8
1390	3CM032	107.65	1.103	0.91	0.316	0.109	25.3	20.5	10.1	4.4	5.2	25.78	1
1391	3CM033	116.99	1.221	0.999	0.338	0.113	28.8	22.5	10.8	4.7	5.1	27.61	1
1392	3CM034	121.44	1.284	1.043	0.349	0.116	30.9	23.7	11	4.8	5	28.63	4
1419	3IA008	140.56	1.426	1.1447	0.3901	0.1363	36.48	28.67	10.83	5.24	4.46	33.44	2
1443	4CM038	142.4	1.47	1.15	0.4	0.13	32	18.6	7.8	4.3	5.6	32.8	8
1811	8CM051	116.99	1.221	0.999	0.338	0.113	28.8	22.5	10.8	4.7	5.1	27.61	1
Low Bound (%)		**-14%**	**-17%**	**-15%**	**-16%**	**-15%**	**-39%**	**-42%**	**-37%**	**-20%**	**-15%**	**-13%**	
Upper Bound (%)		**14%**	**17%**	**15%**	**16%**	**15%**	**39%**	**42%**	**37%**	**20%**	**15%**	**13%**	

It can be seen from Table 9-6 that many emission coefficients have an approximate +/-15% variation from the assumed midpoint. However, some variables such as NOX_REI at different flight phases vary over larger relative ranges, from +/-20% to +/-42%.

9.4.3 Correlation Analysis of AEDT Input Parameters

The AEDT input file for each of the aircraft models generated through EDS is in an XML format. In order to parse the key AEDT input parameters from the XML files, a python script was developed and utilized. Running the script, about 30 AEDT input parameters were collected from roughly 900 EDS aircraft in the LSA class. These aircraft were generated from a preliminary analysis performed on LSA aircraft for PARTNER Project 14. In Project 14, the baseline EDS LSA aircraft was varied by changing aircraft and engine design parameters for the purpose of creating a generic vehicle (GV) that best represents aggregate environmental footprints of major LSA aircraft fleets including the Boeing 737 and Airbus A320 families.

Before probability distributions for the uncertainty propagation analysis were assigned, the input parameters parsed from the XML files of the generic vehicle alternatives were studied. The multivariate plots were generated using the GV data to allow the user to visualize the pairwise correlations between multiple input parameters simultaneously.

Figure 9-5 shows the correlations between Engine Pressure Ratio (OPR) and Bypass Ratio (BPR) with respect to the NOx EIs. As seen from the scatter plot, Engine OPR and NOx EIs have strong positive correlation, which can be explained physically using the thermodynamics of combustion: higher OPR results in higher NOx emissions. Similarly, weak negative correlation was observed between BPR and engine fuel flow indices, which is appropriate since higher BPR helps reduce fuel flow.

The correlations between OPR/BPR and Fuel Flow Indices are illustrated in Figure 9-6. It can be seen that both OPR and BPR have negative correlation with fuel flow indices. This is also consistent with the theory of thermodynamics: higher OPR and BPR can improve the efficiency of the fuel consumption.

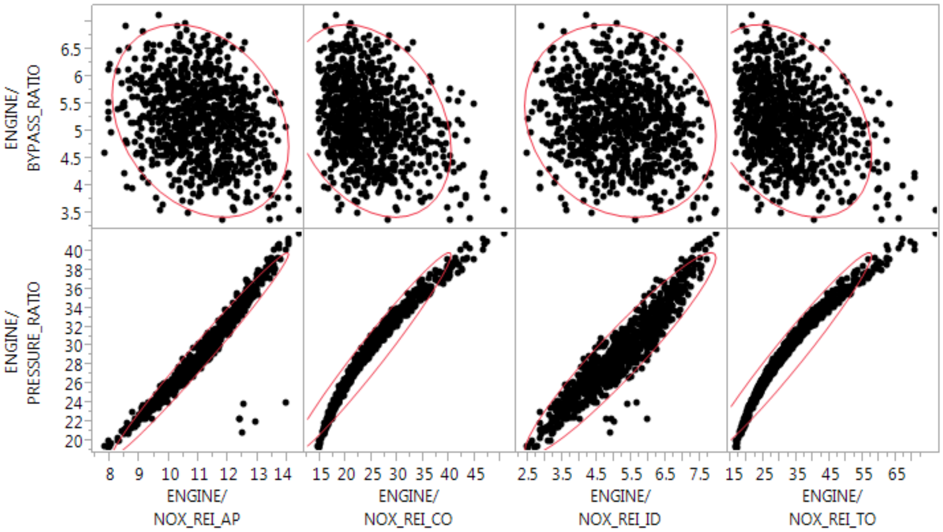


Figure 9-5. Correlation between Engine Bypass Ratio and Pressure Ratio and Engine NOx Emission Indices

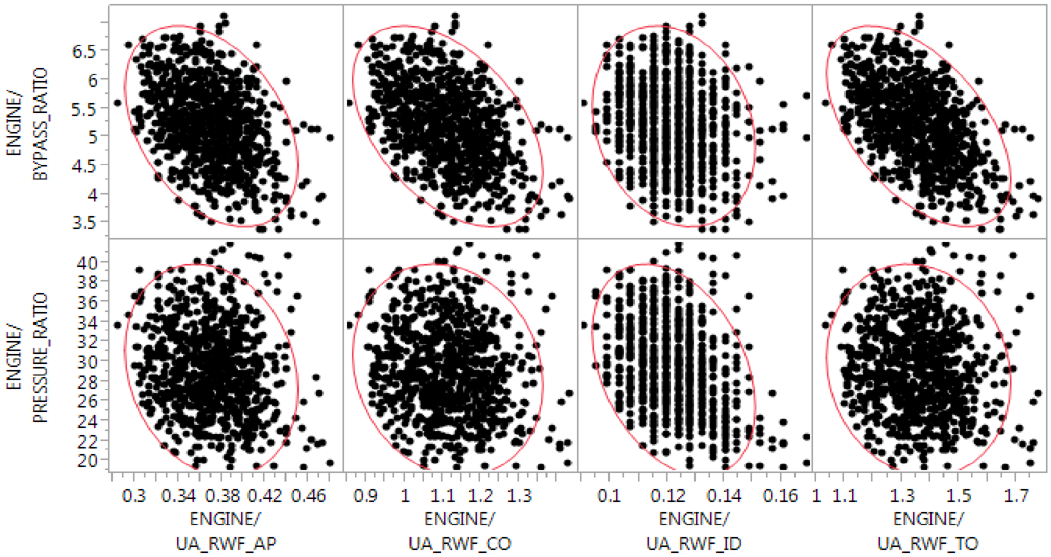


Figure 9-6. Correlation between Engine Bypass Ratio and Pressure Ratio and Engine Fuel Flow Indices

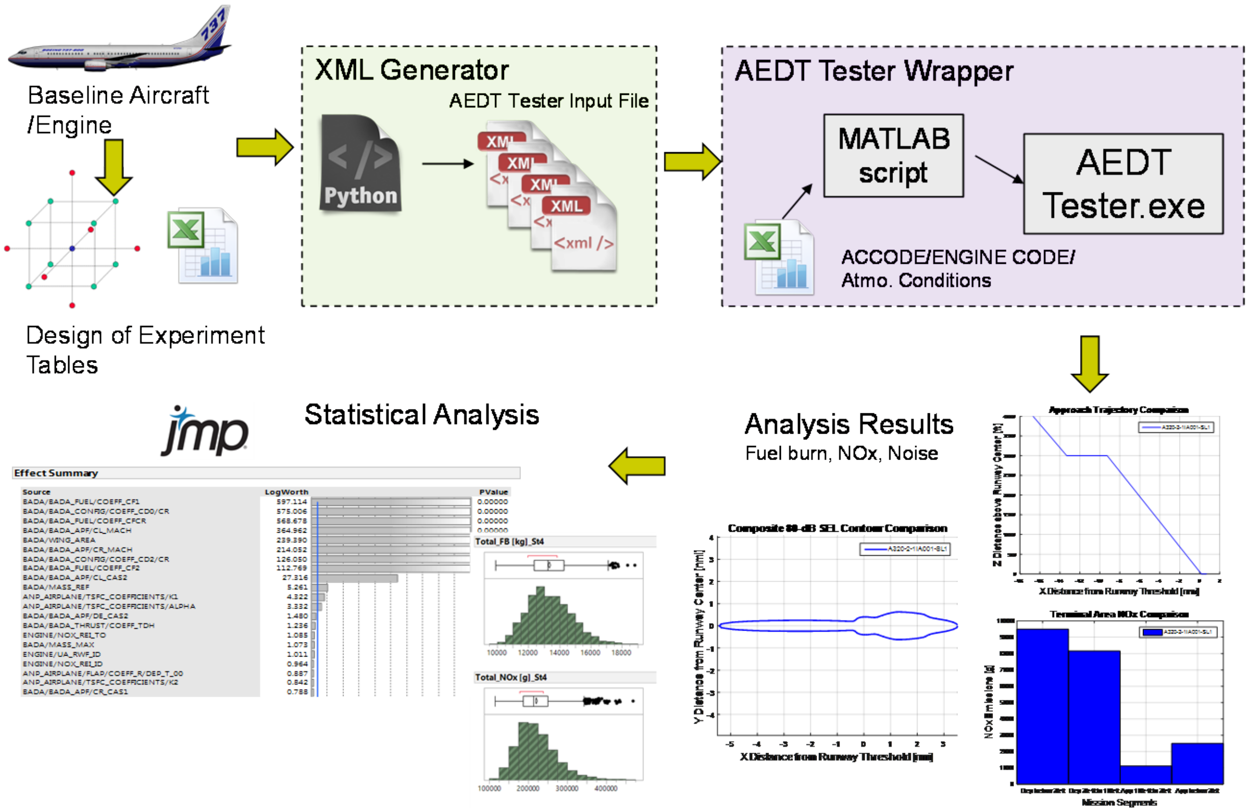
9.5 Experiment Setup

To conduct the parametric uncertainty assessment and achieve the objectives of this research, several analyses needed to be performed, which are summarized in Table 9-7. First, since the number of input parameters is large, a preliminary screening test needed to be carried out in order to filter out the parameters that do not have an impact on the outputs, which are heretofore referred to as Round 1 experiments. This round identified the important input parameters and reduced the required number of runs for the next round of analysis. This screening test featured two steps. In the first step, R1A, a One-Factor-At-a-Time (OFAT) DoE was used for the analysis in order to identify the individual impact of the input parameters on the outputs. In this step, the 55 AEDT input parameters were used to generate an OFAT DoE to calculate the impacts of those parameters on fuel burn and emission. Five atmospheric parameters were varied as well. A similar set of experiments, R1B, were conducted on the parameters representing the NPD curves. These parameters were used to generate an OFAT DoE in conjunction with the five atmospheric parameters to calculate their impacts on noise. The second step of this analysis, heretofore referred to as the Round 2 experiments, used an LHS DoE which can capture the interactions among the input parameters to propagate their combined impact on the outputs. LHS DoEs were generated using the important input parameters from Round 1 to conduct the uncertainty analysis on fuel burn and emissions (R2A experiment), and noise (R2B experiment). The DoEs from this analysis enabled the generation of surrogate models. Finally, these surrogate models were used to perform the uncertainty analysis with the correlations among the input parameters on fuel burn and emissions (R3A experiment), and noise (R3B experiment). The details for each round of experiments are tabulated in Table 9-7.

Table 9-7. Parametric Uncertainty Analysis Setup

Experiment ID	DoE Type	# of AEDT Runs	Parameters Changed	Stage Length	Atmosphere Changed?	# of Input Parameters Changed	Noise Calculated ?	Purpose	Notes
R1A	OFAT	123	BADA ANP Emissions NPDs	1, 2, 3, 4, 5	Yes	55+ 5 + NPDs	Yes	Screening Test Sensitivity Study	Individual Impacts
R1B	LHS	2000	BADA ANP Emissions	1, 2, 3, 4, 5	No	55	No	Screening Test	
R2A	LHS	5000	BADA ANP Emissions	1, 2, 3, 4, 5	Yes	30 + 5	No	Surrogate Modeling Monte Carlo	Captures interactions
R2B	LHS	2000	ANP NPDs	1 only	Yes	15 + 5 + NPDs	Yes	Surrogate Modeling Monte Carlo	Captures interactions
R3A	LHS	NA	BADA ANP Emissions	1, 2, 3, 4, 5	Yes	30 + 5	No	Monte Carlo	Correlations are considered
R3B	LHS	NA	ANP NPDs	1 only	Yes	15 + 5 + NPDs	Yes	Monte Carlo	Correlations are considered

For each analysis described above, the process for implementing the analysis is depicted in Figure 9-7. First, a baseline aircraft is selected, and its AEDT input file is created in XML format. A DoE is generated based on the range of each input parameter that defines the variation of the parameter. A Python script is run using the DoE table and the baseline input file to generate an AEDT Tester input file in XML format for each case defined in the DoE. With the atmosphere uncertainty taken into account, AEDT Tester was used to run each case, and the results were parsed for statistical analysis. During the statistical analysis, the distribution of the outputs can be studied, the sensitivity analysis can be performed between the input parameters and outputs, and the surrogate models can be developed for further analysis.



Effect Summary

Source	LogWorth	PValue
BADA/BADA_FUEL/COEFF_CF1	597.114	0.00000
BADA/BADA_CONFIG/COEFF_CD0/CR	575.006	0.00000
BADA/BADA_FUEL/COEFF_CFCR	568.678	0.00000
BADA/BADA_APF/CL_MACH	364.962	0.00000
BADA/WING_AREA	239.390	
BADA/BADA_APF/CR_MACH	214.052	
BADA/BADA_CONFIG/COEFF_CD2/CR	126.050	
BADA/BADA_FUEL/COEFF_CF2	112.769	
BADA/BADA_APF/CL_CAS2	27.316	
BADA/MASS_REF	5.261	
ANP_AIRPLANE/TSFC_COEFFICIENTS/K1	4.322	
ANP_AIRPLANE/TSFC_COEFFICIENTS/ALPHA	3.332	
BADA/BADA_APF/DE_CAS2	1.480	
BADA/BADA_THRUST/COEFF_TDH	1.236	
ENGINE/NOX_REI_TO	1.085	
BADA/MASS_MAX	1.073	
ENGINE/UA_RWF_ID	1.011	
ENGINE/NOX_REI_ID	0.964	
ANP_AIRPLANE/FLAP/COEFF_R/DEP_T_00	0.887	
ANP_AIRPLANE/TSFC_COEFFICIENTS/K2	0.842	
BADA/BADA_APF/CR_CAS1	0.788	

Figure 9-7. Parametric Uncertainty Assessment Work Flow

The ranges of the input parameters for each analysis are shown from Table 9-8 to Table 9-12 for ANP, BADA, emissions, atmosphere, and NPD parameters. The outcome of a sensitivity study and an uncertainty propagation analysis are completely driven by the assumptions on the amount of variation for each of the input parameters. In general, the minimum and maximum ranges of the input parameters are determined either from existing data or expert judgments. Previous research on AEDT 2a UQ used both of these approaches. For experiments R1A and R1B, the same minimum/maximum ranges from the previous research were used for the purpose of complimenting the information provided in those studies. The readers can refer to the AEDT 2a UQ report[16] and AEDT Alpha UQ report[18] for detailed justifications on the ranges.

For experiments R2A and R2B, further engineering adjustments were made for some of the input parameters based on the data analysis on the AEDT Fleet DB (Section 9.4.2). The ranges of some thrust, speed, and drag related coefficients were adjusted to avoid AEDT run failures due to unfeasible combinations of extreme input values. AEDT run failures and adjustments of the ranges are discussed in Section 9.7.1. In addition, those input variables that had no effects based on the sensitivity analyses (Section 9.6) and initial screening tests (Section 9.7.1) were dropped for R2A and R2B analyses to reduce burdens on computing resources.

Table 9-8. ANP Coefficients with Associated Min/Max Ranges

AEDT COEFFICIENTS	AEDT2a UQ		R1A and B		R2A		R2B	
	Low Bound	Upper Bound	Low Bound	Upper Bound	Low Bound	Upper Bound	Low Bound	Upper Bound
ANP/FLAP/COEFF_B/DEP_T_05	-14%	14%	-14%	14%	-14%	14%	-14%	14%
ANP/FLAP/COEFF_C_D/DEP_T_05	-14%	14%	Not Changed		-14%	14%	-14%	14%
ANP/FLAP/COEFF_R/DEP_T_00	-14%	14%	-14%	14%	-14%	14%	-14%	14%
ANP/FLAP/COEFF_R/DEP_T_05	-14%	14%	-14%		-14%	14%	-14%	14%
ANP/WEIGHT/APP	-10%	10%	-10%	10%	DROP		-10%	10%
ANP/WEIGHT/DEP	-10%	10%	-10%	10%	-10%	10%	-10%	10%
ANP/THR_STATIC	Not Changed		-15%	15%	Only impacts noise		-10%	10%
ANP/THRUST/COEFF_E/C	-15%	15%	-15%	15%	-10%	10%	-10%	10%
ANP/THRUST/COEFF_E/T	-15%	15%	-15%	15%	-10%	10%	-10%	10%
ANP/THRUST/COEFF_F/C	-15%	15%	-15%	15%	DROP		-10%	-10%
ANP/THRUST/COEFF_F/T	-15%	15%	-15%	15%	DROP		-10%	-10%
ANP/THRUST/COEFF_GA/C	-2.5%	2.5%	-2.5%	2.5%	-35%	35%	-35%	35%
ANP/THRUST/COEFF_GA/T	-2.5%	2.5%	-2.5%	2.5%	-35%	35%	-35%	35%
ANP/THRUST/COEFF_GB/C	-2.5%	2.5%	Not Changed		Not Changed		Not Changed	
ANP/THRUST/COEFF_GB/T	-2.5%	2.5%	Not Changed		Not Changed		Not Changed	
ANP/TSFC/ALPHA	-10%	10%	-10%	10%	-20%	20%	Not used for Noise	
ANP/TSFC/BETA1	-10%	10%	-10%	10%	-50%	50%	Not used for Noise	
ANP/TSFC/BETA2	-10%	10%	-10%	10%	-10%	10%	Not used for Noise	
ANP/TSFC/BETA3	-10%	10%	-10%	10%	-35%	35%	Not used for Noise	
ANP/TSFC/K1	-10%	10%	-10%	10%	-10%	10%	Not used for Noise	
ANP/TSFC/K2	-10%	10%	-10%	10%	-20%	20%	Not used for Noise	
ANP/TSFC/K3	-10%	10%	-10%	10%	DROP		DROP	
ANP/TSFC/K4	-10%	10%	-10%	10%	-50%	50%	Not used for Noise	

Table 9-9. BADA Coefficients with Associated Min/Max Ranges

AEDT COEFFICIENTS	AEDT2a UQ		R1A and B		R2A		R2B	
	Low Bound	Upper Bound	Low Bound	Upper Bound	Low Bound	Upper Bound	Low Bound	Upper Bound
BADA/CL_CAS2	-15%	15%	-15%	15%	-5%	5%	Not used for Noise	
BADA/CL_MACH	-15%	15%	-15%	15%	-2.5%	2.5%	Not used for Noise	
BADA/CR_CAS2	-15%	15%	-15%	15%	DROP		DROP	
BADA/CR_MACH	-15%	15%	-15%	15%	-5%	5%	Not used for Noise	
BADA/DE_CAS2	-15%	15%	-15%	15%	-5%	5%	Not used for Noise	
BADA/DE_MACH	-15%	15%	-15%	15%	-5%	5%	Not used for Noise	
BADA/COEFF_CD0	-14%	14%	-14%	14%	-5%	5%	Not used for Noise	
BADA/COEFF_CD2	-14%	14%	-14%	14%	-5%	5%	Not used for Noise	
BADA/FUEL/CF1	Not Changed		-10%	10%	-5%	5%	Not used for Noise	
BADA/FUEL/CF2	Not Changed		-10%	10%	-50%	50%	Not used for Noise	
BADA/FUEL/CFCR	Not Changed		-10%	10%	-5%	5%	Not used for Noise	
BADA/THRUST/TC1	-15%	15%	-15%	15%	-5%	5%	Not used for Noise	
BADA/THRUST/TC2	-2.5%	2.5%	-2.5%	2.5%	-5%	5%	Not used for Noise	
BADA/THRUST/TC3	-2.5%	2.5%	-2.5%	2.5%	DROP		DROP	
BADA/THRUST/TC4	-2%	2%	-2%	2%	DROP		Not used for Noise	
BADA/THRUST/TC5	-2%	2%	-2%	2%	DROP		Not used for Noise	
BADA/THRUST/TDH	-10%	10%	-10%	10%	-45%	45%	Not used for Noise	
BADA/THRUST/TDL	-10%	10%	-10%	10%	-200%	200%	Not used for Noise	
BADA/MASS_MAX	-10%	10%	-10%	10%	DROP		DROP	
BADA/MASS_MIN	-10%	10%	-10%	10%	DROP		DROP	
BADA/MASS_PAYLD	Not Changed		-10%	10%	DROP		DROP	
BADA/MASS_REF	Not Changed		-10%	10%	-10%	10%	Not used for Noise	
BADA/WING_AREA	Not Changed		-10%	10%	-5%	5%	Not used for Noise	

Table 9-10. Emissions Input Parameters with Associated Min/Max Ranges

AEDT COEFFICIENTS	AEDT2a UQ		R1A and B		R2A		R2B	
	Low Bound	Upper Bound	Low Bound	Upper Bound	Low Bound	Upper Bound	Low Bound	Upper Bound
EN/BYPASS_RATIO	Not Changed		-10%	10%	DROP		DROP	
EN/NOX_REI_AP	-24%	24%	-24%	24%	-24%	24%	Not used for Noise	
EN/NOX_REI_CO	-24%	24%	-24%	24%	-24%	24%		
EN/NOX_REI_ID	-24%	24%	-24%	24%	-24%	24%		
EN/NOX_REI_TO	-24%	24%	-24%	24%	-24%	24%		
EN/PRESSURE_RATIO	Not Changed		-10%	10%	DROP		DROP	
EN/RATED_OUT	Not Changed		-15%	15%	DROP		DROP	
EN/UA_RWF_AP	-5%	5%	-5%	5%	-5%	5%	Not used for Noise	
EN/UA_RWF_CO	-5%	5%	-5%	5%	-5%	5%		
EN/UA_RWF_ID	-5%	5%	-5%	5%	-5%	5%		
EN/UA_RWF_TO	-5%	5%	-5%	5%	-5%	5%		

Table 9-11. Airport Atmosphere with Associated Min/Max Ranges

AEDT COEFFICIENTS	AEDT2a UQ		R1A and B		R2A		R2B	
	Low Bound	Upper Bound	Low Bound	Upper Bound	Low Bound	Upper Bound	Low Bound	Upper Bound
Elevation	Not Changed		0 ft	1000 ft	0	1000 ft	0	1000 ft
Temperature_D	-20%	20%	-20%	20%	-20%	20%	-20%	20%
Pressure_D	-3%	3%	-3%	3%	-3%	3%	-3%	3%
Headwind_D	-125%	100%	-100%	100%	-100%	100%	-100%	100%
Relative Humidity_D	-15%	15%	-15%	15%	-15%	15%	-15%	15%
Temperature_A	-20%	20%	-20%	20%	-20%	20%	-20%	20%
Pressure_A	-3%	3%	-3%	3%	-3%	3%	-3%	3%
Headwind_A	-125%	100%	-100%	100%	-100%	100%	-100%	100%
Relative Humidity_A	-15%	15%	-15%	15%	-15%	15%	-15%	15%

Table 9-12. Aircraft Noise Input Parameters with Associated Min/Max Ranges

NPD	AEDT2a UQ		R1A and B		R2A		R2B	
	Low Bound	Upper Bound	Low Bound	Upper Bound	Low Bound	Upper Bound	Low Bound	Upper Bound
Delta_NPD_Dep_ShortD (<4000 ft)	-1.5	1.5	-1.5	1.5	NA	NA	-1.5	1.5
Delta_NPD_Dep_MidD (6300-10000 ft)							-2	2
Delta_NPD_Dep_LongD (>16000 ft)							-3	3
Delta_NPD_Dep_ShortD (<4000 ft)							-1.5	1.5
Delta_NPD_Dep_MidD (6300-10000 ft)							-2	2
Delta_NPD_Dep_LongD (>16000 ft)							-3	3

9.6 Sensitivity Analysis

The first sensitivity analysis was performed by conducting experiment R1A. Experiment R1A used the OFAT DoE to change each of the aircraft performance, engine emissions, and airport atmospheric parameters one at a time while fixing other parameters at the baseline values. Some 55 BADA/ANP/Emissions coefficients, five atmospheric parameters, and NPD curves were varied one by one, and then the changes in the AEDT outputs were calculated with respect to the outputs of the baseline aircraft.

In this research, four representative aircraft were chosen as the baseline aircraft from each of the following four aircraft classes: LSA, regional jet (RJ), small twin aisle (STA), and large twin aisle (LTA). For this report, only the results for the LSA aircraft are presented. Results for the RJ, STA, and LTA are provided in Appendix D. For all four aircraft, standard sea level atmospheric conditions were used as a baseline for both departure and arrival airports. All four aircraft were flown for all the stage lengths they could fly. In order to manage the amount of information provided, the results included in this report for mission fuel, mission NOx, departure fuel burn and emissions, and departure noise results are limited to the most frequently flown stage lengths, unless otherwise noted. The maximum stage length and the representative stage length of the four aircraft chosen for the analyses are shown in Table 9-13.

Both departure and arrival sound exposure level (SEL) noise contour areas were calculated for decibel levels ranging from 55dB SEL to 90dB SEL in 5dB increments. Only the results for 80dB SEL contours are presented in this section in order to manage the amount of information. This SEL decibel level was chosen because the 80dB SEL contour areas for a single event roughly correspond to the dimensions of a DNL 65-dB contour for a busy airport with 1,000 daily departures and 1,000 daily arrivals.

Table 9-13. Representative Stage Length

Vehicle Class	Maximum Stage Length	Representative Stage Length
Regional Jet	3 (1350 nm)	1 (350 nm)
Large Single Aisle	5 (3200 nm)	1 (350 nm)
Small Twin Aisle	7 (5200 nm)	4 (2200 nm)
Large Twin Aisle	7 (5200 nm)	6 (4200 nm)

9.6.1 AEDT Output Sensitivity to ANP Coefficients

Sensitivities of the key environmental metrics to ANP coefficients are provided in Table 9-14. The table lists the ANP parameters in the first column and their min/max percentage changes in the second and third columns, respectively. For each of the ANP coefficients, the upper row shows the impact of the minimum percentage change of the ANP coefficient on the corresponding outputs, while the lower row shows the impact of the maximum percentage change. For example, the first row shows the impact to the outputs when ANP/FLAP/COEEF_B/DEP_T_05 is changed by -14%. The second row shows the impact to the outputs when the same coefficient is changed by +14%. Green colors indicate a reduction in environmental impacts while red colors indicate an increase in environmental impacts.

Different ANP coefficients had different relative impacts on each of the output parameters. The departure weight (ANP/WEIGHT/DEP) had ~5% impact on fuel burn and ~10% impact on terminal area emissions and 80dB departure contour areas. Flap coefficients also had up to 13% impact on the departure emissions. Thrust coefficients had strong impacts on the departure emissions and noise. Among the TSFC coefficients, ANP/TSFC/ALPHA had the most significant impacts on the approach emissions, and ANP/TSFC/K1 had the most significant impacts on the departure emissions. None of the ANP parameters except the engine reverse thrust (ANP/THR_STATIC) had any impact on the noise at any dB level. This result was expected since the aircraft selected for the LSA analysis uses a fixed points profile in its ANP model. Fixed points profiles define approach trajectories by specifying the distance and altitude points along with speed and engine thrust settings. Some aircraft manufacturers use fixed points profiles for approach instead of procedural profiles in the ANP models of their aircraft. When fixed points are used, the aircraft performs the approach segment of a flight as defined in the ANP model. Changing ANP coefficients does not change the trajectory, fuel burn, or emission. Only the reverse thrust input has impacts, since it is used on the ground after touchdown.

One of the most important known sources of uncertainty in performing environmental impact assessment is the lack of accurate data on aircraft departure weight. In real world operations, aircraft departure weight varies due to changes in passenger and belly freight weights as well as the amount of fuel an aircraft carries, which depends on the destination and weather. However, due to the difficulty of collecting this data, AEDT uses an assumption of 65% of maximum structural payload capacity and fuel weight based on the stage length. This simplifying assumption can result in variation of aircraft weight by as much as 10%. According to Table 9-14, 10% over- or underestimation on the departure weight results in greater than 10% over or underestimation of terminal NOx and noise contour areas at the departure airport.

Another important known discrepancy due to the lack of data is takeoff thrust. More airlines have adopted the practice of reduced thrust takeoff procedures in order to save maintenance cost, increase engine life, and mitigate noise during departure climb-out. Typically, engine thrusts are reduced down to 80% of maximum thrust depending on a number of factors, with weight being the most dominant factor. The results in the table can be interpreted that when 90% of thrust was actually used instead of 100% in a real operation, AEDT will overestimate terminal NOx by about 13% and noise contour area by 26% at the departure airport.

This error can be further exacerbated when both departure weight and takeoff thrust are simultaneously overestimated. While the R1A analysis cannot quantify the combined impact of weight and thrust, it can be deduced that when the actual departure weight is lighter than the

AEDT assumption and reduced thrust takeoff is used, the discrepancies in NOx and noise calculations should increase more. The next experiments, R2A and R2B, allow for quantification of changes in AEDT outputs when multiple aircraft performance parameters and airport atmospheric conditions change together.

Table 9-14. AEDT Output Sensitivity to ANP Coefficients

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80db_area [nmi^2]	Dep_80db_width [nmi]	Dep_80db_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
ANP/FLAP/COEFF_B/DEP_T_05	-14%	14%	-0.4%	-4.8%	0.0%	-0.7%	-5.0%	0.0%	-2.0%	0.0%	-1.9%	0.0%	0.0%	0.0%
			0.4%	4.8%	0.0%	0.7%	5.0%	0.0%	1.9%	0.0%	1.7%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_C_D/DEP_T_05	-14%	14%	1.2%	13.5%	0.0%	1.9%	14.0%	0.0%	10.5%	10.8%	3.0%	0.0%	0.0%	0.0%
			-1.0%	-11.2%	0.0%	-1.6%	-11.6%	0.0%	-9.2%	-7.5%	-3.4%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/DEP_T_00	-14%	14%	-0.4%	-1.4%	0.0%	-0.6%	-1.2%	0.0%	-2.1%	0.0%	-2.3%	0.0%	0.0%	0.0%
			0.4%	1.6%	0.0%	0.6%	1.4%	0.0%	2.4%	0.0%	2.5%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/DEP_T_05	-14%	14%	-0.1%	-1.2%	0.0%	-0.2%	-1.2%	0.0%	-1.1%	-0.5%	-0.8%	0.0%	0.0%	0.0%
			0.1%	1.4%	0.0%	0.2%	1.4%	0.0%	1.2%	0.5%	0.8%	0.0%	0.0%	0.0%
ANP/WEIGHT/APP	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/WEIGHT/DEP	-10%	10%	-5.4%	-11.9%	0.0%	-9.1%	-11.7%	0.0%	-11.0%	1.1%	-11.6%	0.0%	0.0%	0.0%
			5.0%	12.8%	0.0%	8.8%	12.5%	0.0%	11.3%	-1.1%	12.1%	0.0%	0.0%	0.0%
ANP_AIRPLANE/THR_STATIC	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.9%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	0.1%
ANP/THRUST/COEFF_E/C	-15%	15%	0.1%	6.4%	0.0%	-2.0%	1.5%	0.0%	-21.3%	-0.5%	-16.1%	0.0%	0.0%	0.0%
			0.0%	-1.4%	0.0%	1.5%	0.9%	0.0%	16.1%	0.5%	9.9%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_E/T	-15%	15%	-0.2%	3.5%	-1.5%	-2.2%	-12.8%	-2.4%	-8.9%	-25.8%	9.9%	0.0%	0.0%	0.0%
			0.3%	-0.7%	2.1%	0.2%	-0.6%	3.5%	8.5%	16.1%	-2.5%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_F/C	-15%	15%	0.0%	-0.9%	0.0%	1.0%	0.4%	0.0%	8.9%	0.0%	6.6%	0.0%	0.0%	0.0%
			0.0%	1.1%	0.0%	-0.8%	-0.3%	0.0%	-6.7%	0.0%	-5.9%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_F/T	-15%	15%	-0.1%	-0.9%	0.0%	-0.1%	-0.8%	0.0%	2.0%	6.5%	-1.7%	0.0%	0.0%	0.0%
			0.1%	1.0%	0.0%	0.1%	0.7%	0.0%	-1.9%	-6.5%	1.7%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_GA/C	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.2%	0.0%	-0.2%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_GA/T	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/ALPHA	-10%	10%	-0.5%	0.0%	-6.4%	-0.5%	0.0%	-10.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.5%	0.0%	6.4%	0.5%	0.0%	11.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/BETA1	-10%	10%	-0.3%	0.0%	-3.3%	-0.3%	0.0%	-5.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.3%	0.0%	3.3%	0.3%	0.0%	5.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/BETA2	-10%	10%	-0.1%	0.0%	-0.3%	-0.1%	0.0%	-0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.1%	0.0%	0.3%	0.1%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/BETA3	-10%	10%	0.2%	0.0%	1.5%	0.2%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.2%	0.0%	-1.0%	-0.1%	0.0%	-1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/K1	-10%	10%	-1.2%	-7.2%	0.0%	-3.0%	-11.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			1.2%	7.2%	0.0%	2.8%	8.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/K2	-10%	10%	-0.5%	-2.0%	0.0%	-1.2%	-2.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.5%	2.0%	0.0%	1.2%	2.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/K3	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/K4	-10%	10%	-0.1%	-0.7%	0.0%	-0.2%	-0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.1%	0.7%	0.0%	0.2%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

9.6.2 AEDT Output Sensitivity to BADA Coefficients

Sensitivities of key environmental metrics to BADA coefficients are provided in Table 9-15. The table lists the BADA parameters in the first column and their min/max percentage changes in the second and third columns, respectively. For each of the BADA coefficients, the upper row shows the impact of the minimum percentage changes of the BADA coefficients on the corresponding outputs, and the lower row shows the impact of the maximum percentage change. For example, the first row shows the impact on the outputs when the calibrated airspeed (CAS) climb above the transition altitude (CL_CAS2) is changed by -15%. The second row shows the impact on the outputs when the same coefficient is changed by +15%. Once again, green colors indicate reductions in environmental impacts, and red colors indicate increases in environmental impacts.

Since the BADA algorithm is only used for aircraft performance above 10,000 ft AFE, none of the BADA coefficients impacted terminal area fuel burn or emissions. BADA coefficients had no impact on any of the noise calculations as expected. BADA coefficients only impacted mission fuel burn and NOx emissions. Overall, fuel flow coefficients had the strongest impacts on mission fuel burn and NOx, with drag and speed coefficients having secondary importance. BADA thrust coefficients had marginal effects. Min, Max, and Reference weight coefficients also had minimal effects. The payload input in BADA had no impact on any of the outputs. This occurs because the BADA algorithm uses the departure weight minus the fuel weight consumed below 10,000 ft as the starting gross weight of the aircraft when the BADA algorithm takes over the performance calculation at 10,000 ft AFE.

Whenever the mission fuel changed, mission NOx changed in the same direction, since NOx is calculated as a function of the fuel flow in AEDT. Sometimes a change in mission fuel burn resulted in an even greater degree change in mission NOx emissions. This difference is most pronounced for climb speed coefficients (CL_CAS2 and CL_MACH). For example, a 15% higher climb Mach increased fuel burn by about 3.5% and NOx by 8.7%. The difference was less pronounced for cruise coefficients. These results indicate that there is higher sensitivity of NOx EIs in climb than in cruise.

One of the most important observations is the sensitivity to cruise speed. A 15% reduction in cruise Mach resulted in about 4% reduction in mission fuel burn. A 15% increase in cruise Mach reduced fuel burn by 1%. The baseline cruise Mach in the BADA DB for this LSA aircraft is Mach 0.78. The 15% higher speed (Mach 0.897) is much higher than the aircraft can achieve in level flight due to the thrust limit. Even if it could cruise at that high speed, fuel burn would be significantly higher due to aerodynamic inefficiencies. The fact that AEDT successfully flew the aircraft at Mach 0.897 indicates that it lacks a drag divergence model that captures performance impacts due to shock formulation on the upper surface of the wing. Since BADA is designed to work best during normal cruise, it is expected that fuel burn would not be accurate outside normal cruise. In fact, none of the single aisle aircraft in the world are operated in that high speed, and therefore the users of AEDT should not use those high input values. However, the fact that AEDT did not model drag divergence and calculated fuel burn reduction instead of an anticipated severe increase indicates a potential area of improvement for future development.

Table 9-15. AEDT Output Sensitivity to BADA Coefficients

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80db_area [nmi^2]	Dep_80db_width [nmi]	Dep_80db_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
BADA/CL_CAS2	-15%	15%	-2.2%	0.0%	0.0%	-7.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			1.1%	0.0%	0.0%	4.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CL_MACH	-15%	15%	-1.0%	0.0%	0.0%	-6.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			3.5%	0.0%	0.0%	8.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CR_CAS2	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CR_MACH	-15%	15%	4.1%	0.0%	0.0%	5.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-1.0%	0.0%	0.0%	-1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/DE_CAS2	-15%	15%	-2.8%	0.0%	0.0%	-3.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			1.7%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/DE_MACH	-15%	15%	-1.4%	0.0%	0.0%	-2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			1.7%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/COEFF_CD0	-14%	14%	-7.5%	0.0%	0.0%	-10.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			7.5%	0.0%	0.0%	10.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/COEFF_CD2	-14%	14%	-2.4%	0.0%	0.0%	-3.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			1.7%	0.0%	0.0%	2.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CF1	-10%	10%	-6.7%	0.0%	0.0%	-11.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			6.7%	0.0%	0.0%	12.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CF2	-10%	10%	2.1%	0.0%	0.0%	3.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-1.7%	0.0%	0.0%	-2.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CFCR	-10%	10%	-6.7%	0.0%	0.0%	-11.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			6.7%	0.0%	0.0%	12.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC1	-15%	15%	1.0%	0.0%	0.0%	-1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-1.5%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC2	-2.5%	2.5%	-0.1%	0.0%	0.0%	-0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.7%	0.0%	0.0%	-0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC3	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC4	-2%	2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC5	-2%	2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TDH	-10%	10%	0.2%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.2%	0.0%	0.0%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TDL	-10%	10%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_MAX	-10%	10%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_MIN	-10%	10%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_PAYLD	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_REF	-10%	10%	0.3%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.2%	0.0%	0.0%	-1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/WING_AREA	-10%	10%	-4.4%	0.0%	0.0%	-6.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			4.0%	0.0%	0.0%	5.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

9.6.3 AEDT Output Sensitivity to Emissions and Atmospheric Coefficients

Sensitivities of key environmental metrics to the emissions coefficients are provided in Table 9-16. As already indicated in Figure 9-4, emissions coefficients had no effects on fuel burn and noise. Most of them had effects on mission, departure, and approach NOx. Among the four NOx EI's for takeoff, climb, approach, and idle, the climb EI had the most significant effects on mission NOx. Takeoff NOx EI had the most dominant effects on terminal area departure NOx below 3,000 ft. It was interesting to observe that climb EI had some effects on terminal area approach NOx below 3,000 ft.

Table 9-16. AEDT Output Sensitivity to Emissions Parameters

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80db_area [nmi^2]	Dep_80db_width [nmi]	Dep_80db_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
ENGINE/BYPASS_RATIO	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_AP	-24%	24%	0.0%	0.0%	0.0%	-5.5%	0.0%	-21.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	4.9%	0.0%	20.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_CO	-24%	24%	0.0%	0.0%	0.0%	-15.1%	-3.2%	-3.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	14.4%	3.0%	2.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_ID	-24%	24%	0.0%	0.0%	0.0%	-0.5%	0.0%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.5%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_TO	-24%	24%	0.0%	0.0%	0.0%	-3.8%	-21.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	3.6%	20.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/PRESSURE_RATIO	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/RATED_OUT	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.7%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_AP	-5%	5%	0.0%	0.0%	0.0%	-0.7%	0.0%	-3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	2.6%	0.7%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_CO	-5%	5%	0.0%	0.0%	0.0%	-2.4%	-1.0%	-0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_ID	-5%	5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.3%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_TO	-5%	5%	0.0%	0.0%	0.0%	-0.3%	-0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Finally, AEDT output sensitivity to airport atmospheric parameters and NPD curves are listed in Table 9-17. As can be seen, the changes in airport atmospheric conditions did not have significant effects on mission fuel burn or NOx as expected. Changing NPD curves by +/-1.5 dB had direct impact on the noise contour areas, but this impact was more than expected. A 1.5 dB increase in the NPD curves at all thrust settings and distances increased the departure 80dB contour area by 35% and the approach 80 dB contour area by 31%. A 1.5 dB measurement error in NPD noise tests is typically accepted. Moreover, due to the limitation in the coverage of the ANP DB, a number of aircraft types are matched to the NPDs of similar aircraft types further increasing potential discrepancies in the NPD curves. In order to improve the noise calculations in AEDT, the highest priority should be to improve the accuracy of the NPD curves.

Two anomalies were identified from the airport atmospheric sensitivity tests. First, the airport humidity had no impact to any of the outputs. This result was certainly unexpected. After further investigation, it was found that AEDT overwrites the humidity input by the user when a full gate-to-gate mission is flown. No matter what humidity levels were specified for either or both the departure and arrival airports, AEDT would switch them to the standard day values. This does not happen if only a terminal area departure or arrival flight is simulated in AEDT. This issue has been resolved in the AEDT 2d release. Changing airport humidity in AEDT 2d had impacts to NOx and noise results. Increasing humidity by 15% decreased departure NOx emissions by -1.9% and arrival NOx by -3.6%. Decreasing humidity by 15% had opposite effects in similar degrees. Changing NOx in AEDT 2d had no impacts to fuel burn. While relative humidity does not impact aircraft performance and fuel burn, it directly impacts the NOx calculation through the Boeing Fuel Flow Method 2.

Table 9-17. AEDT Output Sensitivity to Airport Atmosphere and NPD Curves

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80db_area [nmi^2]	Dep_80db_width [nmi]	Dep_80db_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
Atmo_Elevation	1000ft		-1.1%	1.3%	-3.6%	-0.2%	1.9%	-3.6%	5.0%	0.0%	4.9%	-3.3%	-1.5%	-1.1%
Atmosphere Temperature (F)	-9.15%	9.15%	-1.0%	-0.5%	-0.4%	-3.6%	-2.2%	-3.3%	0.5%	0.5%	0.2%	0.4%	0.0%	0.1%
			0.2%	0.5%	0.3%	2.6%	1.7%	3.4%	-0.5%	-0.5%	-0.2%	-0.4%	0.0%	-0.1%
Atmo_SLP Pressure	-3%	3%	2.6%	31.2%	-2.9%	6.0%	32.8%	-3.2%	4.0%	0.0%	3.8%	-2.7%	-1.5%	-1.0%
			0.2%	-0.9%	3.0%	-1.3%	-1.3%	3.0%	-3.7%	0.0%	-3.4%	2.7%	1.5%	0.7%
Atmo_Humidity	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Atmo_Headwind	-100%	100%	0.1%	2.7%	0.0%	0.5%	3.1%	0.0%	1.8%	-1.6%	3.1%	0.0%	0.0%	0.0%
			-0.1%	-2.7%	0.0%	-0.5%	-3.1%	0.0%	-1.8%	1.6%	-3.1%	0.0%	0.0%	0.0%
NPD Curves	-1.5dB	+1.5dB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-24.3%	-11.8%	-14.6%	-28.1%	-16.2%	-14.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	34.6%	12.4%	19.7%	30.8%	19.1%	7.1%

Another unexpected result was the more than 30% increase in departure fuel burn and NOx when the airport pressure was decreased by 3%. The result was not symmetric as a 3% increase in pressure decreased departure fuel burn and NOx by about 1%. This significant hike in departure fuel burn was only observed for the shortest stage length 1 flight, and not for the four other stage lengths simulated for this aircraft. This unexpected result was also observed from the LTA aircraft studied, but the other two aircraft in RJ and STA classes (as provided in Appendix D) showed reasonable sensitivities to the airport pressure. In order to examine how the LSA aircraft flew differently for different atmospheric pressure, departure trajectories were plotted as shown in Figure 9-8. Departure noise contours were compared, as shown in Figure 9-9. The departure trajectory was shallower than the baseline trajectory for reduced atmospheric pressure due to lower rate of climb, which explains the increase in fuel burn and NOx emissions below 3,000 ft.

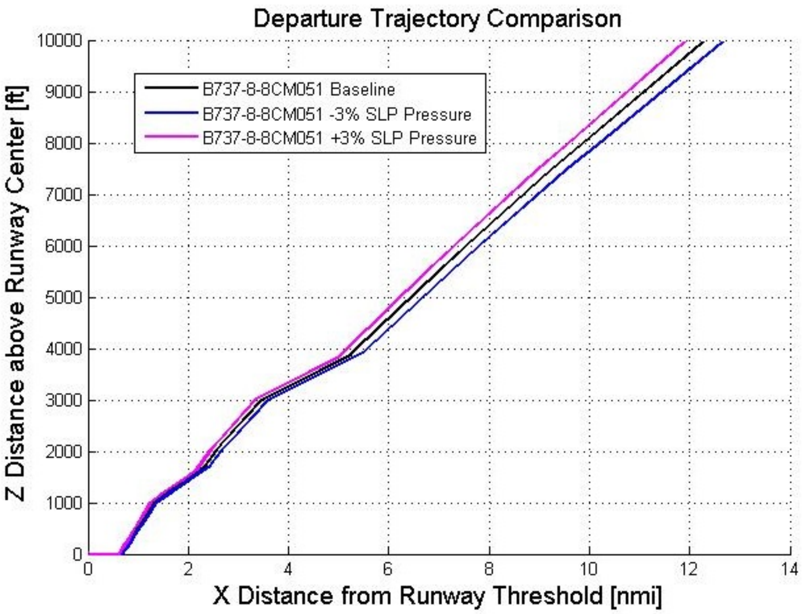


Figure 9-8. Comparisons of Departure Trajectory Due to Atmospheric Pressure Changes

Figure 9-9. Comparisons of Departure 80dB Contour Due to Atmospheric Pressure Changes

It is important to note that the sensitivity results presented in this section are valid with respect to the following two conditions: 1) the baseline values of the aircraft and airport atmospheric conditions and 2) the ranges by which they were varied. When the same aircraft is flown in different atmospheric conditions, the sensitivity results can be different. For example, a particular aircraft performance parameter may have no impact on emissions if that parameter's function is to make corrections in aircraft engine performance when temperature changes. The R1A experiment does not capture those cases. The next set of experiments employ a set of DoEs that vary airport performance and atmosphere simultaneously. However, future research is recommended to vary the atmospheric conditions in a manner that captures performance sensitivities at airports with more extreme atmospheric conditions such as Denver and Tampa.

9.7 Uncertainty Propagation

After the sensitivity study utilizing OFAT DoE in Experiment R1A, the subsequent experiments were conducted using LHS DoEs. Unlike the OFAT DoE, LHS DoEs evenly sample data points from the probability space defined by the random variables and their associated ranges. Therefore, the LHS allows for uncertainty assessment and captures the interactions among the random variables. The LHS DoE generates a dataset that is suitable to create surrogate models as well. Three different sets of LHS DoE runs were performed for Experiments R1B, R2A, and R2B. The purpose of R1B was to screen out those AEDT input parameters that have no effects on AEDT outputs even when the interaction effects are captured. The results from R1B are presented in Section 9.7.1.

Based on the observations from the R1B results, the DoE ranges for R2A and R2B were adjusted. The round 2 runs were used to generate data points for creating surrogate models for fuel burn, NOx, and noise. R2A runs were limited to fuel burn and NOx. Sensitivity studies and Monte Carlo Simulation results for fuel burn and emissions are presented in Section 9.7.2. Then, with the experiment R2B, sensitivity and MCS analysis of noise results are presented in Section 9.7.3.

9.7.1 Analysis of Failed Cases

Sensitivity studies based on the R1A analysis in the previous section do not assess the impact of AEDT output when AEDT inputs are changed simultaneously. Therefore, it does not capture the potential interaction effects of the AEDT input parameters on the AEDT outputs. The next experiment (R1B) was an intermediate step before the full uncertainty propagation was performed in the R2A and R2B experiments. In this experiment, 2,000 LHC samples were generated based on the representative LSA aircraft in the AEDT Fleet DB. Again, a total of 55 BADA/ANP/Emission coefficients were varied using the same min/max assumptions from the AEDT2a study. For initial screening test purposes, NPD and atmospheric conditions were kept the same as the baseline in order to reduce the computational time.

The results show that out of 2,000 sample aircraft generated by LHS method, 78 aircraft failed to fly the mission in AEDT. In order to identify the causes of the failures, results from 2,000 aircraft runs were examined in pairwise scatterplots like those shown in Figure 9-10. After thorough data analyses in multiple dimensions, it turned out that all of the failures were caused by certain combinations of BADA coefficient values. In Figure 9-10, the 2,000 data points are plotted for some of the key BADA coefficients that were related to the AEDT failures. Red x's represent aircraft that failed to fly in AEDT. Grey circles represent aircraft that successfully flew in AEDT. For a particular column or row in the matrix, random scatter of red x's indicate weak correlation between the BADA variable and failed cases. For example, Climb CAS (BADA/CL_CAS2) and cruise Mach (BADA/CR_MACH) do not show a clear pattern of red x's distribution. On the other hand, in the column of climb Mach (BADA/CL_MACH), the red x's are mostly clumped on the right side (high Mach setting) of the subplots. This indicates that high climb Mach was one of the main causes of AEDT failure. Other main contributors to failed AEDT cases include high zero lift drag (BADA/COEFF_CD0) and low values of maximum climb thrust (BADA/THRUST/TC1). Obviously, it is most likely that a combination of high climb Mach, low thrust, and high drag can result in a mission analysis failure. It seems that the cause of failure is lack of thrust to climb near top-of-climb (ToC). It is noted that none of the 2,000 aircraft sampling wide ranges of ANP/BADA/Emission coefficients failed during terminal area operations, cruise, and descent. Mission analysis failure during climb is one of the most common failure types in aircraft performance models. Commercial transports are most constrained (in terms of excess power) at ToC when aircraft and engines are sized to meet the airworthiness certification requirements and maximize fuel efficiency. Therefore, the fact that AEDT experienced these failures indicates that AEDT's aircraft performance module (APM) captures the flight physics correctly.

On the other hand, Experiment R1B also revealed unrealistic trends due to the lack of proper transonic aerodynamics model in AEDT that was mentioned in Section 9.6.2. When the cruise Mach number was increased up to Mach 0.897, most of the missions flew successfully even when high cruise drag (CD0 and CD2) and low thrust were applied. This limitation would result in inaccurate results when cruise speeds are changed in AEDT. Thus, it is not recommended to perform cruise speed sensitivity studies with AEDT. Modeling unconventional future aircraft in AEDT may encounter greater discrepancies between reality and simulations, which may need to be addressed in future AEDT development.

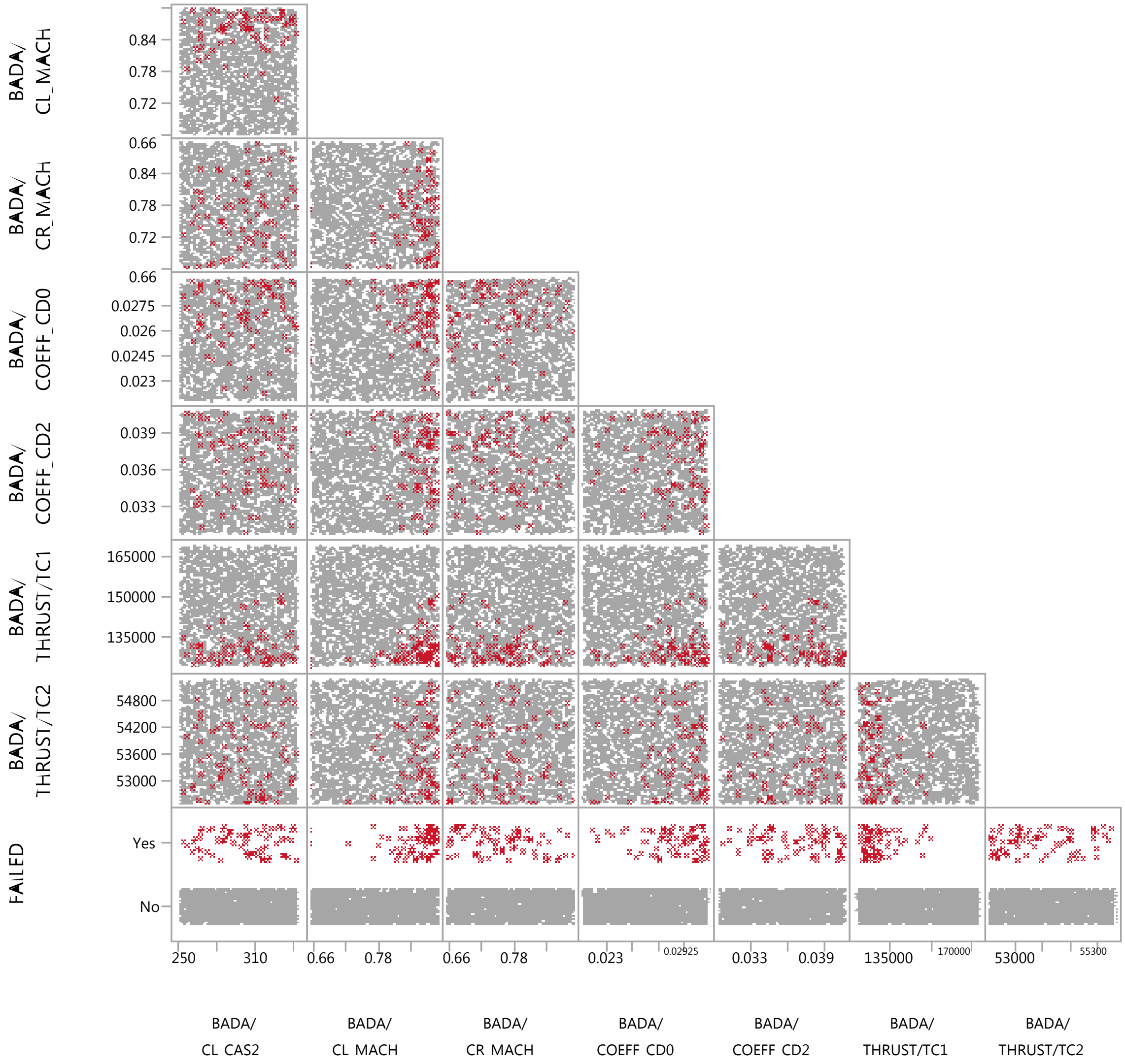


Figure 9-10. Scatter Plot Matrix of 2000 Aircraft from R1B LHS DoE

Before proceeding to Experiment R2A, another round of failure analysis was performed to ensure that the DoE ranges for R2A would be adequate without AEDT run failures. BADA CAS and Mach ranges were reduced since +/-15% changes in climb, cruise, and descent speeds were beyond normal operational ranges. The ranges for BADA Thrust coefficients were adjusted to better capture the variability in those coefficients among similar LSA aircraft in the AEDT Fleet DB. Ranges for drag coefficient were also reduced. With increased ranges, the thrust adjustment coefficient for altitude (BADA/THRUST/TC2) became one of the important contributors to mission analysis failure. Again, combinations of high climb Mach, high drag, and low thrust due to low maximum climb thrust (BADA/THRUST/TC1) and high thrust lapse rate (BADA/THRUST/TC2) values lead to a lack of excess power to reach ToC. Based on the second failure analysis, the DoE was further adjusted to finalize the setting for Experiment R2A as provided in Table 9-8 through Table 9-12.

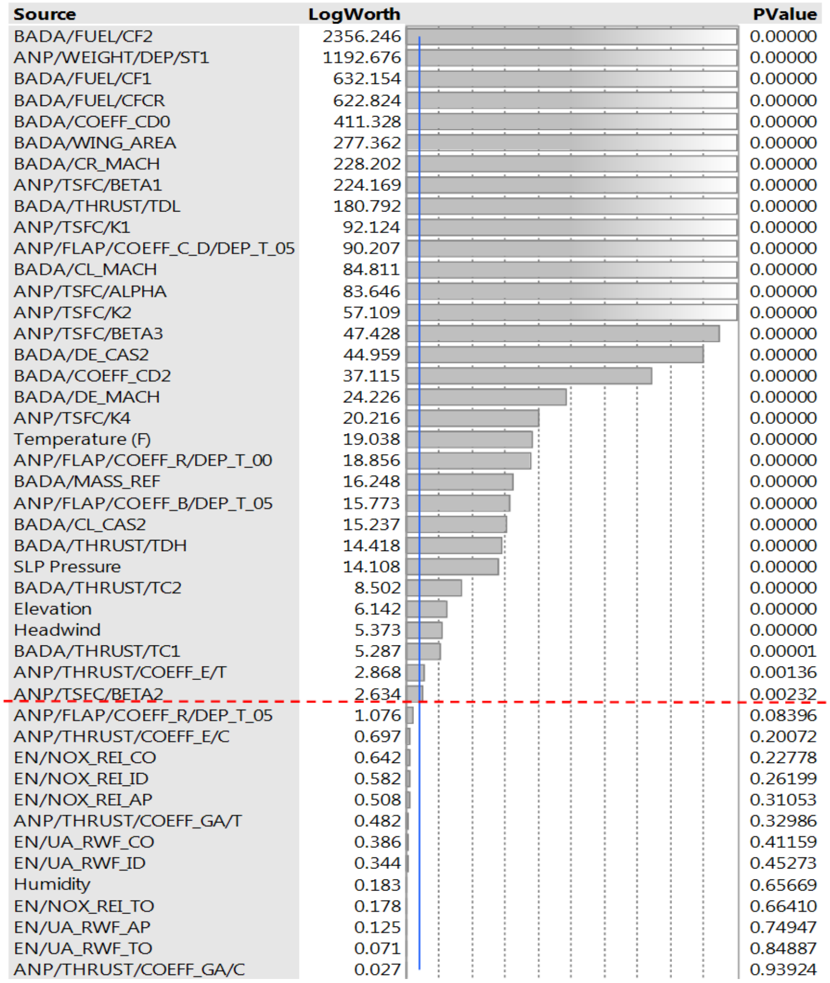
9.7.2 Fuel Burn and Emission Assessment

After the OFAT sensitivities and failure analyses, the effects of AEDT inputs on AEDT outputs were quantified when AEDT inputs were varied together. AEDT runs were separated for fuel burn/emissions versus noise in order to better use the computational resources. This section provides sensitivities and MCS results for fuel burn and emissions based on Experiment R2A. In this test, 5,000 LHS samples were generated based on the selected LSA aircraft from AEDT BADA Fleet DB. Based on the sensitivity study results from the previous section, those input parameters with no or negligible impacts were dropped. A total of 30 BADA/ANP/Emission coefficients and five atmospheric conditions were varied. The NPD curves were kept unchanged since no noise analyses are performed in this test. With the min/max ranges given in R2A DoE, all 5,000 sampled aircraft ran in AEDT successfully. Subsequent sections present the data analysis process and results of the screening test surrogate modeling, Monte Carlo Simulations, and global sensitivity analyses for the LSA aircraft.

9.7.2.1 Screening Test

In order to reduce the number of variables for the surrogate models, a screening test was conducted first with the 5,000 data samples. Screening tests are based on a linear model that estimates the main effects of each variable. The linear model only accounts for main effects (i.e. no interactions), and allows for rapid investigation of many variables to gain a first understanding of the problem. A regression analysis of this model, based on an Analysis of Variance (ANOVA) test, yields a Pareto plot that enables the identification of the most statistically significant contributors, as shown in Figure 9-11. This linear model allows one to reduce the number of variables such that RSEs with second order or higher order effects or more complex ANNs may be created with a smaller number of variables that matter the most.

Figure 9-11 is the result of an ANOVA test for mission fuel at stage length 1. The test result ranks the AEDT input variables by the order of main effects which is measured using the P-values. The lower the P-value, the greater its effect on mission fuel. Typically in a statistical test, the significance level, alpha, is set at 0.01 or 0.05. Alpha of 0.01 means that there is a less than 1% risk of concluding that parameters significantly impact the output when in reality no relation exists between that input parameter and the output metric. Since the P-values get too small for highly significant input parameters, LogWorth defined as -log10 (P-value) can be used as a substitute. A P-value of 0.01 is equal to a LogWorth of 2. Figure 9-11 shows the list of AEDT input parameters sorted by the level of effects on mission fuel for a stage length 1 mission. Both LogWorth and P-values are provided for each of the variables. Parameters above the red dotted horizontal line are the ones with P-values lower than 0.01 or LogWorth greater than 2. The most influential input variables to mission fuel burn were BADA fuel flow coefficients, the ANP departure weight, and the BADA parasite drag coefficient. Input variables below the red dotted line had P-values greater than 0.01. Those variables showed negligible effects on mission fuel burn results.



Source	LogWorth	PValue
BADA/FUEL/CF2	2356.246	0.00000
ANP/WEIGHT/DEP/ST1	1192.676	0.00000
BADA/FUEL/CF1	632.154	0.00000
BADA/FUEL/CFCR	622.824	0.00000
BADA/COEFF_CD0	411.328	0.00000
BADA/WING_AREA	277.362	0.00000
BADA/CR_MACH	228.202	0.00000
ANP/TSFC/BETA1	224.169	0.00000
BADA/THRUST/TDL	180.792	0.00000
ANP/TSFC/K1	92.124	0.00000
ANP/FLAP/COEFF_C_D/DEP_T_05	90.207	0.00000
BADA/CL_MACH	84.811	0.00000
ANP/TSFC/ALPHA	83.646	0.00000
ANP/TSFC/K2	57.109	0.00000
ANP/TSFC/BETA3	47.428	0.00000
BADA/DE_CAS2	44.959	0.00000
BADA/COEFF_CD2	37.115	0.00000
BADA/DE_MACH	24.226	0.00000
ANP/TSFC/K4	20.216	0.00000
Temperature (F)	19.038	0.00000
ANP/FLAP/COEFF_R/DEP_T_00	18.856	0.00000
BADA/MASS_REF	16.248	0.00000
ANP/FLAP/COEFF_B/DEP_T_05	15.773	0.00000
BADA/CL_CAS2	15.237	0.00000
BADA/THRUST/TDH	14.418	0.00000
SLP Pressure	14.108	0.00000
BADA/THRUST/TC2	8.502	0.00000
Elevation	6.142	0.00000
Headwind	5.373	0.00000
BADA/THRUST/TC1	5.287	0.00001
ANP/THRUST/COEFF_E/T	2.868	0.00136
ANP/TSFC/BETA2	2.634	0.00232
ANP/FLAP/COEFF_R/DEP_T_05	1.076	0.08396
ANP/THRUST/COEFF_E/C	0.697	0.20072
EN/NOX_REI_CO	0.642	0.22778
EN/NOX_REI_ID	0.582	0.26199
EN/NOX_REI_AP	0.508	0.31053
ANP/THRUST/COEFF_GA/T	0.482	0.32986
EN/UA_RWF_CO	0.386	0.41159
EN/UA_RWF_ID	0.344	0.45273
Humidity	0.183	0.65669
EN/NOX_REI_TO	0.178	0.66410
EN/UA_RWF_AP	0.125	0.74947
EN/UA_RWF_TO	0.071	0.84887
ANP/THRUST/COEFF_GA/C	0.027	0.93924

Figure 9-11. P-value and LogWorth for Mission Fuel

The ANOVA test was repeated for other AEDT outputs including mission fuel burn and NOx for a stage length 4 mission, terminal area departure NOx, and terminal area approach NOx. Departure NOx was analyzed for the stage length 1 mission. The resulting LogWorth values are summarized in Table 9-18. In order to compare the sensitivities for different metrics side-by-side, the input parameters are not listed in the order of Pareto rankings, but instead are sorted alphabetically. Color coding was used to visualize the degree of sensitivities. No color indicates negligible impact of the input parameter on the output. Dark blue or green means strong effects on NOx or fuel burn, respectively. The input parameters are grouped by the four categories previously described: ANP coefficients, BADA coefficients, Emission index, and Atmospheric conditions. It is clear to see that most BADA coefficients had no effect on departure and approach NOx. Only the BADA thrust adjustment for temperature at low altitude (BADA/THRUST/TDL) showed any effect on departure NOx. It is interesting to observe that ANP coefficients that were important for departure barely overlap with the coefficients that are important for approach. As expected, emissions coefficients had no effects on fuel burn.

Table 9-18. LogWorth Values for Mission Fuel, Mission NOx, and Terminal NOx

Categories	Departure NOx Stage1	Departure NOx Stage1	Approach NOx	TOTAL NOx Stage1	TOTAL NOx Stage4	Fuel Burn Stage1	Fuel Burn Stage4
	Source	LogWorth	LogWorth	LogWorth	LogWorth	LogWorth	LogWorth
ANP	ANP/FLAP/COEFF_B/DEP_T_05	96.725	0.667	2.924	0.378	15.773	0.678
	ANP/FLAP/COEFF_C_D/DEP_T_05	458.86	0.326	29.538	2.935	90.207	4.055
	ANP/FLAP/COEFF_R/DEP_T_00	4.082	0.028	6.251	1.62	18.856	2.212
	ANP/FLAP/COEFF_R/DEP_T_05	8.689	0.091	0.572	0.17	1.076	0.093
	ANP/THRUST/COEFF_E/C	2.243	0.151	29.907	2.365	0.697	0.419
	ANP/THRUST/COEFF_E/T	20.842	167.789	3.712	0.381	2.868	0.482
	ANP/THRUST/COEFF_GA/C	0.265	0.241	2.835	0.881	0.027	0.232
	ANP/THRUST/COEFF_GA/T	0.025	0.477	0.241	0.155	0.482	0.433
	ANP/TSFC/ALPHA	0.146	2658.604	15.748	0.707	83.646	3.536
	ANP/TSFC/BETA1	0.869	3177.843	38.976	5.168	224.169	14.12
	ANP/TSFC/BETA2	0.615	11.23	0.734	0.098	2.634	0.192
	ANP/TSFC/BETA3	0.006	1142.068	7.019	0.876	47.428	2.276
	ANP/TSFC/K1	343.17	0.237	74.902	2.531	92.124	2.061
	ANP/TSFC/K2	121.82	0.607	46.094	3.436	57.109	2.606
	ANP/TSFC/K4	83.159	0.588	15.162	1.868	20.216	1.558
	ANP/WEIGHT/DEP/ST1	431.259	0.524	708.744	561.444	1192.676	843.8
BADA	BADA/CL_CAS2	0.176	0.232	29.284	2.116	15.237	0.636
	BADA/CL_MACH	0.103	0.246	67.325	278.006	84.811	249.148
	BADA/COEFF_CD0	1.729	2.565	146.529	217.652	411.328	385.485
	BADA/COEFF_CD2	0.025	0.239	16.633	32.997	37.115	62.172
	BADA/CR_MACH	0.05	0.29	84.873	289.876	228.202	473.099
	BADA/DE_CAS2	0.548	0.418	9.699	1.087	44.959	2.786
	BADA/DE_MACH	0.152	0.717	6.267	1.033	24.226	1.292
	BADA/FUEL/CF1	0.707	1.164	350.734	438.91	632.154	674.034
	BADA/FUEL/CF2	0.102	0.002	1730.867	2001.628	2356.246	2489.899
	BADA/FUEL/CFCR	0.167	1.654	342.086	430.924	622.824	657.604
	BADA/MASS_REF	0.239	0.157	27.943	2.197	16.248	1.074
	BADA/THRUST/TC1	0.186	0.359	4.101	0.333	5.287	0.36
	BADA/THRUST/TC2	0.65	0	0.774	0.597	8.502	1.709
	BADA/THRUST/TDH	1.316	1.568	8.57	0.474	14.418	0.778
	BADA/THRUST/TDL	39.94	0.166	2.048	1.782	180.792	8.569
	BADA/WING_AREA	0.448	0.035	96.194	126.121	277.362	229.475
EMISSIONS	EN/NOX_REI_AP	0.747	2513.931	225.527	558.771	0.508	0.122
	EN/NOX_REI_CO	38.826	334.555	1040.91	949.824	0.642	0.765
	EN/NOX_REI_ID	0.606	6.413	5.951	1.6	0.582	0.803
	EN/NOX_REI_TO	953.747	0.057	335.726	37.593	0.178	0.033
	EN/UA_RWF_AP	0.011	634.288	16.188	49.32	0.125	0.289
	EN/UA_RWF_CO	31.304	31.957	216.531	132.41	0.386	0.308
	EN/UA_RWF_ID	0.322	0.737	0.062	0.211	0.344	0.496
	EN/UA_RWF_TO	11.278	0.711	19.122	2.481	0.071	0.076
ATMOSPHERE	Elevation	5.895	92.257	1.541	3.181	6.142	0.996
	Headwind	84.722	0.766	4.172	0.621	5.373	0.347
	Humidity	0.202	0.682	0.088	0.148	0.183	0.371
	SLP Pressure	195.237	255.238	62.192	9.021	14.108	3.317
	Temperature (F)	32.678	285.301	87.554	34.705	19.038	19.007

9.7.2.2 Surrogate Modeling

In order to enable rapid MCS for uncertainty propagation and quantification analysis, a surrogate modeling approach was implemented. Surrogate models were created for each of the key environmental metrics. In order to manage the number of independent variables in a surrogate model, only those variables with LogWorth value greater than 10 were used. Both RSMs and ANN Models were developed. Both techniques worked well, but ANN fits were selected for mission fuel burn. Figure 9-12 shows the ANN architecture for mission fuel burn for stage length 1 (350nm) and 4 (2,200nm) missions. It shows the list of input variables on the left and output variables on the right. Inputs and outputs are mapped by hidden nodes in two layers. Out of 5,000 data points, 2/3 of the points were used to train the ANNs and 1/3 of the points to validate the ANNs. Table 9-19 provides summary statistics for mission fuel burn ANNs. Figure 9-13 shows residuals against predicted values from the ANNs, which were used to evaluate the goodness of fit for these surrogate models. Surrogate models for mission NOx and terminal NOx were also created. ANNs for mission NOx had a similar architecture but included more input variables to include emissions EIs.

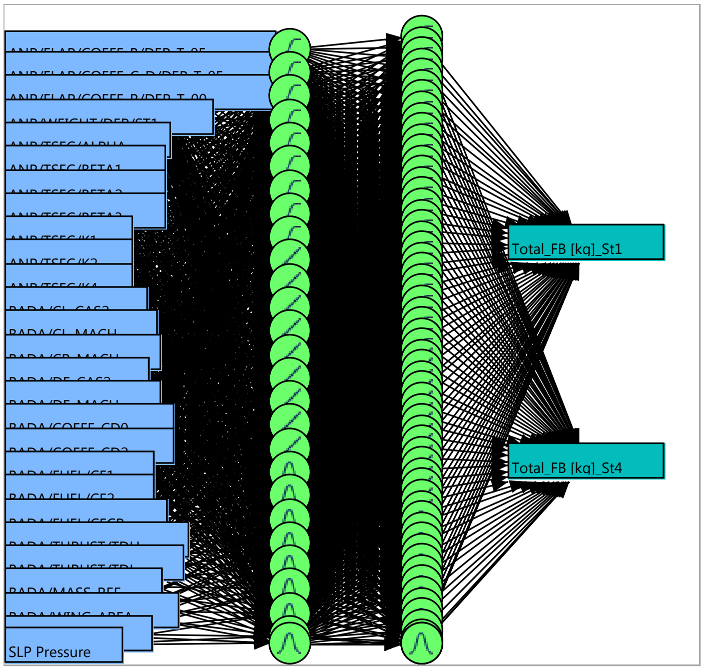
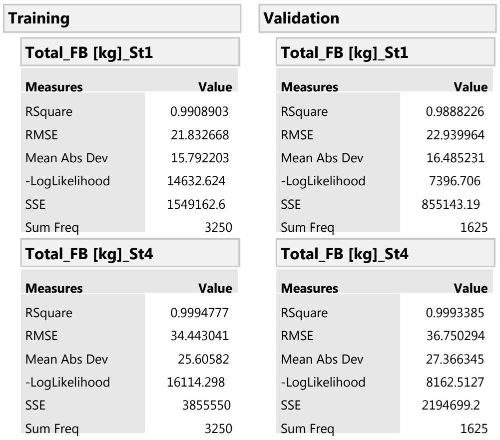


Figure 9-12. Artificial Neural Network Architecture for Mission Fuel

Table 9-19. Summary Statistics of Mission Fuel ANN



Training

Total_FB [kg]_St1

Measures	Value
RSquare	0.9908903
RMSE	21.832668
Mean Abs Dev	15.792203
-LogLikelihood	14632.624
SSE	1549162.6
Sum Freq	3250

Total_FB [kg]_St4

Measures	Value
RSquare	0.9994777
RMSE	34.443041
Mean Abs Dev	25.60582
-LogLikelihood	16114.298
SSE	3855550
Sum Freq	3250

Validation

Total_FB [kg]_St1

Measures	Value
RSquare	0.9888226
RMSE	22.939964
Mean Abs Dev	16.485231
-LogLikelihood	7396.706
SSE	855143.19
Sum Freq	1625

Total_FB [kg]_St4

Measures	Value
RSquare	0.9993385
RMSE	36.750294
Mean Abs Dev	27.366345
-LogLikelihood	8162.5127
SSE	2194699.2
Sum Freq	1625

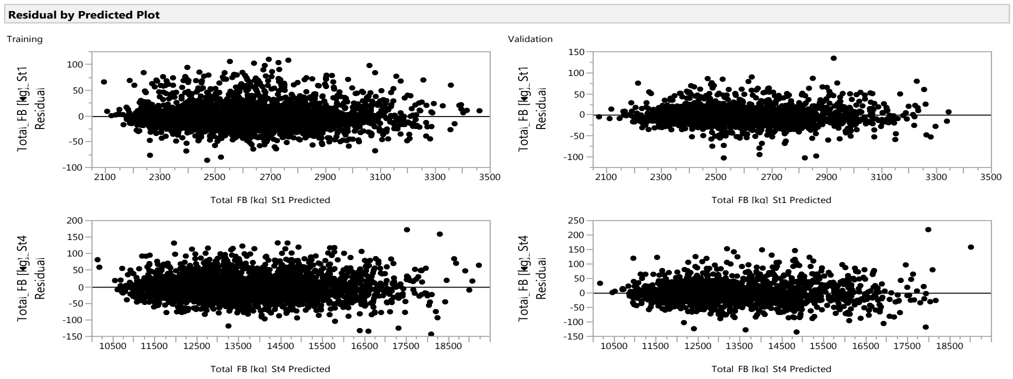


Figure 9-13. Residual vs Predicted Plot for Mission Fuel ANN

9.7.2.3 Monte Carlo Simulation

9.7.2.3.1 Monte Carlo Simulation Setup and Input Probability Distributions

In order to assess uncertainties in AEDT outputs due to uncertainties in AEDT inputs, Monte Carlo Simulations were performed utilizing the surrogate models created in the previous step. The ANN models enable very rapid Monte Carlo runs of a large number of samples. It takes approximately one second to populate 100,000 samples using the surrogate models. Since the MCS results are driven by the assumptions on input distributions, MCS are performed with three different sets of input distributions:

(a) Triangular distributions

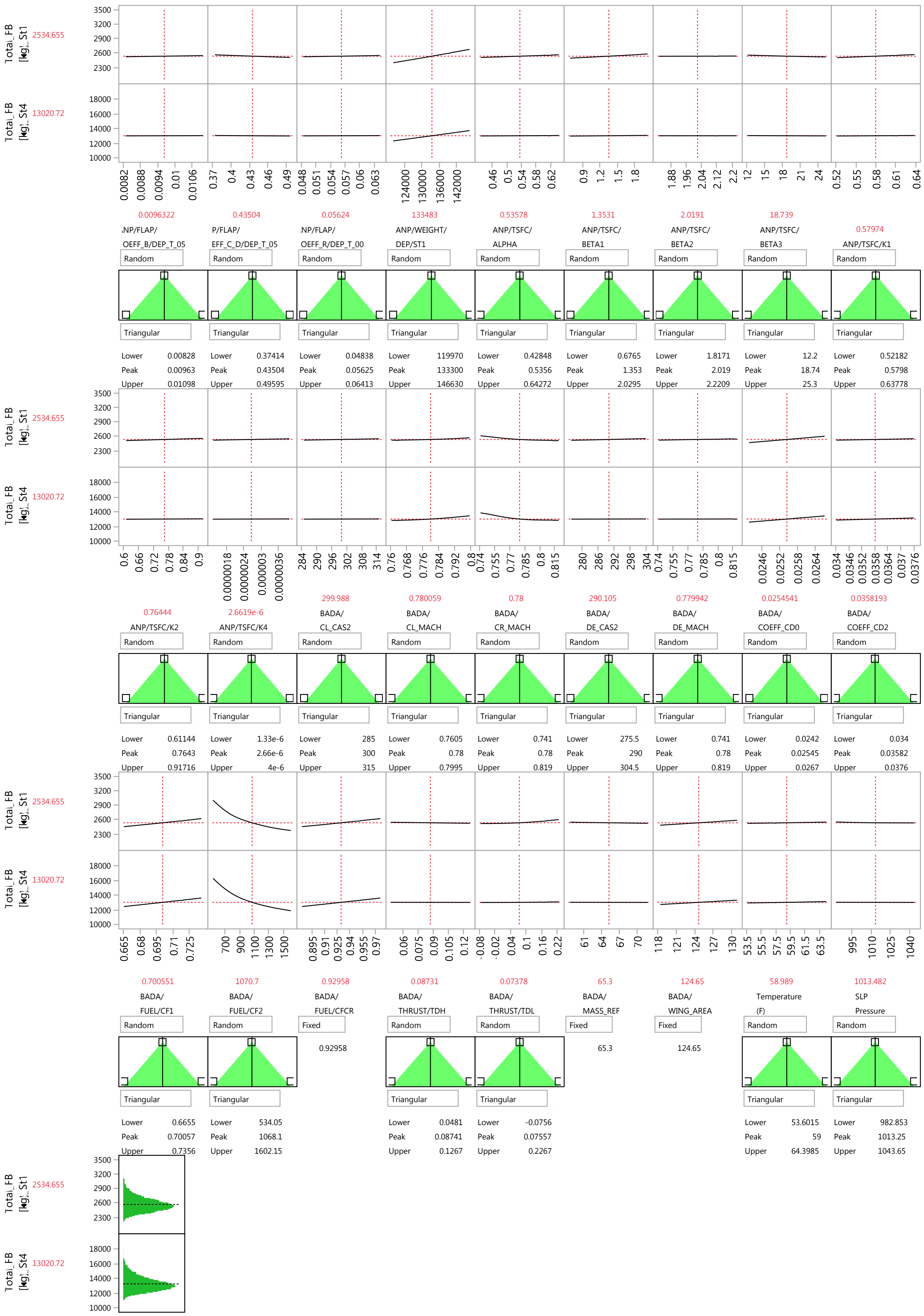
(b) Truncated Gaussian distributions

(c) Truncated Gaussian Copulas functions

For each of the input parameters, the distribution type is selected, and then min/max values are set to match the -/+% range of the R2A DoE tables as given in Table 9-8 through Table 9-11. Figure 9-14 is a snapshot of the MCS setup using triangular distributions in a commercial statistical software package, JMP® from SAS Institute.

For the triangular distribution, the most likely values were set at the baseline aircraft values. For the Gaussian distributions and Gaussian Copulas, the mean and standard deviation were set to define the distributions. Baseline aircraft values were used to set the mean values. The standard deviations were set to match the standard deviations of the triangular distributions. Since Gaussian distributions are defined from negative infinity to positive infinity, the MCS can generate samples outside the valid region. To prevent physically unfeasible data points being populated, min/max bounds were imposed on the Gaussian and Gaussian Copulas functions. The min/max bounds were set to match the -/+% range of the R2A DoE tables.

All the input variables were assumed to be independent of each other for the MCS with triangular and Gaussian distributions. For the Gaussian Copulas, dependencies among key input variables were defined by using the correlation coefficients observed from EDS Generic Vehicle fleet studies as discussed in Section 9.4.3. Atmospheric variables were assumed to be independent of each other. The matrices of correlation coefficients used for the Copulas MCS are provided in Table 9-20, Table 9-21, and Table 9-22.



.NP/FLAP/OEFF_B/DEP_T_05: 0.0096322, Random, Triangular, Lower 0.00828, Peak 0.00963, Upper 0.01098

P/FLAP/EFF_C_D/DEP_T_05: 0.43504, Random, Triangular, Lower 0.37414, Peak 0.43504, Upper 0.49595

.NP/FLAP/OEFF_R/DEP_T_00: 0.05624, Random, Triangular, Lower 0.04838, Peak 0.05625, Upper 0.06413

ANP/WEIGHT/DEP/ST1: 133483, Random, Triangular, Lower 119970, Peak 133300, Upper 146630

ANP/TSFC/ALPHA: 0.53578, Random, Triangular, Lower 0.42848, Peak 0.5356, Upper 0.64272

ANP/TSFC/BETA1: 1.3531, Random, Triangular, Lower 0.6765, Peak 1.353, Upper 2.0295

ANP/TSFC/BETA2: 2.0191, Random, Triangular, Lower 1.8171, Peak 2.019, Upper 2.2209

ANP/TSFC/BETA3: 18.739, Random, Triangular, Lower 12.2, Peak 18.74, Upper 25.3

ANP/TSFC/K1: 0.57974, Random, Triangular, Lower 0.52182, Peak 0.5798, Upper 0.63778

ANP/TSFC/K2: 0.76444, Random, Triangular, Lower 0.61144, Peak 0.7643, Upper 0.91716

ANP/TSFC/K4: 2.6619e-6, Random, Triangular, Lower 1.33e-6, Peak 2.66e-6, Upper 4e-6

BADA/CL_CAS2: 299.988, Random, Triangular, Lower 285, Peak 300, Upper 315

BADA/CL_MACH: 0.780059, Random, Triangular, Lower 0.7605, Peak 0.78, Upper 0.7995

BADA/CR_MACH: 0.78, Random, Triangular, Lower 0.741, Peak 0.78, Upper 0.819

BADA/DE_CAS2: 290.105, Random, Triangular, Lower 275.5, Peak 290, Upper 304.5

BADA/DE_MACH: 0.779942, Random, Triangular, Lower 0.741, Peak 0.78, Upper 0.819

BADA/COEFF_CD0: 0.0254541, Random, Triangular, Lower 0.0242, Peak 0.02545, Upper 0.0267

BADA/COEFF_CD2: 0.0358193, Random, Triangular, Lower 0.034, Peak 0.03582, Upper 0.0376

BADA/FUEL/CF1: 0.700551, Random, Triangular, Lower 0.6655, Peak 0.70057, Upper 0.7356

BADA/FUEL/CF2: 1070.7, Random, Triangular, Lower 534.05, Peak 1068.1, Upper 1602.15

BADA/FUEL/CFCR: 0.92958, Fixed 0.92958

BADA/THRUST/TDH: 0.08731, Random, Triangular, Lower 0.0481, Peak 0.08741, Upper 0.1267

BADA/THRUST/TDL: 0.07378, Random, Triangular, Lower -0.0756, Peak 0.07557, Upper 0.2267

BADA/MASS_REF: 65.3, Fixed 65.3

BADA/WING_AREA: 124.65, Fixed 124.65

Temperature (F): 58.989, Random, Triangular, Lower 53.6015, Peak 59, Upper 64.3985

SLP Pressure: 1013.482, Random, Triangular, Lower 982.853, Peak 1013.25, Upper 1043.65

Figure 9-14. Monte Carlo Simulation Set Up with Triangular Probability Density Functions for Mission Fuel Calculation

Table 9-20. Correlation Matrix for Mission Fuel MCS with Copulas Functions

Mission Fuel	ANP/WEIGHT/DEP/ST1	ANP/TSFC/ALPHA	ANP/TSFC/BETA1	ANP/TSFC/BETA2	ANP/TSFC/BETA3	ANP/TSFC/K1	ANP/TSFC/K2	ANP/TSFC/K4	BADA/COEFF_CD0	BADA/COEFF_CD2	BADA/FUEL/CF1	BADA/FUEL/CF2	BADA/THRUST/TDH	BADA/THRUST/TDL
ANP/WEIGHT/DEP/ST1	1	0.0465	-0.0816	-0.0911	0.2176	-0.0611	0.0808	-0.0164	0.6912	0.0214	-0.077	-0.1222	-0.4533	-0.4776
ANP/TSFC/ALPHA	0.0465	1	-0.7731	0.001	0.2781	-0.3588	0.9093	0.924	-0.2788	0.0137	0.9685	0.8994	0.7562	0.7591
ANP/TSFC/BETA1	-0.0816	-0.7731	1	0.5337	-0.2894	0.8217	-0.5545	-0.9215	0.2055	-0.0092	-0.6635	-0.7276	-0.7193	-0.7195
ANP/TSFC/BETA2	-0.0911	0.001	0.5337	1	0.0974	0.7175	0.2098	-0.2744	-0.0294	-0.0139	0.0645	-0.1578	-0.2461	-0.2463
ANP/TSFC/BETA3	0.2176	0.2781	-0.2894	0.0974	1	-0.0914	0.1251	0.2405	0.1208	0.0097	0.1684	0.0922	0.0358	0.0113
ANP/TSFC/K1	-0.0611	-0.3588	0.8217	0.7175	-0.0914	1	-0.2139	-0.672	0.1097	-0.0124	-0.225	-0.3466	-0.448	-0.4566
ANP/TSFC/K2	0.0808	0.9093	-0.5545	0.2098	0.1251	-0.2139	1	0.79	-0.2253	0.0211	0.9003	0.7693	0.5933	0.6037
ANP/TSFC/K4	-0.0164	0.924	-0.9215	-0.2744	0.2405	-0.672	0.79	1	-0.3164	0.0131	0.8566	0.853	0.8005	0.8085
BADA/COEFF_CD0	0.6912	-0.2788	0.2055	-0.0294	0.1208	0.1097	-0.2253	-0.3164	1	0.008	-0.3628	-0.3926	-0.668	-0.6947
BADA/COEFF_CD2	0.0214	0.0137	-0.0092	-0.0139	0.0097	-0.0124	0.0211	0.0131	0.008	1	0.0106	0.0063	-0.0121	-0.0153
BADA/FUEL/CF1	-0.077	0.9685	-0.6635	0.0645	0.1684	-0.225	0.9003	0.8566	-0.3628	0.0106	1	0.9526	0.803	0.806
BADA/FUEL/CF2	-0.1222	0.8994	-0.7276	-0.1578	0.0922	-0.3466	0.7693	0.853	-0.3926	0.0063	0.9526	1	0.8755	0.8742
BADA/THRUST/TDH	-0.4533	0.7562	-0.7193	-0.2461	0.0358	-0.448	0.5933	0.8005	-0.668	-0.0121	0.803	0.8755	1	0.9844
BADA/THRUST/TDL	-0.4776	0.7591	-0.7195	-0.2463	0.0113	-0.4566	0.6037	0.8085	-0.6947	-0.0153	0.806	0.8742	0.9844	1

Table 9-21. Correlation Matrix for Mission NOx MCS with Copulas Functions

Mission NOx	ANP/WEIGHT/DEP/ST1	ANP/THRUST/COEFF_E/C	ANP/TSFC/ALPHA	ANP/TSFC/BETA1	ANP/TSFC/K1	ANP/TSFC/K2	ANP/TSFC/K4	BADA/COEFF_CD0	BADA/COEFF_CD2	BADA/FUEL/CF1	BADA/FUEL/CF2	EN/NOX_REI_AP	EN/NOX_REI_CO	EN/NOX_REI_TO	EN/UA_RWF_AP	EN/UA_RWF_CO	EN/UA_RWF_TO
ANP/WEIGHT/DEP/ST1	1	0.9451	0.0465	-0.0816	-0.0611	0.0808	-0.0164	0.6912	0.0214	-0.077	-0.1222	0	0	0	0	0	0
ANP/THRUST/COEFF_E/C	0.9451	1	0.0471	-0.1051	-0.0925	0.0773	-0.007	0.6724	0.0259	-0.0845	-0.1228	0	0	0	0	0	0
ANP/TSFC/ALPHA	0.0465	0.0471	1	-0.7731	-0.3588	0.9093	0.924	-0.2788	0.0137	0.9685	0.8994	0	0	0	0	0	0
ANP/TSFC/BETA1	-0.0816	-0.1051	-0.7731	1	0.8217	-0.5545	-0.9215	0.2055	-0.0092	-0.6635	-0.7276	0	0	0	0	0	0
ANP/TSFC/K1	-0.0611	-0.0925	-0.3588	0.8217	1	-0.2139	-0.672	0.1097	-0.0124	-0.225	-0.3466	0	0	0	0	0	0
ANP/TSFC/K2	0.0808	0.0773	0.9093	-0.5545	-0.2139	1	0.79	-0.2253	0.0211	0.9003	0.7693	0	0	0	0	0	0
ANP/TSFC/K4	-0.0164	-0.007	0.924	-0.9215	-0.672	0.79	1	-0.3164	0.0131	0.8566	0.853	0	0	0	0	0	0
BADA/COEFF_CD0	0.6912	0.6724	-0.2788	0.2055	0.1097	-0.2253	-0.3164	1	0.008	-0.3628	-0.3926	0	0	0	0	0	0
BADA/COEFF_CD2	0.0214	0.0259	0.0137	-0.0092	-0.0124	0.0211	0.0131	0.008	1	0.0106	0.0063	0	0	0	0	0	0
BADA/FUEL/CF1	-0.077	-0.0845	0.9685	-0.6635	-0.225	0.9003	0.8566	-0.3628	0.0106	1	0.9526	0	0	0	0	0	0
BADA/FUEL/CF2	-0.1222	-0.1228	0.8994	-0.7276	-0.3466	0.7693	0.853	-0.3926	0.0063	0.9526	1	0	0	0	0	0	0
EN/NOX_REI_AP	0	0	0	0	0	0	0	0	0	0	0	1	0.962	0.9555	-0.2367	-0.2056	-0.1782
EN/NOX_REI_CO	0	0	0	0	0	0	0	0	0	0	0	0.962	1	0.9981	-0.1922	-0.1633	-0.1352
EN/NOX_REI_TO	0	0	0	0	0	0	0	0	0	0	0	0.9555	0.9981	1	-0.1689	-0.1373	-0.106
EN/UA_RWF_AP	0	0	0	0	0	0	0	0	0	0	0	-0.2367	-0.1922	-0.1689	1	0.992	0.9803
EN/UA_RWF_CO	0	0	0	0	0	0	0	0	0	0	0	-0.2056	-0.1633	-0.1373	0.992	1	0.9963
EN/UA_RWF_TO	0	0	0	0	0	0	0	0	0	0	0	-0.1782	-0.1352	-0.106	0.9803	0.9963	1

Table 9-22. Correlation Matrix for Terminal NOx MCS with Copulas Functions

Terminal NOx	ANP/WEIGHT/DEP/ST1	ANP/THRUST/COEFF_E/T	ANP/TSFC/ALPHA	ANP/TSFC/BETA1	ANP/TSFC/BETA2	ANP/TSFC/BETA3	ANP/TSFC/K1	ANP/TSFC/K2	ANP/TSFC/K4	BADA/THRUST/TDL	EN/NOX_REI_AP	EN/NOX_REI_CO	EN/NOX_REI_TO	EN/UA_RWF_AP	EN/UA_RWF_CO	EN/UA_RWF_TO
ANP/WEIGHT/DEP/ST1	1	0.946	0.0465	-0.0816	-0.0911	0.2176	-0.0611	0.0808	-0.0164	-0.4776	0	0	0	0	0	0
ANP/THRUST/COEFF_E/T	0.946	1	0.048	-0.1022	-0.128	0.2105	-0.0871	0.0794	-0.0084	-0.4389	0	0	0	0	0	0
ANP/TSFC/ALPHA	0.0465	0.048	1	-0.7731	0.001	0.2781	-0.3588	0.9093	0.924	0.7591	0	0	0	0	0	0
ANP/TSFC/BETA1	-0.0816	-0.1022	-0.7731	1	0.5337	-0.2894	0.8217	-0.5545	-0.9215	-0.7195	0	0	0	0	0	0
ANP/TSFC/BETA2	-0.0911	-0.128	0.001	0.5337	1	0.0974	0.7175	0.2098	-0.2744	-0.2463	0	0	0	0	0	0
ANP/TSFC/BETA3	0.2176	0.2105	0.2781	-0.2894	0.0974	1	-0.0914	0.1251	0.2405	0.0113	0	0	0	0	0	0
ANP/TSFC/K1	-0.0611	-0.0871	-0.3588	0.8217	0.7175	-0.0914	1	-0.2139	-0.672	-0.4566	0	0	0	0	0	0
ANP/TSFC/K2	0.0808	0.0794	0.9093	-0.5545	0.2098	0.1251	-0.2139	1	0.79	0.6037	0	0	0	0	0	0
ANP/TSFC/K4	-0.0164	-0.0084	0.924	-0.9215	-0.2744	0.2405	-0.672	0.79	1	0.8085	0	0	0	0	0	0
BADA/THRUST/TDL	-0.4776	-0.4389	0.7591	-0.7195	-0.2463	0.0113	-0.4566	0.6037	0.8085	1	0	0	0	0	0	0
EN/NOX_REI_AP	0	0	0	0	0	0	0	0	0	0	1	0.962	0.9555	-0.2367	-0.2056	-0.1782
EN/NOX_REI_CO	0	0	0	0	0	0	0	0	0	0	0.962	1	0.9981	-0.1922	-0.1633	-0.1352
EN/NOX_REI_TO	0	0	0	0	0	0	0	0	0	0	0.9555	0.9981	1	-0.1689	-0.1373	-0.106
EN/UA_RWF_AP	0	0	0	0	0	0	0	0	0	0	-0.2367	-0.1922	-0.1689	1	0.992	0.9803
EN/UA_RWF_CO	0	0	0	0	0	0	0	0	0	0	-0.2056	-0.1633	-0.1373	0.992	1	0.9963
EN/UA_RWF_TO	0	0	0	0	0	0	0	0	0	0	-0.1782	-0.1352	-0.106	0.9803	0.9963	1

9.7.2.3.2 Monte Carlo Simulation Results

For the three sets of probability density functions (PDF), MCS's were performed with 100,000 random samples. The results were PDFs for the AEDT outputs. Basic statistics and the distribution shapes for mission fuel burn are provided in Figure 9-15 and Table 9-23. The PDFs for mission fuel at stage length 1 and stage length 4 had similar distribution shapes. The mean values were also similar between the PDFs for the three input types. However, as is clear from the figure, the output PDF was narrower for the Copulas functions than the two other distribution types. When correlations among AEDT input parameters were captured by using Copulas Gaussian, the standard deviations of the fuel burn output decreased by 21% for stage length 1 and 17% for stage length 4. This means that a UQ study involving mission fuel may overestimate the variability of fuel burn when correlations among input parameters are ignored.

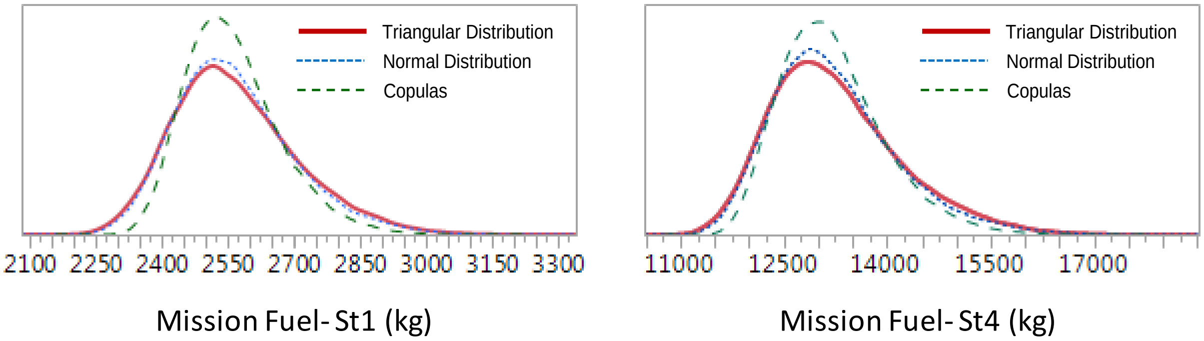


Figure 9-15. Comparison of Histograms of Mission Fuel

Table 9-23. MCS Results for Mission Fuel

	Fuel Burn - St1 (kg)			Fuel Burn - St4 (kg)		
Summary Statistics	Triangular	Gaussian	Copulas	Triangular	Gaussian	Copulas
Mean	2568.3367	2565.9402	2561.9937	13248.373	13231.919	13203.22
Std Dev	142.77437	136.59724	108.57901	949.89484	909.212	753.8691
Change in Std Dev due to Correlation	NA	DATUM	-21%	NA	DATUM	-17%

The PDFs for mission NOx at stage lengths 1 and 4 are provided in Figure 9-16 along with summary statistics in Table 9-24. The three output distributions from three different types of input PDFs had similar mean values. However, the standard deviation increased when correlations were captured among input parameters (Gaussian Copulas) compared to a case where independent Gaussian distributions were used. The standard deviations increased by 13% for a stage length 1 and 7% for a stage length 4 mission. This means that uncertainty assessment can underestimate uncertainties on mission NOx emissions when correlation is not incorporated.

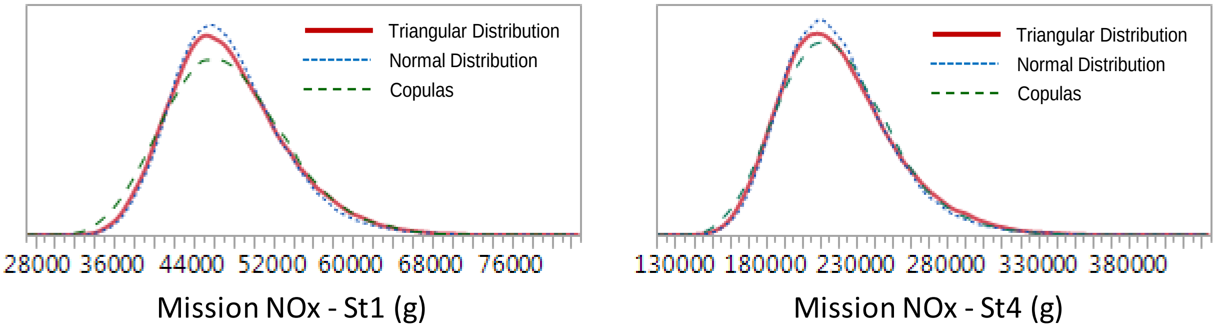


Figure 9-16. Comparison of Histograms of Mission NOx

Table 9-24. MCS Results for Mission NOx

	Mission NOx - St1 (g)			Mission NOx - St4 (g)		
Summary Statistics	Triangular	Gaussian	Copulas	Triangular	Gaussian	Copulas
Mean	47474.58	47346.182	47330.23	220083.18	219279.67	219219
Std Dev	5743.2933	5424.4968	6103.1243	31403.453	29679.663	31135.58
Change in Std Dev due to Correlation	NA	DATUM	13%	NA	DATUM	5%

The PDFs for departure and approach NOx emissions are provided in Figure 9-17 along with summary statistics in Table 9-25. For departure NOx, the three output distributions had similar shapes with similar mean and standard deviation. Standard deviation increased by 6% when Copulas functions were used. For approach NOx, the trend was opposite. When correlations were modeled in the MCS, the output variability decreased by 21%. This means that uncertainty assessment can overestimate uncertainties on approach NOx emissions when correlation is not incorporated.

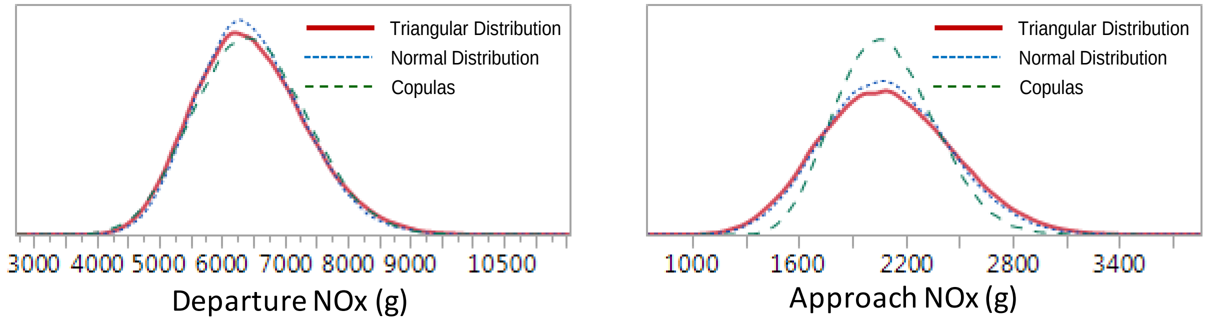


Figure 9-17. Comparison of Histograms of Terminal NOx

Table 9-25. MCS Results for Terminal NOx

	Departure NOx (g)			Approach NOx (g)		
Summary Statistics	Triangular	Gaussian	Copulas	Triangular	Gaussian	Copulas
Mean	6461.8508	6462.8302	6476.3782	2098.365	2093.8161	2091.583
Std Dev	889.69756	842.58625	889.04273	367.51647	346.33052	272.2637
Change in Std Dev due to Correlation	NA	DATUM	6%	NA	DATUM	-21%

9.7.2.4 Global Sensitivity Analysis

Finally, global sensitivity analyses are performed by running a series of MCS on the surrogate models developed for each of the AEDT output parameters. The results of global sensitivity analyses are total sensitivity indices (TSI) that quantify significance of input distributions to variance in output distributions. Global sensitivity analysis not only captures the main effects of each of the input distributions, but also captures total effects, which is main effects plus interactions of pairs of input variables.

Table 9-26 and Table 9-27 provide both main and total effects on mission fuel at stage length 1 and stage length 4, respectively. The AEDT input parameters were ranked based on the main and total effects. The rankings did not change whether only the main effects or both the main and interaction effects are captured or not. The TSI table gives clear indication of those key input variables that drive the uncertainties in output. For mission fuel, BADA fuel flow coefficients, ANP departure weight, and BADA parasite drag (BADA/COEFF_CD0) were among the most important contributors.

Table 9-26. TSI for Mission Fuel at Stage Length 1

	Total_FB [kg]_St1	
Input Parameter	Main Effect	Total Effect
BADA/FUEL/CF2	0.411	0.616
ANP/WEIGHT/DEP/ST1	0.084	0.171
BADA/FUEL/CF1	0.039	0.081
BADA/FUEL/CFCR	0.039	0.08
BADA/COEFF_CD0	0.027	0.056
BADA/WING_AREA	0.021	0.043
BADA/CR_MACH	0.02	0.043
BADA/THRUST/TDL	0.018	0.037
ANP/TSFC/BETA1	0.017	0.034
BADA/CL_MACH	0.012	0.026
ANP/TSFC/K1	0.01	0.021
ANP/FLAP/COEFF_C_D/DE	0.009	0.019
ANP/TSFC/ALPHA	0.009	0.018
ANP/TSFC/BETA3	0.007	0.014
ANP/TSFC/K2	0.007	0.014
SLP Pressure	0.006	0.013
BADA/DE_CAS2	0.005	0.011
BADA/COEFF_CD2	0.005	0.011
Temperature (F)	0.005	0.01
BADA/DE_MACH	0.005	0.01

Table 9-27. TSI for Mission Fuel at Stage Length 4

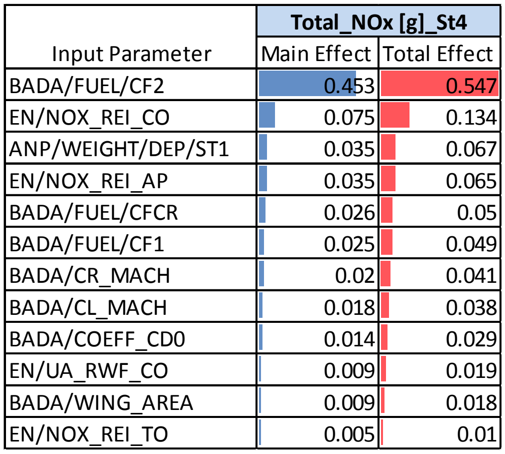
	Total_FB [kg]_St4	
Input Parameter	Main Effect	Total Effect
BADA/FUEL/CF2	0.526	0.69
ANP/WEIGHT/DEP/ST1	0.049	0.099
BADA/FUEL/CF1	0.036	0.075
BADA/FUEL/CFCR	0.036	0.074
BADA/CR_MACH	0.031	0.067
BADA/COEFF_CD0	0.023	0.047
BADA/CL_MACH	0.02	0.042
BADA/WING_AREA	0.015	0.031
BADA/COEFF_CD2	0.006	0.012
Temperature (F)	0.005	0.01

Table 9-28 and Table 9-29 provide both main and total effects for mission NOx at stage length 1 and stage length 4, respectively. The TSI table gives clear indication of those key input variables that drive the uncertainties in output. For mission fuel, BADA fuel flow coefficients, ANP departure weight, and NOx emission EI for climb (EN/NOX_REI_CO) and takeoff (EN/NOX_REI_TO) were among the most important contributors.

Table 9-28. TSI for Mission NOx at Stage Length 1

	Total_NOx [g]_St1	
Input Parameter	Main Effect	Total Effect
BADA/FUEL/CF2	0.368	0.48
EN/NOX_REI_CO	0.099	0.168
ANP/WEIGHT/DEP/ST1	0.056	0.105
EN/NOX_REI_TO	0.03	0.067
BADA/FUEL/CFCR	0.025	0.049
BADA/FUEL/CF1	0.024	0.048
EN/UA_RWF_CO	0.015	0.031
EN/NOX_REI_AP	0.016	0.031
BADA/COEFF_CD0	0.012	0.025
BADA/CR_MACH	0.009	0.018
Temperature (F)	0.009	0.018
BADA/WING_AREA	0.009	0.017
BADA/CL_MACH	0.008	0.016
EN/UA_RWF_TO	0.007	0.015
ANP/TSFC/K1	0.007	0.015
SLP Pressure	0.007	0.014
ANP/TSFC/K2	0.007	0.013

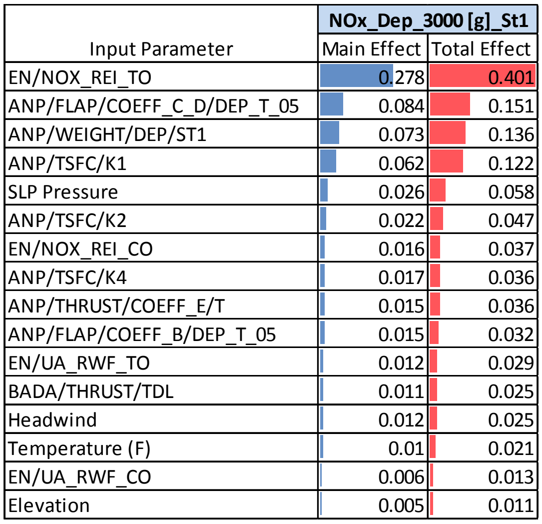
Table 9-29. TSI for Mission NOx at Stage Length 4



Input Parameter	Total_NOx [g]_St4	
	Main Effect	Total Effect
BADA/FUEL/CF2	0.453	0.547
EN/NOX_REI_CO	0.075	0.134
ANP/WEIGHT/DEP/ST1	0.035	0.067
EN/NOX_REI_AP	0.035	0.065
BADA/FUEL/CFCR	0.026	0.05
BADA/FUEL/CF1	0.025	0.049
BADA/CR_MACH	0.02	0.041
BADA/CL_MACH	0.018	0.038
BADA/COEFF_CD0	0.014	0.029
EN/UA_RWF_CO	0.009	0.019
BADA/WING_AREA	0.009	0.018
EN/NOX_REI_TO	0.005	0.01

Table 9-30 and Table 9-31 provide both main and total effects for departure and approach NOx, respectively. The AEDT input parameters were ranked based on the main and total effects. The rankings did not change whether only the main effects or both the main and interaction effects are captured or not. The TSI table gives clear indication of those key input variables that drive the uncertainties in output. For departure NOx, NOx emission EI for takeoff (EN/NOX_REI_TO) had the most significant effect, followed by an ANP flap coefficient and ANP departure weight. ANP TSFC coefficients for departure (K1, K2, and K4) also showed some marginal impacts. For approach NOx, ANP TSFC coefficients for approach (BETA1, ALPHA, and BETA3) had strong effects along with NOx emission EI for approach (EN/NOX_REI_AP). Past research[31] has identified increased errors in fuel burn calculation in terminal area due to inaccuracies of TSFC modeling in some of the ANP aircraft. Some ANP aircraft use an updated methodology proposed by Senzig, et al[31], which is more accurate. However, a large number of ANP aircraft use the old ANP TSFC coefficients. BADA version 4 from EUROCONTROL provides an improved methodology and data for terminal area fuel burn estimation, but its license is not available to general AEDT users.

Table 9-30. TSI for Departure NOx



Input Parameter	NOx_Dep_3000 [g]_St1	
	Main Effect	Total Effect
EN/NOX_REI_TO	0.278	0.401
ANP/FLAP/COEFF_C_D/DEP_T_05	0.084	0.151
ANP/WEIGHT/DEP/ST1	0.073	0.136
ANP/TSFC/K1	0.062	0.122
SLP Pressure	0.026	0.058
ANP/TSFC/K2	0.022	0.047
EN/NOX_REI_CO	0.016	0.037
ANP/TSFC/K4	0.017	0.036
ANP/THRUST/COEFF_E/T	0.015	0.036
ANP/FLAP/COEFF_B/DEP_T_05	0.015	0.032
EN/UA_RWF_TO	0.012	0.029
BADA/THRUST/TDL	0.011	0.025
Headwind	0.012	0.025
Temperature (F)	0.01	0.021
EN/UA_RWF_CO	0.006	0.013
Elevation	0.005	0.011

Table 9-31. TSI for Approach NOx

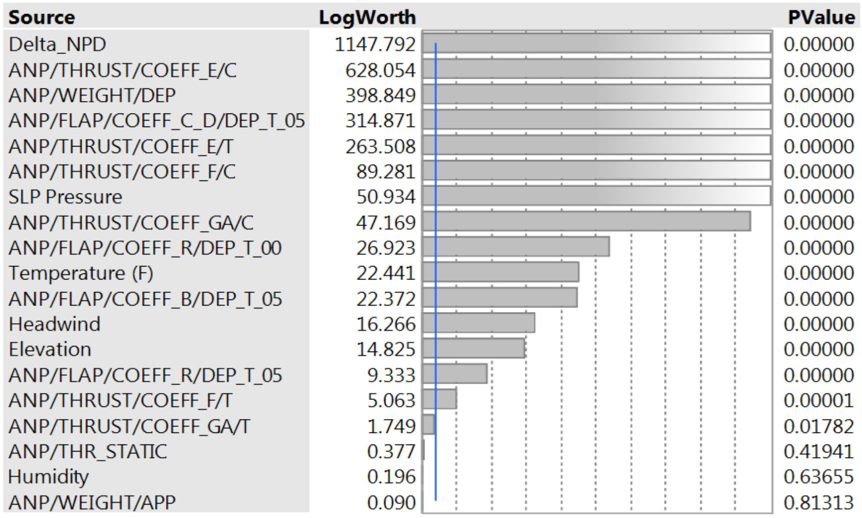
	NOx_App_3000 [g]	
Input Parameter	Main Effect	Total Effect
ANP/TSFC/BETA1	0.35	0.432
ANP/TSFC/ALPHA	0.18	0.253
EN/NOX_REI_AP	0.152	0.223
ANP/TSFC/BETA3	0.029	0.055
EN/UA_RWF_AP	0.012	0.023
EN/NOX_REI_CO	0.01	0.022
Temperature (F)	0.005	0.011
SLP Pressure	0.005	0.01
ANP/THRUST/COEFF_E/T	0.005	0.01

9.7.3 Noise Assessment

This section provides sensitivities and MCS results for departure and approach noise based on Experiment R2B. In this test, 2,000 LHS samples were generated based on the selected LSA aircraft from AEDT Fleet DB. Based on the sensitivity study results from Section 9.6, those input parameters with no or negligible impacts were set to default values and not included for surrogate model generation. None of the BADA, Emissions coefficients, or ANP TSFC coefficients were used in the noise runs. Thirteen ANP coefficients and 5 atmospheric conditions were varied. The NPDs were changed by from +/-1.5dB to +/-3dB depending on the slant distance. Both M and S type NPDs were changed simultaneously. Both departure and approach noise contour shapes were calculated from 55dB to 90dB in 5dB increments. In order to quantify the contour size and shape, contour area, length, and width were used as noise metrics. With the min/max ranges given in R2B DoE, all 2,000 sampled aircraft ran successfully in AEDT. Subsequent sections present the data analysis process and results of screening tests, surrogate modeling, Monte Carlo Simulations, and global sensitivity analyses for the LSA aircraft.

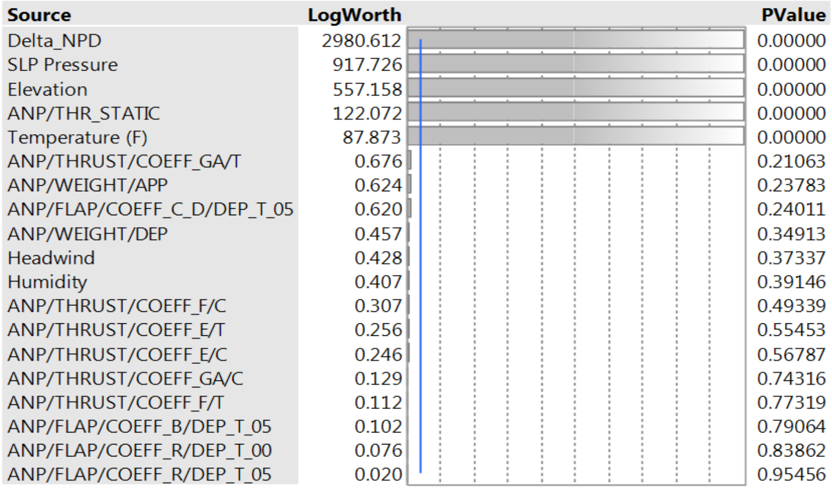
9.7.3.1 Screening Test

In order to reduce the number of variables for the surrogate models, a screening test was conducted first with the 2,000 data samples. Figure 9-18 and Figure 9-19 are the results of ANOVA tests for departure and approach 80dB contour areas. The test results rank the AEDT input variables by the order of main effects, which is measured using the P-values. The lower the P-value, the higher its impact on noise contour areas. Typically, those input variables with P-values greater than 0.01 (or equivalently, LogWorth value less than 2) are regarded as ineffective to the output.



Source	LogWorth	PValue
Delta_NPD	1147.792	0.00000
ANP/THRUST/COEFF_E/C	628.054	0.00000
ANP/WEIGHT/DEP	398.849	0.00000
ANP/FLAP/COEFF_C_D/DEP_T_05	314.871	0.00000
ANP/THRUST/COEFF_E/T	263.508	0.00000
ANP/THRUST/COEFF_F/C	89.281	0.00000
SLP Pressure	50.934	0.00000
ANP/THRUST/COEFF_GA/C	47.169	0.00000
ANP/FLAP/COEFF_R/DEP_T_00	26.923	0.00000
Temperature (F)	22.441	0.00000
ANP/FLAP/COEFF_B/DEP_T_05	22.372	0.00000
Headwind	16.266	0.00000
Elevation	14.825	0.00000
ANP/FLAP/COEFF_R/DEP_T_05	9.333	0.00000
ANP/THRUST/COEFF_F/T	5.063	0.00001
ANP/THRUST/COEFF_GA/T	1.749	0.01782
ANP/THR_STATIC	0.377	0.41941
Humidity	0.196	0.63655
ANP/WEIGHT/APP	0.090	0.81313

Figure 9-18. P-value and LogWorth for Departure 80dB Contour Area



Source	LogWorth	PValue
Delta_NPD	2980.612	0.00000
SLP Pressure	917.726	0.00000
Elevation	557.158	0.00000
ANP/THR_STATIC	122.072	0.00000
Temperature (F)	87.873	0.00000
ANP/THRUST/COEFF_GA/T	0.676	0.21063
ANP/WEIGHT/APP	0.624	0.23783
ANP/FLAP/COEFF_C_D/DEP_T_05	0.620	0.24011
ANP/WEIGHT/DEP	0.457	0.34913
Headwind	0.428	0.37337
Humidity	0.407	0.39146
ANP/THRUST/COEFF_F/C	0.307	0.49339
ANP/THRUST/COEFF_E/T	0.256	0.55453
ANP/THRUST/COEFF_E/C	0.246	0.56787
ANP/THRUST/COEFF_GA/C	0.129	0.74316
ANP/THRUST/COEFF_F/T	0.112	0.77319
ANP/FLAP/COEFF_B/DEP_T_05	0.102	0.79064
ANP/FLAP/COEFF_R/DEP_T_00	0.076	0.83862
ANP/FLAP/COEFF_R/DEP_T_05	0.020	0.95456

Figure 9-19. P-value and LogWorth for Approach 80dB Contour Area

The ANOVA test was repeated for departure and approach noise contour widths and lengths. The resulting LogWorth values are summarized in Table 9-32. In order to compare the sensitivities for different metrics side-by-side, the input parameters are not listed in the order of effectiveness rankings, but are sorted alphabetically. Color coding is used to visualize the degree of sensitivities. No color indicates negligible effect of the input parameter on the output. Dark red or yellow means strong effect on noise contours. Changes in NPD curves had the strongest effect on both departure and approach noise. ANP flap, thrust, and departure weight also had measurable impact on departure noise contours. Airport atmosphere also showed some effect on departure noise. For example, head wind and pressure had greater effect on contour length than on contour width. On the other hand, approach noise contour was almost completely driven by the NPD curves with some minor effect from airport atmospheric conditions. Only the reverse thrust (ANP/THR_STATIC) showed marginal impact on approach area among all the ANP coefficients. This insensitivity of approach noise to ANP coefficients is due to the fact that the LSA aircraft selected in this study uses fixed points profiles for approach instead of procedure profiles. Some aircraft in the ANP DB still use fixed point profiles, which prescribe exactly how the aircraft is flown at terminal area regardless of other ANP inputs. The use of fixed point profiles provides less flexibility in running AEDT modeling on complicated terminal area operations. It defeats the purpose of AEDT's high fidelity algorithm due to the limitations in the data in ANP DB. It would be necessary to coordinate with the aircraft manufactures to improve the ANP models for aircraft with fixed point profiles.

Table 9-32. LogWorth Values for Departure and Approach Noise Contours

Categories	Input Parameters	Departure 80 dB Contour			Approach 80 dB Contour		
		AREA	WIDTH	LENGTH	AREA	WIDTH	LENGTH
		LogWorth	LogWorth	LogWorth	LogWorth	LogWorth	LogWorth
NPD	Delta_NPD	1147.792	1231.473	1198.787	2980.612	2301.576	1580.29
ANP	ANP/FLAP/COEFF_B/DEP_T_05	22.372	2.038	56.267	0.102	1.088	0.644
	ANP/FLAP/COEFF_C_D/DEP_T_05	314.871	779.186	143.007	0.62	0.349	0.726
	ANP/FLAP/COEFF_R/DEP_T_00	26.923	0.782	107.045	0.076	0.245	0.037
	ANP/FLAP/COEFF_R/DEP_T_05	9.333	10.956	13.6	0.02	0.419	0
	ANP/THR_STATIC	0.377	0.478	0.397	122.072	0.736	1.12
	ANP/THRUST/COEFF_E/C	628.054	42.233	785.377	0.246	0.129	0.1
	ANP/THRUST/COEFF_E/T	263.508	1382.842	230.456	0.256	0.122	0.158
	ANP/THRUST/COEFF_F/C	89.281	2.938	156.518	0.307	0.032	0.453
	ANP/THRUST/COEFF_F/T	5.063	233.861	15.87	0.112	0.071	0.017
	ANP/THRUST/COEFF_GA/C	47.169	1.142	115.41	0.129	0.495	0.562
	ANP/THRUST/COEFF_GA/T	1.749	11.935	0.013	0.676	0.096	0.413
	ANP/WEIGHT/APP	0.09	0.112	0.096	0.624	0.77	0.678
	ANP/WEIGHT/DEP	398.849	12.15	853.52	0.457	0.413	1.295
AIRPORT ATMOSPHERE	Elevation	14.825	2.285	64.876	557.158	313.533	43.038
	Headwind	16.266	53.248	135.957	0.428	0.16	0.144
	Humidity	0.196	0.026	0.318	0.407	0.731	0.556
	SLP Pressure	50.934	0.539	166.493	917.726	413.203	108.393
	Temperature (F)	22.441	38.446	15.37	87.873	22.317	3.317

9.7.3.2 Surrogate Modeling

In order to enable rapid MCS in uncertainty propagation and quantification, a surrogate modeling approach was implemented. Surrogate models were created for each of the noise metrics. In order to manage the number of independent variables in a surrogate model, only those variables with LogWorth values greater than 10 were used. Both RSMs and ANN Models were developed. Both techniques worked well, but ANN models were selected for noise contours. Figure 9-20 shows the ANN architecture for departure noise (on the left) and approach noise (on the right). The diagrams show the list of input variables on the left and output variables on the right. Input and outputs are mapped by hidden nodes in a single layer. Out of 2,000 data points, two-thirds of the points were used to train the ANN and one-third of the points to validate the ANNs. Table 9-33 provides summary statistics for noise contour ANNs.

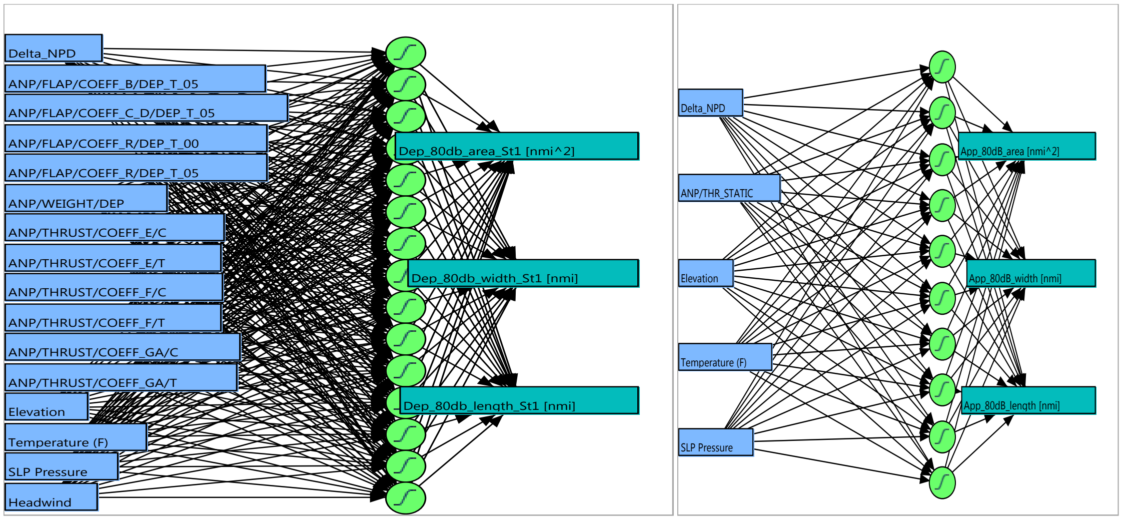
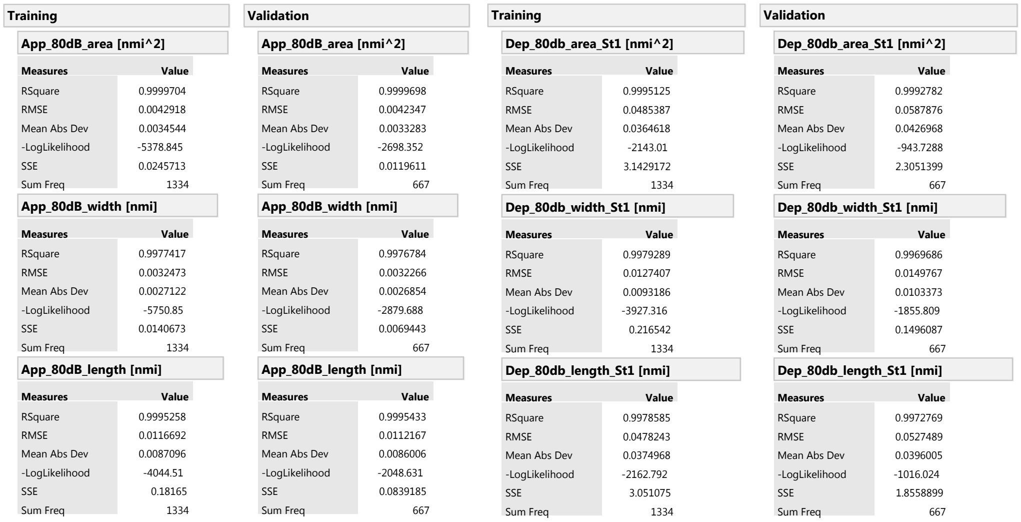


Figure 9-20. Artificial Neural Network Architecture for Departure (left) and Approach (right) Noise

Table 9-33. Summary Statistics of Noise ANNs



	Training	Validation	Training	Validation
Measures	App_80dB_area [nmi^2]	App_80dB_area [nmi^2]	Dep_80db_area_St1 [nmi^2]	Dep_80db_area_St1 [nmi^2]
RSquare	0.9999704	0.9999698	0.9995125	0.9992782
RMSE	0.0042918	0.0042347	0.0485387	0.0587876
Mean Abs Dev	0.0034544	0.0033283	0.0364618	0.0426968
-LogLikelihood	-5378.845	-2698.352	-2143.01	-943.7288
SSE	0.0245713	0.0119611	3.1429172	2.3051399
Sum Freq	1334	667	1334	667

	Training	Validation	Training	Validation
Measures	App_80dB_width [nmi]	App_80dB_width [nmi]	Dep_80db_width_St1 [nmi]	Dep_80db_width_St1 [nmi]
RSquare	0.9977417	0.9976784	0.9979289	0.9969686
RMSE	0.0032473	0.0032266	0.0127407	0.0149767
Mean Abs Dev	0.0027122	0.0026854	0.0093186	0.0103373
-LogLikelihood	-5750.85	-2879.688	-3927.316	-1855.809
SSE	0.0140673	0.0069443	0.216542	0.1496087
Sum Freq	1334	667	1334	667

	Training	Validation	Training	Validation
Measures	App_80dB_length [nmi]	App_80dB_length [nmi]	Dep_80db_length_St1 [nmi]	Dep_80db_length_St1 [nmi]
RSquare	0.9995258	0.9995433	0.9978585	0.9972769
RMSE	0.0116692	0.0112167	0.0478243	0.0527489
Mean Abs Dev	0.0087096	0.0086006	0.0374968	0.0396005
-LogLikelihood	-4044.51	-2048.631	-2162.792	-1016.024
SSE	0.18165	0.0839185	3.051075	1.8558899
Sum Freq	1334	667	1334	667

9.7.3.3 Monte Carlo Simulation

9.7.3.3.1 Monte Carlo Simulation Setup and Input Probability Distributions

To quantify uncertainties in departure and approach noise, Monte Carlo Simulations are performed with three different sets of input distributions:

(a) Triangular distributions

(b) Truncated Gaussian distributions

(c) Truncated Gaussian Copulas functions (departure noise only)

For each of the input variables, the distribution type is selected, and then min/max values are set to match the -/+% range of the R2B DoE tables as given in Table 9-8 to Table 9-12. Figure 9-21 is a snapshot of the MCS setup using triangular distributions in JMP®. For the triangular distribution, the most likely values were set at the baseline aircraft values. For the Gaussian distributions and Gaussian Copulas, the mean and standard deviation are set to define the distributions. Baseline aircraft values were used to set the mean values. Standard deviations were set to match the standard deviations of the triangular distributions. Since Gaussian distributions are defined from negative infinity and positive infinity, the MCS can generate samples outside the valid region. To prevent physically unfeasible data points being populated, min/max bounds were imposed on the Gaussian and Gaussian Copulas functions. The min/max bounds were set to match the -/+% range of the R2B DoE tables. For each of the MCS runs, 100,000 random samples were generated.

All the input variables were assumed to be independent of each other for the MCS with triangular and Gaussian distributions. For the Gaussian Copulas, dependencies among key input variables were defined by using the coefficients of correlation from EDS Generic Vehicle fleet as discussed in Section 9.4.3. The matrix of correlation coefficients used for the Copulas MCS are provided in Table 9-34. For the approach noise contours, all the input variables were assumed to be independent of each other. Thus, no MCS was performed using Copulas functions. Atmospheric variables were assumed to be independent of each other.

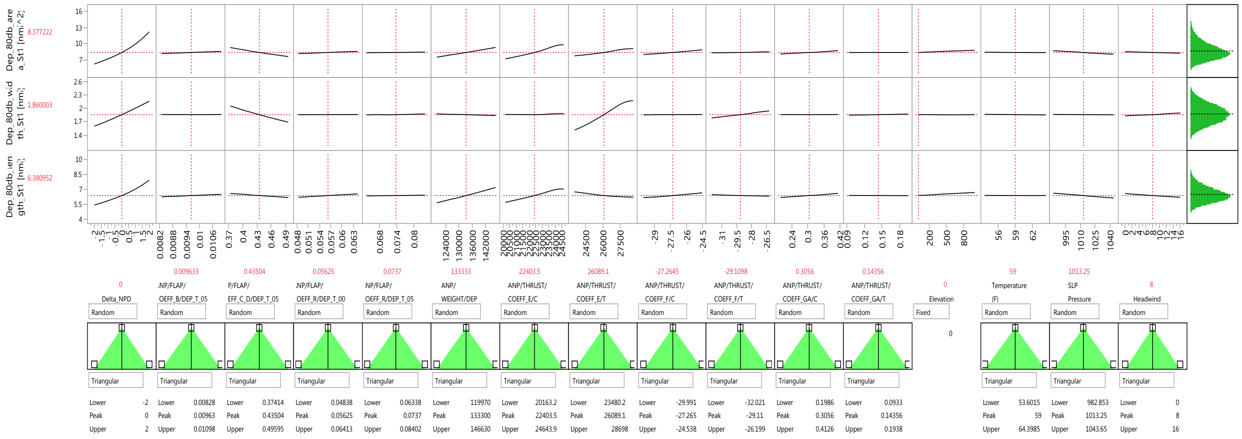


Figure 9-21. Monte Carlo Simulation Set Up for Departure Noise with Triangular Probability Distribution Functions

Table 9-34. Correlation Matrix for Departure Noise MCS with Copulas Functions

Departure Noise	ANP/WEIGHT/DEP	ANP/THRUST/COEFF_E/C	ANP/THRUST/COEFF_E/T	ANP/THRUST/COEFF_F/C	ANP/THRUST/COEFF_F/T	ANP/THRUST/COEFF_GA/C	ANP/THRUST/COEFF_GA/T
ANP/WEIGHT/DEP	1	0.9454	0.9464	-0.7823	-0.7899	0.4447	0.7827
ANP/THRUST/COEFF_E/C	0.9454	1	0.9987	-0.8293	-0.8345	0.4816	0.8256
ANP/THRUST/COEFF_E/T	0.9464	0.9987	1	-0.8276	-0.8356	0.4795	0.8253
ANP/THRUST/COEFF_F/C	-0.7823	-0.8293	-0.8276	1	0.9731	-0.4362	-0.9335
ANP/THRUST/COEFF_F/T	-0.7899	-0.8345	-0.8356	0.9731	1	-0.363	-0.9019
ANP/THRUST/COEFF_GA/C	0.4447	0.4816	0.4795	-0.4362	-0.363	1	0.4912
ANP/THRUST/COEFF_GA/T	0.7827	0.8256	0.8253	-0.9335	-0.9019	0.4912	1

9.7.3.3.2 Monte Carlo Simulation Results

For the three sets of PDFs, MCS's were performed with 100,000 random samples. The results are PDFs of the noise contour areas. Basic statistics and the distributions shapes for departure noise 80dB contour areas are provided in Figure 9-22 and Table 9-35. The PDFs for departure and approach noise contour areas had similar distribution shapes and mean values. For the departure noise contour area, the output distribution was wider when Copulas functions were used. The standard deviation increased by 15% when correlation among ANP input parameters was modeled using Gaussian Copulas compared to the independent Gaussian distributions. A UQ study involving departure noise may underestimate the variability of contour area when correlations among input parameters are ignored.

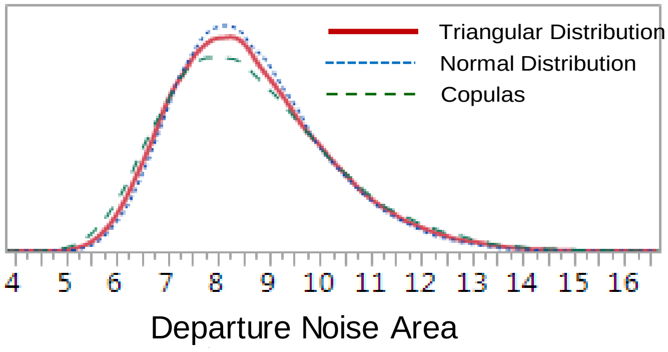


Figure 9-22. Comparison of Histograms of Departure Noise

Table 9-35. MCS Results for Departure Noise 80dB Contour Area

	Departure Noise Area (nm^2)		
Summary Statistics	Triangular	Gaussian	Copulas
Mean	8.633906	8.630712	8.637761
Std Dev	1.539888	1.452732	1.674308
Change in Std Dev due to Correlation	NA	DATUM	15%

The probability distributions for approach noise 80dB contour areas are provided in Figure 9-23 along with summary statistics in Table 9-36. For the approach noise, input uncertainties on NPDs, ANP reverse thrust, airport temperature, and airport pressure were modeled. Since uncertainties in NPDs are the dominating factor with approach noise, the output distribution results in a triangular PDF when triangular distributions were used for the NPDs. When a Normal distribution was used for the NPDs, the output distribution for noise contour area followed a Normal distribution shape.

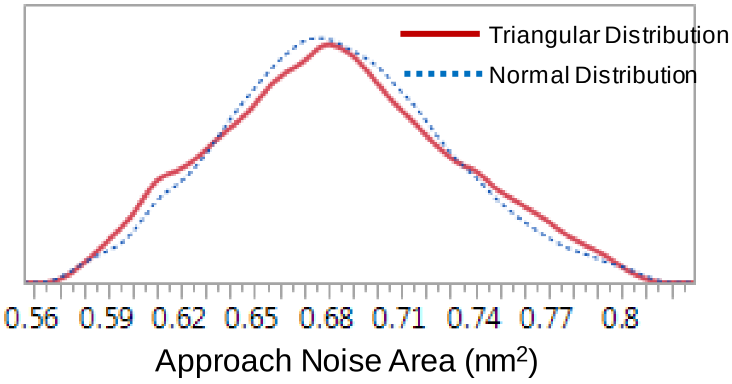


Figure 9-23. Comparison of Histograms of Approach Noise 80dB Contour Area

Table 9-36. MCS Results for Approach Noise

	Approach Noise Area (nm^2)	
Summary Statistics	Triangular	Gaussian
Mean	4.5259573	4.5253113
Std Dev	0.5611595	0.5318306

9.7.3.4 Global Sensitivity Analysis

Global sensitivity analyses were performed for departure and approach noise contours by running a series of MCS on the surrogate models developed for noise. Table 9-37, Table 9-38, and Table 9-39 provide both main and total impacts on departure 80dB contour area, width, and length, respectively. The AEDT input parameters were ranked based on the main and total effects. The rankings did not change whether only the main effects or both the main and interaction effects are captured or not. The TSI table gives clear indication of those key input variables that drive the uncertainties in output. For departure contour area, NPD curves had the most impacts, followed by ANP climb thrust and ANP departure weight. ANP takeoff thrust had the strongest impact on departure contour width.

Table 9-37. TSI for Departure 80dB Contour Area

Dep_80db_area_St1 [nmi^2]		
Input Parameter	**Main Effect**	**Total Effect**
Delta_NPD	0.555	0.653
ANP/THRUST/COEFF_E/C	0.094	0.168
ANP/WEIGHT/DEP	0.042	0.081
ANP/FLAP/COEFF_C_D/DEP_T_05	0.029	0.056
ANP/THRUST/COEFF_E/T	0.023	0.046
ANP/THRUST/COEFF_F/C	0.009	0.02
ANP/THRUST/COEFF_GA/C	0.007	0.015
SLP Pressure	0.005	0.011
Temperature (F)	0.005	0.011

Table 9-38. TSI for Departure 80dB Contour Width

Dep_80db_width_St1 [nmi]		
Input Parameter	**Main Effect**	**Total Effect**
ANP/THRUST/COEFF_E/T	0.382	0.511
Delta_NPD	0.243	0.357
ANP/FLAP/COEFF_C_D/DEP_T_05	0.062	0.121
ANP/THRUST/COEFF_F/T	0.013	0.028
ANP/THRUST/COEFF_E/C	0.009	0.019
Temperature (F)	0.006	0.013

Table 9-39. TSI for Departure 80dB Contour Length

Dep_80db_length_St1 [nmi]		
Column	Main Effect	Total Effect
Delta_NPD	0.377	0.511
ANP/WEIGHT/DEP	0.125	0.218
ANP/THRUST/COEFF_E/C	0.098	0.186
ANP/THRUST/COEFF_E/T	0.016	0.033
ANP/THRUST/COEFF_F/C	0.013	0.028
SLP Pressure	0.012	0.026
ANP/THRUST/COEFF_GA/C	0.011	0.025
ANP/FLAP/COEFF_C_D/DEP_T_05	0.011	0.022
Headwind	0.01	0.021
ANP/FLAP/COEFF_R/DEP_T_00	0.009	0.019
Temperature (F)	0.006	0.013
Elevation	0.006	0.013
ANP/FLAP/COEFF_B/DEP_T_05	0.005	0.011

Global sensitivity analysis on the 80dB approach noise contours confirmed the previous observations that changes in NPD curves was the only dominating factor for approach noise. Table 9-40, Table 9-41, and Table 9-42 provide main and total effects on approach contour area, width, and length. Compared to the NPD curves, other input parameters had negligible effects on the variance of approach contour area.

Table 9-40. TSI for Approach 80dB Contour Area

App_80dB_area [nmi^2]		
Input Parameter	**Main Effect**	**Total Effect**
Delta_NPD	0.886	0.99
SLP Pressure	0.007	0.013

Table 9-41. TSI for Approach 80dB Contour Width

App_80dB_width [nmi]		
Input Parameter	**Main Effect**	**Total Effect**
Delta_NPD	0.809	0.989
SLP Pressure	0.01	0.021
Elevation	0.008	0.017

Table 9-42. TSI for Approach 80dB Contour Length

App_80dB_length [nmi]		
Input Parameter	**Main Effect**	**Total Effect**
Delta_NPD	0.739	1
SLP Pressure	0.014	0.029
Elevation	0.008	0.016

9.8 Conclusion

9.8.1 Summary of Findings

In this section of the AEDT UQ report, parametric uncertainty and sensitivity analysis was performed in order to identify main contributors to AEDT output uncertainties and gain better insights on the areas of future AEDT improvements. In order to achieve this objective, the following subtasks performed: 1) Review of prior AEDT UQ studies to properly define the problem and the analysis scope; 2) Perform uncertainty characterization to identify the source of the uncertainties among AEDT 2b input parameters, their variability, and the correlation among them; and 3) Perform sensitivity analysis and uncertainty propagation to quantify how individual and combined changes in AEDT input parameters impact AEDT outputs. Specifically, the parametric UQ study completed sensitivity analyses, surrogate modeling, Monte Carlo Simulation, and Global Sensitivity Analyses for mission fuel, mission NOx, terminal NOx, and departure and approach noise.

Sensitivity studies and MCS quantified individual and combined impacts of aircraft performance (BADA and ANP coefficients), engine emissions, and airport atmospheric conditions on the key environmental metrics. Each of the AEDT input variables was varied based on expert judgement and data compiled from the AEDT 2a and AEDT Alpha UQ studies. However, min/max ranges for some coefficients related to climb speed, cruise speed, cruise drag, and climb thrust were reduced in order to reduce the number of failed AEDT cases. Those cases that sampled high speed, high drag, and low thrust caused the aircraft to fail to climb to the cruise altitude due to lack of excess power. In addition, statistical analysis of real world aircraft performance variation using the data in the AEDT Fleet DB provided additional guidance on setting the minimum and maximum ranges of AEDT BADA and ANP coefficients.

For each of the output metrics, MCS was performed using Triangular distributions, Truncated Gaussian distributions, and Truncated Gaussian Copulas functions. MCS with Gaussian Copulas functions captured physical correlations that exist among AEDT input parameters. The correlation among AEDT input parameters were identified by utilizing FAA's aircraft design tool, the Environmental Design Space (EDS). Correlation analyses on about 1,000 EDS aircraft generated by varying aircraft and engine design parameters informed correlations among aircraft and engine performance parameters, which are direct inputs to AEDT.

Incorporation of correlation among AEDT inputs had 20+% changes in some AEDT output variability. When correlation among AEDT input parameters was captured by using Copulas Gaussian, the standard deviations of fuel burn output decreased by 21% for stage length 1 and 17% for stage length 4. This means that a UQ study involving mission fuel may overestimate the variability of fuel burn when correlations among input parameters are ignored. For approach NOx, the output variability decreased by 21% when correlations were modeled in the MCS. This means that uncertainty assessment can overestimate uncertainties on approach NOx emissions when correlation is not incorporated. For the departure noise contour area, the output distribution was wider when Copulas functions were used. The standard deviation increased by 15% when correlation among ANP input parameters were modeled using Gaussian Copulas compared to the independent Gaussian distributions. A UQ study involving departure noise may underestimate the variability of contour area when correlation among input parameters is ignored. In short, ignoring the physical correlation between AEDT input parameters can have a significant influence on the sensitivity results.

For each of the key environmental metrics, those input parameters that had the most effects were identified. Sensitivity studies on mission fuel at two different stage lengths found that BADA fuel flow coefficients, ANP departure weight, and BADA parasite drag (BADA/COEFF_CD0) had the most significant effects on mission fuel burn. While not significant, ANP flap, thrust, and TSFC coefficients also had some effects on mission fuel burn, particularly for short stage length missions. All the input parameters that were important for mission fuel burn were also important for mission NOx emissions. In addition, NOx EI for climb (EN/NOX_REI_CO) and takeoff (EN/NOX_REI_TO) were among the most important contributors to mission NOx emission.

For departure NOx, NOx emission EI for takeoff (EN/NOX_REI_TO) had the most significant effect followed by an ANP flap coefficient and ANP departure weight. ANP TSFC coefficients for departure (K1, K2, and K4) also showed some marginal impacts. For approach NOx, ANP TSFC coefficients for approach (BETA1, ALPHA, and BETA3) had strong effects along with NOx emission EI for approach (EN/NOX_REI_AP). A large number of ANP aircraft use the old ANP TSFC coefficients that are known to be less accurate than improved methods implemented for some ANP aircraft. Therefore, expanded implementation of the improved approach would reduce uncertainties in terminal area NOx calculation. BADA version 4 from EUROCONTROL provides an improved methodology and data for terminal area fuel burn estimation, but its license is not available to general AEDT users.

Uncertainties in departure and approach noise contour areas, width, and length were also analyzed. Changes in NPD curves had the strongest effects on both departure and approach noise. A 1.5dB change in NPD resulted in from 20% to 40% changes in departure and approach contour areas depending on the aircraft types. Since 1.5dB is the accepted measurement error for NPD measurements, the observed degree of variability in contour area was deemed significant. For departure contour area, NPD curves had the most impacts, followed by ANP climb thrust and ANP departure weight. ANP takeoff thrust had the strongest impact on departure contour width. Airport atmospheric conditions also showed some effects on departure noise. For example, headwind and pressure had greater effects on contour length than on contour width. On the other hand, approach noise contours were almost completely driven by NPD curves with some minor effects on airport atmospheric conditions. Only the reverse thrust (ANP/THR_STATIC) showed marginal impact on approach area among all the ANP coefficients. This insensitivity of ANP coefficients to approach noise is due to the fact that the LSA and LTA aircraft selected in this study use fixed point profiles for approach instead of procedure profiles. The RJ and STA aircraft had marginal sensitivities to ANP flap coefficients.

Sensitivity studies of cruise Mach to mission fuel revealed the lack of a proper drag divergence model in the BADA algorithm. A 15 % increase in cruise Mach (Mach 0.897) for an LSA aircraft reduced fuel burn by 1%. A 15% increase in cruise Mach (Mach 0.97) for an LTA aircraft reduced fuel burn by 3%. Even if those two aircraft could cruise at such high speeds, fuel burn would be significantly higher due to aerodynamic inefficiencies. The fact that AEDT successfully flew the aircraft at Mach 0.897 or 0.97 indicates that it lacks a drag divergence model that captures performance impacts due to formation of shock waves on the upper surface of the wing. Since BADA is designed to work best during normal cruise, it is expected that fuel burn would not be accurate outside normal cruise. In fact, none of the single aisle aircraft in the world are operated in that high speed, and therefore the users of AEDT should not use those high input values. However, the fact that AEDT did not model drag divergence and calculated fuel burn reduction instead of an anticipated severe increase indicates a potential area of improvement for future AEDT development.

The airport atmospherics sensitivity tests showed no sensitivity on the outputs to the airport humidity. After further investigation, it was found that AEDT overwrites the humidity input by the user when a full gate-to-gate mission is flown. No matter what the humidity inputs are used, either or both at the departure or the arrival airport, AEDT would switch them to the standard day values. This does not happen if only departure or arrival portions of the flight are simulated in AEDT. This issue has been resolved in the AEDT 2d release. Changing airport humidity in AEDT 2d impacts NOx and noise results.

9.8.2 Recommendations

Based on the observations made in this study, the following items are identified as potential areas for improvement in future AEDT development.

Better takeoff weight and thrust data would significantly reduce uncertainties in departure emissions and noise. AEDT currently uses an assumption of 65% of maximum structural payload capacity and fuel weight based on the stage length. These simplifying assumptions can result in errors in aircraft weight as much as 10%. Ten percent over- or underestimation on the departure weight results in more than 10% over or underestimation on terminal NOx and noise contour at the departure airport. Another important known discrepancy due to the lack of data is takeoff thrust. More airlines have adopted the practice of reduced takeoff procedures in order to save maintenance cost, increase engine life, and mitigate noise for a large portion of the departure trajectory. Typically, engine thrusts are reduced down to 80% of maximum thrust depending on a number of factors, with weight being the most dominant factor. The sensitivity study showed that when 90% of the thrust was actually used instead of 100% in a real operation, AEDT will overestimate terminal NOx by about 13% and noise contour area by 26% at the departure airport. The error can be further exacerbated when both departure weight and takeoff thrust are both overestimated.

AEDT did not capture the sensitivity of cruise speed change properly. In future AEDT development, it is recommended that a better drag divergence model be incorporated into the BADA aerodynamic model. The current AEDT 2b version would work well within normal cruise Mach ranges. However, it would be necessary to improve the BADA drag divergence model if AEDT is used to conduct cruise speed sensitivity analysis or to model unconventional aircraft types.

Differences in approach noise sensitivities were observed depending on whether ANP aircraft used fixed point profiles or procedure profiles. Those ANP aircraft with fixed point profiles showed sensitivities to most of the ANP coefficients for approach noise calculations. Some aircraft in ANP DB still use fixed points profiles, which prescribes exactly how the aircraft is flown at the terminal area regardless of other ANP inputs. The use of fixed point profiles provides no flexibility in running AEDT modeling in complicated terminal area operations. It defeats the purpose of high fidelity algorithms due to the limitations in the data in ANP DB. It would be necessary to coordinate with the aircraft manufactures to improve the ANP models with fixed point profiles.

It was found that ANP TSFC coefficients had significant effects on approach fuel burn and NOx emissions in the terminal area. However, a large number of ANP aircraft still use the old ANP TSFC coefficients, which are known to be less accurate. BADA version 4 from EUROCONTROL provides an improved methodology and data for terminal area fuel burn estimation, but its license is not available to general AEDT users. It would be important to more broadly adopt the methodology and data used in BADA 4 by expanding the coverage of aircraft models and the user base in order to improve estimation of terminal area fuel burn and emissions.

While somewhat obvious, the NOx EIs had significant effects on mission and terminal area NOx emissions. NOx EIs showed almost -1% to 1% sensitivities to terminal area NOx. NOx EIs come from the ICAO Engine Emissions Data Bank based on engine certification tests. The assumed up to 24% uncertainties in NOx EIs come from when the certification test is limited to only one engine model. Repetition of the certification tests to multiple engine models can reduce the variability in NOx EIs at additional cost.

In terms of uncertainties involving airport noise contours, potential uncertainties in NPD curves were the dominating source of uncertainties. Uncertainties in ANP and airport atmospheric conditions had marginal effects compared to the effects from changes in NPD curves. The tested +/-1.5dB changes in NPD curves resulted in from 20% to 40% changes in departure and approach contour areas depending on the aircraft type. Since +/-1.5dB is the accepted measurement error in noise certification tests, this sensitivity is considered significant.

A 1.5 dB is the typically accepted measurement error in NPD noise tests. Moreover, due to the limitation in the coverage of the ANP DB, a number of aircraft types are matched to the NPDs of similar aircraft types, further increasing potential discrepancies in the NPD curves. In order to improve the noise calculations in AEDT, the highest priority should be to improve the accuracy of the NPD curves.

The last recommendation is not related to AEDT itself, but to UQ methodology. In the field of aerospace, a common practice in uncertainty quantification studies is to assume independence of input variables. This study attempted to capture dependences between AEDT input parameters. The comparisons of MCS results showed that incorporation of correlation could result in more than 20% changes in the uncertainty bands of some of the environmental metrics. The either +20% or -20% changes in the uncertainty bands may be important when impacts from two policy options are close enough so that large portion of their uncertainty bands overlap each other. Therefore, it is recommended that correlations in inputs be considered in the future UQ studies.

9.8.3 Recommended Future Work

The parametric uncertainty quantification study presented in this report did not cover all potential sources of uncertainties that may contribute to uncertainties in AEDT outputs. It is recommended that the following items be investigated in the future AEDT UQ efforts.

The parametric UQ study in this report utilized a surrogate modeling approach to facilitate rapid execution of MCS with various sets of input probability distributions. Since sensitivity and MCS results are driven by input assumptions, surrogate modeling approaches enable rapid reassessment of output uncertainties when input assumptions are changed. The MCS results can be updated in the future when better data on takeoff weight, takeoff thrust, and/or airport weather, etc., become available.

The sensitivity and MCS results did not identify airport atmospheric conditions as major contributors in mission fuel burn, terminal area fuel burn, NOx, and airport noise. The study used the standard day as the baseline for all four aircraft and all the stage length flights. It is recommended that the sensitivity study be expanded to consider diverse, extreme airport atmospheric conditions as the baselines. The atmospheric conditions at Denver or Tampa airport in the summer or winter may increase sensitivities of uncertainties in airport atmospheric conditions to uncertainties in terminal NOx and noise.

The UQ study conducted here is the first attempted in systematically quantifying the uncertainties in AEDT when a gate-to-gate mission is flown. While the study examined impacts from BADA and ANP coefficients, the assumed standard day atmosphere above terminal area was not perturbed at all. It is recommended that future UQ study investigate the impacts of en-route weather to mission fuel and emissions.

The initial effort in parametric UQ focused on the influence of changes at the vehicle level and how that effects output results from AEDT. However, this is not the only uncertainty associated with the analysis that AEDT is used for in policy making. Specifically, many assumptions are made on the fleet and the evolution of the fleet that may actually be a larger driver than the uncertainty at the vehicle level. A past research has identified that the mix of aircraft within the fleet and the number of operations that those aircraft carry out at a given airport, or globally, may have a more significant impact on fleet-wide metrics than the specific definition of an aircraft within the Fleet DB. Thus, it is recommended that a future UQ effort seek to understand the quantitative implications of the fleet assumptions versus the individual aircraft input assumptions to AEDT.

10 Conclusion

This report provides thorough documentation of the uncertainty quantification effort for AEDT Version 2b. This effort sought to quantify AEDT 2b's overall utility to meet its intended purpose as a software tool for evaluating aviation-related noise, emissions, and fuel consumption environmental consequences associated with specific Use Cases. This work has built confidence in AEDT 2b's capability, fidelity, and connection to the precedent of valued legacy tools it replaces. Confidence has been derived from the expert review conducted throughout the tool's development history, a verification and validation of the software's methodologies and performance in comparison with legacy models, a demonstration of its capability to conduct the analyses for which it was designed, and a parametric uncertainty/sensitivity analysis that serves to inform stakeholders for future use and development.

10.1 Expert Review

The methodologies, algorithms, and processes implemented by AEDT 2b have been thoroughly and rigorously reviewed during the entire development cycle through the participation by key expert organizations. This effort built on the AEDT 2a expert review with several key organizations conducting reviews of AEDT 2b's technical components and practical usability throughout its entire development cycle. The AEDT Design Review Group, composed of a diverse international group of users and stakeholders, met regularly during the development process and provided valuable feedback to the development team through its use of development versions of the software. The SAE A-21 committee and its publications provided the basis for many of the core flight performance, noise, and emissions calculations in AEDT 2a which were built upon in AEDT 2b. ECAC's Doc. 29 also guided the development of AEDT 2a and subsequently AEDT 2b. AEDT has been built to comply with this widely accepted noise modeling standard. ICAO's Doc. 9911 provided guidance as to the noise modeling methodologies used in AEDT 2a and AEDT 2b. Finally, ICAO CAEP conducted an evaluation of the model and approved it for use in the analyses performed to support the committee's international policy scenario assessment work.

10.2 Use Case Evaluation

Since AEDT 2b replaces legacy software tools (e.g., INM, EDMS, and AEDT 2a), each Use Case was designed as a capability demonstration for executing AEDT 2b in the same capacity as the legacy tools it replaces. Within the capability demonstration, all relevant functionality specific to a given Use Case was determined to function as intended. Each Use Case conducted verification and validation by evaluating against the associated legacy tool in order to compare results with previous modeling approaches (the exception being Use Case F).

10.2.1 Use Case A: Inventory Analysis

Capability Demonstration and Functionality Evaluation

AEDT 2b functionality satisfied the needs of conducting an inventory analysis. There were three issues identified in the version of the tool used for Use Case A. All of the functional issues were addressed in subsequent versions of AEDT 2b. The remaining issue, the extracting of extremely large number of segment level results (i.e. 3 million flights) is inherent to the limitations of a GUI. AEDT's architecture allows users to leverage SQL to accomplish extraction and analysis on exceptionally large results.

Verification and Validation

AEDT 2b was used to perform a large scale analysis consisting of approximately three million flights, and its runtime, fuel consumption, and noise contour area closely matched those for NEAT. Slight differences in fuel burn are explained by a change in the aircraft performance model.

10.2.2 Use Case B and C: NEPA/CAA Analysis

Capability Demonstration and Functionality Evaluation

The results of Use Cases B and C show that AEDT 2b is capable of executing an airport air quality analysis associated with NEPA and CAA. A comparison of the AEDT 2b and EDMS input parameters associated with the airport study showed that they are identical and therefore the functionality associated with importing those input parameters via ASIF is working as intended in AEDT 2b with two exceptions: the EDMS to AEDT importer does not import the taxi time and airport weather. Consequently, the users need to manually change the values of taxi time and airport weather if they need to match the EDMS and AEDT settings.

Verification and Validation

AEDT 2b and EDMS have comparable results, although there are some noted differences. The fuel burn, CO_2, H_2O, SOx, NOx, CO, HC, VOC, NMHC, and TOG emissions inventory comparisons between AEDT 2b and EDMS are within a reasonable range, and the main reason for the difference is that AEDT 2b and EDMS use different fuel consumption models. The difference in PM estimation is relatively bigger and it is due to the fact that AEDT 2b uses FOA 3.0 while EDMS uses FOA 3.0 for the non-US airports and FOA 3.0a for US airports to estimate PM. In addition, the AERMOD versions used in AEDT 2b and EDMS are different, resulting in different setup for AREA sources. This leads to the differences in CO and NOx pollutant concentrations between AEDT 2b and EDMS in the air quality dispersion analysis.

For Use Case B, the differences in pollutant concentrations between the two models were greater than those for Use Case C. This can mainly be attributed to the difference in how the pseudo-schedule is generated for Use Case B between AEDT 2b and EDMS.

10.2.3 Use Case D: Part 150 Analysis

Capability Demonstration and Functionality Evaluation

The results of Use Cases D show that AEDT 2b is capable of executing an airport Part 150 analysis. Three phases of testing were covered that included full airport studies (typical of Part 150 analyses), functionality not included in the previous studies, and a specific focus on terrain modeling. Although the majority of the AEDT 2b functionality was confirmed in Use Case D, specific bugs were identified. The majority of these bugs have been rectified in subsequent versions of AEDT 2b. The remaining issues are included in development plans for future versions of AEDT.

Verification and Validation

A comparison of the AEDT 2b and INM 7.0d showed that the models have comparable noise results in most cases, although some differences were noted. Some differences seen in this analysis highlighted differences in APM versions, flight path segmentation methods and contouring methods between the two models, as well as database updates/improvements in AEDT. Overall, the noise contour and receptor grid results are within a reasonable range, indicating that the noise functionality is operating as intended in AEDT 2b. For some test cases, the INM and AEDT results showed unreasonably large differences. Further investigations found that the differences were attributed to either or combinations of 1) a bug in AEDT's contouring algorithm and 2) differences in engine installation locations for some aircraft between INM and AEDT. The bug in AEDT's contouring algorithm was fixed for the AEDT 2c release. The updated Fleet DB in AEDT 2c SP3 also addressed the incorrect engine installation locations.

10.2.4 Use Case E Part 1: Air Traffic Airspace and Procedure Analysis

Capability Demonstration and Functionality Evaluation

Use Case E Part 1 evaluated two large airspace analyses that were run in both AEDT 2a SP2 and AEDT 2b SP2 for the purposes of comparison. These analyses were based on real-world legacy studies, with modifications made to ensure an “apples-to-apples” comparison between AEDT 2a SP2 and AEDT 2b SP2. AEDT 2b was able to successfully complete a capability demonstration for an applicable NEPA analysis for an airspace redesign project. It has all the functionality needed to complete the required steps to fulfill the requirements under NEPA.

Verification and Validation

Since the flight performance and noise models have evolved from those found in AEDT 2a SP2, some results are expected to be different, as they are driven by flight performance differences. The two tools show generally similar results, with expected differences driven by the fact that AEDT 2b implements different advanced algorithms and methods, particularly in flight performance calculations that affect noise exposure calculations.

10.2.5 Use Case E Part 2: Airspace Redesign Environmental Analyses

Capability Demonstration and Functionality Evaluation

For Use Case E Part 2, an AEDT study based on one originally generated for an airspace re-design environmental analysis was run in both AEDT 2a SP2 and AEDT 2b SP2. The legacy study that served as a basis for the analysis was from the DC Metroplex Project (part of the FAA NextGen Metroplex initiative). The goal was to demonstrate that AEDT 2b SP2 is suitable for this use case. Intentional differences between AEDT 2a SP2 and AEDT 2b SP2, especially in the area of aircraft performance, resulted in noise and aircraft performance differences. These differences are expected and deemed acceptable.

Verification and Validation

An analysis of the acoustic results revealed that perceived levels of noise at population point receptors was very similar in both versions of the tool, with the majority of population receptors reporting a decibel or less of a difference between the two versions of the tool. As a whole, a larger number of receptors reported a decrease in noise in AEDT 2b SP2 rather than an increase. There were a few, localized sets of population points that reported non-negligible differences (both decreases and increases in AEDT 2b SP2). An in-depth comparison of aircraft performance was conducted in order to reveal differences that would explain noise differences. This analysis of aircraft performance revealed specific instances of flights whose dissimilar flight performance parameters (i.e., thrust, speed, position) in the two versions of the tool, would contribute to the few, non-negligible differences in noise.

An examination of emissions results pertinent to Use Case E (i.e., fuel-burn and CO_2) showed that most flight modes experienced only slight variances in computed emissions values. Only the “Above 10,000 feet AFE” flight mode experienced a significant difference in emissions. However, it was concluded that this difference is entirely expected based on aircraft performance improvements introduced into AEDT 2b SP2.

In conclusion, AEDT 2b SP2 is capable of conducting a Use Case E analysis and the results produced from such an analysis are compatible and comparable with the analogous results produced by AEDT 2a SP2.

10.2.6 Use Case F: Full Functionality Single Study

Capability Demonstration and Functionality Evaluation

Use Case F is designed to exercise as much AEDT 2b SP2 functionality as possible within a single study. Study KIAD was designed to utilize all of the available aircraft types, operations, and track definitions in order to generate the full list of available noise, fuel burn and emissions results and their associated reports. As this study does not represent real world operations, and since previous use cases have validated results from AEDT 2b SP2 against AEDT 2a SP2, validation and verification was not performed on study KIAD. Use Case F successfully demonstrated that AEDT 2b SP2 was able to exercise nearly all available input data in a single study, providing broad flexibility to conduct multiple types of noise and emissions analyses.

10.3 Parametric Uncertainty and Sensitivity Analysis

The parametric uncertainty and sensitivity analysis was performed in order to identify main contributors to AEDT output uncertainties and gain better insights on the areas of future AEDT improvements. The parametric uncertainty analysis was conducted at the vehicle level for an aircraft performing a single flight. In order to achieve this objective, the following subtasks were performed: 1) Review of prior AEDT UQ studies to properly define the problem and the analysis scope; 2) Uncertainty characterization to identify the source of the uncertainties among AEDT 2b input parameters, their variability, and the correlation among them; and 3) Sensitivity analysis and uncertainty propagation to quantify how individual and combined changes in AEDT input parameters impact AEDT outputs. Specifically, the parametric UQ study completed sensitivity analyses, surrogate modeling, Monte Carlo Simulation (MCS), and Global Sensitivity Analyses for mission fuel, mission NOx, terminal NOx, and departure and approach noise.

Sensitivity studies and MCS quantified individual and combined impacts of aircraft performance (BADA and ANP coefficients), engine emissions, and airport atmospheric conditions on the key environmental metrics. Each of the AEDT input variables was varied based on expert judgment and data compiled from the previous AEDT 2a and AEDT Alpha UQ studies. In addition, statistical analysis of real world aircraft performance variation using the data in the AEDT Fleet DB provided further guidance on setting the minimum and maximum ranges of AEDT BADA and ANP coefficients.

For each of the output metrics, MCS was performed using Triangular distributions, Truncated Gaussian distributions, and Truncated Gaussian Copulas functions. MCS with Gaussian Copulas functions captured physical correlations that exist among AEDT input parameters. The correlation between AEDT input parameters was identified by utilizing FAA’s aircraft design tool, the Environmental Design Space (EDS). Correlation analyses on about 1,000 EDS aircraft generated by varying aircraft and engine design parameters informed correlations among aircraft and engine performance parameters, which are direct inputs to AEDT. For each of the key environmental metrics, those input parameters that had the most effects were identified.

Results from the parametric sensitivity analysis show which inputs are of higher relative importance for conducting an accurate analysis. Sensitivity studies on mission fuel at two different stage lengths found that BADA fuel flow coefficients, ANP departure weight, and BADA parasite drag had the most significant effects on mission fuel consumption. All the input parameters that were important for mission fuel consumption were also important for mission NOx emissions. In addition, NOx emission indices (EI) for climb and takeoff were among the most important contributors to mission NOx emission. Expanded implementation of the improved approach would reduce uncertainties in terminal area NOx calculation. BADA version 4 from EUROCONTROL would provide an improved methodology and data for terminal area fuel consumption estimation. Changes in NPD curves had the strongest effects on both departure and approach noise. For departure contour area, NPD curves had the most impact, followed by ANP climb thrust and ANP departure weight. ANP takeoff thrust had the strongest impact on departure contour width. Another significant conclusion from the parametric uncertainty analysis was that ignoring the physical correlation between AEDT input parameters can have a significant influence on the sensitivity results (this held for fuel consumption, NOx emissions, and noise calculations.)

10.4 Final Notes

This uncertainty quantification effort has proven extremely valuable to the development of AEDT 2b. The documentation of this work is intended to inform the end user as to the methodologies, capability, and fidelity of the tool. These efforts included expert review, verification and validation, capability demonstrations, and parametric uncertainty/sensitivity analyses. The FAA may choose to release supplementary UQ reports for any service packs or upgrades to AEDT. Similar analyses will continue in parallel during the development of future AEDT versions.

Appendix A. NEPA/CAA Analysis

This appendix lists the input and resulting tables for Use Case B and C.

A.1 Input Data

Table A-1. List of Unique Aircraft for Use Cases B and C

Aircraft ID	Equipment ID	Description	Airframe ID	Engine ID	Engine Mod ID	Engine Description	AC Code
1	967	Airbus A319-100 Series 3CM028	4539	1386	140	CFM56-5B6/P	A319-1
2	957	Airbus A319-100 Series 3IA006	4539	1417	140	V2522-A5	A319-1
3	992	Airbus A320-100 Series 1IA003	4541	1250	140	V2527-A5	A320-1
4	991	Airbus A320-200 Series 1CM008	4542	1213	140	CFM56-5-A1	A320-2
5	1031	Airbus A321-100 Series 3CM025	4543	1383	140	CFM56-5B3/P	A321-1
8	2203	Boeing 727-200 Series 1PW010	4586	1267	5	JT8D-15	B727-2
9	2311	Boeing 737-200 Series 1PW011	4588	1268	2	JT8D-15A	B737-2
10	2601	Boeing 737-300 Series 1CM004	4589	1209	13	CFM56-3-B1	B737-3
11	2613	Boeing 737-300 Series 1CM007	4589	1212	13	CFM56-3C-1	B737-3
12	2636	Boeing 737-400 Series 1CM005	4590	1210	13	CFM56-3B-2	B737-4
13	2657	Boeing 737-500 Series 1CM004	4591	1209	13	CFM56-3-B1	B737-5
14	2669	Boeing 737-500 Series 1CM007	4591	1212	13	CFM56-3C-1	B737-5
15	176	Boeing 737-700 Series 3CM031	4593	1389	140	CFM56-7B22	B737-7
16	2804	Boeing 757-200 Series 4PW072	4605	1456	25	PW2037	B757-2
17	2802	Boeing 757-200 Series 3RR028	4605	1424	25	RB211-535E4	B757-2
18	376	Boeing 757-300 Series 4PW073	4606	1457	140	PW2040	B757-3
19	2979	Boeing DC-9-30 Series 1PW007	4717	1264	1	JT8D-9series	DC9-3
20	2060	Boeing MD-81 1PW017	4869	1274	140	JT8D-209	MD81

Aircraft ID	Equipment ID	Description	Airframe ID	Engine ID	Engine Mod ID	Engine Description	AC Code
21	2065	Boeing MD-82 1PW017	4870	1274	140	JT8D-209	MD82
22	2069	Boeing MD-82 4PW068	4870	1452	140	JT8D-217	MD82
23	2068	Boeing MD-82 4PW069	4870	1453	140	JT8D-217A	MD82
24	2070	Boeing MD-83 4PW068	4871	1452	140	JT8D-217	MD83
25	2081	Boeing MD-87 1PW017	4872	1274	140	JT8D-209	MD87
26	2077	Boeing MD-88 4PW071	4873	1455	140	JT8D-219	MD88
27	1249	Bombardier CRJ-100 5GE084	4698	1465	140	CF34-3B	CRJ1
28	1250	Bombardier CRJ-200 5GE084	4699	1465	140	CF34-3B	CRJ2
29	1253	Bombardier CRJ-700 5GE083	4700	1464	140	CF34-8C1	CRJ7
30	1237	Bombardier Challenger 600 5GE084	4658	1465	140	CF34-3B	CL600
31	1248	Bombardier Challenger 604 5GE084	4661	1465	140	CF34-3B	CL604
32	1780	Bombardier Global Express 4BR009	4793	1439	140	BR700-710A2-20	GLOBAL EXPRESS
33	2005	Bombardier Learjet 25 CJ6106	4853	1535	140	CJ610-6	LEAR25
34	2027	Bombardier Learjet 31 1AS001	4857	1204	140	TFE731-2-2B	LEAR31
35	2028	Bombardier Learjet 35 1AS001	4858	1204	140	TFE731-2-2B	LEAR35
36	2436	Bombardier Learjet 35A/36A (C-21A) 1AS001	5069	1204	134	TFE731-2-2B	MIL-C21
37	1882	Cessna 150 Series O200	4665	1593	140	O-200	CNA150
38	1265	Cessna 172 Skyhawk TSIO36	4666	1745	68	TSIO-360C	CNA172
39	2105	Cessna 208 Caravan P6114A	4669	1595	140	PT6A-114A	CNA208
40	1201	Cessna 337 Skymaster TSIO36	4672	1745	140	TSIO-360C	CNA337

Aircraft ID	Equipment ID	Description	Airframe ID	Engine ID	Engine Mod ID	Engine Description	AC Code
41	1278	Cessna 441 Conquest II TPE8	4679	1744	140	TPE331-8	CNA441
42	1288	Cessna 500 Citation I 1PW035	4680	1292	140	JT15D-1series	CNA500
43	1292	Cessna 550 Citation II 1PW036	4683	1293	140	JT15D-4series	CNA550
44	1298	Cessna 560 Citation V 1PW037	4687	1294	140	JT15D-5,-5A,-5B	CNA560
45	1235	Cessna 650 Citation III 1AS002	4690	1205	140	TFE731-3	CNA650
46	2018	Dassault Falcon 100 1AS001	4775	1204	140	TFE731-2-2B	FAL100
47	1872	Dassault Falcon 20-C CF700D	4779	1531	140	CF700-2D	FAL20-C
48	1311	Dassault Falcon 2000-EX 7PW080	4778	1521	140	PW308C	FAL2000 EX
49	1318	Dassault Falcon 50 1AS002	4784	1205	140	TFE731-3	FAL50
50	1313	Dornier 328 Jet 7PW078	4737	1519	140	PW306B	DO328JE T
51	1899	EADS Socata TB-10 Tobago TSIO36	5003	1745	140	TSIO-360C	TB10
52	1726	Embraer ERJ135 6AL013	4744	1483	140	AE3007A1/3	ERJ135
53	1747	Embraer ERJ145 4AL003	4748	1431	140	AE3007A	ERJ145
54	1746	Embraer ERJ145 6AL020	4748	1490	140	AE3007A1E	ERJ145
55	1591	Fairchild SA-226-T Merlin III TPE3U	4971	1739	140	TPE331-3U	SA226
56	1782	Fokker F70 1RR020	4773	1331	140	TAYMk620-15	F28-70
57	1907	Gulfstream G200 7PW077	4798	1518	140	PW306A	GULF200
58	1920	Gulfstream G400 1RR019	4803	1330	140	TAYMk611-8	GULF4
59	1932	Gulfstream G500 4BR008	4806	1438	140	BR700-710A1-10	GULF5
60	1909	Gulfstream II 1RR016	4797	1327	140	SPEYMk511	GULF2
61	1910	Gulfstream II-B 1RR016	4799	1327	140	SPEYMk511	GULF2-B
62	2009	Hawker HS-125 Series 1 1AS002	4810	1205	140	TFE731-3	HS125-1

Aircraft ID	Equipment ID	Description	Airframe ID	Engine ID	Engine Mod ID	Engine Description	AC Code
63	2013	Hawker HS-125 Series 700 1AS002	4815	1205	140	TFE731-3	HS125-7
64	1972	Israel IAI-1124 Westwind I 1AS002	4826	1205	140	TFE731-3	IAI1124
65	1974	Israel IAI-1125 Astra 1AS002	4828	1205	140	TFE731-3	IAI1125
66	3194	Lockheed C-130 Hercules T56A15	4894	1681	67	T56-A-15	MIL-C130
67	2101	Mitsubishi MU-300 Diamond 1PW036	4938	1293	140	JT15D-4series	MU300
68	1502	Pilatus PC-6 Porter PT6A27	4923	1618	140	PT6A-27	MIL-PC6
69	1901	Piper PA-24 Comanche TIO540	4950	1715	140	TIO-540-J2B2	PA24
70	1194	Piper PA-27 Aztec TIO540	4951	1715	140	TIO-540-J2B2	PA27
71	1887	Piper PA-28 Cherokee Series O320	4952	1594	140	O-320	PA28
72	2104	Piper PA-30 Twin Comanche IO320	4953	1566	140	IO-320-D1AD	PA30
73	779	Piper PA-31 Navajo TIO540	4954	1715	140	TIO-540-J2B2	PA31
74	1279	Piper PA-31T Cheyenne PT6A28	4955	1619	140	PT6A-28	PA31T
75	1271	Piper PA-32 Cherokee Six TIO540	4956	1715	140	TIO-540-J2B2	PA32
76	1482	Piper PA-42 Cheyenne Series PT6A41	4958	1624	140	PT6A-41	PA42
77	33	Raytheon Beech 1900-D PT67D	4634	1613	140	PT6A-67D	BEECH1900-D
78	2024	Raytheon Beechjet 400 1PW037	4638	1294	140	JT15D-5,-5A,-5B	BEECH400
79	1468	Raytheon King Air 100 PT6A28	4631	1619	140	PT6A-28	BEECH100
80	1469	Raytheon King Air 90 PT6A28	4642	1619	140	PT6A-28	BEECH90
81	1478	Raytheon Super King Air 200 PT6A41	4635	1624	106	PT6A-41	BEECH200
82	1513	Raytheon Super King Air 300 PT660A	4636	1609	140	PT6A-60A	BEECH300

Aircraft ID	Equipment ID	Description	Airframe ID	Engine ID	Engine Mod ID	Engine Description	AC Code
83	3027	Rockwell Sabreliner 75 CF700D	5036	1531	140	CF700-2D	SABR75
84	810	Saab 340-A CT75A2	4977	1537	140	CT7-5A2	SAAB340-A
85	1492	DeHavilland DHC-6-100 Twin Otter PT6A20	4722	1616	140	PT6A-20	DHC6-1

Table A-2. Quarter-Hour Operational Profiles

Quarter ID	Quarter Hour	Quarter Hour Weighting by Source				
		Aircraft	Cargo	Off-Airport	On-Airport	Deicing
QH01	00:00.0	0.1092	0	0.1807	0.1777	0.7143
QH02	15:00.0	0.0712	0.0039	0.1807	0.1777	0.7143
QH03	30:00.0	0.0452	0	0.1807	0.1777	0.7143
QH04	45:00.0	0.0274	0	0.1807	0.1777	0.7143
QH05	00:00.0	0.0226	0.0039	0.1118	0.0967	0.757
QH06	15:00.0	0.0144	0	0.1118	0.0967	0.757
QH07	30:00.0	0.0135	0	0.1118	0.0967	0.757
QH08	45:00.0	0.0087	0	0.1118	0.0967	0.757
QH09	00:00.0	0.0067	0	0.0605	0.046	0.8015
QH10	15:00.0	0.0048	0.0039	0.0605	0.046	0.8015
QH11	30:00.0	0.0029	0.0039	0.0605	0.046	0.8015
QH12	45:00.0	0.0038	0.0079	0.0605	0.046	0.8015
QH13	00:00.0	0.0269	0.0079	0.0546	0.0683	0.8293
QH14	15:00.0	0.0154	0	0.0546	0.0683	0.8293
QH15	30:00.0	0.0024	0	0.0546	0.0683	0.8293
QH16	45:00.0	0.001	0.0039	0.0546	0.0683	0.8293
QH17	00:00.0	0.0019	0	0.0849	0.18	0.859
QH18	15:00.0	0.0019	0.0039	0.0849	0.18	0.859
QH19	30:00.0	0.0029	0.0039	0.0849	0.18	0.859
QH20	45:00.0	0.0029	0	0.0849	0.18	0.859
QH21	00:00.0	0.0048	0.0039	0.2292	0.4146	0.8831
QH22	15:00.0	0.0024	0.0039	0.2292	0.4146	0.8831
QH23	30:00.0	0.0115	0	0.2292	0.4146	0.8831
QH24	45:00.0	0.0327	0.0079	0.2292	0.4146	0.8831
QH25	00:00.0	0.5469	0.0433	0.4987	0.5774	0.9295
QH26	15:00.0	0.4632	0.3268	0.4987	0.5774	0.9295
QH27	30:00.0	0.7042	0.4803	0.4987	0.5774	0.9295
QH28	45:00.0	0.5676	0.6417	0.4987	0.5774	0.9295

Quarter ID	Quarter Hour	Quarter Hour Weighting by Source				
		Aircraft	**Cargo**	**Off-Airport**	**On-Airport**	**Deicing**
QH29	00:00.0	0.7802	0.7717	0.7236	0.6914	0.9462
QH30	15:00.0	0.5575	0.3031	0.7236	0.6914	0.9462
QH31	30:00.0	0.5358	0.126	0.7236	0.6914	0.9462
QH32	45:00.0	0.5734	0.0945	0.7236	0.6914	0.9462
QH33	00:00.0	0.6623	0.1181	0.8167	0.7	0.987
QH34	15:00.0	0.5907	0.1376	0.8167	0.7	0.987
QH35	30:00.0	0.4704	0.1024	0.8167	0.7	0.987
QH36	45:00.0	0.6792	0.1102	0.8167	0.7	0.987
QH37	00:00.0	0.6999	0.0787	0.7579	0.6887	0.9981
QH38	15:00.0	0.822	0.0669	0.7579	0.6887	0.9981
QH39	30:00.0	0.809	0.0709	0.7579	0.6887	0.9981
QH40	45:00.0	0.6753	0.0551	0.7579	0.6887	0.9981
QH41	00:00.0	0.657	0.0354	0.7699	0.7424	1
QH42	15:00.0	0.7961	0.0354	0.7699	0.7424	1
QH43	30:00.0	0.8581	0.0197	0.7699	0.7424	1
QH44	45:00.0	0.632	0.0157	0.7699	0.7424	1
QH45	00:00.0	0.7167	0.0197	0.8547	0.8463	0.9722
QH46	15:00.0	0.7278	0.0354	0.8547	0.8463	0.9722
QH47	30:00.0	0.721	0.0157	0.8547	0.8463	0.9722
QH48	45:00.0	0.7561	0.0197	0.8547	0.8463	0.9722
QH49	00:00.0	0.3939	0.0157	0.9375	0.8579	0.8646
QH50	15:00.0	0.4858	0.0157	0.9375	0.8579	0.8646
QH51	30:00.0	0.5642	0.0197	0.9375	0.8579	0.8646
QH52	45:00.0	0.48	0.0157	0.9375	0.8579	0.8646
QH53	00:00.0	0.5474	0.0157	0.8958	0.8573	0.7681
QH54	15:00.0	0.7258	0.0079	0.8958	0.8573	0.7681
QH55	30:00.0	0.6902	0.0039	0.8958	0.8573	0.7681
QH56	45:00.0	0.7528	0.0039	0.8958	0.8573	0.7681
QH57	00:00.0	0.8365	0.0118	0.9228	0.8666	0.6327
QH58	15:00.0	0.6936	0	0.9228	0.8666	0.6327
QH59	30:00.0	0.5825	0.0039	0.9228	0.8666	0.6327
QH60	45:00.0	0.5613	0	0.9228	0.8666	0.6327
QH61	00:00.0	0.4815	0.0039	0.9626	0.8425	0.5306
QH62	15:00.0	0.6282	0	0.9626	0.8425	0.5306
QH63	30:00.0	0.671	0	0.9626	0.8425	0.5306
QH64	45:00.0	0.6224	0.0276	0.9626	0.8425	0.5306
QH65	00:00.0	0.7244	0.0157	1	1	0.4805
QH66	15:00.0	0.9004	0.0276	1	1	0.4805
QH67	30:00.0	0.937	0.0551	1	1	0.4805

Quarter ID	Quarter Hour	Quarter Hour Weighting by Source				
		Aircraft	Cargo	Off-Airport	On-Airport	Deicing
QH68	45:00.0	0.9168	0.0984	1	1	0.4805
QH69	00:00.0	1	0.0827	0.9887	0.9063	0.4471
QH70	15:00.0	0.8822	0.063	0.9887	0.9063	0.4471
QH71	30:00.0	0.8644	0.0945	0.9887	0.9063	0.4471
QH72	45:00.0	0.8451	0.0945	0.9887	0.9063	0.4471
QH73	00:00.0	0.9784	0.0354	0.8416	0.7221	0.436
QH74	15:00.0	0.7229	0.0591	0.8416	0.7221	0.436
QH75	30:00.0	0.6676	0.0394	0.8416	0.7221	0.436
QH76	45:00.0	0.646	0.0591	0.8416	0.7221	0.436
QH77	00:00.0	0.5507	0.0591	0.6951	0.5799	0.4193
QH78	15:00.0	0.5685	0.0669	0.6951	0.5799	0.4193
QH79	30:00.0	0.5026	0.0276	0.6951	0.5799	0.4193
QH80	45:00.0	0.518	0.0512	0.6951	0.5799	0.4193
QH81	00:00.0	0.4598	0.0039	0.6244	0.5254	0.4564
QH82	15:00.0	0.5118	0.3307	0.6244	0.5254	0.4564
QH83	30:00.0	0.5589	1	0.6244	0.5254	0.4564
QH84	45:00.0	0.4204	0.7008	0.6244	0.5254	0.4564
QH85	00:00.0	0.5623	0.7165	0.5265	0.5512	0.525
QH86	15:00.0	0.5897	0.189	0.5265	0.5512	0.525
QH87	30:00.0	0.4752	0.1142	0.5265	0.5512	0.525
QH88	45:00.0	0.3603	0.0551	0.5265	0.5512	0.525
QH89	00:00.0	0.4603	0.063	0.3925	0.465	0.6011
QH90	15:00.0	0.4736	0.0433	0.3925	0.465	0.6011
QH91	30:00.0	0.3632	0.0551	0.3925	0.465	0.6011
QH92	45:00.0	0.4137	0.0236	0.3925	0.465	0.6011
QH93	00:00.0	0.4036	0.0157	0.2767	0.3655	0.6623
QH94	15:00.0	0.2977	0.0079	0.2767	0.3655	0.6623
QH95	30:00.0	0.2828	0.0079	0.2767	0.3655	0.6623
QH96	45:00.0	0.2347	0.0157	0.2767	0.3655	0.6623

Table A-3. Daily Operational Profiles

PROFILE	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Aircraft-Baseline-KPVD	0.8889	0.9354	0.9565	0.9494	1.0000	0.9494	0.8103
Cargo-Baseline-KPVD	0.7500	0.7500	1.0000	1.0000	1.0000	0.8000	0.7500

Table A-4. Monthly Operational Profiles

PROFILE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Aircraft	0.6097	0.7680	0.7468	0.6508	0.7803	0.9452	0.9967	1.0000	0.9630	0.9657	0.8889	0.8374

PROFILE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Boilers	1.0000	0.6324	0.4972	0.3652	0.0468	0.0009	0.0000	0.0000	0.0000	0.0903	0.3803	0.6641
Deicing	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000

Table A-5. Receptors

Discrete Receptor ID (Group Name)	Latitude (deg.)	Longitude (deg.)	X	Y	Height (m)	Elevation (m)
1	41.75569223	-71.40173463	2202.7896	3520.44	1.8014	16.76
2	41.73212666	-71.41418216	1167.9936	902.8176	1.8014	16.76
3	41.76263056	-71.38607723	3504.5904	4291.584	1.8014	16.76
4	41.75582276	-71.39696285	2599.6392	3535.0704	1.8014	16.76
5	41.75394953	-71.39141888	3060.8016	3327.1968	1.8014	16.76
6	41.75552506	-71.3845023	3635.9592	3502.4568	1.8014	16.76
7	41.74985298	-71.39842791	2478.024	2871.976	1.8014	16.76
8	41.75313115	-71.41318077	1250.8992	3235.7568	1.8014	16.76
9	41.74829453	-71.38614523	3499.7136	2699.3088	1.8014	16.76
10	41.75003352	-71.39160435	3045.5616	2892.2472	1.8014	16.76
11	41.72254687	-71.41844802	813.2064	-161.2392	1.8014	16.76
12	41.72169722	-71.38650324	3471.3672	-254.8128	1.8014	16.76
13	41.75775708	-71.38702966	3425.6472	3750.2592	1.8014	16.76
14	41.723644	-71.39892721	2437.4856	-39.0144	1.8014	16.76
15	41.74621837	-71.38973402	3201.3144	2468.5752	1.8014	16.76
16	41.72274353	-71.41067135	1460.2968	-139.2936	1.8014	16.76
17	41.74106624	-71.39486315	2774.8992	1896.1608	1.8014	16.76
18	41.7153128	-71.4164713	977.7984	-964.692	1.8014	16.76
19	41.73581264	-71.39132665	3069.336	1312.7736	1.8014	16.76
20	41.72446003	-71.42745907	63.3984	51.2064	1.8014	16.76
21	41.7335797	-71.38597165	3514.9536	1064.9712	1.8014	16.76
22	41.74477527	-71.41673343	955.548	2307.6408	1.8014	16.76
23	41.72912138	-71.38911411	3253.74	569.6712	1.8014	16.76
24	41.72954711	-71.39967187	2375.3064	616.6104	1.8014	16.76
25	41.7264939	-71.4048201	1947.0624	277.368	1.8014	16.76
26	41.73558548	-71.40398879	2015.9472	1287.1704	1.8014	16.76
27	41.73027889	-71.4082514	1661.4648	697.6872	1.8014	16.76
28	41.72508177	-71.41150225	1391.1072	120.396	1.8014	16.76
29	41.71794849	-71.42200824	516.998712	-671.998656	1.8014	16.76
30	41.72730814	-71.41809196	842.772	367.5888	1.8014	16.76

Discrete Receptor ID (Group Name)	Latitude (deg.)	Longitude (deg.)	X	Y	Height (m)	Elevation (m)
31	41.72380406	-71.42348094	394.4112	-21.6408	1.8014	16.76
32	41.73146578	-71.41904383	763.524	829.3608	1.8014	16.76
33	41.73565625	-71.41875013	787.908	1294.7904	1.8014	16.76
34	41.74163893	-71.41425328	1161.9056	1959.3248	1.8014	16.76
35	41.74706703	-71.42024201	663.6768	2562.1488	1.8014	16.76
36	41.74772231	-71.41401753	1181.4048	2634.996	1.8014	16.76
37	41.75259262	-71.4088052	1614.8304	3176.016	1.8014	16.76
38	41.74961229	-71.4065025	1806.431424	2845.043224	1.8014	16.76

A.2 Resulting Data

Table A-6. Use Case B: CO 1-Hour Concentrations for All Sources

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averagin g Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON)	Date (DATE(CON)
1	2202.79	3520.44	1108.14	1041.90	6.4%	1-HR	ALL	2ND	08/02/2004 21 hr	08/02/2004 21 hr
2	1167.99	902.82	1152.36	1898.29	-39.3%	1-HR	ALL	2ND	10/18/2004 19 hr	04/14/2004 19 hr
3	3504.59	4291.58	819.51	577.92	41.8%	1-HR	ALL	2ND	06/04/2004 23 hr	06/14/2004 23 hr
4	2599.64	3535.07	1635.12	931.33	75.6%	1-HR	ALL	2ND	11/11/2004 19 hr	08/25/2004 21 hr
5	3060.8	3327.2	1133.69	893.52	26.9%	1-HR	ALL	2ND	10/29/2004 21 hr	12/22/2004 07 hr
6	3635.96	3502.46	752.41	681.03	10.5%	1-HR	ALL	2ND	11/23/2004 19 hr	11/21/2004 20 hr
7	2478.02	2871.98	1827.58	1428.17	28.0%	1-HR	ALL	2ND	10/29/2004 21 hr	11/21/2004 20 hr
8	1250.9	3235.76	1330.77	1607.25	-17.2%	1-HR	ALL	2ND	11/11/2004 20 hr	07/29/2004 21 hr
9	3499.71	2699.31	776.19	566.58	37.0%	1-HR	ALL	2ND	10/01/2004 23 hr	06/20/2004 20 hr
10	3045.56	2892.25	1296.89	1227.67	5.6%	1-HR	ALL	2ND	05/04/2004 23 hr	08/25/2004 22 hr
11	813.21	-161.24	415.05	728.96	-43.1%	1-HR	ALL	2ND	07/26/2004 22 hr	02/07/2004 08 hr
12	3471.37	-254.81	359.88	298.41	20.6%	1-HR	ALL	2ND	05/30/2004 19 hr	11/21/2004 17 hr
13	3425.65	3750.26	770.94	577.55	33.5%	1-HR	ALL	2ND	05/19/2004 21 hr	10/29/2004 21 hr
14	2437.49	-39.01	254.90	294.16	-13.3%	1-HR	ALL	2ND	10/27/2004 20 hr	11/03/2004 19 hr
15	3201.31	2468.58	771.74	600.71	28.5%	1-HR	ALL	2ND	10/13/2004 21 hr	01/02/2004 07 hr
16	1460.3	-139.29	580.81	525.88	10.4%	1-HR	ALL	2ND	11/22/2004 18 hr	10/18/2004 19 hr
17	2774.9	1896.16	964.85	937.59	2.9%	1-HR	ALL	2ND	07/10/2004 22 hr	09/26/2004 18 hr
18	977.8	-964.69	391.01	350.98	11.4%	1-HR	ALL	2ND	07/06/2004 24 hr	04/14/2004 19 hr
19	3069.34	1312.77	533.87	653.30	-18.3%	1-HR	ALL	2ND	12/29/2004 22 hr	11/15/2004 17 hr
20	63.4	51.21	665.15	754.95	-11.9%	1-HR	ALL	2ND	10/14/2004 07 hr	12/19/2004 23 hr
21	3514.95	1064.97	419.26	458.83	-8.6%	1-HR	ALL	2ND	10/26/2004 21 hr	11/14/2004 19 hr
22	955.55	2307.64	1811.35	1474.92	22.8%	1-HR	ALL	2ND	10/29/2004 19 hr	10/28/2004 17 hr
23	3253.74	569.67	496.40	354.40	40.1%	1-HR	ALL	2ND	05/30/2004 19 hr	12/15/2004 19 hr
24	2375.31	616.61	675.46	543.34	24.3%	1-HR	ALL	2ND	11/21/2004 17 hr	11/03/2004 19 hr
25	1947.06	277.37	362.65	328.42	10.4%	1-HR	ALL	2ND	02/19/2004 08 hr	10/27/2004 20 hr
26	2015.95	1287.17	1013.92	772.46	31.3%	1-HR	ALL	2ND	05/30/2004 19 hr	11/03/2004 19 hr
27	1661.46	697.69	584.37	650.08	-10.1%	1-HR	ALL	2ND	12/24/2004 20 hr	01/18/2004 17 hr
28	1391.11	120.4	741.92	578.90	28.2%	1-HR	ALL	2ND	11/22/2004 18 hr	12/16/2004 07 hr

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averagin g Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON)	Date (DATE(CON)
29	517	-672	370.09	368.06	0.6%	1-HR	ALL	2ND	07/26/2004 22 hr	07/25/2004 23 hr
30	842.77	367.59	557.08	634.61	-12.2%	1-HR	ALL	2ND	02/16/2004 22 hr	07/25/2004 23 hr
31	394.41	-21.64	669.51	827.08	-19.1%	1-HR	ALL	2ND	10/27/2004 17 hr	10/27/2004 17 hr
32	763.52	829.36	1579.27	1867.53	-15.4%	1-HR	ALL	2ND	07/26/2004 22 hr	10/27/2004 17 hr
33	787.91	1294.79	2161.32	2039.59	6.0%	1-HR	ALL	2ND	07/06/2004 23 hr	07/06/2004 23 hr
34	1161.91	1959.32	3558.13	3629.50	-2.0%	1-HR	ALL	2ND	10/29/2004 19 hr	10/28/2004 17 hr
35	663.68	2562.15	817.26	812.62	0.6%	1-HR	ALL	2ND	11/23/2004 20 hr	08/13/2004 21 hr
36	1181.4	2635	2297.77	2067.58	11.1%	1-HR	ALL	2ND	09/06/2004 19 hr	07/29/2004 21 hr
37	1614.83	3176.02	1956.00	1477.17	32.4%	1-HR	ALL	2ND	11/20/2004 17 hr	11/30/2004 22 hr
38	1806.43	2845.04	3240.02	2215.86	46.2%	1-HR	ALL	2ND	10/13/2004 20 hr	08/02/2004 21 hr

Table A-7 Use Case B: CO 8-Hour Concentrations for All Sources

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC) [ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON)	Date (DATE(CON)
1	2202.79	3520.44	251.49	162.90	54.4%	8-HR	ALL	2ND	10/13/2004 24 hr	10/13/2004 24 hr
2	1167.99	902.82	186.84	284.49	-34.3%	8-HR	ALL	2ND	07/06/2004 24 hr	11/30/2004 08 hr
3	3504.59	4291.58	179.64	108.42	65.7%	8-HR	ALL	2ND	08/25/2004 24 hr	10/06/2004 24 hr
4	2599.64	3535.07	342.84	223.53	53.4%	8-HR	ALL	2ND	09/23/2004 24 hr	09/23/2004 24 hr
5	3060.8	3327.2	269.72	239.25	12.7%	8-HR	ALL	2ND	11/21/2004 24 hr	09/26/2004 24 hr
6	3635.96	3502.46	134.06	147.18	-8.9%	8-HR	ALL	2ND	11/21/2004 24 hr	11/23/2004 24 hr
7	2478.02	2871.98	399.09	359.44	11.0%	8-HR	ALL	2ND	11/21/2004 24 hr	09/26/2004 24 hr
8	1250.9	3235.76	256.32	273.97	-6.4%	8-HR	ALL	2ND	09/07/2004 24 hr	07/29/2004 24 hr
9	3499.71	2699.31	142.26	120.61	17.9%	8-HR	ALL	2ND	10/13/2004 24 hr	06/20/2004 24 hr
10	3045.56	2892.25	234.99	166.34	41.3%	8-HR	ALL	2ND	09/02/2004 24 hr	08/25/2004 24 hr
11	813.21	-161.24	102.20	92.48	10.5%	8-HR	ALL	2ND	07/26/2004 24 hr	02/07/2004 08 hr
12	3471.37	-254.81	62.67	49.74	26.0%	8-HR	ALL	2ND	08/31/2004 24 hr	11/21/2004 24 hr
13	3425.65	3750.26	179.76	146.65	22.6%	8-HR	ALL	2ND	09/26/2004 24 hr	12/22/2004 08 hr
14	2437.49	-39.01	58.37	70.92	-17.7%	8-HR	ALL	2ND	11/03/2004 24 hr	11/03/2004 24 hr
15	3201.31	2468.58	177.74	133.04	33.6%	8-HR	ALL	2ND	10/28/2004 24 hr	10/01/2004 24 hr
16	1460.3	-139.29	117.34	92.59	26.7%	8-HR	ALL	2ND	11/22/2004 24 hr	11/30/2004 08 hr

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC) [ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON)	Date (DATE(CON)
17	2774.9	1896.16	239.43	235.42	1.7%	8-HR	ALL	2ND	09/26/2004 24 hr	11/22/2004 24 hr
18	977.8	-964.69	60.25	59.41	1.4%	8-HR	ALL	2ND	07/06/2004 24 hr	04/14/2004 24 hr
19	3069.34	1312.77	173.39	180.19	-3.8%	8-HR	ALL	2ND	11/15/2004 24 hr	11/15/2004 24 hr
20	63.4	51.21	132.58	136.90	-3.2%	8-HR	ALL	2ND	09/05/2004 24 hr	12/19/2004 24 hr
21	3514.95	1064.97	111.54	105.82	5.4%	8-HR	ALL	2ND	11/15/2004 24 hr	11/14/2004 24 hr
22	955.55	2307.64	386.40	270.01	43.1%	8-HR	ALL	2ND	08/13/2004 24 hr	08/13/2004 24 hr
23	3253.74	569.67	113.21	76.73	47.5%	8-HR	ALL	2ND	02/01/2004 24 hr	02/01/2004 24 hr
24	2375.31	616.61	112.78	139.86	-19.4%	8-HR	ALL	2ND	11/21/2004 24 hr	02/01/2004 24 hr
25	1947.06	277.37	72.35	85.83	-15.7%	8-HR	ALL	2ND	11/09/2004 24 hr	11/09/2004 24 hr
26	2015.95	1287.17	219.78	236.43	-7.0%	8-HR	ALL	2ND	08/31/2004 24 hr	11/21/2004 24 hr
27	1661.46	697.69	130.13	154.06	-15.5%	8-HR	ALL	2ND	11/09/2004 24 hr	12/24/2004 24 hr
28	1391.11	120.4	145.41	113.99	27.6%	8-HR	ALL	2ND	11/22/2004 24 hr	12/16/2004 08 hr
29	517	-672	75.90	50.02	51.8%	8-HR	ALL	2ND	07/25/2004 24 hr	07/25/2004 24 hr
30	842.77	367.59	131.76	96.41	36.7%	8-HR	ALL	2ND	07/26/2004 24 hr	02/16/2004 24 hr
31	394.41	-21.64	111.31	103.44	7.6%	8-HR	ALL	2ND	08/16/2004 24 hr	10/27/2004 24 hr
32	763.52	829.36	223.65	233.55	-4.2%	8-HR	ALL	2ND	10/03/2004 24 hr	10/27/2004 24 hr
33	787.91	1294.79	416.27	362.71	14.8%	8-HR	ALL	2ND	08/16/2004 24 hr	09/11/2004 24 hr
34	1161.91	1959.32	919.23	722.61	27.2%	8-HR	ALL	2ND	08/13/2004 24 hr	08/04/2004 24 hr
35	663.68	2562.15	183.11	137.43	33.2%	8-HR	ALL	2ND	05/31/2004 24 hr	11/23/2004 24 hr
36	1181.4	2635	418.57	416.12	0.6%	8-HR	ALL	2ND	09/06/2004 24 hr	07/29/2004 24 hr
37	1614.83	3176.02	382.96	364.89	5.0%	8-HR	ALL	2ND	11/20/2004 24 hr	10/13/2004 24 hr
38	1806.43	2845.04	659.35	535.57	23.1%	8-HR	ALL	2ND	09/23/2004 24 hr	05/09/2014 24 hr

Table A-8. Use Case B: NOx 1-Hour Concentrations for All Sources

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON))	Date (DATE(CON))
1	2202.79	3520.44	175.05	150.73	16.1%	1-HR	ALL	8TH	08/02/2004 21 hr	10/13/2004 19 hr
2	1167.99	902.82	128.96	130.69	-1.3%	1-HR	ALL	8TH	11/17/2004 16 hr	8/16/2004 20 hr
3	3504.59	4291.58	119.58	94.34	26.8%	1-HR	ALL	8TH	08/25/2004 21 hr	10/6/2004 22 hr
4	2599.64	3535.07	194.79	169.09	15.2%	1-HR	ALL	8TH	06/04/2004 23 hr	10/7/2004 19 hr
5	3060.8	3327.2	171.24	180.99	-5.4%	1-HR	ALL	8TH	12/02/2004 08 hr	11/10/2004 23 hr
6	3635.96	3502.46	173.18	146.79	18.0%	1-HR	ALL	8TH	10/08/2004 24 hr	10/8/2004 24 hr
7	2478.02	2871.98	248.96	229.13	8.7%	1-HR	ALL	8TH	05/19/2004 20 hr	12/12/2004 22 hr
8	1250.9	3235.76	162.97	145.07	12.3%	1-HR	ALL	8TH	11/30/2004 19 hr	11/10/2004 21 hr
9	3499.71	2699.31	156.25	175.77	-11.1%	1-HR	ALL	8TH	05/19/2004 21 hr	10/13/2004 21 hr
10	3045.56	2892.25	235.47	238.94	-1.5%	1-HR	ALL	8TH	09/26/2004 20 hr	11/21/2004 20 hr
11	813.21	-161.24	115.91	177.54	-34.7%	1-HR	ALL	8TH	04/14/2004 19 hr	4/14/2004 19 hr
12	3471.37	-254.81	65.13	59.53	9.4%	1-HR	ALL	8TH	02/01/2004 19 hr	2/25/2004 18 hr
13	3425.65	3750.26	140.84	129.64	8.6%	1-HR	ALL	8TH	10/04/2004 20 hr	10/16/2004 21 hr
14	2437.49	-39.01	75.74	70.11	8.0%	1-HR	ALL	8TH	11/29/2004 22 hr	12/15/2004 23 hr
15	3201.31	2468.58	177.03	161.65	9.5%	1-HR	ALL	8TH	12/30/2004 21 hr	10/29/2004 21 hr
16	1460.3	-139.29	86.67	161.80	-46.4%	1-HR	ALL	8TH	07/06/2004 24 hr	11/22/2004 18 hr
17	2774.9	1896.16	154.41	142.00	8.7%	1-HR	ALL	8TH	07/10/2004 22 hr	12/30/2004 21 hr
18	977.8	-964.69	59.06	59.43	-0.6%	1-HR	ALL	8TH	07/10/2004 24 hr	1/27/2004 17 hr
19	3069.34	1312.77	116.08	126.48	-8.2%	1-HR	ALL	8TH	10/27/2004 18 hr	10/5/2004 23 hr
20	63.4	51.21	77.44	109.64	-29.4%	1-HR	ALL	8TH	07/26/2004 23 hr	9/13/2004 21 hr
21	3514.95	1064.97	101.45	111.77	-9.2%	1-HR	ALL	8TH	11/03/2004 19 hr	9/1/2004 19 hr
22	955.55	2307.64	171.20	172.95	-1.0%	1-HR	ALL	8TH	05/26/2004 19 hr	10/29/2004 19 hr
23	3253.74	569.67	101.74	91.20	11.6%	1-HR	ALL	8TH	02/01/2004 22 hr	5/30/2004 19 hr
24	2375.31	616.61	107.30	113.28	-5.3%	1-HR	ALL	8TH	10/05/2004 19 hr	7/2/2004 23 hr
25	1947.06	277.37	95.71	112.28	-14.8%	1-HR	ALL	8TH	02/16/2004 18 hr	12/24/2004 20 hr

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON)	Date (DATE(CON)
26	2015.95	1287.17	143.08	136.25	5.0%	1-HR	ALL	8TH	02/01/2004 18 hr	2/25/2004 18 hr
27	1661.46	697.69	122.39	151.57	-19.3%	1-HR	ALL	8TH	11/29/2004 18 hr	1/18/2004 17 hr
28	1391.11	120.4	101.60	147.61	-31.2%	1-HR	ALL	8TH	09/13/2004 24 hr	2/7/2004 08 hr
29	517	-672	88.51	114.66	-22.8%	1-HR	ALL	8TH	02/06/2004 22 hr	9/13/2004 22 hr
30	842.77	367.59	128.55	128.90	-0.3%	1-HR	ALL	8TH	02/06/2004 22 hr	7/25/2004 23 hr
31	394.41	-21.64	80.99	121.66	-33.4%	1-HR	ALL	8TH	03/30/2004 23 hr	7/28/2004 21 hr
32	763.52	829.36	112.45	119.65	-6.0%	1-HR	ALL	8TH	08/16/2004 21 hr	8/5/2004 21 hr
33	787.91	1294.79	138.67	175.48	-21.0%	1-HR	ALL	8TH	10/14/2004 07 hr	10/27/2004 17 hr
34	1161.91	1959.32	396.54	326.96	21.3%	1-HR	ALL	8TH	07/25/2004 21 hr	10/29/2004 19 hr
35	663.68	2562.15	105.31	91.01	15.7%	1-HR	ALL	8TH	09/16/2004 19 hr	9/16/2004 19 hr
36	1181.4	2635	244.20	223.55	9.2%	1-HR	ALL	8TH	10/07/2004 18 hr	11/22/2004 16 hr
37	1614.83	3176.02	200.41	183.15	9.4%	1-HR	ALL	8TH	05/19/2004 20 hr	8/17/2004 23 hr
38	1806.43	2845.04	378.83	302.90	25.1%	1-HR	ALL	8TH	06/07/2004 23 hr	8/2/2004 21 hr

Table A-9. Use Case B: NOx Annual Concentrations for All Sources

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]				
1	2202.79	3520.44	2.72	2.43	12.1%	ANNUAL	ALL	1
2	1167.99	902.82	2.91	2.87	1.4%	ANNUAL	ALL	1
3	3504.59	4291.58	1.14	1.04	9.8%	ANNUAL	ALL	1
4	2599.64	3535.07	2.89	2.49	16.1%	ANNUAL	ALL	1
5	3060.8	3327.2	2.41	2.22	8.8%	ANNUAL	ALL	1
6	3635.96	3502.46	1.63	1.48	10.1%	ANNUAL	ALL	1
7	2478.02	2871.98	6.65	5.86	13.5%	ANNUAL	ALL	1
8	1250.9	3235.76	1.96	1.86	5.2%	ANNUAL	ALL	1
9	3499.71	2699.31	2.20	2.22	-1.1%	ANNUAL	ALL	1
10	3045.56	2892.25	3.31	3.18	4.1%	ANNUAL	ALL	1
11	813.21	-161.24	1.16	1.19	-2.6%	ANNUAL	ALL	1
12	3471.37	-254.81	0.86	0.92	-6.9%	ANNUAL	ALL	1
13	3425.65	3750.26	1.60	1.43	11.9%	ANNUAL	ALL	1
14	2437.49	-39.01	1.26	1.42	-11.6%	ANNUAL	ALL	1
15	3201.31	2468.58	3.14	3.15	-0.3%	ANNUAL	ALL	1
16	1460.3	-139.29	1.16	1.32	-12.4%	ANNUAL	ALL	1

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]				
17	2774.9	1896.16	4.93	5.18	-4.7%	ANNUAL	ALL	1
18	977.8	-964.69	0.54	0.58	-7.1%	ANNUAL	ALL	1
19	3069.34	1312.77	2.77	2.99	-7.4%	ANNUAL	ALL	1
20	63.4	51.21	0.79	0.83	-4.6%	ANNUAL	ALL	1
21	3514.95	1064.97	1.76	1.88	-6.8%	ANNUAL	ALL	1
22	955.55	2307.64	2.15	2.06	4.2%	ANNUAL	ALL	1
23	3253.74	569.67	1.57	1.68	-6.2%	ANNUAL	ALL	1
24	2375.31	616.61	2.40	2.68	-10.4%	ANNUAL	ALL	1
25	1947.06	277.37	2.00	2.27	-11.8%	ANNUAL	ALL	1
26	2015.95	1287.17	6.46	6.85	-5.8%	ANNUAL	ALL	1
27	1661.46	697.69	5.16	5.79	-10.9%	ANNUAL	ALL	1
28	1391.11	120.4	1.56	1.74	-10.3%	ANNUAL	ALL	1
29	517	-672	0.77	0.78	-1.0%	ANNUAL	ALL	1
30	842.77	367.59	1.59	1.62	-1.5%	ANNUAL	ALL	1
31	394.41	-21.64	0.96	0.98	-2.8%	ANNUAL	ALL	1
32	763.52	829.36	1.52	1.54	-0.9%	ANNUAL	ALL	1
33	787.91	1294.79	1.92	1.95	-1.4%	ANNUAL	ALL	1
34	1161.91	1959.32	9.34	9.24	1.1%	ANNUAL	ALL	1
35	663.68	2562.15	1.07	0.99	8.4%	ANNUAL	ALL	1
36	1181.4	2635	3.37	3.30	2.0%	ANNUAL	ALL	1
37	1614.83	3176.02	3.17	2.86	10.9%	ANNUAL	ALL	1
38	1806.43	2845.04	7.53	6.21	21.3%	ANNUAL	ALL	1

Table A-10. Use Case B: $PM_{2.5}$ 24-Hour Concentrations for All Sources

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON))	Date (DATE(CON))
1	2202.79	3520.44	0.668	0.606	10.2%	24-HR	ALL	8TH	04/11/2004 24 hr	10/13/2004 24 hr
2	1167.99	902.82	0.380	0.397	-4.3%	24-HR	ALL	8TH	09/13/2004 24 hr	7/6/2004 24 hr
3	3504.59	4291.58	0.334	0.359	-6.9%	24-HR	ALL	8TH	10/04/2004 24 hr	2/2/2004 24 hr
4	2599.64	3535.07	0.548	0.561	-2.3%	24-HR	ALL	8TH	02/02/2004 24 hr	8/17/2004 24 hr
5	3060.8	3327.2	0.468	0.543	-13.9%	24-HR	ALL	8TH	06/28/2004 24 hr	10/2/2004 24 hr
6	3635.96	3502.46	0.354	0.380	-6.9%	24-HR	ALL	8TH	09/03/2004 24 hr	9/26/2004 24 hr
7	2478.02	2871.98	0.966	1.118	-13.6%	24-HR	ALL	8TH	10/01/2004 24 hr	10/2/2004 24 hr
8	1250.9	3235.76	0.533	0.503	6.0%	24-HR	ALL	8TH	08/02/2004 24 hr	8/2/2004 24 hr
9	3499.71	2699.31	0.477	0.384	24.2%	24-HR	ALL	8TH	11/26/2004 24 hr	12/2/2004 24 hr
10	3045.56	2892.25	0.438	0.563	-22.2%	24-HR	ALL	8TH	11/26/2004 24 hr	10/2/2004 24 hr
11	813.21	-161.24	0.450	0.451	-0.2%	24-HR	ALL	8TH	12/03/2004 24 hr	1/1/2004 24 hr

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON))	Date (DATE(CON))
12	3471.37	-254.81	0.162	0.174	-7.0%	24-HR	ALL	8TH	02/16/2004 24 hr	5/30/2004 24 hr
13	3425.65	3750.26	0.430	0.415	3.6%	24-HR	ALL	8TH	05/19/2004 24 hr	8/17/2004 24 hr
14	2437.49	-39.01	0.234	0.263	-11.2%	24-HR	ALL	8TH	02/19/2004 24 hr	11/3/2004 24 hr
15	3201.31	2468.58	0.427	0.538	-20.6%	24-HR	ALL	8TH	01/12/2004 24 hr	7/10/2004 24 hr
16	1460.3	-139.29	0.293	0.343	-14.7%	24-HR	ALL	8TH	11/30/2004 24 hr	7/20/2004 24 hr
17	2774.9	1896.16	0.543	0.575	-5.5%	24-HR	ALL	8TH	07/10/2004 24 hr	10/28/2004 24 hr
18	977.8	-964.69	0.291	0.291	0.1%	24-HR	ALL	8TH	12/03/2004 24 hr	12/3/2004 24 hr
19	3069.34	1312.77	0.373	0.396	-5.9%	24-HR	ALL	8TH	10/05/2004 24 hr	10/5/2004 24 hr
20	63.4	51.21	1.085	1.085	0.0%	24-HR	ALL	8TH	07/29/2004 24 hr	7/29/2004 24 hr
21	3514.95	1064.97	0.287	0.307	-6.6%	24-HR	ALL	8TH	09/20/2004 24 hr	9/20/2004 24 hr
22	955.55	2307.64	0.726	0.714	1.7%	24-HR	ALL	8TH	09/08/2004 24 hr	12/9/2004 24 hr
23	3253.74	569.67	0.221	0.247	-10.7%	24-HR	ALL	8TH	05/30/2004 24 hr	12/9/2004 24 hr
24	2375.31	616.61	0.312	0.341	-8.4%	24-HR	ALL	8TH	12/29/2004 24 hr	12/29/2004 24 hr
25	1947.06	277.37	0.250	0.295	-15.3%	24-HR	ALL	8TH	02/16/2004 24 hr	2/2/2004 24 hr
26	2015.95	1287.17	0.549	0.565	-2.8%	24-HR	ALL	8TH	12/15/2004 24 hr	10/18/2004 24 hr
27	1661.46	697.69	0.385	0.465	-17.2%	24-HR	ALL	8TH	02/15/2004 24 hr	12/25/2004 24 hr
28	1391.11	120.4	0.330	0.382	-13.6%	24-HR	ALL	8TH	11/22/2004 24 hr	2/6/2004 24 hr
29	517	-672	0.489	0.522	-6.2%	24-HR	ALL	8TH	12/03/2004 24 hr	10/12/2004 24 hr
30	842.77	367.59	0.412	0.412	0.0%	24-HR	ALL	8TH	09/25/2004 24 hr	9/25/2004 24 hr
31	394.41	-21.64	0.983	0.983	0.0%	24-HR	ALL	8TH	08/07/2004 24 hr	8/7/2004 24 hr
32	763.52	829.36	0.501	0.608	-17.6%	24-HR	ALL	8TH	09/13/2004 24 hr	10/4/2004 24 hr
33	787.91	1294.79	0.598	0.666	-10.2%	24-HR	ALL	8TH	09/05/2004 24 hr	12/19/2004 24 hr
34	1161.91	1959.32	2.015	2.038	-1.1%	24-HR	ALL	8TH	07/13/2004 24 hr	8/4/2004 24 hr
35	663.68	2562.15	0.343	0.357	-3.8%	24-HR	ALL	8TH	09/15/2004 24 hr	9/15/2004 24 hr
36	1181.4	2635	0.896	0.908	-1.3%	24-HR	ALL	8TH	11/23/2004 24 hr	10/1/2004 24 hr
37	1614.83	3176.02	0.899	0.868	3.6%	24-HR	ALL	8TH	06/24/2004 24 hr	9/24/2004 24 hr
38	1806.43	2845.04	2.547	1.875	35.9%	24-HR	ALL	8TH	08/02/2004 24 hr	11/10/2004 24 hr

Table A-11. Use Case B: PM$_{2.5}$ Annual Concentrations for All Sources

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]				
1	2202.79	3520.44	0.09243	0.09102	1.6%	ANNUAL	ALL	1
2	1167.99	902.82	0.09758	0.11503	-15.2%	ANNUAL	ALL	1
3	3504.59	4291.58	0.03834	0.03930	-2.4%	ANNUAL	ALL	1
4	2599.64	3535.07	0.08577	0.08557	0.2%	ANNUAL	ALL	1
5	3060.8	3327.2	0.06825	0.07103	-3.9%	ANNUAL	ALL	1
6	3635.96	3502.46	0.04282	0.04592	-6.8%	ANNUAL	ALL	1
7	2478.02	2871.98	0.17299	0.18360	-5.8%	ANNUAL	ALL	1
8	1250.9	3235.76	0.08689	0.08961	-3.0%	ANNUAL	ALL	1
9	3499.71	2699.31	0.06330	0.06851	-7.6%	ANNUAL	ALL	1
10	3045.56	2892.25	0.08143	0.09179	-11.3%	ANNUAL	ALL	1
11	813.21	-161.24	0.09569	0.10081	-5.1%	ANNUAL	ALL	1
12	3471.37	-254.81	0.03363	0.03702	-9.2%	ANNUAL	ALL	1
13	3425.65	3750.26	0.04823	0.04969	-2.9%	ANNUAL	ALL	1
14	2437.49	-39.01	0.04850	0.05530	-12.3%	ANNUAL	ALL	1
15	3201.31	2468.58	0.08023	0.09193	-12.7%	ANNUAL	ALL	1
16	1460.3	-139.29	0.06227	0.06862	-9.3%	ANNUAL	ALL	1
17	2774.9	1896.16	0.11502	0.12873	-10.7%	ANNUAL	ALL	1
18	977.8	-964.69	0.05687	0.05904	-3.7%	ANNUAL	ALL	1
19	3069.34	1312.77	0.07205	0.08166	-11.8%	ANNUAL	ALL	1
20	63.4	51.21	0.13806	0.14184	-2.7%	ANNUAL	ALL	1
21	3514.95	1064.97	0.05257	0.05846	-10.1%	ANNUAL	ALL	1
22	955.55	2307.64	0.10289	0.10771	-4.5%	ANNUAL	ALL	1
23	3253.74	569.67	0.04847	0.05458	-11.2%	ANNUAL	ALL	1
24	2375.31	616.61	0.07317	0.08479	-13.7%	ANNUAL	ALL	1
25	1947.06	277.37	0.06281	0.07321	-14.2%	ANNUAL	ALL	1
26	2015.95	1287.17	0.14104	0.16470	-14.4%	ANNUAL	ALL	1
27	1661.46	697.69	0.11302	0.13781	-18.0%	ANNUAL	ALL	1
28	1391.11	120.4	0.06676	0.07496	-10.9%	ANNUAL	ALL	1
29	517	-672	0.09545	0.09862	-3.2%	ANNUAL	ALL	1
30	842.77	367.59	0.09667	0.10395	-7.0%	ANNUAL	ALL	1
31	394.41	-21.64	0.18420	0.18904	-2.6%	ANNUAL	ALL	1
32	763.52	829.36	0.10456	0.11426	-8.5%	ANNUAL	ALL	1
33	787.91	1294.79	0.11547	0.12178	-5.2%	ANNUAL	ALL	1
34	1161.91	1959.32	0.45439	0.46983	-3.3%	ANNUAL	ALL	1
35	663.68	2562.15	0.05794	0.06081	-4.7%	ANNUAL	ALL	1
36	1181.4	2635	0.16346	0.16772	-2.5%	ANNUAL	ALL	1
37	1614.83	3176.02	0.13515	0.13297	1.6%	ANNUAL	ALL	1
38	1806.43	2845.04	0.40647	0.34009	19.5%	ANNUAL	ALL	1

Table A-12. Use Case C: CO 1-Hour Concentrations for All Sources

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON)	Date (DATE(CON)
1	2202.79	3520.44	439.118	423.254	3.7%	1-HR	ALL	2ND	10/7/2004 19 hr	9/23/2004 20 hr
2	1167.99	902.82	268.154	247.126	8.5%	1-HR	ALL	2ND	4/14/2004 19 hr	4/14/2004 19 hr
3	3504.59	4291.58	219.579	250.853	-12.5%	1-HR	ALL	2ND	6/4/2004 23 hr	6/4/2004 23 hr
4	2599.64	3535.07	347.767	336.148	3.5%	1-HR	ALL	2ND	8/25/2004 21 hr	8/25/2004 21 hr
5	3060.8	3327.2	286.165	243.767	17.4%	1-HR	ALL	2ND	10/2/2004 22 hr	7/21/2004 23 hr
6	3635.96	3502.46	246.341	264.794	-7.0%	1-HR	ALL	2ND	11/23/2004 19 hr	3/11/2004 23 hr
7	2478.02	2871.98	367.904	309.617	18.8%	1-HR	ALL	2ND	10/2/2004 22 hr	11/23/2004 19 hr
8	1250.9	3235.76	224.516	213.573	5.1%	1-HR	ALL	2ND	11/30/2004 19 hr	9/7/2004 20 hr
9	3499.71	2699.31	201.644	219.976	-8.3%	1-HR	ALL	2ND	5/18/2004 24 hr	12/31/2004 07 hr
10	3045.56	2892.25	324.971	368.706	-11.9%	1-HR	ALL	2ND	5/4/2004 23 hr	9/2/2004 21 hr
11	813.21	-161.24	215.752	219.066	-1.5%	1-HR	ALL	2ND	7/26/2004 22 hr	7/26/2004 22 hr
12	3471.37	-254.81	109.403	103.342	5.9%	1-HR	ALL	2ND	5/30/2004 19 hr	12/9/2004 07 hr
13	3425.65	3750.26	225.55	222.056	1.6%	1-HR	ALL	2ND	8/25/2004 21 hr	9/22/2004 20 hr
14	2437.49	-39.01	151.363	134.009	12.9%	1-HR	ALL	2ND	2/21/2004 18 hr	2/19/2004 08 hr
15	3201.31	2468.58	285.384	240.416	18.7%	1-HR	ALL	2ND	11/15/2004 19 hr	9/1/2004 20 hr
16	1460.3	-139.29	192.838	222.021	-13.1%	1-HR	ALL	2ND	12/24/2004 20 hr	11/30/2004 07 hr
17	2774.9	1896.16	150.086	153.749	-2.4%	1-HR	ALL	2ND	9/26/2004 20 hr	11/22/2004 07 hr
18	977.8	-964.69	180.393	155.097	16.3%	1-HR	ALL	2ND	4/14/2004 19 hr	4/14/2004 19 hr
19	3069.34	1312.77	166.179	123.569	34.5%	1-HR	ALL	2ND	10/26/2004 20 hr	10/26/2004 20 hr
20	63.4	51.21	241.979	217.745	11.1%	1-HR	ALL	2ND	9/5/2004 23 hr	9/5/2004 23 hr
21	3514.95	1064.97	148.963	113.932	30.7%	1-HR	ALL	2ND	10/26/2004 20 hr	8/31/2004 22 hr
22	955.55	2307.64	254.936	265.664	-4.0%	1-HR	ALL	2ND	8/13/2004 20 hr	8/13/2004 20 hr
23	3253.74	569.67	128.342	150.714	-14.8%	1-HR	ALL	2ND	8/31/2004 22 hr	8/31/2004 22 hr
24	2375.31	616.61	138.069	152.496	-9.5%	1-HR	ALL	2ND	2/21/2004 18 hr	2/21/2004 18 hr
25	1947.06	277.37	163.472	164.102	-0.4%	1-HR	ALL	2ND	2/19/2004 08 hr	2/21/2004 18 hr
26	2015.95	1287.17	160.924	157.505	2.2%	1-HR	ALL	2ND	11/21/2004 17 hr	11/21/2004 17 hr
27	1661.46	697.69	186.983	186.42	0.3%	1-HR	ALL	2ND	10/18/2004 19 hr	11/3/2004 19 hr

Discrete Receptor ID (Group Name)	**X**	**Y**	**AEDT**	**EDMS**	**Percentage Difference between AEDT 2b and EDMS Concentrations**	**Averaging Period (AVE)**	**Source Group (GRP)**	**Rank**	**AEDT**	**EDMS**
			Concentration (AVERAGE CONC)[ug/m^3]	**Concentration (AVERAGE CONC) [ug/m^3]**					**Date (DATE(CON)**	**Date (DATE(CON)**
28	1391.11	120.4	251.087	252.48	-0.6%	1-HR	ALL	2ND	12/15/2004 23 hr	12/15/2004 23 hr
29	517	-672	188.493	194.163	-2.9%	1-HR	ALL	2ND	7/26/2004 22 hr	3/10/2004 07 hr
30	842.77	367.59	225.64	225.965	-0.1%	1-HR	ALL	2ND	7/25/2004 23 hr	7/25/2004 23 hr
31	394.41	-21.64	266.645	265.176	0.6%	1-HR	ALL	2ND	11/24/2004 07 hr	3/10/2004 07 hr
32	763.52	829.36	407.977	393.923	3.6%	1-HR	ALL	2ND	10/27/2004 17 hr	11/24/2004 07 hr
33	787.91	1294.79	396.155	395.544	0.2%	1-HR	ALL	2ND	6/3/2004 21 hr	6/3/2004 21 hr
34	1161.91	1959.32	429.998	414.189	3.8%	1-HR	ALL	2ND	10/28/2004 17 hr	8/13/2004 20 hr
35	663.68	2562.15	178.094	187.692	-5.1%	1-HR	ALL	2ND	8/13/2004 20 hr	8/13/2004 20 hr
36	1181.4	2635	365.195	332.314	9.9%	1-HR	ALL	2ND	9/7/2004 20 hr	9/15/2004 20 hr
37	1614.83	3176.02	359.12	339.721	5.7%	1-HR	ALL	2ND	11/20/2004 17 hr	11/30/2004 22 hr
38	1806.43	2845.04	667.275	670.072	-0.4%	1-HR	ALL	2ND	10/13/2004 20 hr	10/13/2004 20 hr

Table A-13. Use Case C: CO 8-Hour Concentrations for All Sources

Discrete Receptor ID (Group Name)	**X**	**Y**	**AEDT**	**EDMS**	**Percentage Difference between AEDT 2b and EDMS Concentrations**	**Averaging Period (AVE)**	**Source Group (GRP)**	**Rank**	**AEDT**	**EDMS**
			Concentration (AVERAGE CONC) [ug/m^3]	**Concentration (AVERAGE CONC) [ug/m^3]**					**Date (DATE(CON)**	**Date (DATE(CON)**
1	2202.79	3520.44	109.792	105.436	4.1%	8-HR	ALL	2ND	10/13/2004 24 hr	10/13/2004 24 hr
2	1167.99	902.82	64.0412	57.3427	11.7%	8-HR	ALL	2ND	4/14/2004 24 hr	7/6/2004 24 hr
3	3504.59	4291.58	59.8507	55.5484	7.7%	8-HR	ALL	2ND	8/25/2004 24 hr	9/23/2004 24 hr
4	2599.64	3535.07	82.0859	80.4978	2.0%	8-HR	ALL	2ND	8/25/2004 24 hr	8/25/2004 24 hr
5	3060.8	3327.2	88.2939	87.7029	0.7%	8-HR	ALL	2ND	10/6/2004 24 hr	9/26/2004 24 hr
6	3635.96	3502.46	54.9651	60.7878	-9.6%	8-HR	ALL	2ND	11/21/2004 24 hr	9/26/2004 24 hr
7	2478.02	2871.98	111.605	111.351	0.2%	8-HR	ALL	2ND	10/6/2004 24 hr	11/21/2004 24 hr
8	1250.9	3235.76	55.7881	57.478	-2.9%	8-HR	ALL	2ND	9/7/2004 24 hr	9/7/2004 24 hr
9	3499.71	2699.31	46.412	50.4463	-8.0%	8-HR	ALL	2ND	9/26/2004 24 hr	9/26/2004 24 hr
10	3045.56	2892.25	68.0012	75.0032	-9.3%	8-HR	ALL	2ND	5/4/2004 24 hr	8/25/2004 24 hr
11	813.21	-161.24	38.0171	47.299	-19.6%	8-HR	ALL	2ND	9/13/2004 24 hr	9/13/2004 24 hr
12	3471.37	-254.81	21.0286	23.4226	-10.2%	8-HR	ALL	2ND	8/31/2004 24 hr	12/15/2004 24 hr
13	3425.65	3750.26	56.5741	58.9973	-4.1%	8-HR	ALL	2ND	9/26/2004 24 hr	11/21/2004 24 hr
14	2437.49	-39.01	31.7003	31.9227	-0.7%	8-HR	ALL	2ND	10/18/2004 24 hr	10/18/2004 24 hr
15	3201.31	2468.58	57.2551	56.5573	1.2%	8-HR	ALL	2ND	11/15/2004 24 hr	11/26/2004 24 hr
16	1460.3	-139.29	46.5587	47.0587	-1.1%	8-HR	ALL	2ND	11/29/2004 24 hr	11/29/2004 24 hr
17	2774.9	1896.16	68.237	66.3561	2.8%	8-HR	ALL	2ND	11/15/2004 24 hr	9/26/2004 24 hr
18	977.8	-964.69	30.7701	26.7547	15.0%	8-HR	ALL	2ND	4/14/2004 24 hr	4/14/2004 24 hr
19	3069.34	1312.77	56.3415	52.5395	7.2%	8-HR	ALL	2ND	10/26/2004 24 hr	10/26/2004 24 hr
20	63.4	51.21	57.8191	55.3296	4.5%	8-HR	ALL	2ND	7/6/2004 24 hr	10/14/2004 08 hr
21	3514.95	1064.97	47.0198	44.2795	6.2%	8-HR	ALL	2ND	10/26/2004 24 hr	10/26/2004 24 hr
22	955.55	2307.64	54.5834	57.5093	-5.1%	8-HR	ALL	2ND	5/3/2004 24 hr	2/20/2004 24 hr
23	3253.74	569.67	41.944	37.4256	12.1%	8-HR	ALL	2ND	11/15/2004 24 hr	8/31/2004 24 hr
24	2375.31	616.61	43.3456	45.9978	-5.8%	8-HR	ALL	2ND	11/15/2004 24 hr	2/1/2004 24 hr
25	1947.06	277.37	45.5601	45.1837	0.8%	8-HR	ALL	2ND	10/18/2004 24 hr	10/18/2004 24 hr
26	2015.95	1287.17	50.9054	55.0811	-7.6%	8-HR	ALL	2ND	10/18/2004 24 hr	10/18/2004 24 hr
27	1661.46	697.69	57.9355	60.9514	-4.9%	8-HR	ALL	2ND	2/1/2004 24 hr	2/16/2004 24 hr

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC) [ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON)	Date (DATE(CON)
28	1391.11	120.4	51.2336	54.0707	-5.2%	8-HR	ALL	2ND	11/22/2004 24 hr	11/30/2004 08 hr
29	517	-672	32.3364	39.8134	-18.8%	8-HR	ALL	2ND	9/13/2004 24 hr	9/13/2004 24 hr
30	842.77	367.59	52.4577	52.5979	-0.3%	8-HR	ALL	2ND	9/13/2004 24 hr	9/13/2004 24 hr
31	394.41	-21.64	50.5598	49.8487	1.4%	8-HR	ALL	2ND	9/13/2004 24 hr	8/16/2004 24 hr
32	763.52	829.36	75.6675	72.4859	4.4%	8-HR	ALL	2ND	10/14/2004 08 hr	7/26/2004 24 hr
33	787.91	1294.79	95.8978	98.8676	-3.0%	8-HR	ALL	2ND	8/16/2004 24 hr	8/16/2004 24 hr
34	1161.91	1959.32	122.682	112.67	8.9%	8-HR	ALL	2ND	8/13/2004 24 hr	6/3/2004 24 hr
35	663.68	2562.15	39.5107	37.2839	6.0%	8-HR	ALL	2ND	11/17/2004 24 hr	9/6/2004 24 hr
36	1181.4	2635	80.4889	72.7263	10.7%	8-HR	ALL	2ND	9/7/2004 24 hr	9/7/2004 24 hr
37	1614.83	3176.02	90.1379	94.7557	-4.9%	8-HR	ALL	2ND	10/7/2004 24 hr	11/20/2004 24 hr
38	1806.43	2845.04	184.668	187.788	-1.7%	8-HR	ALL	2ND	10/13/2004 24 hr	11/30/2004 24 hr

Table A-14. Use Case C: NOx 1-Hour Concentrations for All Sources

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON)	Date (DATE(CON)
1	2202.79	3520.44	133.957	127.222	5.3%	1-HR	ALL	8TH	11/11/2004 20 hr	8/2/2004 22 hr
2	1167.99	902.82	133.101	125.027	6.5%	1-HR	ALL	8TH	7/6/2004 23 hr	10/28/2004 17 hr
3	3504.59	4291.58	81.8152	82.2932	-0.6%	1-HR	ALL	8TH	12/2/2004 08 hr	12/2/2004 08 hr
4	2599.64	3535.07	180.342	177.848	1.4%	1-HR	ALL	8TH	8/25/2004 21 hr	11/20/2004 17 hr
5	3060.8	3327.2	187.024	166.057	12.6%	1-HR	ALL	8TH	8/25/2004 21 hr	11/10/2004 23 hr
6	3635.96	3502.46	139.613	129.436	7.9%	1-HR	ALL	8TH	10/8/2004 24 hr	9/22/2004 20 hr
7	2478.02	2871.98	217.9	227.521	-4.2%	1-HR	ALL	8TH	7/8/2004 22 hr	7/19/2004 23 hr
8	1250.9	3235.76	137.617	127.399	8.0%	1-HR	ALL	8TH	11/11/2004 20 hr	9/7/2004 20 hr
9	3499.71	2699.31	144.546	157.983	-8.5%	1-HR	ALL	8TH	5/5/2004 23 hr	10/13/2004 21 hr
10	3045.56	2892.25	203.179	196.056	3.6%	1-HR	ALL	8TH	10/29/2004 21 hr	8/25/2004 22 hr
11	813.21	-161.24	137.881	125.928	9.5%	1-HR	ALL	8TH	9/24/2004 07 hr	11/21/2004 08 hr
12	3471.37	-254.81	59.5322	62.8166	-5.2%	1-HR	ALL	8TH	2/19/2004 08 hr	9/27/2004 24 hr

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON)	Date (DATE(CON)
13	3425.65	3750.26	154.891	153.777	0.7%	1-HR	ALL	8TH	11/21/2004 24 hr	8/25/2004 20 hr
14	2437.49	-39.01	70.9938	78.5447	-9.6%	1-HR	ALL	8TH	12/3/2004 20 hr	11/22/2004 18 hr
15	3201.31	2468.58	156.887	174.503	-10.1%	1-HR	ALL	8TH	9/26/2004 18 hr	1/12/2004 17 hr
16	1460.3	-139.29	82.7735	117.717	-29.7%	1-HR	ALL	8TH	12/24/2004 20 hr	11/9/2004 23 hr
17	2774.9	1896.16	112.065	117.066	-4.3%	1-HR	ALL	8TH	12/30/2004 21 hr	7/10/2004 22 hr
18	977.8	-964.69	53.285	50.9976	4.5%	1-HR	ALL	8TH	2/16/2004 22 hr	2/16/2004 22 hr
19	3069.34	1312.77	106.965	110.319	-3.0%	1-HR	ALL	8TH	2/21/2004 18 hr	12/18/2004 07 hr
20	63.4	51.21	88.9325	87.2127	2.0%	1-HR	ALL	8TH	11/24/2004 07 hr	3/5/2004 07 hr
21	3514.95	1064.97	97.0629	109.395	-11.3%	1-HR	ALL	8TH	2/16/2004 20 hr	2/16/2004 20 hr
22	955.55	2307.64	149.131	150.107	-0.7%	1-HR	ALL	8TH	8/6/2004 19 hr	10/26/2004 18 hr
23	3253.74	569.67	74.1371	73.021	1.5%	1-HR	ALL	8TH	10/27/2004 18 hr	8/31/2004 20 hr
24	2375.31	616.61	81.62	104.935	-22.2%	1-HR	ALL	8TH	1/2/2004 20 hr	12/28/2004 07 hr
25	1947.06	277.37	98.056	96.2267	1.9%	1-HR	ALL	8TH	1/18/2004 17 hr	2/7/2004 08 hr
26	2015.95	1287.17	139.356	155.28	-10.3%	1-HR	ALL	8TH	9/22/2004 20 hr	12/21/2004 20 hr
27	1661.46	697.69	116.833	119.112	-1.9%	1-HR	ALL	8TH	3/10/2004 07 hr	2/7/2004 08 hr
28	1391.11	120.4	109.901	105.343	4.3%	1-HR	ALL	8TH	2/6/2004 22 hr	2/6/2004 22 hr
29	517	-672	87.2481	89.0764	-2.1%	1-HR	ALL	8TH	9/13/2004 22 hr	9/13/2004 22 hr
30	842.77	367.59	132.985	114.541	16.1%	1-HR	ALL	8TH	9/11/2004 20 hr	8/5/2004 21 hr
31	394.41	-21.64	100.667	91.5861	9.9%	1-HR	ALL	8TH	7/6/2004 23 hr	1/2/2004 17 hr
32	763.52	829.36	125.141	119.668	4.6%	1-HR	ALL	8TH	11/24/2004 07 hr	11/24/2004 07 hr
33	787.91	1294.79	120.993	118.657	2.0%	1-HR	ALL	8TH	10/28/2004 17 hr	10/27/2004 17 hr
34	1161.91	1959.32	203.98	215.847	-5.5%	1-HR	ALL	8TH	9/16/2004 19 hr	8/13/2004 21 hr
35	663.68	2562.15	93.026	98.2877	-5.4%	1-HR	ALL	8TH	5/26/2004 19 hr	5/26/2004 19 hr
36	1181.4	2635	161.621	164.17	-1.6%	1-HR	ALL	8TH	9/15/2004 20 hr	10/29/2004 19 hr
37	1614.83	3176.02	146.757	147.353	-0.4%	1-HR	ALL	8TH	12/31/2004 08 hr	12/31/2004 08 hr
38	1806.43	2845.04	156.402	159.264	-1.8%	1-HR	ALL	8TH	9/7/2004 20 hr	11/10/2004 22 hr

Table A-15. Use Case C: NOx Annual Concentrations for All Sources

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]				
1	2202.79	3520.44	2.21541	2.14364	3.3%	ANNUAL	ALL	1
2	1167.99	902.82	2.82959	2.68816	5.3%	ANNUAL	ALL	1
3	3504.59	4291.58	0.957621	0.941209	1.7%	ANNUAL	ALL	1
4	2599.64	3535.07	2.41062	2.3232	3.8%	ANNUAL	ALL	1
5	3060.8	3327.2	2.14337	2.07302	3.4%	ANNUAL	ALL	1
6	3635.96	3502.46	1.38336	1.33591	3.6%	ANNUAL	ALL	1
7	2478.02	2871.98	5.48473	5.34652	2.6%	ANNUAL	ALL	1
8	1250.9	3235.76	1.63534	1.55531	5.1%	ANNUAL	ALL	1
9	3499.71	2699.31	2.12783	2.11668	0.5%	ANNUAL	ALL	1
10	3045.56	2892.25	2.91881	2.87748	1.4%	ANNUAL	ALL	1
11	813.21	-161.24	1.19279	1.11881	6.6%	ANNUAL	ALL	1
12	3471.37	-254.81	0.831682	0.867349	-4.1%	ANNUAL	ALL	1
13	3425.65	3750.26	1.4325	1.3948	2.7%	ANNUAL	ALL	1
14	2437.49	-39.01	1.26496	1.31759	-4.0%	ANNUAL	ALL	1
15	3201.31	2468.58	2.96513	2.97374	-0.3%	ANNUAL	ALL	1
16	1460.3	-139.29	1.19507	1.19528	0.0%	ANNUAL	ALL	1
17	2774.9	1896.16	4.75701	4.84736	-1.9%	ANNUAL	ALL	1
18	977.8	-964.69	0.541989	0.541163	0.2%	ANNUAL	ALL	1
19	3069.34	1312.77	2.77544	2.85869	-2.9%	ANNUAL	ALL	1
20	63.4	51.21	0.722207	0.698603	3.4%	ANNUAL	ALL	1
21	3514.95	1064.97	1.7433	1.77184	-1.6%	ANNUAL	ALL	1
22	955.55	2307.64	1.74435	1.71886	1.5%	ANNUAL	ALL	1
23	3253.74	569.67	1.5262	1.53561	-0.6%	ANNUAL	ALL	1
24	2375.31	616.61	2.36621	2.44567	-3.2%	ANNUAL	ALL	1
25	1947.06	277.37	2.02607	2.10157	-3.6%	ANNUAL	ALL	1
26	2015.95	1287.17	6.41385	6.53263	-1.8%	ANNUAL	ALL	1
27	1661.46	697.69	5.25205	5.51983	-4.9%	ANNUAL	ALL	1
28	1391.11	120.4	1.62866	1.60991	1.2%	ANNUAL	ALL	1
29	517	-672	0.774551	0.736544	5.2%	ANNUAL	ALL	1
30	842.77	367.59	1.5557	1.48418	4.8%	ANNUAL	ALL	1
31	394.41	-21.64	0.909865	0.874384	4.1%	ANNUAL	ALL	1
32	763.52	829.36	1.4296	1.37672	3.8%	ANNUAL	ALL	1
33	787.91	1294.79	1.65346	1.6293	1.5%	ANNUAL	ALL	1
34	1161.91	1959.32	6.84242	6.82552	0.2%	ANNUAL	ALL	1
35	663.68	2562.15	0.891037	0.87392	2.0%	ANNUAL	ALL	1
36	1181.4	2635	2.67793	2.64199	1.4%	ANNUAL	ALL	1
37	1614.83	3176.02	2.41892	2.34321	3.2%	ANNUAL	ALL	1
38	1806.43	2845.04	4.49538	4.39724	2.2%	ANNUAL	ALL	1

Table A-16. Use Case C: PM2.5 24-Hour Concentrations for All Sources

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON)	Date (DATE(CON)
1	2202.79	3520.44	0.486337	0.541	-10.1%	24-HR	ALL	8TH	11/11/2004 24 hr	11/11/2004 24 hr
2	1167.99	902.82	0.432382	0.480	-9.9%	24-HR	ALL	8TH	4/3/2004 24 hr	2/07/2004 24 hr
3	3504.59	4291.58	0.316593	0.347	-8.8%	24-HR	ALL	8TH	8/26/2004 24 hr	8/26/2004 24 hr
4	2599.64	3535.07	0.56362	0.596	-5.4%	24-HR	ALL	8TH	6/4/2004 24 hr	10/29/2004 24 hr
5	3060.8	3327.2	0.52873	0.568	-6.9%	24-HR	ALL	8TH	9/3/2004 24 hr	9/3/2004 24 hr
6	3635.96	3502.46	0.319975	0.385	-16.9%	24-HR	ALL	8TH	10/6/2004 24 hr	10/6/2004 24 hr
7	2478.02	2871.98	0.93032	1.010	-7.9%	24-HR	ALL	8TH	9/3/2004 24 hr	9/3/2004 24 hr
8	1250.9	3235.76	0.682805	0.725	-5.8%	24-HR	ALL	8TH	11/11/2004 24 hr	11/11/2004 24 hr
9	3499.71	2699.31	0.361396	0.406	-11.0%	24-HR	ALL	8TH	7/29/2004 24 hr	8/03/2004 24 hr
10	3045.56	2892.25	0.49132	0.551	-10.8%	24-HR	ALL	8TH	11/18/2004 24 hr	11/18/2004 24 hr
11	813.21	-161.24	0.204507	0.226	-9.5%	24-HR	ALL	8TH	12/19/2004 24 hr	7/25/2004 24 hr
12	3471.37	-254.81	0.143358	0.172	-16.7%	24-HR	ALL	8TH	12/15/2004 24 hr	12/24/2004 24 hr
13	3425.65	3750.26	0.397724	0.471	-15.6%	24-HR	ALL	8TH	10/6/2004 24 hr	10/02/2004 24 hr
14	2437.49	-39.01	0.21862	0.250	-12.6%	24-HR	ALL	8TH	2/23/2004 24 hr	1/08/2004 24 hr
15	3201.31	2468.58	0.47806	0.539	-11.3%	24-HR	ALL	8TH	9/20/2004 24 hr	12/16/2004 24 hr
16	1460.3	-139.29	0.275196	0.313	-12.1%	24-HR	ALL	8TH	2/16/2004 24 hr	2/16/2004 24 hr
17	2774.9	1896.16	0.589349	0.635	-7.2%	24-HR	ALL	8TH	10/5/2004 24 hr	8/25/2004 24 hr
18	977.8	-964.69	0.13751	0.156	-11.9%	24-HR	ALL	8TH	11/20/2004 24 hr	12/11/2004 24 hr
19	3069.34	1312.77	0.430157	0.483	-10.9%	24-HR	ALL	8TH	10/5/2004 24 hr	10/5/2004 24 hr
20	63.4	51.21	0.322591	0.340	-5.1%	24-HR	ALL	8TH	7/26/2004 24 hr	7/26/2004 24 hr
21	3514.95	1064.97	0.301419	0.342	-11.9%	24-HR	ALL	8TH	10/5/2004 24 hr	10/5/2004 24 hr
22	955.55	2307.64	0.927216	0.963	-3.7%	24-HR	ALL	8TH	9/8/2004 24 hr	9/8/2004 24 hr
23	3253.74	569.67	0.247893	0.271	-8.5%	24-HR	ALL	8TH	12/14/2004 24 hr	12/03/2004 24 hr
24	2375.31	616.61	0.354424	0.406	-12.7%	24-HR	ALL	8TH	1/2/2004 24 hr	12/15/2004 24 hr
25	1947.06	277.37	0.288278	0.341	-15.5%	24-HR	ALL	8TH	11/3/2004 24 hr	12/09/2004 24 hr
26	2015.95	1287.17	0.719435	0.763	-5.7%	24-HR	ALL	8TH	11/3/2004 24 hr	11/3/2004 24 hr

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank	AEDT	EDMS
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]					Date (DATE(CON)	Date (DATE(CON)
27	1661.46	697.69	0.491018	0.569	-13.7%	24-HR	ALL	8TH	10/27/2004 24 hr	02/16/2004 24 hr
28	1391.11	120.4	0.318113	0.373	-14.7%	24-HR	ALL	8TH	2/16/2004 24 hr	2/16/2004 24 hr
29	517	-672	0.216703	0.248	-12.6%	24-HR	ALL	8TH	11/1/2004 24 hr	9/13/2004 24 hr
30	842.77	367.59	0.305124	0.358	-14.8%	24-HR	ALL	8TH	3/8/2004 24 hr	9/13/2004 24 hr
31	394.41	-21.64	0.303135	0.344	-11.9%	24-HR	ALL	8TH	10/27/2004 24 hr	7/09/2004 24 hr
32	763.52	829.36	0.627306	0.701	-10.5%	24-HR	ALL	8TH	11/24/2004 24 hr	8/16/2004 24 hr
33	787.91	1294.79	0.748228	0.804	-6.9%	24-HR	ALL	8TH	9/13/2004 24 hr	9/24/2004 24 hr
34	1161.91	1959.32	3.04002	3.140	-3.2%	24-HR	ALL	8TH	12/18/2004 24 hr	12/18/2004 24 hr
35	663.68	2562.15	0.467752	0.504	-7.2%	24-HR	ALL	8TH	12/18/2004 24 hr	7/18/2004 24 hr
36	1181.4	2635	1.1663	1.200	-2.8%	24-HR	ALL	8TH	9/6/2004 24 hr	9/6/2004 24 hr
37	1614.83	3176.02	1.07545	1.130	-4.8%	24-HR	ALL	8TH	12/31/2004 24 hr	7/08/2004 24 hr
38	1806.43	2845.04	1.91525	2.010	-4.7%	24-HR	ALL	8TH	9/15/2004 24 hr	9/15/2004 24 hr

Table A-17. Use Case C: PM2.5 Annual Concentrations for All Sources

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]				
1	2202.79	3520.44	0.083412	0.094196	-11.4%	ANNUAL	ALL	1
2	1167.99	902.82	0.085933	0.103738	-17.2%	ANNUAL	ALL	1
3	3504.59	4291.58	0.03412	0.038899	-12.3%	ANNUAL	ALL	1
4	2599.64	3535.07	0.0783	0.08879	-11.8%	ANNUAL	ALL	1
5	3060.8	3327.2	0.063459	0.072672	-12.7%	ANNUAL	ALL	1
6	3635.96	3502.46	0.040171	0.046044	-12.8%	ANNUAL	ALL	1
7	2478.02	2871.98	0.151282	0.176619	-14.3%	ANNUAL	ALL	1
8	1250.9	3235.76	0.094784	0.101694	-6.8%	ANNUAL	ALL	1
9	3499.71	2699.31	0.062168	0.071929	-13.6%	ANNUAL	ALL	1
10	3045.56	2892.25	0.076689	0.089718	-14.5%	ANNUAL	ALL	1
11	813.21	-161.24	0.045497	0.052874	-14.0%	ANNUAL	ALL	1
12	3471.37	-254.81	0.02584	0.030284	-14.7%	ANNUAL	ALL	1
13	3425.65	3750.26	0.044793	0.051121	-12.4%	ANNUAL	ALL	1
14	2437.49	-39.01	0.035335	0.042173	-16.2%	ANNUAL	ALL	1
15	3201.31	2468.58	0.079986	0.09382	-14.7%	ANNUAL	ALL	1
16	1460.3	-139.29	0.039772	0.046667	-14.8%	ANNUAL	ALL	1
17	2774.9	1896.16	0.118595	0.137669	-13.9%	ANNUAL	ALL	1
18	977.8	-964.69	0.030605	0.035075	-12.7%	ANNUAL	ALL	1
19	3069.34	1312.77	0.071533	0.08386	-14.7%	ANNUAL	ALL	1
20	63.4	51.21	0.028115	0.031543	-10.9%	ANNUAL	ALL	1
21	3514.95	1064.97	0.047453	0.0552	-14.0%	ANNUAL	ALL	1

Discrete Receptor ID (Group Name)	X	Y	AEDT	EDMS	Percentage Difference between AEDT 2b and EDMS Concentrations	Averaging Period (AVE)	Source Group (GRP)	Rank
			Concentration (AVERAGE CONC)[ug/m^3]	Concentration (AVERAGE CONC) [ug/m^3]				
22	955.55	2307.64	0.112548	0.121379	-7.3%	ANNUAL	ALL	1
23	3253.74	569.67	0.045083	0.051824	-13.0%	ANNUAL	ALL	1
24	2375.31	616.61	0.06365	0.07504	-15.2%	ANNUAL	ALL	1
25	1947.06	277.37	0.051076	0.061383	-16.8%	ANNUAL	ALL	1
26	2015.95	1287.17	0.156222	0.180597	-13.5%	ANNUAL	ALL	1
27	1661.46	697.69	0.103363	0.127067	-18.7%	ANNUAL	ALL	1
28	1391.11	120.4	0.047412	0.055884	-15.2%	ANNUAL	ALL	1
29	517	-672	0.043675	0.050283	-13.1%	ANNUAL	ALL	1
30	842.77	367.59	0.054148	0.064654	-16.2%	ANNUAL	ALL	1
31	394.41	-21.64	0.060695	0.071224	-14.8%	ANNUAL	ALL	1
32	763.52	829.36	0.073997	0.085179	-13.1%	ANNUAL	ALL	1
33	787.91	1294.79	0.110566	0.12164	-9.1%	ANNUAL	ALL	1
34	1161.91	1959.32	0.635003	0.656347	-3.3%	ANNUAL	ALL	1
35	663.68	2562.15	0.050189	0.055543	-9.6%	ANNUAL	ALL	1
36	1181.4	2635	0.195178	0.20559	-5.1%	ANNUAL	ALL	1
37	1614.83	3176.02	0.150099	0.161548	-7.1%	ANNUAL	ALL	1
38	1806.43	2845.04	0.335346	0.356526	-5.9%	ANNUAL	ALL	1

A.3 AEDT Fuel Consumption Models

A.3.1 Senzig-Fleming-Iovinelli (SFI) fuel burn model (turbofan engine only)

- Departure:

$$f_{n_{dep}} = (K_1 + K_2 M + K_3 h_{MSL} + \frac{K_4 F_n}{\delta})\sqrt{\theta} F_n$$

where

K_1 Aircraft-specific terminal-area departure TSFC constant coefficient (kg/min/kN);

K_2 Aircraft-specific terminal-area departure TSFC Mach coefficient (kg/min/kN);

K_3 Aircraft-specific terminal-area departure TSFC altitude coefficient (kg/min/kN/foot);

K_4 Aircraft-specific terminal-area departure TSFC thrust coefficient (kg/min/kN/lb);

h_{MSL} Aircraft altitude (ft, MSL);

M Aircraft Mach number (dimensionless);

θ Ratio of temperature at aircraft altitude to sea level ISA temperature (dimensionless);

$\frac{F_n}{\delta}$ Aircraft corrected net thrust per engine (lbf);

F_n Aircraft net thrust per engine (kN).

- Arrival

$$f_{n_{arr}} = (\alpha + \beta_1 M + \beta_2 e^{-\left(\frac{\frac{\beta_3 F_n}{\delta}}{F_{n_0}}\right)})\sqrt{\theta} F_n$$

where

α Aircraft-specific terminal-area arrival TSFC constant coefficient (kg/min/kN);

β_1 Aircraft-specific terminal-area arrival TSFC Mach coefficient (kg/min/kN);

β_2 Aircraft-specific terminal-area arrival TSFC thrust coefficient (kg/min/kN);

β_3 Aircraft-specific terminal-area arrival TSFC thrust ratio coefficient (dimensionless); h_{MSL} Aircraft altitude (ft, MSL);

M Aircraft Mach number (dimensionless);

θ Ratio of temperature at aircraft altitude to sea level ISA temperature (dimensionless);

$\frac{F_n}{\delta}$ Aircraft corrected net thrust per engine (lbf);

F_n Aircraft net thrust per engine (kN);

F_{n_0} ISA sea-level static thrust (lbf).

A.3.2 BADA

total fuel flow rate – nominal state

$$f_{nom} = (1 + \frac{V_T}{C_{f_2}})C_{f_1}F$$

where

V_T Aircraft true airspeed (speed in the still-air frame of reference) (kt);

C_{f_1} Aircraft-specific 1st thrust specific fuel consumption coefficient (kg/min/kN);

C_{f_2} Aircraft-specific 2nd thrust specific fuel consumption coefficient (kt);

F Aircraft total net thrust from its engines (kN)

total fuel flow rate – idle state

$$f_{min} = (1 - \frac{h}{C_{f_4}})C_{f_3}$$

where

h Altitude above MSL (ft);

C_{f_3} Aircraft-specific 1st descent fuel flow coefficient (kg/min);

C_{f_4} Aircraft-specific 2nd descent fuel flow coefficient (ft)

total fuel flow rate – cruise state

$$f_{CR} = C_{f_{CR}} f_{nom}$$

where

$C_{f_{CR}}$ Aircraft-specific cruise fuel flow correction coefficient (dimensionless);

f_{nom} Nominal total rate of fuel flow (kg/min);

A.3.3 Boeing Fuel Flow Method 2 (BFFM2)

$$W_f = \frac{B_m RW_f \delta}{\theta^{3.8} e^{0.2M^2}}$$

where

W_f Fuel flow at non-reference conditions (kg/s);

B_m Modal-specific adjustment factors (dimensionless);

RW_f Fuel flow at reference conditions (kg/s);

F Aircraft total net thrust from its engines (kN)

M Aircraft Mach number (dimensionless);

θ Temperature ratio (ambient to sea level standard - dimensionless);

Pressure ratio (ambient to sea level standard- dimensionless).

The fuel flow at reference conditions used in the BFFM2 are the fuel flow data found in the ICAO emissions database

Appendix B. Additional Use Case D Results

Table B-1. ANC – DNL without Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	259.363	272.168	-12.805	4.7
60	93.966	97.428	-3.462	3.5
65	42.834	44.365	-1.531	3.5
70	20.022	20.677	-0.655	3.2
75	8.874	9.139	-0.265	2.9
80	3.901	3.969	-0.068	1.7
85	1.293	0.346	0.947	-274.2

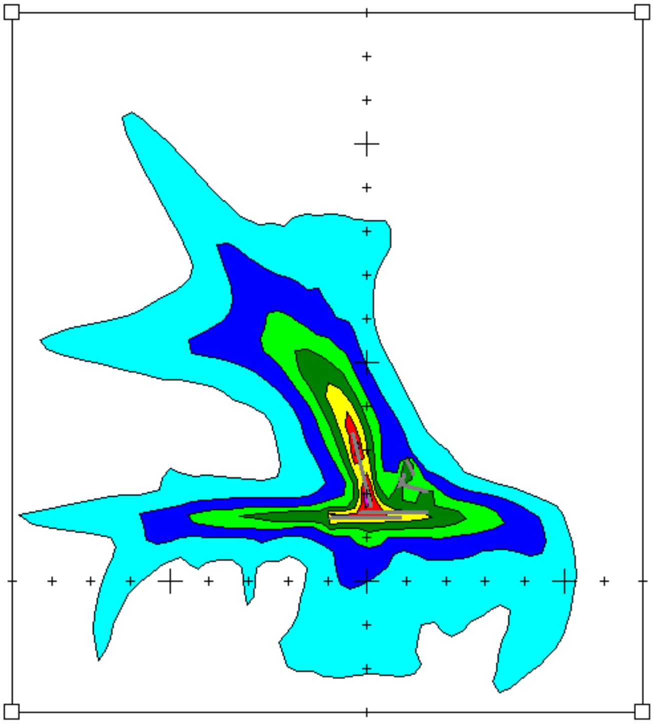


Figure 4-15. ANC – DNL without Bank Angle INM Contours

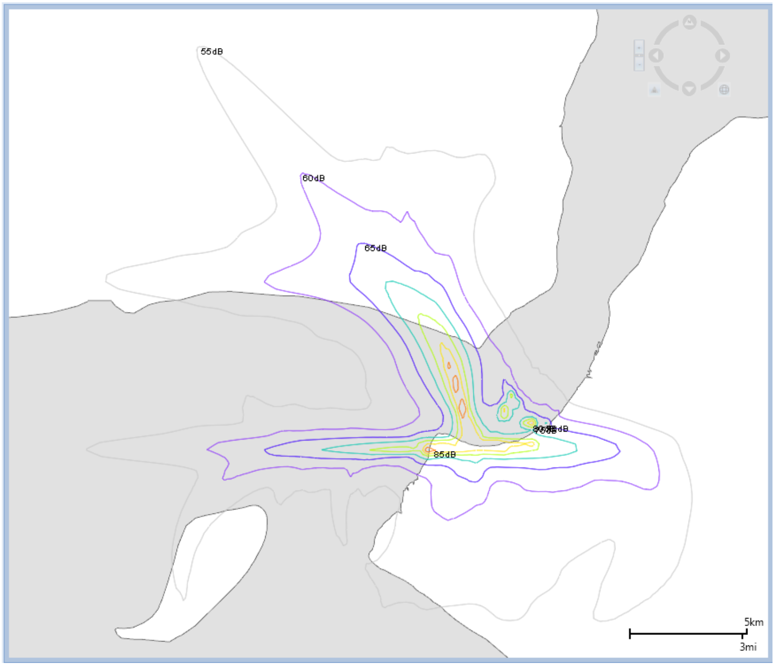


Figure 4-16. ANC – DNL without Bank Angle AEDT 2b Contours

For the ANC study with bank angle turned off, the differences between the AEDT 2b and INM DNL contour area results were less than 4.7% for the contour areas of interest (with the difference for the 65 dB DNL contour being 3.5%). A visual comparison of the contour plots showed that the AEDT 2b and INM contours had similar shapes. At higher noise levels that produce smaller contour areas (e.g., 85 dB DNL), the differences became greater than 10%, but this is attributed to differences in contouring methods and contour resolution.

Table B-2. ANC – LAMAX without Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
90	113.137	115.751	-2.614	2.3
95	51.497	N/A	N/A	N/A
100	29.602	29.510	0.092	-0.3
105	11.937	12.066	-0.129	1.1
110	5.040	4.886	0.154	-3.1
115	2.609	2.276	0.333	-14.6
120	1.239	0.915	0.324	-35.4

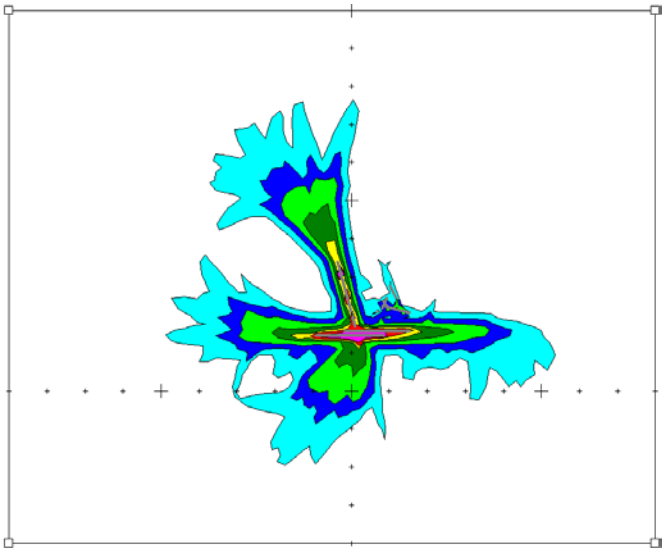


Figure B-1. ANC – LAMAX without Bank Angle INM Contours

Figure B-2. ANC – LAMAX without Bank Angle AEDT 2b Contours

For the ANC study with bank angle turned off, the difference between the AEDT 2b and INM LAMAX contour area results were less than 3.1% for the contour areas that were greater than 3 sq. km. A visual comparison of the contour plots showed that the AEDT 2b and INM contours had similar shapes. At higher noise levels that produce smaller contour areas (e.g., 115 dB LAMAX), the difference became greater than 10%, but this is attributed to differences in contouring methods and contour resolution.

Table B-3. JFK – DNL without Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	326.319	312.818	13.501	-4.3
60	140.642	136.131	4.511	-3.3
65	49.309	53.486	-4.177	7.8
70	20.335	0.011	20.324	N/A
75	9.591	9.746	-0.155	1.6
80	4.637	0.098	4.539	N/A
85	1.934	1.857	0.077	-4.2

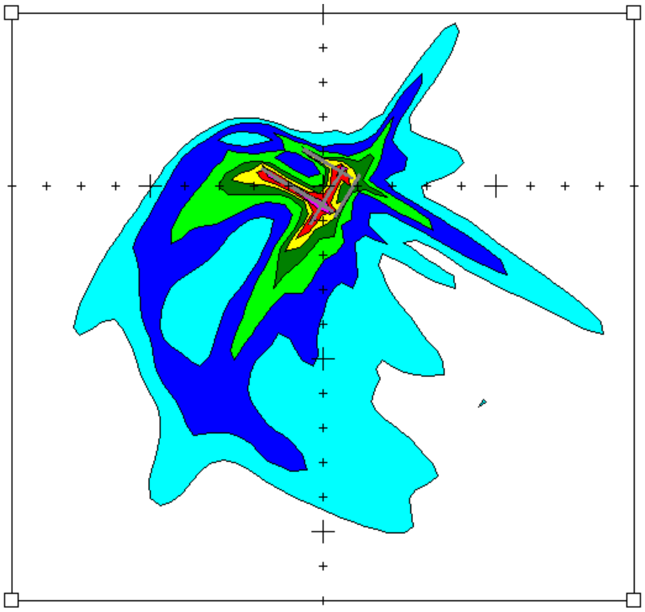


Figure B-3. JFK – DNL without Bank Angle INM Contours

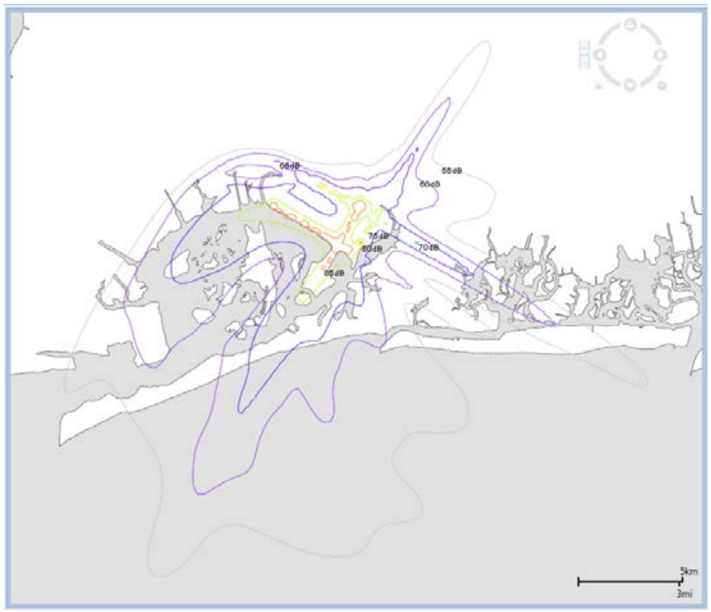


Figure B-4. JFK – DNL without Bank Angle AEDT 2b Contours

For the JFK study with bank angle turned off, the difference between the AEDT 2b and INM DNL contour area results were less than 7.8% for the contour areas of interest (with the difference for the DNL 65 dB contour being 7.8%). A visual comparison of the contour plots showed that the AEDT 2b and INM contours had similar shapes. These results have similar trends as the JFK with bank angle DNL results, including the presence of two unrealistically small (DNL 70 and 80 dB). These unrealistically small contour areas were caused by the bug in AEDT's contouring algorithm, which failed to account for all the DNL 70 and 80 dB areas. The bug was fixed for the AEDT 2c release.

Table B-4. JFK – LAMAX without Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
90	412.669	323.951	88.718	-27.4
95	217.739	161.551	56.188	-34.8
100	84.292	82.341	1.951	-2.4
105	37.364	44.534	-7.170	16.1
110	22.636	0.000	22.636	0.0
115	15.799	25.202	-9.403	37.3
120	9.897	9.615	0.282	-2.9

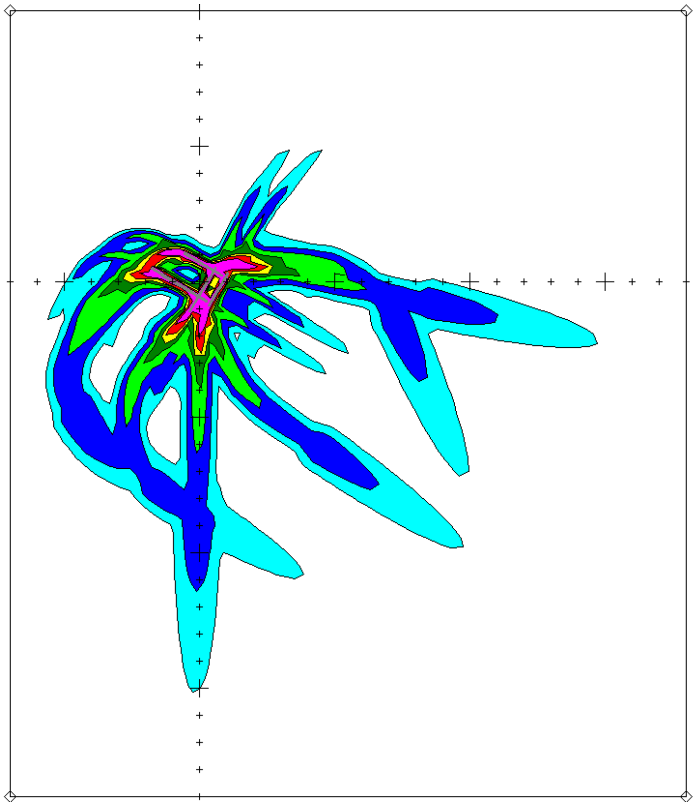


Figure B-5. JFK – LAMAX without Bank Angle INM Contours

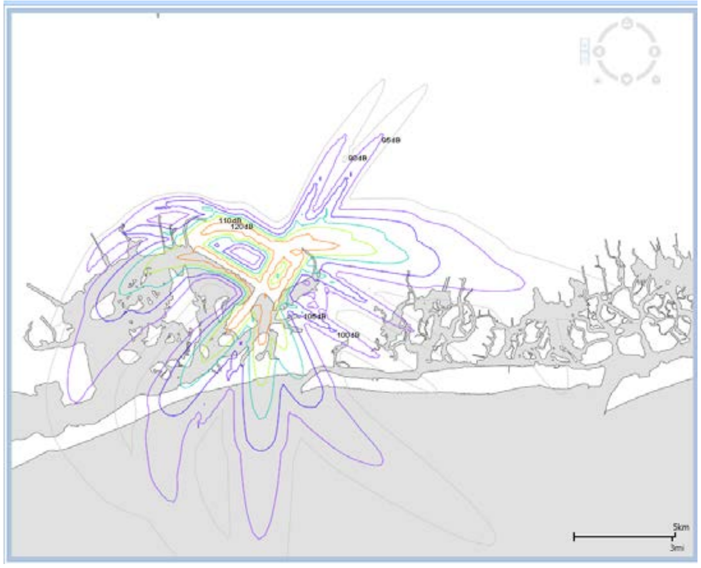


Figure B-6. JFK – LAMAX without Bank Angle AEDT 2b Contours

For the JFK study with bank angle turned off, large differences between the AEDT 2b and INM LAMAX contour results were also observed for some of the contour levels, similar to those seen in the LAMAX with bank angle case. In these cases, the AEDT 2b results were much lower than INM. For one contour (110 dB LAMAX), AEDT 2b failed to generate a contour at all. The cause of these small (or missing) contours in AEDT 2b is the aforementioned bug in AEDT's contouring algorithm.

Table B-5. PHL – DNL without Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	220.403	256.073	-35.670	13.9
60	86.921	102.555	-15.634	15.2
65	37.657	44.156	-6.499	14.7
70	18.374	21.072	-2.698	12.8
75	9.588	10.942	-1.354	12.4
80	4.530	5.281	-0.751	14.2
85	2.215	2.662	-0.447	16.8

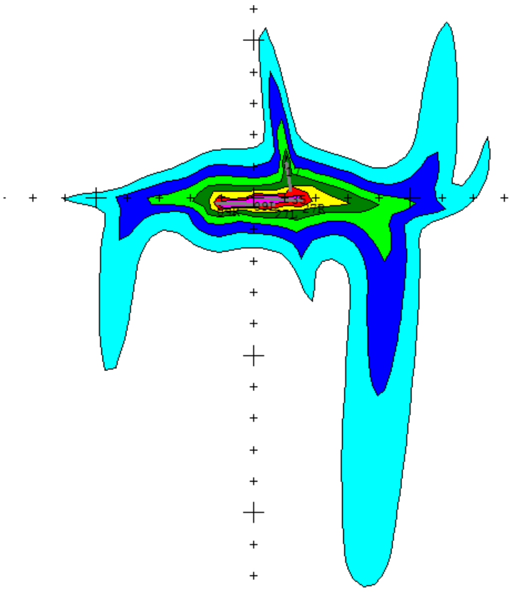


Figure B-7. PHL – DNL without Bank Angle INM Contours

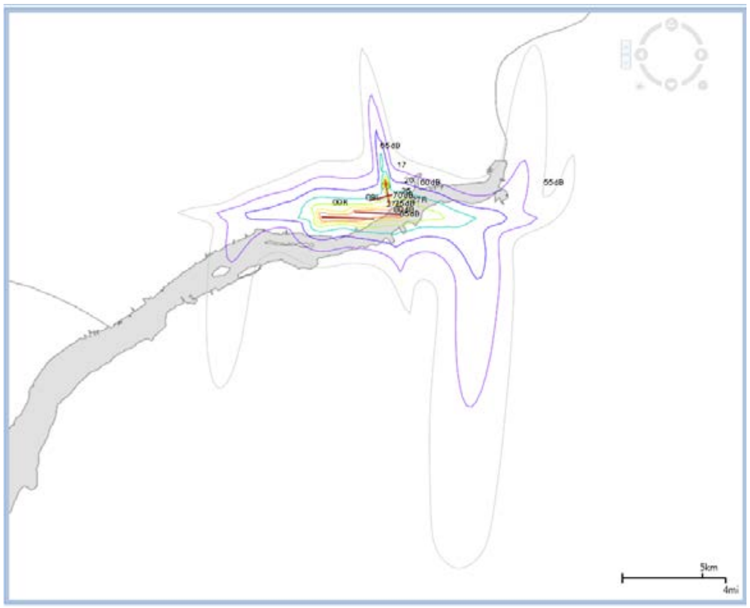


Figure B-8. PHL – DNL without Bank Angle AEDT 2b Contours

For the PHL study with bank angle turned off, the differences between the AEDT 2b and INM DNL contour area results were less than 16.8% for the contour areas of interest (with the difference for the 65 dB DNL contour being 14.7%). For all the contour levels, the AEDT 2b contours were slightly larger than the INM contours, similar to the trend seen in the SFO with bank angle study. The main contributor to the differences is a large portion of 727Q15 operations in the PHL study. Please, see Section 5.4 for the details.

Table B-6. PHL – LAMAX without Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
90	23.581	26.624	-3.043	11.4
95	14.460	15.862	-1.402	8.8
100	8.723	9.684	-0.961	9.9
105	3.995	4.349	-0.354	8.1
110	2.291	2.188	0.103	-4.7
115	1.377	0.936	0.441	-47.1
120	0.570	0.321	0.249	-77.4

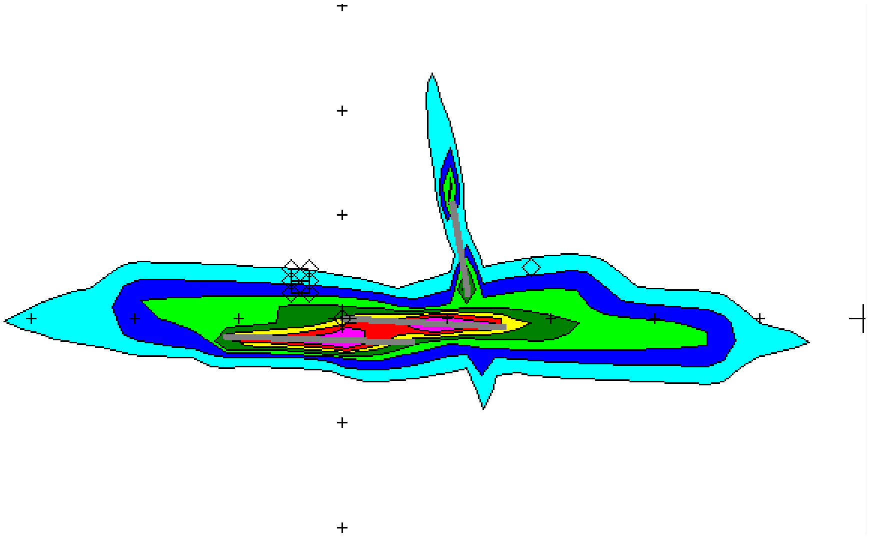


Figure B-9. PHL – LAMAX without Bank Angle INM Contours

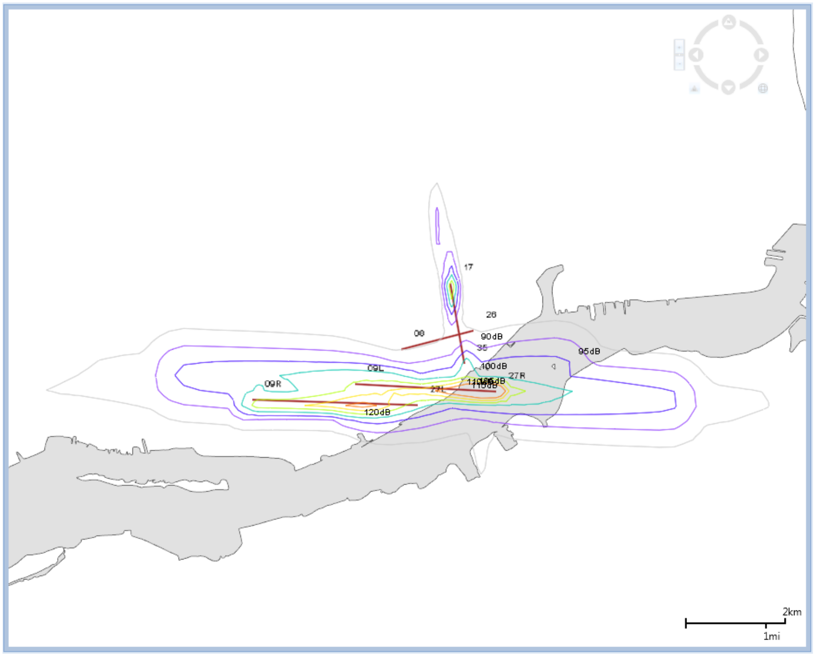


Figure B-10. PHL – LAMAX without Bank Angle AEDT 2b Contours

For the PHL study with bank angle turned off, the differences between the AEDT 2b and INM LAMAX contour area results were less than 11.4% for the contour areas of interest. For all the contours with areas greater than 3 sq. km, the AEDT 2b contours were slightly larger than the INM contours. The main contributor to the differences is a large portion of 727Q15 operations in the PHL study. Please, see Section 5.4 for the details.

Table B-7. SFO – DNL without Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
55	182.174	194.060	-11.886	6.1
60	82.218	89.003	-6.785	7.6
65	33.040	35.938	-2.898	8.1
70	16.189	17.698	-1.509	8.5
75	7.174	8.025	-0.851	10.6
80	3.197	3.619	-0.422	11.6
85	1.066	1.272	-0.206	16.2

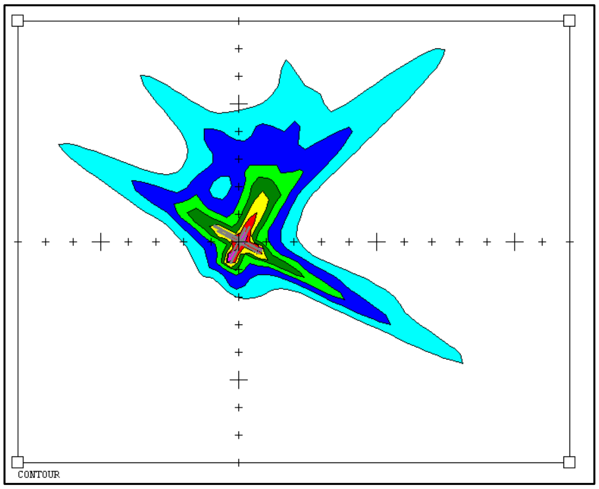


Figure B-11. SFO – DNL without Bank Angle INM Contours

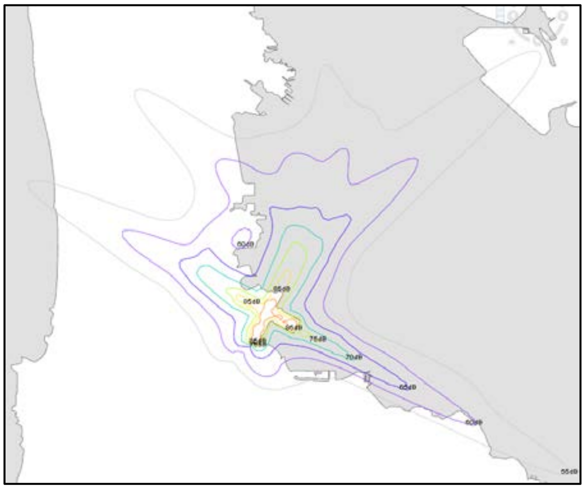


Figure B-12. SFO – DNL without Bank Angle AEDT 2b Contours

For the SFO study with bank angle turned off, the differences between the AEDT 2b and INM DNL contour area results were less than 8.5% for the contour areas of interest (with the difference for the 65 dB DNL contour being 8.1%), with the higher contours with areas smaller than 8.2 sq. km having a larger difference. For all the contour levels, the AEDT 2b contours were slightly larger than the INM contours, following a similar trend as the bank angle case. A visual comparison of the contour plots showed that the AEDT and INM contours have similar shapes. The main contributor to the differences is a large portion of 727Q15 operations in the SFO study. Please, see Section 5.4 for the details.

Table B-8. SFO – LAMAX without Bank Angle Testing Results

Level (dB)	INM (sq km)	AEDT (sq km)	Diff [INM -AEDT] (sq km)	Diff (%)
85	90.353	101.845	-11.492	11.3
90	44.999	50.280	-5.281	10.5
95	27.825	30.712	-2.887	9.4
100	16.029	17.937	-1.908	10.6
105	5.993	6.568	-0.575	8.7
110	3.105	3.513	-0.408	11.6
115	1.517	1.949	-0.432	22.2
120	0.761	0.935	-0.174	18.6
125	0.365	0.448	-0.083	18.5

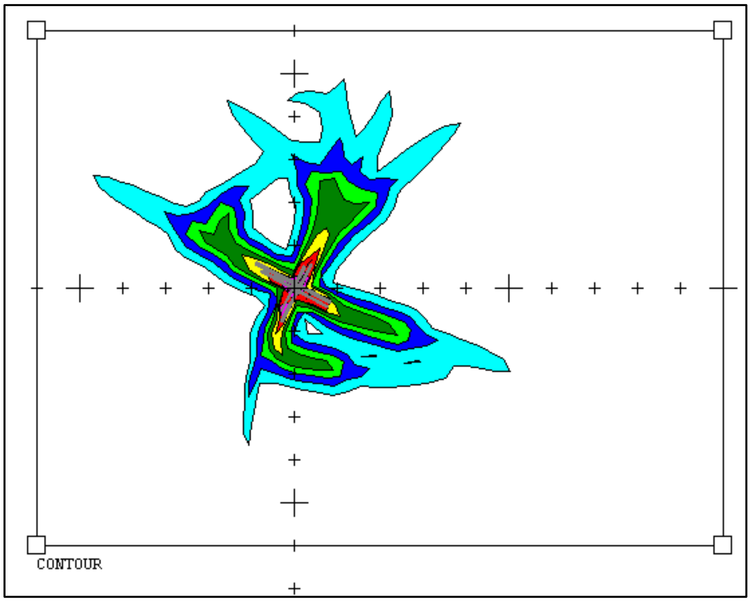


Figure B-13. SFO – LAMAX without Bank Angle INM Contours

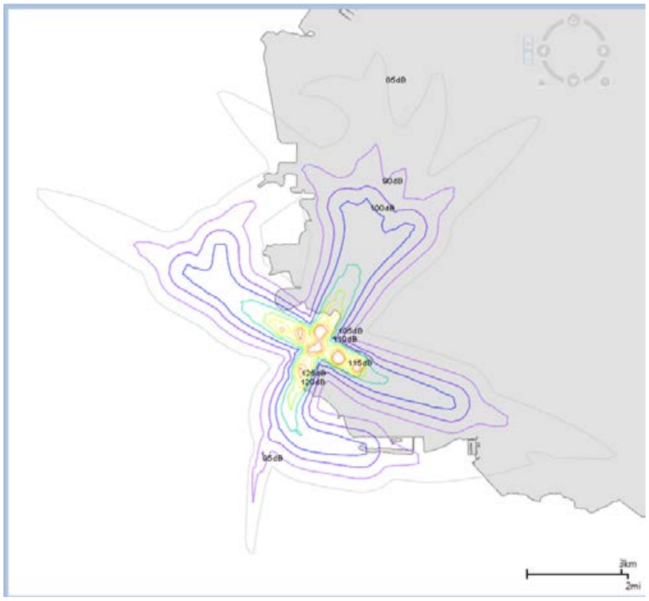


Figure B-14. SFO – LAMAX without Bank Angle AEDT 2b Contours

For the SFO study with bank angle turned off, the differences between the AEDT 2b and INM LAMAX contour area results were less than 11.6% for the contour areas of interest, with the higher contours with areas smaller than 2 sq. km having a larger difference. For all the contour levels, the AEDT 2b contours were slightly larger than the INM contours. A visual comparison of the contour plots showed that the AEDT 2b and INM contours have similar shapes. The main contributor to the differences is a large portion of 727Q15 operations in the SFO study. Please, see Section 5.4 for the details.

Appendix C. Supplementary Flight Performance Comparison Test Cases

This appendix contains the flight performance focused test cases used as a means of comparisons between AEDT 2b and AEDT 2a SP2.

Table B-1 provides an overview of the tests that were run.

Table C-1. Test Summary Overview

Purpose of Test	Project Test Conditions
Runway Parameters Test: Analyze and isolate runway elevation effects on flight profile performance generation.	A single aircraft departs and arrives at three runways, above, at, and below airport elevation using a straight in/out track set.
Profile Generation Test: Test flight performance logic for default, and custom profiles.	A representative set of all aircraft from the AEDT FLEET database set fly both straight in/out and U-shaped tracks for default, custom, hold down, and climbing profiles.

C.1 Test Background

Table B-2 provides an overview of the two tests, tracks, aircraft, operations, runways, and airports examined.

Table C-2. Test Case Overview

Test Case	Measured Results	Track Set	Aircraft and Operations Sets	Run ways	Grid & Metrics	Test Airport
Runway Parameters	Profiles	Straight	Single aircraft arrival & departure	ALL	No	NENG
Profile Generation	Profiles	Straight & Curved with standard, custom, and overflight profiles	All aircraft included using arrival & departure operations	01C	No	NENG

The sections below explain the aircraft used for these two flight performance tests.

C.1.1 Representative Flight Performance Model Aircraft Set

The Representative Flight Performance Model (FPM) aircraft set consists of a representative set of arrival and departure profile aircraft , including military and commercial aircraft, all profile types (both procedure-step profiles and point profiles[7]), and stage lengths. This aircraft set is used in combination with the procedure step flight performance set for the profile generation

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[7] Procedure-step profiles utilize a set of algorithms, aircraft parameters, and environmental conditions to generate the aircraft profile (distance vs. altitude, speed, and thrust). Point profiles are predefined static profiles (distance vs. altitude, speed, and thrust) and do not vary with altitude, temperature, or any other environmental parameters. While procedure-step profiles are preferred, some aircraft only come defined with the static point profiles.

tests. For this set and the other aircraft sets tested, AEDT 2b's Fleet Database contains all of the necessary aircraft for direct comparison to this aircraft set.

C.1.2 Procedure-Step Flight Performance Model Aircraft Set

The procedure-step aircraft set consists of a representative set of arrival and departure profile that use procedure-steps for profile generation. This includes all stage lengths over all procedure-step profiles. This aircraft set is used in combination with the representative flight performance model aircraft set for the profile generation test.

C.1.3 Single Aircraft

The single aircraft used in the runway parameters test is a B737-300 commercial jet using procedure- step profiles. This aircraft was chosen as a common representative single-aisle commercial aircraft.

C.2 Runway Parameters Test

The Runway Parameters test looks at the effect on flight performance of runways at the same airport but at different elevations. Three user-defined runways were created to check that runway elevations are correctly considered for flight performance. The runways' locations and other parameters are described in Table B–3 and Table B–4.

Table C-3. Runway End Locations

Airport / Runway	Start Latitude	Start Longitude	End Latitude	End Longitude
NENG 01*	42.362972	-71.006417	42.39631723562306	-71.006417
WEST 01*	39.861656	-104.673177	39.89501575960256	-104.673177
** - same for all runways, 01L, 01C, 01R*				

For this test, runway 01C has an elevation of 20 feet above mean sea level (MSL) (the same elevation as the New-England airport reference point), runway 01L has an elevation of -80 feet MSL (100 feet below airport elevation), and runway 01R has an elevation of 120 feet MSL (100 feet above airport elevation). While the runway elevation differences are large when considering changes over an airport property, they are relatively small when considering the effects upon flight profiles. They served the purpose of demonstrating the effects of runway elevation on flight performance.

Note that while some of these parameters may be extreme or seem out of place (e.g., US does not use a 5 degree glide slope), it is the purpose of the tests to make sure the algorithms are doing the correct computations with the data given to them and to compare that they are doing the same calculations (if the models are similar) in both AEDT 2b and AEDT 2a SP2.

Table C-4. Runway Parameters

Name	Elevation (feet MSL)	ADT (feet)	DDT (feet)	GS (degrees)	TCH (feet)	PWC (%)
NENG 01L	-80 = (-100 AFE)	50	60	5	75	-50
NENG 01C	20	0*	0*	3*	50*	0*
NENG 01R	120 = (+100 AFE)	100	120	2	25	100
WEST 01C	5431	0*	0*	3*	50*	0*
ADT – Approach Displacement Threshold *DDT – Departure Displacement Threshold* *GS – Glide Slope* *TCH – Threshold Crossing Height* *PWC – Percent Wind Change* ** - Default values*						

The events for these test cases consist of a single B737-300 procedure-step aircraft departing and arriving at all three runways for NENG(01L, 01C, 01R) and WEST(01C) using a straight in/out track set.

Figure C-1 shows two graphs: the departure profiles (top graph) for all runways from both AEDT 2a SP2 and AEDT 2b, and the arrival profiles (bottom graph) for all the runways (altitudes are in AFE). Zoomed-in insets are displayed in the upper left corner of both graphs, providing better visibility of the low altitude sections of the departure and arrival. Table B-5 shows a summary of the profile altitude differences for departures up to 10,000 feet AFE and arrivals up to 6,000 feet AFE.

As can be seen there are hardly any noticeable differences between the matching AEDT 2a and 2b profiles and in the case of the arrivals they match almost perfectly. Additionally, the actual MSL altitude data was examined for each profile generated to confirm that runway elevations are being properly taken into account during profile generation.

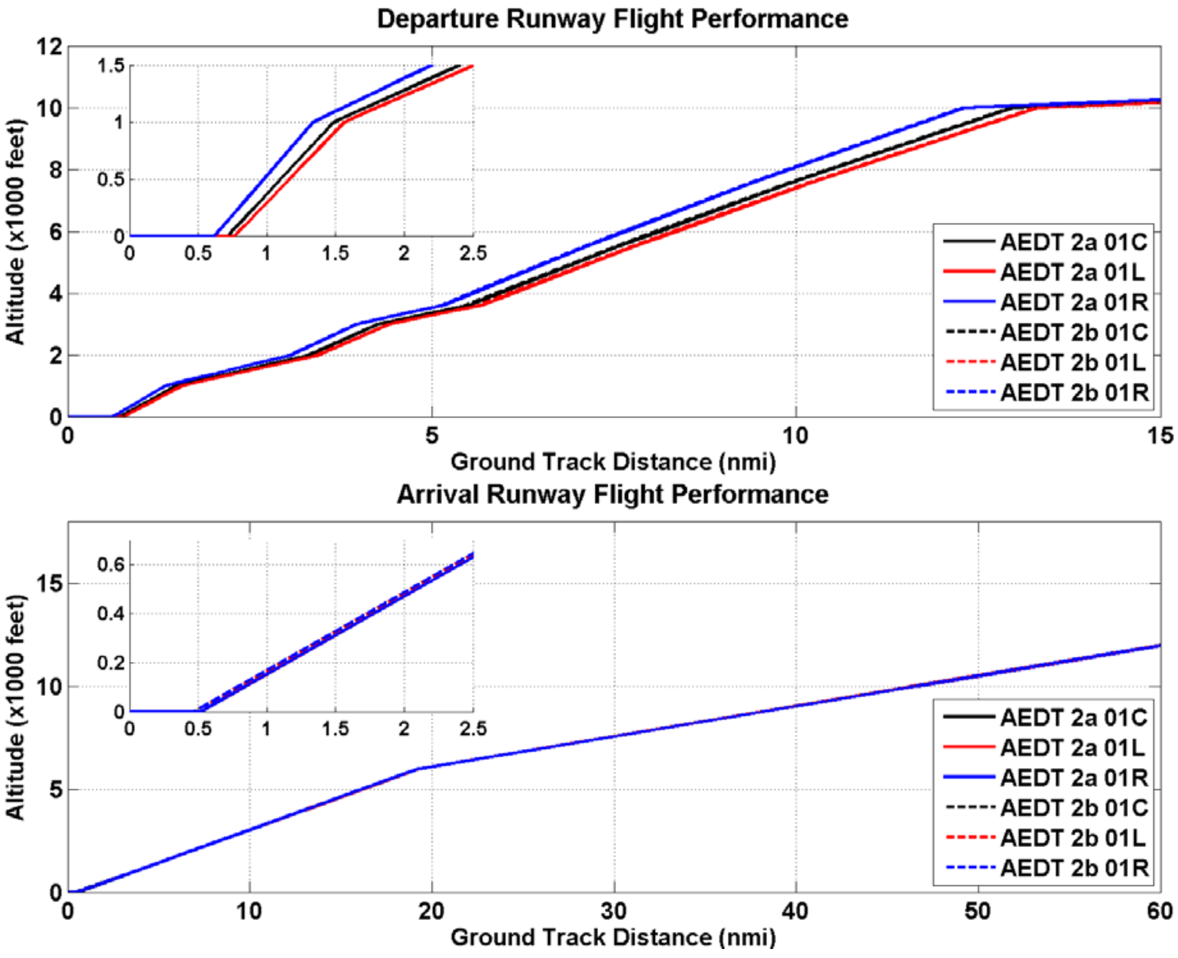


Figure C-1. Variable Runway Elevation Flight Performance (Altitudes in AFE)

Table C-5. Variable Runway Flight Performance Differences Summary

Operation Type and Runway	Average Altitude Difference (feet)	Average Altitude Difference (%)	Max Altitude Difference (feet)	Max Altitude Difference (%)*
Departure 01C	19	0.34 %	31	0.76 %
Departure 01L	20	0.35 %	31	0.80 %
Departure 01R	18	0.29 %	31	0.70 %
Arrival 01C	15	1.25 %	15	9.64 %
Arrival 01L	15	1.22 %	15	9.45 %
Arrival 01R	16	1.30 %	16	10.04 %

* The Max Altitude Percentage Difference may occur at a difference location on the profile than the Max Altitude Difference.

AEDT 2a SP2 and AEDT 2b profiles differed by less than 20 feet on average for departures and less than 16 feet on average for arrivals over the default profile sections for the test aircraft.

C.3 Profile Generation

In this test, different aircraft profile sets are used to test the flight performance results and confirm that the profile types are appropriately modeled in AEDT 2b. These types of profiles are detailed in Table B–6.

Table C-6. Profile Set Descriptions

Profile Set	Description
Standard Profiles	This set consists of every aircraft in the database that has either point or procedure step profiles.
Hold Down Profiles	This set consists of only those aircraft with procedure step profiles. The profiles are purposely held down to test the flight path processing logic. The arrivals start from an altitude of 5,000 feet AFE and the departures finish at an altitude of 8,000 feet AFE.
Climbing Profiles	This set consists of only those aircraft with procedure step profiles. The profiles are set to climb higher than the standard profiles at the end of the track. The arrivals start from an altitude of 18,000 feet AFE, descend to 14,000 feet AFE, and then descend to the runway. The departures climb to 14,000 feet AFE and finish at an altitude of 18,000 feet AFE.

The profile generation test uses the representative flight performance model aircraft set as well as all of the profile types and stage lengths. These aircraft fly both straight in/out tracks as well as “U” shaped tracks to cover bank angle comparisons. All tracks utilize the NENG 01C runway.

C.3.1 Default Profiles

With no altitude control codes, the models in AEDT 2a SP2 and AEDT 2b use only the default information provided for each aircraft to compute the flight performance. For this test over 2600 unique track, aircraft, operation, and profile combinations were input into both applications. The profile results for a few aircraft types, which are representative of the profile results for all computed aircraft, are shown below.

Figure C-2 and Figure C-3 show both the arrival and departure the profile results for the 1900D and 737300 aircraft, respectively— he arrival graphs are at the top of the figures and the departure graphs are at the bottom of the figures. Table B–7 and Table B–8 summarize the quantified flight profile differences for the 1900D and 73700 respectively.

Both aircraft have a single arrival profile. The 1900D has two STANDARD departure profiles of stage-length 1 and 2, while the 737300 has twelve departure profiles (four stage-lengths over three difference departure profile types: STANDARD, ICAO_A, and ICAO_B). Additionally, both of these aircraft profiles are procedure-step profiles, rather than point profiles, so the profiles are generated algorithmically instead of being pre-computed.

The only apparent modeling differences for this first set of test data can be seen in the two figures showing almost identical performance in both the terminal and BADA regimes.

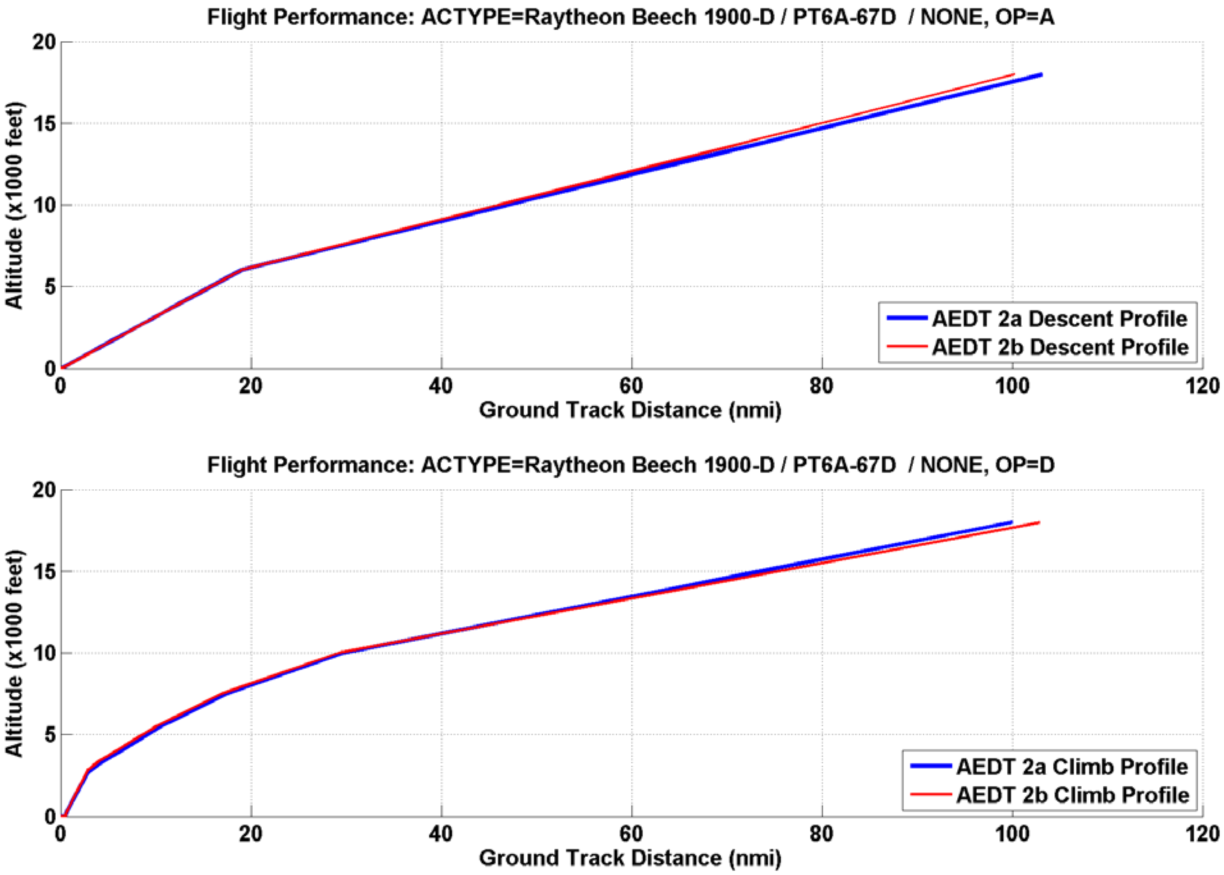


Figure C-2. 1900D Default Flight Performance (Altitude in AFE)

Table C-7. 1900D Default Profile Altitude Differences Summary

Operation Type Profile Type	Average Altitude Difference (feet)	Average Altitude Difference (%)	Max Altitude Difference (feet)	Max Altitude Difference (%)
ARR DEFAULT-1	0	0.00 %	0	0.00 %
DEP DEFAULT-1/2	122	2.37 %	183	5.56 %

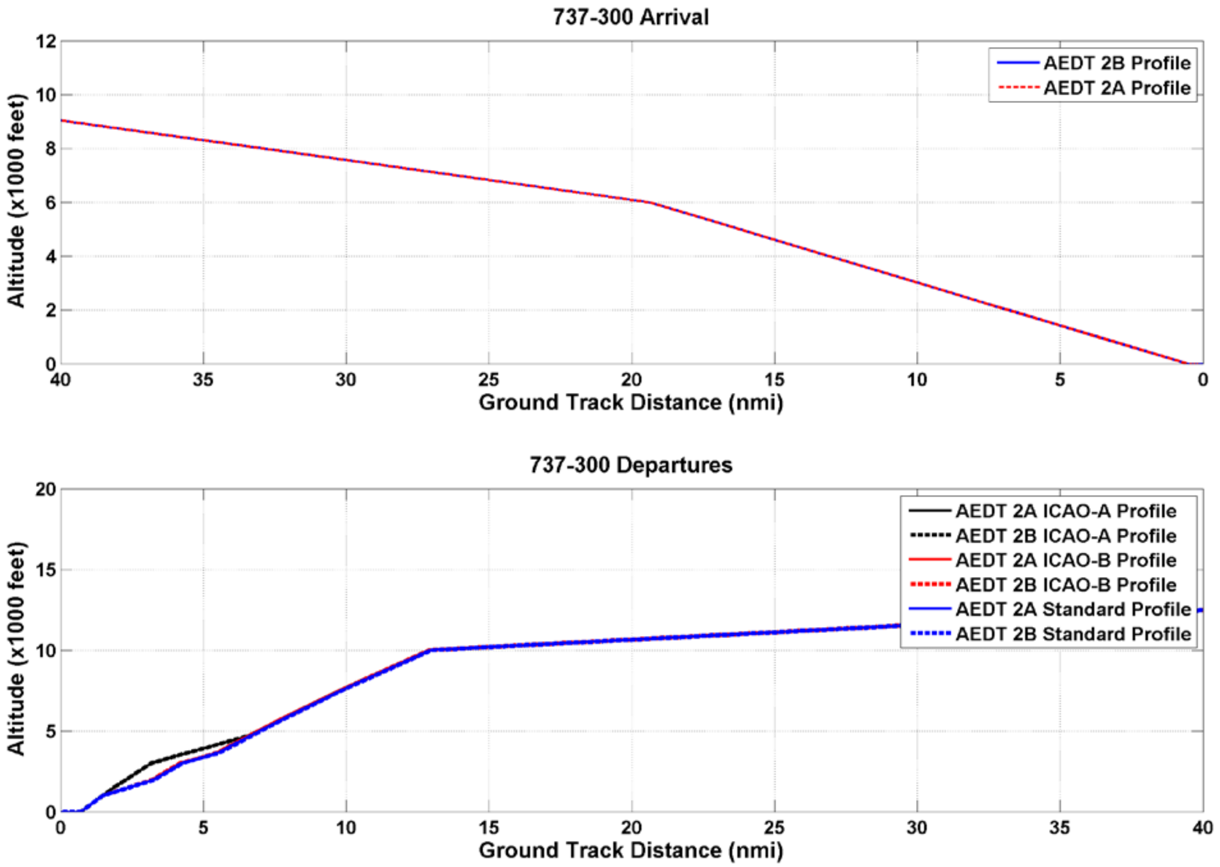


Figure C-3. 737300 Default Flight Performance (Altitude in AFE)

Table C-8. 737300 Default Profile Altitude Differences Summary

Operation Type Profile Type	Average Altitude Difference (feet)	Average Altitude Difference (%)	Max Altitude Difference (feet)	Max Altitude Difference (%)
ARR DEFAULT-1	0	0.00 %	0	0.00 %
DEP DEFAULT-1/4	19	0.34 %	31	0.76 %
DEP ICAO_A-1/4	26	0.37 %	55	1.09 %
DEP ICAO_B-1/4	18	0.32 %	30	0.71 %

The 1900D and 737300 profiles examined here show less than 190 feet maximum altitude difference between AEDT 2a SP2 and AEDT 2b for arrivals and departures, with average altitude differences of 125 feet or less.

C.3.2 Custom Profiles

The next profile test set examined was the profiles with altitude control codes using procedure-step aircraft. The figures shown in this section contain arrival profiles (the top graph) and departure profiles (the bottom graph).

The top arrival profile is a high-descent profile starting at 18,000 feet AFE, descending to 15,000 feet AFE, and then descending to the runway. The second, lower altitude arrival profile starts at 5,000 feet AFE and stays level for most of the profile before descending to the runway.

The top departure profile is a climbing profile starting at the runway, climbing to 15,000 feet, and then climbing to 18,000 feet AFE. The second, lower altitude departure profile is a hold-down profile starting at the runway, then climbing to 8,000 feet AFE, and then staying at 8,000 feet AFE.

Figure C-4 and Figure C-5, which are representative of most of the profiles in the test set, show the AEDT 2a SP2 and AEDT 2b profiles for the 737300 aircraft (Table–E 9 summarizes the quantified profile altitude differences). For both the higher arrival profile and higher departure profile, AEDT 2a SP2 and AEDT 2b produce similar results (less than 100 feet altitude difference for the departures and 0 feet difference for arrivals). For the lower arrival profile, AEDT 2b has a quicker descent than AEDT 2a between the 5,000 feet controlled portion and the runway. Similarly, for the lower departure profile, AEDT 2b has a slower climb than AEDT 2a between the runway and the 8,000 feet controlled altitude.

The differences in the lower profiles can be explained by changes in AEDT 2b flight performance modeling that lead to more aggressive goal seeking. The newer logic in AEDT 2b produces profiles that are intended to more closely relate to real profiles flown by existing aircraft.

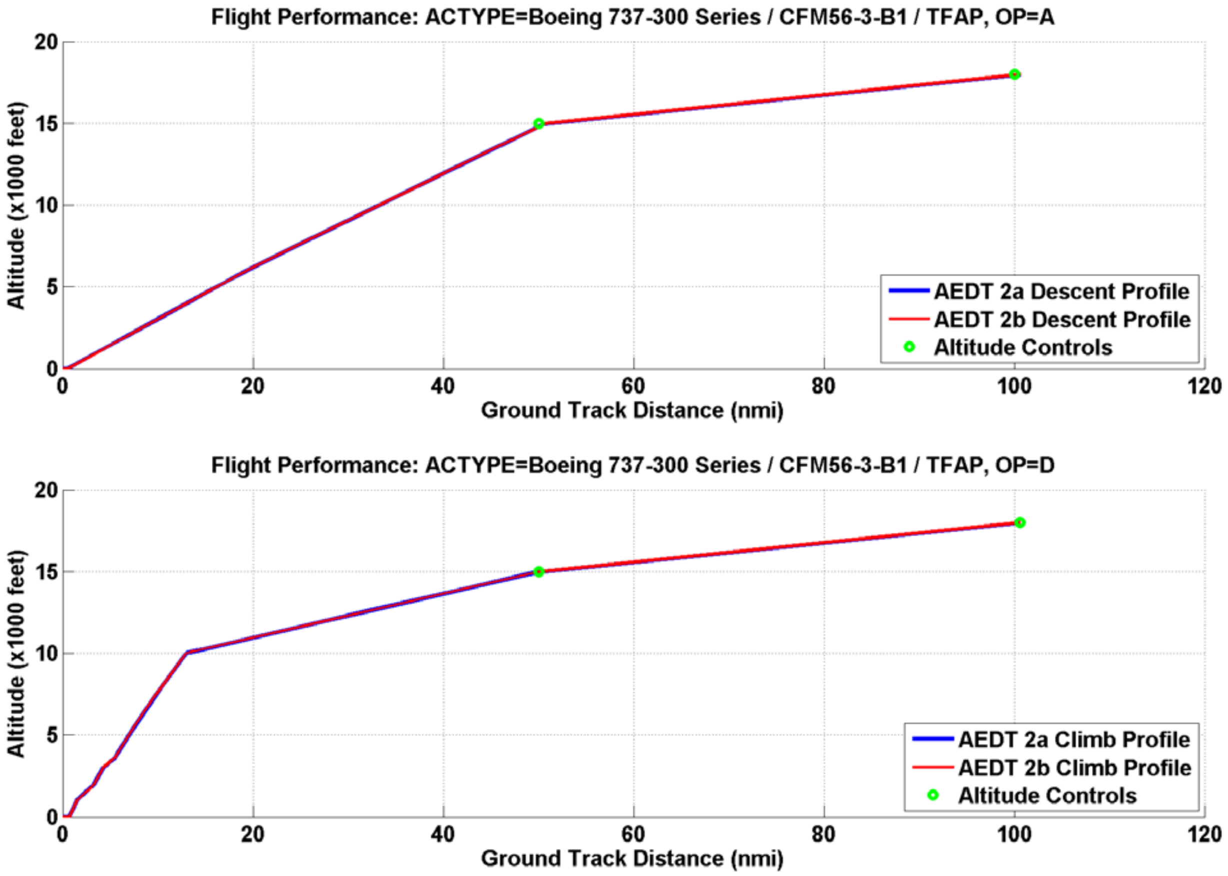


Figure C-4 - 737300 Arrival and Departure Default Profiles (Altitude in AFE)

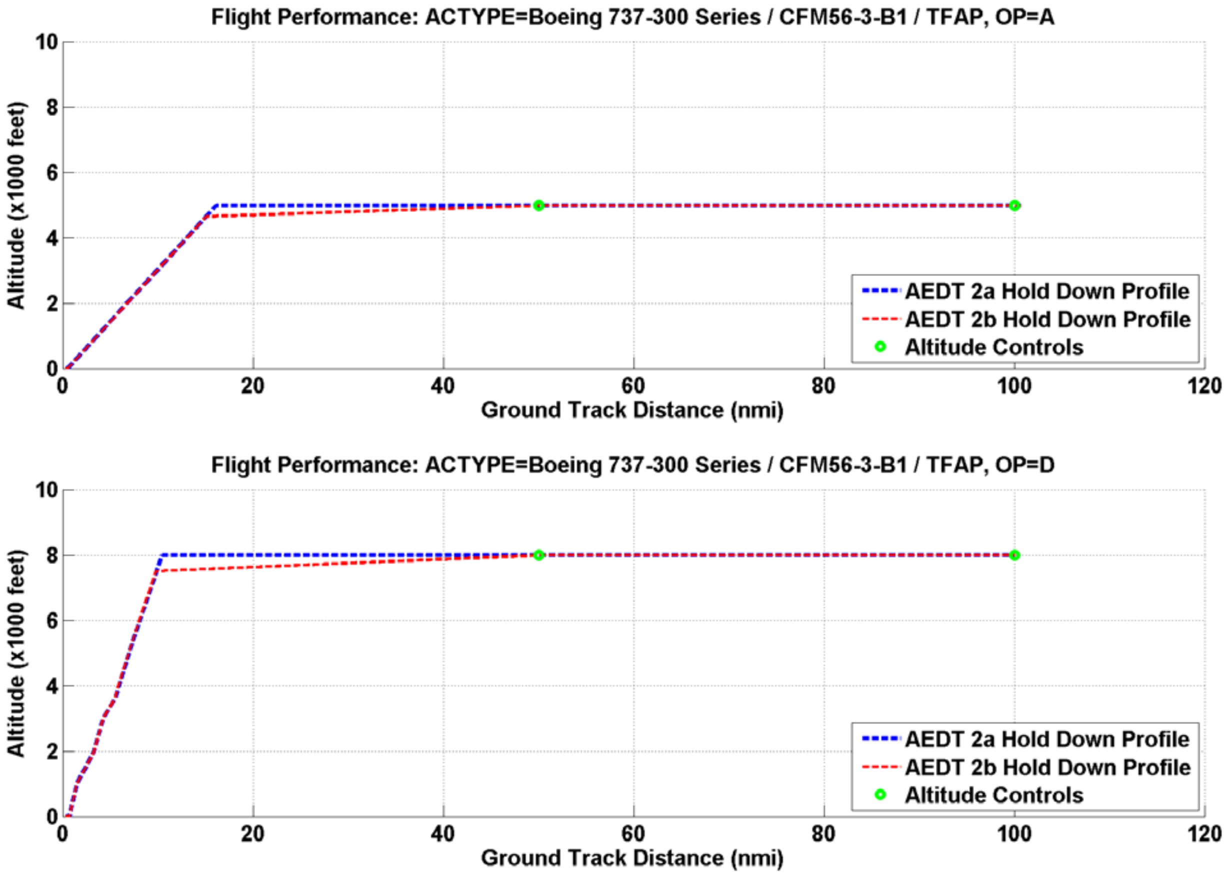


Figure C-5 - 737300 Arrival and Departure Hold-Down Profiles (Altitude in AFE)

Table C-9. 737300 Custom Profile Altitude Differences Summary

Operation Type Profile Type	Average Altitude Difference (feet)	Average Altitude Difference (%)	Max Altitude Difference (feet)	Max Altitude Difference (%)
ARR Hold Down	59	1.20 %	322	6.68 %
ARR Descent	0	0.00 %	0	0.00 %
DEP Hold Down	96	1.24 %	466	6.01 %
DEP Climb	19	0.34%	31	0.76 %

While almost all of the profile test results follow the pattern seen in the above example, the next two figures show results with larger differences. Figure C-6 and Figure C-7 show the profiles for the A300-622R aircraft, and Table B–10 summarizes the altitude differences. The results are very similar to the example above with slightly more pronounced differences in the way 2b achieves the controlled altitudes.

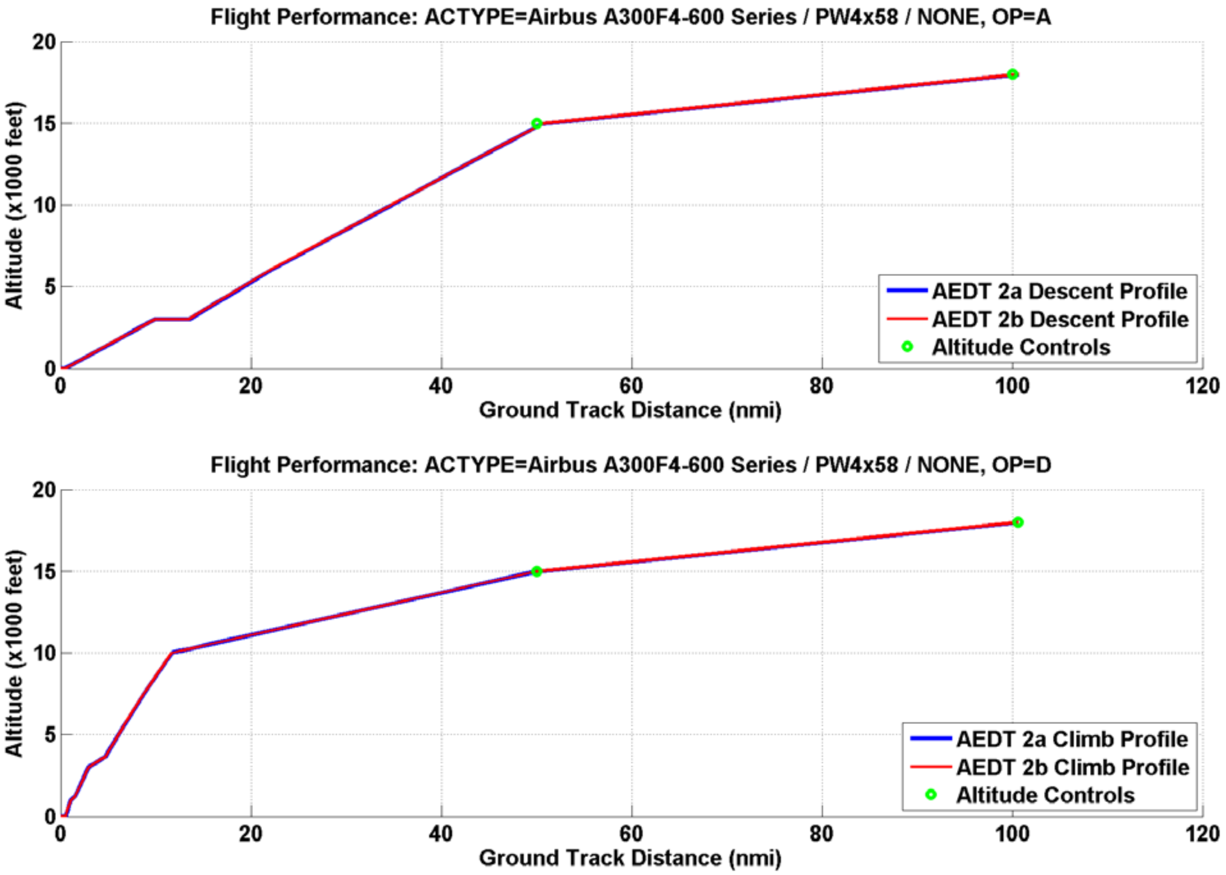


Figure C-6 - A300-622R Arrival and Departure Custom Profiles (Altitude in AFE)

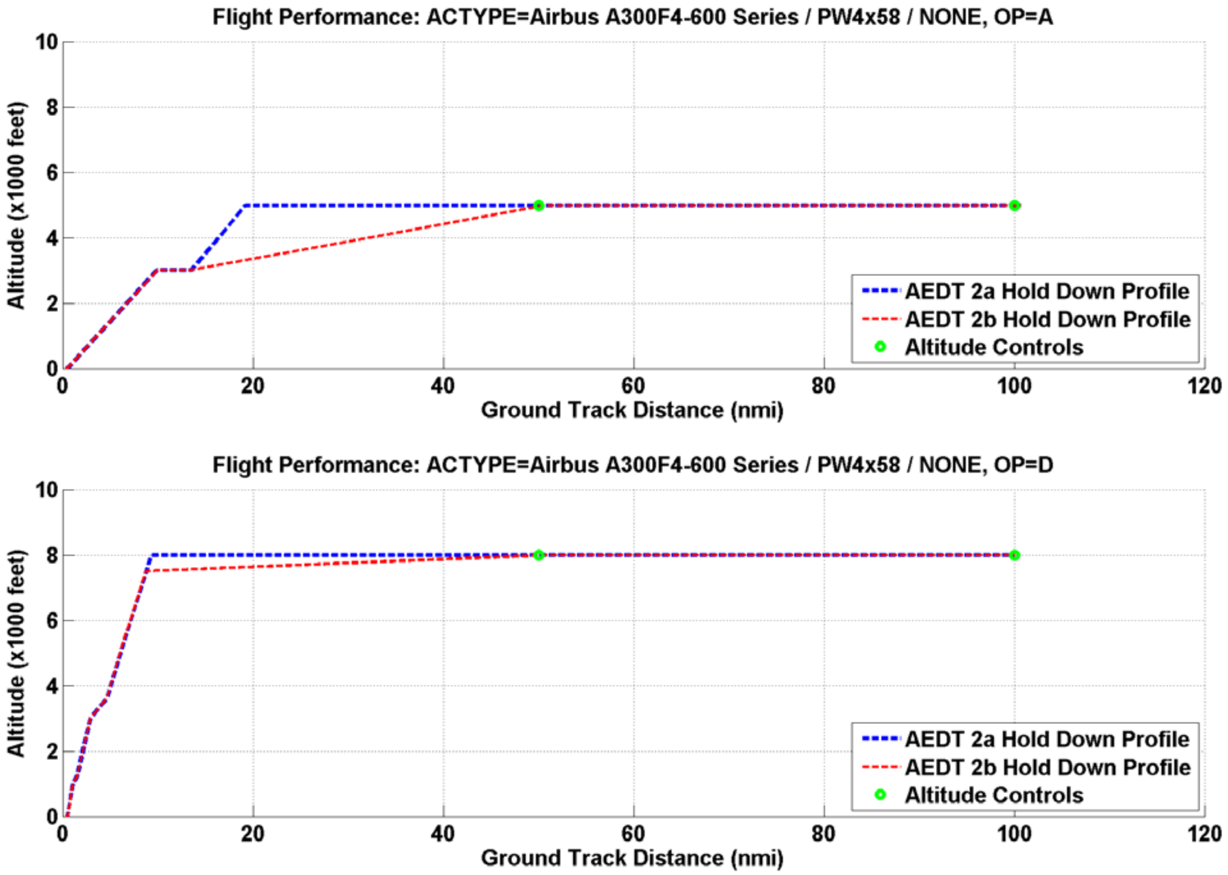


Figure C-7 - A300-622R Arrival and Departure Hold-Down Profiles (Altitude in AFE)

Table C-10. A300-622R Custom Profile Altitude Differences Summary

Operation Type Profile Type	Average Altitude Difference (feet)	Average Altitude Difference (%)	Max Altitude Difference (feet)	Max Altitude Difference (%)
ARR Hold Down	311	7.24 %	1,632	39.42 %
ARR Climb	12	0.27 %	29	0.92 %
DEP Hold Down	23	0.38 %	420	5.40 %
DEP Descent	16	0.28 %	27	0.69 %

C.4 Conclusions on Supplementary Flight Performance Tests

These supplementary flight performance comparisons between AEDT 2a and AEDT 2b provided further validation of the expected behaviors of the two tools related to intentional algorithmic differences relating to flight performance methodology between the two tools.

Table B-11 provides a summary of the results from the runway parameters and profile generation tests.

Table C-11. AEDT 2a SP2 & AEDT 2b Supplementary Flight Performance Test Case Results Summary

Purpose of Test	Result Summary
Test 2 Runway Parameters	AEDT 2a SP2 and AEDT 2b profiles differed by less than 20 feet on average for departures and less than 20 feet on average for arrivals (over the default profile sections for the test aircraft).
Test 3 Profile Generation	The results for the various profile generation tests can be summarized as follows: 1. For default profiles (arrivals up to 6,000 feet AFE and departures up to 10,000 feet AFE), the arrival profiles averaged less than 5 feet in altitude differences, and the departure profiles averaged less than 125 feet in altitude differences. 2. For custom profiles (which includes hold-downs at 5,000 feet and 8,000 feet AFE and climbs/descents to/from 14,000 feet and 18,000 feet AFE), the arrivals averaged less than 350 feet in altitude differences and the departures less than 500 feet in altitude differences. Some outliers can be expected due primarily to modeling differences in arrival and departure hold-down profiles between AEDT 2a SP2 and AEDT 2b.

Appendix D. Parametric Uncertainty Quantification Results

D.1 AEDT Input Parameters

Table D-1. AEDT ANP Coefficients

CATEGORIES		AEDT COEFFICIENT	Description	Units
ANP	Aircraft/ Engine Design	ANP/MX_GW_TKO	Max Take-off Gross Weight	lbs
		ANP/MX_GW_LND	Max Gross Weight Landing	lbs
		ANP/THR_STATIC	Static Max Thrust Rating, should be EXACTLY correlated with RATED_OUT with conversion from kN to lbf	lbf
	Drag	ANP/FLAP/COEFF_R/FLAP_ID	Drag-to-Lift ratio	-
		ANP/FLAP/COEFF_C_D/FLAP_ID	A coefficient that determines landing approach calibrated airspeed for OP_TYPE A (only value given for FLAP_ID: APPRCH) or the initial climb speed for OP_TYPE D	kt/sqrt(lbs)
	Ground Roll	ANP/FLAP/COEFF_B/FLAP_ID	A coefficient that determines ground roll distance referenced to 8-kts headwind.	ft*lbf/(lbs^2)
ANP	Terminal Area Thrust (Takeoff and Climb out only)	ANP/THRUST/COEFF_E/C ANP/THRUST/COEFF_E/T	Intercept term in corrected net thrust per engine equation. Currently only used for THRUST_TYPE T (max-takeoff power) and THRUST_TYPE C (max-climb power).	lbf
		ANP/THRUST/COEFF_F/C ANP/THRUST/COEFF_F/T	Airspeed correction term in corrected net thrust per engine equation. Currently only used for THRUST_TYPE T (max-takeoff power) and THRUST_TYPE C (max-climb power). Should be negative number.	lbf/kt
		ANP/THRUST/COEFF_GA/C ANP/THRUST/COEFF_GA/T	Pressure altitude correction term in corrected net thrust per engine equation. Currently only used for THRUST_TYPE T (max-takeoff power) and THRUST_TYPE C (max-climb power).	lbf/ft
		ANP/THRUST/COEFF_GB/C ANP/THRUST/COEFF_GB/T	Pressure altitude squared correction term in corrected net thrust per engine equation. Currently only used for THRUST_TYPE C (max-climb power).	lbf/ft^2
	TSFC for Depature	ANP/TSFC/K1	Intercept term in terminal area departure TSFC equation (see SenzigMethod PDF).	-
		ANP/TSFC/K2	Mach number correction term in terminal area departure TSFC equation (see SenzigMethod PDF).	-
		ANP/TSFC/K3	Altitude correction term in terminal area departure TSFC equation (see SenzigMethod PDF).	-
		ANP/TSFC/K4	Net corrected thrust correction term in terminal area departure TSFC equation (see SenzigMethod PDF).	-
	TSFC for Arrival	ANP/TSFC/BETA1	Mach number correction term in terminal area arrival TSFC equation (see SenzigMethod PDF).	-
		ANP/TSFC/BETA2	Exponential term coefficient in terminal area arrival TSFC equation (see SenzigMethod PDF).	-
		ANP/TSFC/BETA3	Net corrected thrust correction term in terminal area arrival TSFC equation (see SenzigMethod PDF).	-
		ANP/TSFC/ALPHA	Intercept term in terminal area arrival TSFC equation (see SenzigMethod PDF).	-
ANP	Profile/ Procedure	ANP/WEIGHT/DEP ANP/WEIGHT/APP	These are the starting weights for each of the PROCEDURES. For OP_TYPE: A there is only one procedure. For OP_TYPE: D there are different weights for different stage length procedures, where stage length defined in PROF_ID2 starting at 1 and max value of 9 (max stage length increases with increasing vehicle size).	lbs

Table D-2. AEDT EMISSION and BADA Coefficients

CATEGORIES		AEDT COEFFICIENT	Description	Units
EMISSION	Engine Design	EN/RATED_OUT	Max Rated output thrust	kN
		EN/BYPASS_RATIO	Mass flow rate of air through fan disk that bypasses the core to mass flow rate of air through the engine core	-
		EN/PRESSURE_RATIO	Overall pressure ratio (FPR*LPCPR*HPCPR)	-
	Fuel Flow	EN/UA_RWF_TO	Unadjusted fuel flow at Takeoff (100% Power Setting) for standard atmospheric conditions (sea level)	kg/s
		EN/UA_RWF_CO	Unadjusted fuel flow at Climb-Out (85% Power Setting) for standard atmospheric conditions (sea level)	kg/s
		EN/UA_RWF_AP	Unadjusted fuel flow at Approach (30% Power Setting) for standard atmospheric conditions (sea level)	kg/s
		EN/UA_RWF_ID	Unadjusted fuel flow at Idle (7% Power Setting) for standard atmospheric conditions (sea level)	kg/s
	NOx Emission Index	EN/NOX_REI_TO	NOx emissions index at Takeoff (100% Power Setting) for standard atmospheric conditions. Emissions index is defined as grams of Nox emissions per kilogram of fuel flow	g/kg
		EN/NOX_REI_CO	NOx emissions index at Climb-Out (85% Power Setting) for standard atmospheric conditions. Emissions index is defined as grams of Nox emissions per kilogram of fuel flow	g/kg
		EN/NOX_REI_AP	NOx emissions index at Approach (30% Power Setting) for standard atmospheric conditions. Emissions index is defined as grams of Nox emissions per kilogram of fuel flow	g/kg
		EN/NOX_REI_ID	NOx emissions index at Idle (7% Power Setting) for standard atmospheric conditions. Emissions index is defined as grams of Nox emissions per kilogram of fuel flow	g/kg
BADA	Aircraft Design	BADA/MASS_REF	Reference mass for BADA, combined with reference velocity used to calculate varying aircraft operating speeds with varying aircraft mass (such as stall velocity for example)	kg
		BADA/MASS_PAYLD	BADA maximum payload mass	kg
		BADA/WING_AREA	Area of the wing	m^2
	Drag	BADA/COEFF_CD0	Zero-lift drag coefficient	-
		BADA/COEFF_CD2	Drag coefficient multiplied by square of lift coefficient	-
	Fuel Flow	BADA/FUEL/CF1	Front coefficient in Thrust Specific Fuel Consumption equation	[kg/(min*kN)]
		BADA/FUEL/CF2	True airspeed correction coefficient (VTAS/COEFF_CF2) in Thrust Specific Fuel Consumption equation	kt
		BADA/FUEL/CFCR	Cruise fuel flow factor	-
	Thrust	BADA/THRUST/TC1	Front coefficient in Max Climb Thrust equation	N
		BADA/THRUST/TC2	Altitude correction coefficient (h/COEFF_TC2) in Max Climb Thrust equation	ft
		BADA/THRUST/TC3	Square altitude correction coefficient (COEFF_TC3*h^2) in Max Climb Thrust equation	$1/ft^2$
		BADA/THRUST/TC4	Coefficient for calculating the effective deviation in temperature relative to actual deviation in temperature for non standard atmosphere conditions. Modifies Max Climb Thrust.	K
		BADA/THRUST/TC5	Coefficient determining effective degradation in Max Climb Thrust given effective deviation in temperature.	1/K
		BADA/THRUST/TDL	Thrust correction factor for descent at low altitudes	-
		BADA/THRUST/TDH	Thrust correction factor for descent at high altitudes	-

D.2 Sensitivity Study Result of a Regional Jet Aircraft

Table D-3. AEDT Output Sensitivity to ANP Coefficients

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80db_area [nmi^2]	Dep_80db_width [nmi]	Dep_80db_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
ANP/FLAP/COEFF_B/D-8	-14%	14%	-0.3%	-4.7%	0.0%	-0.4%	-5.1%	0.0%	-2.1%	0.0%	-2.5%	0.0%	0.0%	0.0%
			0.3%	4.7%	0.0%	0.4%	5.1%	0.0%	2.7%	0.0%	2.5%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_C_D/D-45	-14%	14%	1.1%	0.0%	25.4%	1.2%	0.0%	32.4%	0.0%	0.0%	0.0%	2.8%	5.0%	0.0%
			-0.1%	0.0%	-2.1%	-0.1%	0.0%	-1.4%	0.0%	0.0%	0.0%	-2.8%	-2.5%	0.0%
ANP/FLAP/COEFF_C_D/D-8	-14%	14%	0.9%	12.3%	0.0%	1.0%	12.6%	0.0%	10.7%	9.5%	4.4%	0.0%	0.0%	0.0%
			-0.7%	-10.4%	0.0%	-0.8%	-10.5%	0.0%	-10.7%	-6.8%	-5.5%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/O-204	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/O-250	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/20	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/D-45	-14%	14%	-0.5%	0.0%	-10.6%	-0.6%	0.0%	-16.1%	0.0%	0.0%	0.0%	-3.3%	-2.5%	0.0%
			0.5%	0.0%	11.0%	0.6%	0.0%	15.8%	0.0%	0.0%	0.0%	2.8%	5.0%	0.0%
ANP/FLAP/COEFF_R/D-8	-14%	14%	0.0%	-0.7%	0.0%	-0.1%	-0.7%	0.0%	-0.5%	1.4%	-0.8%	0.0%	0.0%	0.0%
			0.0%	0.8%	0.0%	0.1%	0.8%	0.0%	1.1%	1.4%	0.8%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/U-45	-14%	14%	-0.4%	0.0%	-4.8%	-0.4%	0.0%	-5.8%	0.0%	0.0%	0.0%	-2.8%	0.0%	-3.3%
			0.4%	0.0%	4.9%	0.4%	0.0%	6.0%	0.0%	0.0%	0.0%	3.3%	0.0%	3.1%
ANP/FLAP/COEFF_R/U-8	-14%	14%	0.0%	-0.3%	0.0%	0.0%	-0.3%	0.0%	-0.5%	0.0%	-0.3%	0.0%	0.0%	0.0%
			0.0%	0.4%	0.0%	0.0%	0.4%	0.0%	0.5%	1.4%	0.3%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/ZERO	-14%	14%	-0.4%	-1.4%	0.0%	-0.5%	-1.3%	0.0%	-1.6%	0.0%	-1.9%	0.0%	0.0%	0.0%
			0.5%	1.5%	0.0%	0.5%	1.4%	0.0%	1.6%	0.0%	2.2%	0.0%	0.0%	0.0%
ANP/WEIGHT/APP	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-2.2%	0.0%	-1.6%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	2.5%	1.6%
ANP/WEIGHT/DEP	-10%	10%	-5.9%	-11.6%	15.5%	-7.9%	-11.6%	20.9%	-10.7%	2.7%	-12.3%	0.0%	0.0%	0.0%
			6.2%	12.2%	6.9%	8.6%	12.2%	11.2%	11.2%	-1.4%	13.2%	0.0%	0.0%	0.0%
ANP_AIRPLANE/THR_STATIC	-15%	15%	0.0%	0.0%	-0.7%	0.0%	0.0%	-1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.6%	0.0%	0.0%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_E/C	-15%	15%	-0.3%	2.7%	0.0%	-0.8%	0.9%	0.0%	-5.3%	-1.4%	3.8%	0.0%	0.0%	0.0%
			0.2%	-1.0%	0.0%	1.3%	2.9%	0.0%	5.9%	2.7%	1.1%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_E/T	-15%	15%	-0.6%	-0.4%	-3.5%	-1.4%	-8.5%	-4.5%	2.7%	-12.2%	10.4%	0.0%	0.0%	0.0%
			0.6%	1.0%	3.5%	0.7%	1.9%	4.5%	0.0%	9.5%	-4.4%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_F/C	-15%	15%	0.1%	-0.3%	0.0%	0.4%	0.3%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.1%	0.4%	0.0%	-0.2%	0.1%	0.0%	-1.6%	0.0%	0.3%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_F/T	-15%	15%	0.0%	-0.5%	0.0%	0.0%	0.1%	0.0%	-0.5%	2.7%	-1.6%	0.0%	0.0%	0.0%
			0.0%	0.5%	0.0%	-0.1%	-0.7%	0.0%	0.5%	-1.4%	1.6%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_GA/C	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_GA/T	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_GB/C	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_GB/T	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/ALPHA	-10%	10%	-0.4%	0.0%	-3.7%	-0.5%	0.0%	-4.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.4%	0.0%	3.7%	0.5%	0.0%	4.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/BETA1	-10%	10%	-0.2%	0.0%	-1.2%	-0.2%	0.0%	-1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.2%	0.0%	1.2%	0.2%	0.0%	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/BETA2	-10%	10%	-0.2%	0.0%	-1.3%	-0.3%	0.0%	-1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.2%	0.0%	1.3%	0.3%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/BETA3	-10%	10%	0.3%	0.0%	2.6%	0.4%	0.0%	3.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.3%	0.0%	-2.1%	-0.3%	0.0%	-2.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/K1	-10%	10%	-0.8%	-5.4%	-2.5%	-1.3%	-8.2%	-4.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.8%	5.4%	2.5%	1.4%	7.2%	4.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/K2	-10%	10%	-0.4%	-2.1%	-0.9%	-0.6%	-2.9%	-1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.4%	2.1%	0.9%	0.8%	2.9%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/K3	-10%	10%	0.0%	-0.1%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/K4	-10%	10%	-0.3%	-2.4%	-0.4%	-0.5%	-3.8%	-0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.3%	2.4%	0.4%	0.5%	3.2%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table D-4. AEDT Output Sensitivity to BADA Coefficients

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80db_area [nmi^2]	Dep_80db_width [nmi]	Dep_80db_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
BADA/CL_CAS2	-15%	15%	-1.1%	0.0%	0.0%	-3.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.8%	0.0%	0.0%	3.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CL_MACH	-15%	15%	-0.5%	0.0%	0.0%	-1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			3.3%	0.0%	-0.1%	4.3%	0.0%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CR_CAS2	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CR_MACH	-15%	15%	5.3%	0.0%	-0.2%	6.1%	0.0%	-0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.4%	0.0%	0.0%	-0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/DE_CAS2	-15%	15%	-0.7%	0.0%	0.0%	-1.9%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.9%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/DE_MACH	-15%	15%	0.2%	0.0%	0.0%	-0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.9%	0.0%	0.0%	1.5%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/COEFF_CD0	-14%	14%	-6.7%	0.0%	0.2%	-8.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			5.8%	0.0%	-0.2%	7.0%	0.0%	-0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/COEFF_CD2	-14%	14%	-3.2%	0.0%	0.1%	-3.7%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			2.3%	0.0%	-0.1%	2.7%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CF1	-10%	10%	-6.9%	0.0%	0.2%	-9.7%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			6.8%	0.0%	-0.2%	10.5%	0.0%	-0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CF2	-10%	10%	4.0%	0.0%	-0.1%	6.1%	0.0%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-3.3%	0.0%	0.1%	-4.8%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CFCR	-10%	10%	-6.9%	0.0%	0.2%	-9.7%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			6.8%	0.0%	-0.2%	10.5%	0.0%	-0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC1	-15%	15%	0.6%	0.0%	0.0%	-1.8%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.1%	0.0%	0.0%	2.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC2	-2.5%	2.5%	-0.3%	0.0%	0.0%	-0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.8%	0.0%	0.0%	-0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC3	-2.5%	2.5%	-0.1%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC4	-2%	2%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC5	-2%	2%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TDH	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_MAX	-10%	10%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_MIN	-10%	10%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_PAYLD	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_REF	-10%	10%	0.2%	0.0%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.1%	0.0%	0.0%	-1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/WING_AREA	-10%	10%	-3.3%	0.0%	0.1%	-4.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			2.7%	0.0%	-0.1%	3.3%	0.0%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table D-5. AEDT Output Sensitivity to Emissions, Airport Atmosphere and NPD Curves

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80db_area [nmi^2]	Dep_80db_width [nmi]	Dep_80db_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
ENGINE/BYPASS_RATIO	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_AP	-24%	24%	0.0%	0.0%	0.0%	-5.6%	-0.3%	-19.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	5.0%	0.2%	18.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_CO	-24%	24%	0.0%	0.0%	0.0%	-13.4%	-11.0%	-4.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	12.4%	10.7%	3.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_ID	-24%	24%	0.0%	0.0%	0.0%	-0.7%	0.0%	-1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.7%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_TO	-24%	24%	0.0%	0.0%	0.0%	-5.4%	-13.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	5.0%	12.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/PRESSURE_RATIO	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/RATED_OUT	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_AP	-5%	5%	0.0%	0.0%	0.0%	0.3%	0.0%	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-0.3%	0.0%	-1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_CO	-5%	5%	0.0%	0.0%	0.0%	1.1%	1.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-1.1%	-0.6%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_ID	-5%	5%	0.0%	0.0%	0.0%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-0.1%	0.0%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_TO	-5%	5%	0.0%	0.0%	0.0%	0.9%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-0.6%	-1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Atmo_Elevation	1000ft		-1.4%	1.8%	-25.9%	-0.5%	2.9%	-25.7%	3.2%	0.0%	4.1%	-5.0%	-2.5%	-3.3%
Atmosphere Temperature	-9.15%	9.15%	-0.9%	-0.5%	0.0%	-2.3%	-2.7%	-2.0%	0.5%	1.4%	0.0%	1.1%	0.0%	0.7%
			-0.1%	0.5%	0.0%	1.4%	2.0%	2.1%	-0.5%	0.0%	0.0%	-1.1%	0.0%	-0.5%
Atmo_SLP Pressure	-3%	3%	-0.1%	1.0%	-2.0%	1.4%	1.7%	-0.6%	2.1%	0.0%	2.5%	-3.9%	-2.5%	-2.1%
			0.0%	-0.9%	2.0%	-1.3%	-1.9%	0.7%	-2.1%	1.4%	-2.2%	3.9%	2.5%	2.1%
Atmo_Humidity	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Atmo_Headwind	-100%	100%	-0.3%	2.8%	-6.2%	-0.2%	3.4%	-6.7%	2.7%	-1.4%	4.1%	-6.1%	-2.5%	-3.1%
			0.2%	-2.8%	6.9%	0.1%	-3.4%	7.4%	-2.1%	2.7%	-3.8%	6.7%	5.0%	3.5%
NPD Curves	-1.5dB	+1.5dB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-23.5%	-12.2%	-11.0%	-30.0%	-17.5%	-14.9%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	32.6%	13.5%	16.4%	41.7%	20.0%	19.2%

D.3 Sensitivity Study Result of a Small Twin Aisle Aircraft

Table D-6. AEDT Output Sensitivity to ANP Coefficients

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80db_area [nmi^2]	Dep_80db_width [nmi]	Dep_80db_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
ANP_AIRPLANE/FLAP/COEFF_B/DEP_1+F	-14%	14%	-0.1%	-4.7%	0.0%	-0.2%	-5.1%	0.0%	-1.6%	0.0%	-1.4%	0.0%	0.0%	0.0%
			0.1%	4.7%	0.0%	0.2%	5.1%	0.0%	1.6%	0.0%	1.6%	0.0%	0.0%	0.0%
ANP_AIRPLANE/FLAP/COEFF_C_D/APP_3_D	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP_AIRPLANE/FLAP/COEFF_C_D/APP_FULL_D	-14%	14%	0.0%	0.0%	0.2%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%
			0.0%	0.0%	-0.2%	0.0%	0.0%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
ANP/FLAP/COEFF_C_D/DEP_1+F	-14%	14%	0.3%	13.0%	0.0%	0.6%	14.6%	-0.1%	8.0%	8.1%	2.0%	0.0%	0.0%	0.0%
			-0.2%	-11.0%	0.0%	-0.5%	-12.3%	0.1%	-7.7%	-7.6%	-2.4%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/APP_1_A	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/APP_2_D	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/APP_2_U	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/APP_3_D	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/APP_FULL_D	-14%	14%	-0.2%	0.0%	-22.5%	-0.1%	0.0%	-36.8%	0.0%	0.0%	0.0%	-1.7%	-3.8%	0.6%
			0.2%	0.0%	22.5%	0.1%	0.0%	45.6%	0.0%	0.0%	0.0%	2.7%	3.8%	-0.1%
ANP/FLAP/COEFF_R/APP_ZERO_A	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/DEP_1	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/DEP_1+F	-14%	14%	0.0%	-1.1%	0.0%	0.0%	-1.2%	0.0%	-0.9%	-0.6%	-0.5%	0.0%	0.0%	0.0%
			0.0%	1.2%	0.0%	0.1%	1.3%	0.0%	1.0%	0.6%	0.7%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/DEP_ZERO	-14%	14%	0.0%	-1.2%	0.0%	-0.1%	-1.0%	0.0%	-2.1%	0.0%	-2.4%	0.0%	0.0%	0.0%
			-0.1%	1.4%	0.0%	0.1%	1.1%	0.0%	2.3%	0.0%	2.6%	0.0%	0.0%	0.0%
ANP/WEIGHT/APP	-10%	10%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.8%	-1.3%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	1.3%	-0.1%
ANP/WEIGHT/DEP	-10%	10%	0.0%	-11.4%	-8.7%	-8.4%	-11.3%	-15.4%	-11.1%	1.2%	-11.7%	0.0%	0.0%	0.0%
			-4.6%	11.9%	8.6%	11.4%	11.7%	16.6%	11.3%	-1.2%	12.4%	0.0%	0.0%	0.0%
ANP_AIRPLANE/THR_STATIC	-15%	15%	6.0%	0.0%	-1.4%	0.0%	0.0%	-1.8%	0.0%	0.0%	0.0%	-0.2%	0.0%	-0.1%
			0.0%	0.0%	1.4%	0.0%	0.0%	2.2%	0.0%	0.0%	0.0%	0.6%	0.0%	0.0%
ANP/THRUST/COEFF_E/C	-15%	15%	0.0%	2.7%	0.0%	-0.5%	-1.0%	0.0%	-4.5%	0.0%	1.7%	0.0%	0.0%	0.0%
			0.0%	-1.1%	0.0%	0.3%	0.9%	0.0%	9.2%	0.0%	3.0%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_E/T	-15%	15%	0.0%	4.0%	0.0%	-0.6%	-12.1%	0.0%	-2.0%	-19.2%	9.2%	0.0%	0.0%	0.0%
			0.0%	-1.8%	0.0%	0.2%	4.2%	0.0%	5.7%	19.2%	-3.8%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_F/C	-15%	15%	0.0%	-0.1%	0.0%	0.0%	0.1%	0.0%	1.0%	0.0%	0.4%	0.0%	0.0%	0.0%
			0.0%	0.1%	0.0%	0.0%	-0.1%	0.0%	-1.0%	0.0%	-0.3%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_F/T	-15%	15%	0.0%	-0.9%	0.0%	0.1%	1.4%	0.0%	0.5%	4.1%	-1.3%	0.0%	0.0%	0.0%
			0.0%	1.0%	0.0%	-0.1%	-1.4%	0.0%	-0.3%	-4.1%	1.6%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_GA/C	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_GA/T	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_GB/C	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_GB/T	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_H/C	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_H/T	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table D-7. AEDT Output Sensitivity to BADA Coefficients

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80db_area [nmi^2]	Dep_80db_width [nmi]	Dep_80db_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
BADA/CL_CAS2	-15%	15%	0.0%	0.0%	0.4%	-9.7%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-3.1%	0.0%	0.0%	3.2%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CL_MACH	-15%	15%	1.2%	0.0%	0.7%	-19.7%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-4.5%	0.0%	-2.1%	42.7%	0.0%	-3.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CR_CAS1	-15%	15%	15.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CR_CAS2	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CR_MACH	-15%	15%	0.0%	0.0%	-1.3%	18.0%	0.0%	-2.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			9.9%	0.0%	0.4%	-4.8%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/DE_CAS2	-15%	15%	-2.8%	0.0%	0.1%	-1.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.7%	0.0%	-0.1%	0.5%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/DE_MACH	-15%	15%	0.4%	0.0%	0.0%	-0.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.3%	0.0%	-0.1%	0.5%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/COEFF_CD0	-14%	14%	0.4%	0.0%	1.3%	-15.3%	0.0%	2.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-9.3%	0.0%	-1.3%	18.4%	0.0%	-2.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/COEFF_CD2	-14%	14%	10.2%	0.0%	0.4%	-4.8%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-2.8%	0.0%	-0.4%	6.5%	0.0%	-0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CF1	-10%	10%	3.7%	-10.0%	-7.9%	-17.3%	-20.3%	-13.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-9.6%	10.0%	7.6%	18.7%	19.4%	14.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CF2	-10%	10%	9.5%	1.7%	0.8%	7.1%	3.5%	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			3.7%	-1.4%	-0.7%	-5.6%	-2.8%	-1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CF3	-10%	10%	-3.1%	0.0%	-0.9%	0.0%	0.0%	-0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-0.2%	0.0%	0.9%	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CF4	-10%	10%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CFCR	-10%	10%	0.0%	0.0%	1.2%	-16.0%	0.0%	2.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-9.1%	0.0%	-1.2%	17.4%	0.0%	-2.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC1	-15%	15%	9.1%	0.0%	-0.1%	0.1%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.7%	0.0%	0.0%	1.5%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC2	-3%	3%	0.1%	0.0%	0.0%	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.8%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC3	-3%	3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC4	-2%	2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC5	-2%	2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TDH	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TDL	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_MAX	-10%	10%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_MIN	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_PAYLD	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_REF	-10%	10%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.1%	0.0%	0.0%	-0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/WING_AREA	-10%	10%	0.0%	0.0%	0.7%	-8.0%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-4.8%	0.0%	-0.7%	10.9%	0.0%	-1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table D-8. AEDT Output Sensitivity to Emissions, Airport Atmosphere and NPD Curves

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80db_area [nmi^2]	Dep_80db_width [nmi]	Dep_80db_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
ENGINE/BYPASS_RATIO	-10%	10%	6.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_AP	-24%	24%	0.0%	0.0%	0.0%	-12.7%	-0.6%	-9.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	11.5%	0.5%	7.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_CO	-24%	24%	0.0%	0.0%	0.0%	-12.0%	-11.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	10.8%	10.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_ID	-24%	24%	0.0%	0.0%	0.0%	-0.2%	0.0%	-16.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.2%	0.0%	15.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_TO	-24%	24%	0.0%	0.0%	0.0%	-0.6%	-13.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.5%	12.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/PRESSURE_RATIO	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/RATED_OUT	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_AP	-5%	5%	0.0%	0.0%	0.0%	2.1%	0.1%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-2.2%	-0.1%	-1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_CO	-5%	5%	0.0%	0.0%	0.0%	2.2%	2.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-1.9%	-2.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_ID	-5%	5%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	-2.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_TO	-5%	5%	0.0%	0.0%	0.0%	0.2%	4.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-0.1%	-2.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Atmosphere Elevation	1000ft		0.0%	0.9%	-3.6%	1.5%	3.0%	-1.3%	4.6%	0.6%	4.3%	-4.6%	-3.8%	-2.4%
Atmosphere Temperature (F)	-9.15%	9.15%	0.4%	-0.1%	1.0%	-2.5%	-4.7%	-1.7%	0.4%	0.0%	0.1%	1.2%	0.0%	0.5%
			-0.7%	0.1%	-1.0%	4.4%	4.9%	1.7%	-0.3%	-0.6%	0.0%	-1.0%	0.0%	-0.6%
Atmosphere SLP Pressure	-3%	3%	1.7%	0.7%	-2.8%	0.5%	2.6%	-0.9%	3.5%	0.6%	3.0%	-3.7%	-1.3%	-2.1%
			0.0%	-0.6%	2.8%	-0.5%	-2.4%	0.8%	-3.3%	-0.6%	-2.8%	3.9%	1.3%	1.8%
Atmosphere Humidity	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Atmosphere Headwind	-100%	100%	0.0%	2.5%	-9.8%	0.1%	3.5%	-13.0%	2.0%	-1.2%	3.3%	-4.6%	-3.8%	-2.3%
			0.0%	-2.4%	11.0%	-0.1%	-3.4%	14.9%	-2.0%	1.2%	-3.2%	5.4%	3.8%	1.9%
NPD Curves	-1.5dB	+1.5dB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-22.7%	-10.5%	-12.2%	-22.2%	-15.4%	-11.4%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	29.9%	11.0%	15.1%	29.9%	19.2%	12.4%

D.4 Sensitivity Study Result of a Large Twin Aisle Aircraft

Table D-9. AEDT Output Sensitivity to ANP Coefficients

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80dB_area [nmi^2]	Dep_80dB_width [nmi]	Dep_80dB_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
ANP/FLAP/COEFF_B/DEP_T_05_U	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_B/DEP_T_15_U	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_B/DEP_T_20_U	-14%	14%	-0.1%	-4.6%	0.0%	-0.1%	-5.2%	0.0%	-2.3%	-4.2%	-1.6%	0.0%	0.0%	0.0%
			0.1%	4.6%	0.0%	0.1%	5.2%	0.0%	2.2%	4.2%	1.6%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_C_D/APP_L_25_D	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_C_D/APP_L_30_D	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_C_D/DEP_T_05_U	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_C_D/DEP_T_15_U	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_C_D/DEP_T_20_U	-14%	14%	0.2%	14.5%	0.0%	0.3%	14.2%	0.0%	10.9%	7.8%	4.2%	0.0%	0.0%	0.0%
			-0.2%	-11.5%	0.0%	-0.2%	-11.0%	0.0%	-9.6%	-6.2%	-4.6%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/APP_L_25_D	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/APP_L_30_D	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/DEP_T_00_U	-14%	14%	-0.1%	-1.6%	0.0%	-0.1%	-1.4%	0.0%	-2.2%	0.0%	-2.7%	0.0%	0.0%	0.0%
			0.1%	2.0%	0.0%	0.1%	1.8%	0.0%	2.5%	0.0%	3.2%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/DEP_T_05_U	-14%	14%	0.0%	-2.6%	0.0%	0.0%	-2.2%	0.0%	-2.7%	0.0%	-2.2%	0.0%	0.0%	0.0%
			0.0%	3.6%	0.0%	0.1%	3.2%	0.0%	3.9%	0.0%	3.2%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/DEP_T_15_U	-14%	14%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/FLAP/COEFF_R/DEP_T_20_U	-14%	14%	0.0%	-1.0%	0.0%	0.0%	-1.1%	0.0%	-0.7%	0.0%	-0.6%	0.0%	0.0%	0.0%
			0.0%	1.1%	0.0%	0.0%	1.3%	0.0%	0.8%	0.0%	0.7%	0.0%	0.0%	0.0%
ANP/WEIGHT/APP	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/WEIGHT/DEP	-10%	10%	-5.5%	-13.2%	0.0%	-9.0%	-13.3%	0.0%	-12.3%	-3.1%	-13.0%	0.0%	0.0%	0.0%
			5.4%	15.0%	0.0%	9.2%	15.0%	0.0%	13.3%	3.1%	14.3%	0.0%	0.0%	0.0%
ANP_AIRPLANE/THR_STATIC	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.7%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	0.1%
ANP/THRUST/COEFF_E/C	-15%	15%	0.2%	-0.4%	0.0%	-0.2%	-6.1%	0.0%	-2.3%	0.0%	9.5%	0.0%	0.0%	0.0%
			-0.1%	-6.0%	0.0%	0.2%	-0.3%	0.0%	14.0%	0.0%	-0.4%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_E/T	-15%	15%	0.0%	2.0%	-2.2%	-0.2%	-6.5%	-4.6%	-7.4%	-25.0%	3.1%	0.0%	0.0%	0.0%
			0.0%	-0.6%	2.2%	0.2%	7.8%	5.0%	12.1%	30.7%	0.0%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_F/C	-15%	15%	0.0%	-1.9%	0.0%	0.1%	-0.4%	0.0%	2.9%	0.0%	-0.7%	0.0%	0.0%	0.0%
			0.0%	2.4%	0.0%	-0.1%	0.7%	0.0%	-2.5%	0.0%	0.4%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_F/T	-15%	15%	0.0%	-0.8%	0.0%	0.0%	1.1%	0.0%	1.0%	2.1%	-0.7%	0.0%	0.0%	0.0%
			0.0%	0.9%	0.0%	0.0%	-0.9%	0.0%	-0.7%	-1.6%	0.9%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_GA/C	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
ANP/THRUST/COEFF_GA/T	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/ALPHA	-10%	10%	-0.1%	0.0%	-3.5%	-0.1%	0.0%	-7.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.1%	0.0%	3.5%	0.1%	0.0%	8.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/BETA1	-10%	10%	0.0%	0.0%	-1.6%	0.0%	0.0%	-3.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	1.6%	0.0%	0.0%	3.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/BETA2	-10%	10%	0.0%	0.0%	-0.8%	0.0%	0.0%	-1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.8%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/BETA3	-10%	10%	0.0%	0.0%	1.6%	0.0%	0.0%	3.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	-1.3%	0.0%	0.0%	-2.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/K1	-10%	10%	-0.2%	-7.4%	-2.4%	-0.5%	-13.3%	-5.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.2%	7.4%	2.4%	0.6%	16.1%	5.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/K2	-10%	10%	-0.1%	-2.1%	-0.6%	-0.2%	-4.0%	-1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.1%	2.1%	0.6%	0.2%	4.1%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/K3	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ANP/TSFC/K4	-10%	10%	0.0%	-0.5%	0.0%	0.0%	-1.1%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.5%	0.0%	0.0%	1.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table D-10. AEDT Output Sensitivity to BADA Coefficients

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80db_area [nmi^2]	Dep_80db_width [nmi]	Dep_80db_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
BADA/CL_CAS2	-15%	15%	-3.5%	0.0%	0.0%	-12.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.1%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CL_MACH	-15%	15%	-2.9%	0.0%	0.0%	-15.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			8.7%	0.0%	0.0%	18.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CR_CAS2	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/CR_MACH	-15%	15%	7.3%	0.0%	0.0%	12.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			-2.3%	0.0%	0.0%	-3.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/DE_CAS2	-15%	15%	-0.6%	0.0%	0.0%	-0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.2%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/DE_MACH	-15%	15%	-0.2%	0.0%	0.0%	-0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.2%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/COEFF_CD0	-14%	14%	-8.9%	0.0%	0.0%	-14.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			9.0%	0.0%	0.0%	15.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/COEFF_CD2	-14%	14%	-3.0%	0.0%	0.0%	-4.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			2.9%	0.0%	0.0%	4.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CF1	-10%	10%	-9.1%	0.0%	0.0%	-14.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			9.0%	0.0%	0.0%	15.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CF2	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/FUEL/CFCR	-10%	10%	-9.1%	0.0%	0.0%	-14.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			9.0%	0.0%	0.0%	15.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC1	-15%	15%	-0.3%	0.0%	0.0%	-0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.3%	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC2	-2.5%	2.5%	-0.1%	0.0%	0.0%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC3	-2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC4	-2%	2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TC5	-2%	2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TDH	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/THRUST/TDL	-10%	10%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_MAX	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_MIN	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_PAYLD	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/MASS_REF	-10%	10%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BADA/WING_AREA	-10%	10%	-4.3%	0.0%	0.0%	-6.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			4.7%	0.0%	0.0%	7.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table D-11. AEDT Output Sensitivity to Emissions, Airport Atmosphere and NPD Curves

AEDT COEFFICIENT	Min	Max	Total_FB [kg]	FB_Dep_3000 [kg]	FB_App_3000 [kg]	Total_NOx [g]	NOx_Dep_3000 [g]	NOx_App_3000 [g]	Dep_80db_area [nmi^2]	Dep_80db_width [nmi]	Dep_80db_length [nmi]	App_80dB_area [nmi^2]	App_80dB_width [nmi]	App_80dB_length [nmi]
ENGINE/BYPASS_RATIO	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_AP	-24%	-24%	0.0%	0.0%	0.0%	-15.8%	-2.8%	-19.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	14.6%	2.3%	19.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_CO	-24%	-24%	0.0%	0.0%	0.0%	-9.5%	-19.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	8.2%	19.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_ID	-24%	-24%	0.0%	0.0%	0.0%	-0.1%	0.0%	-5.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.1%	0.0%	4.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/NOX_REI_TO	-24%	-24%	0.0%	0.0%	0.0%	-0.1%	-2.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/PRESSURE_RATIO	-10%	10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/RATED_OUT	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_AP	-5%	-5%	0.0%	0.0%	0.0%	2.1%	0.3%	5.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-2.1%	-0.4%	-4.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_CO	-5%	-5%	0.0%	0.0%	0.0%	1.3%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	-1.2%	-4.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_ID	-5%	-5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	-0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENGINE/UA_RWF_TO	-5%	-5%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	-0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Atmo_Elevation	1000ft		-0.2%	1.9%	-3.4%	0.2%	3.4%	-3.4%	4.3%	1.0%	4.5%	-2.1%	-2.5%	-0.3%
Atmosphere Temperature	-9.15%	9.15%	-0.6%	-0.6%	-0.4%	-1.8%	-4.9%	-5.0%	0.4%	0.0%	0.1%	0.3%	0.0%	0.1%
			0.7%	0.6%	0.4%	2.0%	5.5%	5.3%	-0.4%	0.0%	0.0%	-0.3%	-1.3%	0.0%
Atmo_SLP Pressure	-3%	3%	0.4%	20.1%	-2.2%	0.8%	22.9%	-2.7%	3.4%	1.0%	3.5%	-1.9%	-1.3%	-0.3%
			-0.1%	-1.3%	2.8%	-0.3%	-2.3%	2.9%	-3.1%	-1.0%	-3.2%	1.7%	1.3%	0.3%
Atmo_Humidity	-15%	15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Atmo_Headwind	-100%	100%	0.0%	2.4%	0.0%	0.1%	3.5%	0.0%	1.9%	1.0%	3.0%	0.0%	0.0%	0.0%
			0.0%	-2.4%	0.0%	-0.1%	-3.5%	0.0%	-1.9%	-1.0%	-3.0%	0.0%	0.0%	0.0%
NPD Curves	-1.5dB	+1.5dB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-22.0%	-10.9%	-11.6%	-20.6%	-15.0%	-4.6%
			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	29.2%	12.5%	14.2%	20.8%	16.3%	3.4%

D.5 Screening Test Results of a Small Twin Aisle Aircraft

Table D-12. LogWorth Values for Mission Fuel, Mission NOx, and Terminal NOx

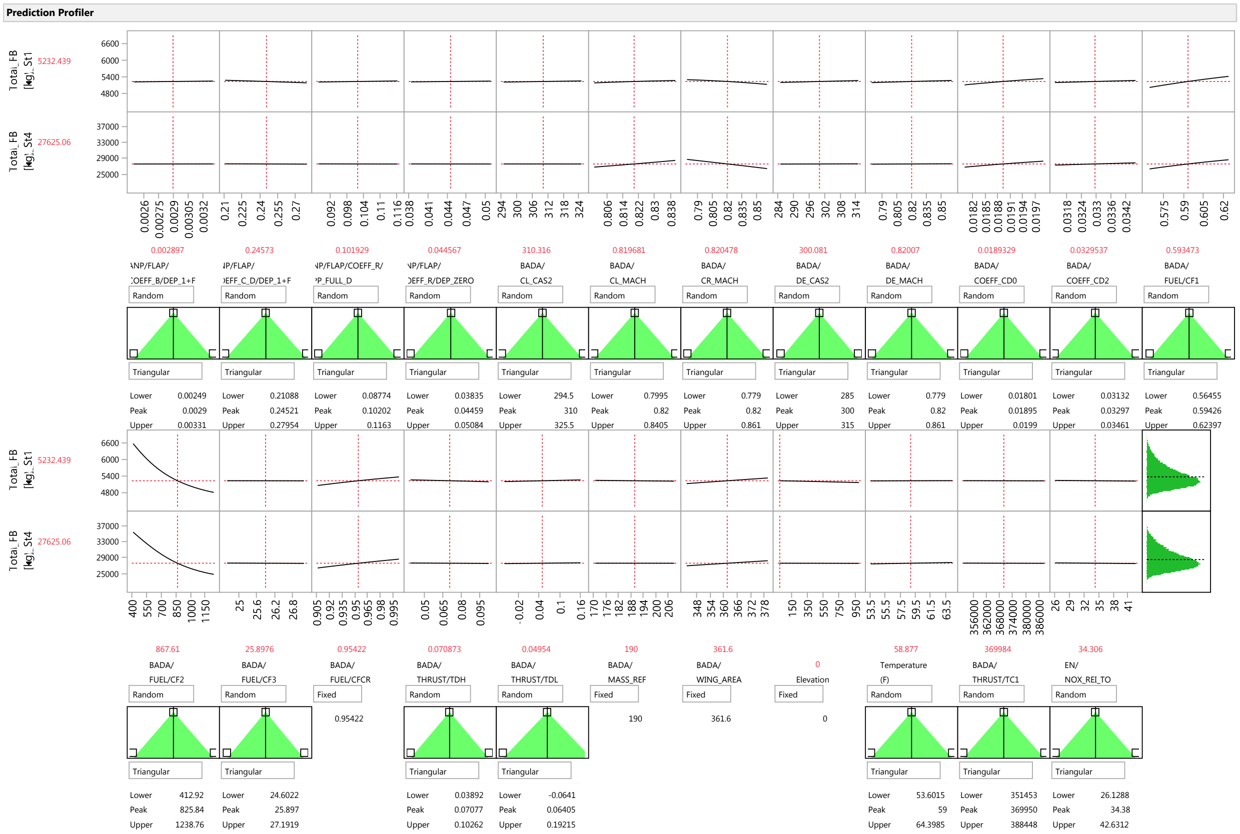
Categories	Source	Departure NOx Stage4	Approach NOx Stage4	TOTAL NOx Stage1	TOTAL NOx Stage4	TOTAL Fuel Burn Stage1	TOTAL Fuel Burn Stage4
		LogWorth	LogWorth	LogWorth	LogWorth	LogWorth	LogWorth
ANP	ANP/FLAP/COEFF_B/DEP_1+F	108.905	0.187	3.172	0.17	6.287	0.102
	ANP/FLAP/COEFF_C_D/DEP_1+F	489.652	0.193	21.643	2.34	43.449	3.497
	ANP/FLAP/COEFF_C_D/APP_FULL_D	0.012	0.051	0.26	0.203	0.29	0.176
	ANP/FLAP/COEFF_R/DEP_1+F	6.595	0.192	0.198	0.409	0.101	0.39
	ANP/FLAP/COEFF_R/APP_FULL_D	2.384	1407.672	0.234	0.529	11.175	0.097
	ANP/FLAP/COEFF_R/DEP_ZERO	7.26	0.327	2.477	0.642	4.47	0.179
	ANP/PROFILE/WEIGHT/ST1	0.143	0.257	0.067	0.312	0.024	0.338
	ANP/PROFILE/WEIGHT/ST4	0.143	0.257	0.067	0.311	0.023	0.338
	ANP/THR_STATIC	0.036	9.358	0.184	0.479	0.04	0.266
	ANP/THRUST/COEFF_E/C	4.963	2.471	13.403	3.715	0.781	1.352
	ANP/THRUST/COEFF_E/T	164.841	0.159	7.591	0.427	0.734	0.558
	ANP/THRUST/COEFF_F/C	0.175	0.964	0.022	0.138	0.088	0.07
	ANP/THRUST/COEFF_F/T	0.792	0.128	0.263	0.173	1.427	0.417
	ANP/THRUST/COEFF_GA/C	0.295	0.085	1.526	0.404	0.384	0.267
	ANP/THRUST/COEFF_GA/T	1.618	0.841	1.706	0.612	0.405	0.206
BADA	BADA/CL_CAS2	0.318	0.665	16.858	0.366	5.091	0.208
	BADA/CL_MACH	0.19	3.446	33.884	205.866	29.888	186.153
	BADA/COEFF_CD0	1.77	4.404	46.171	81.523	143.93	143.923
	BADA/COEFF_CD2	0.444	0.545	5.966	11.883	14.432	19.309
	BADA/CR_MACH	0.14	9.53	42.404	206.184	110.87	328.758
	BADA/DE_CAS2	0.552	0.304	6.455	1.356	25.803	2.17
	BADA/DE_MACH	0.675	0.03	3.69	0.444	12.841	0.669
	BADA/FUEL/CF1	306.186	184.14	266.228	200.215	359.48	288.778
	BADA/FUEL/CF2	549.45	164.818	1081.054	1065.214	1261.263	1249.525
	BADA/FUEL/CF3	0.371	1.148	0.093	0.071	2.727	0.342
	BADA/FUEL/CF4	0.181	0.469	1.347	0.877	0.715	0.756
	BADA/FUEL/CFCR	1.298	7.263	153.418	182.655	234.973	271.706
	BADA/MASS_REF	0.471	0.193	27.497	2.48	12.349	1.235
	BADA/THRUST/TC1	0.068	0.83	3.159	0.134	3.1	1.18
	BADA/THRUST/TC2	1.441	0.131	3.997	0.876	0.726	0.075
	BADA/THRUST/TDH	0.038	0.432	4.537	0.743	15.131	0.749
	BADA/THRUST/TDL	0.397	0.318	9.261	0.187	10.93	2.156
	BADA/WING_AREA	0.055	1.54	37.647	56.581	107.9	101.275
EMISSIONS	EN/NOX_REI_AP	0.381	300.107	98.245	304.408	0.16	0.269
	EN/NOX_REI_CO	357.556	0.557	585.939	328.994	0.188	0.218
	EN/NOX_REI_ID	0.057	548.278	2.257	0.019	0.054	0.327
	EN/NOX_REI_TO	481.95	1.55	24.884	0.309	3.164	2.666
	EN/UA_RWF_AP	0.901	14.367	4.709	14.496	0.082	0.221
	EN/UA_RWF_CO	18.049	0.69	34.991	15.697	0.115	0.018
	EN/UA_RWF_ID	1.246	20.072	0.541	0.896	0.63	1.099
	EN/UA_RWF_TO	20.511	0.407	1.781	0.119	0.416	0.011
ATMOSPHERE	Headwind	52.983	524.817	2.457	0.461	0.553	0.268
	Humidity	0.439	0.04	0.036	0.149	0.012	0.217
	SLP Pressure	12.719	0.565	22.7	4.252	0.457	1.185
	Temperature (F)	67.547	15.041	48.116	30.064	2.938	16.342
	Elevation	1.229	3.52	0.563	2.015	5.681	0.522

Table D-13. LogWorth Values for Departure and Approach Noise Contours

Categories	Input Parameters	Departure 80 dB Contour			Approach 80 dB Contour		
		AREA	WIDTH	LENGTH	AREA	WIDTH	LENGTH
		LogWorth	LogWorth	LogWorth	LogWorth	LogWorth	LogWorth
NPD	Delta_NPD	1402.521	1703.456	1467.568	2144.525	2308.207	2513.589
ANP	ANP/FLAP/COEFF_B/DEP_1+F	34.58	0.08	109.765	0.167	0.457	0.097
	ANP/FLAP/COEFF_C_D/DEP_1+F	439.296	1281.948	203.967	0.074	0.078	1.191
	ANP/FLAP/COEFF_C_D/APP_FULL_D	0.099	0.865	0.071	1.132	0.506	0.163
	ANP/FLAP/COEFF_R/DEP_1+F	10.191	18.112	23.529	0.489	0.597	0.119
	ANP/FLAP/COEFF_R/APP_FULL_D	0.553	0.479	0.282	406.461	998.233	9.75
	ANP/FLAP/COEFF_R/DEP_ZERO	70.587	0.015	278.419	0.966	1.032	0.752
	ANP/THR_STATIC	1.997	1.209	0.877	5.649	1.716	2.505
	ANP/THRUST/COEFF_E/C	556.278	8.64	379.686	0.277	0.577	0.455
	ANP/THRUST/COEFF_E/T	119.536	1775.321	488.42	0.766	0.432	0.344
	ANP/THRUST/COEFF_F/C	4.506	0.319	4.254	0.285	0.296	0.832
	ANP/THRUST/COEFF_F/T	0.611	486.243	53.943	1.043	0.41	0.004
	ANP/THRUST/COEFF_GA/C	55.638	0.084	78.763	0.242	0.518	0.208
	ANP/THRUST/COEFF_GA/T	0.65	115.451	4.188	0.016	0.944	0.364
	ANP/WEIGHT/APP	1.438	0.885	1.421	68.027	321.414	5.308
	ANP/WEIGHT/DEP	668.839	132.065	1281.628	0.824	0.4	0.096
ATMOSPHERE	Elevation	57.612	22.028	148.676	347.9	409.295	529.739
	Headwind	42.22	142.906	352.507	774.858	1058.543	853.557
	Humidity	0.548	0.024	0.801	0.818	1.304	1.134
	SLP Pressure	104.95	55.978	284.406	578.844	559.844	897.926
	Temperature (F)	5.952	8.702	3.905	76.618	73.928	164.358

D.6 Monte Carlo Simulation Results of a Small Twin Aisle Aircraft

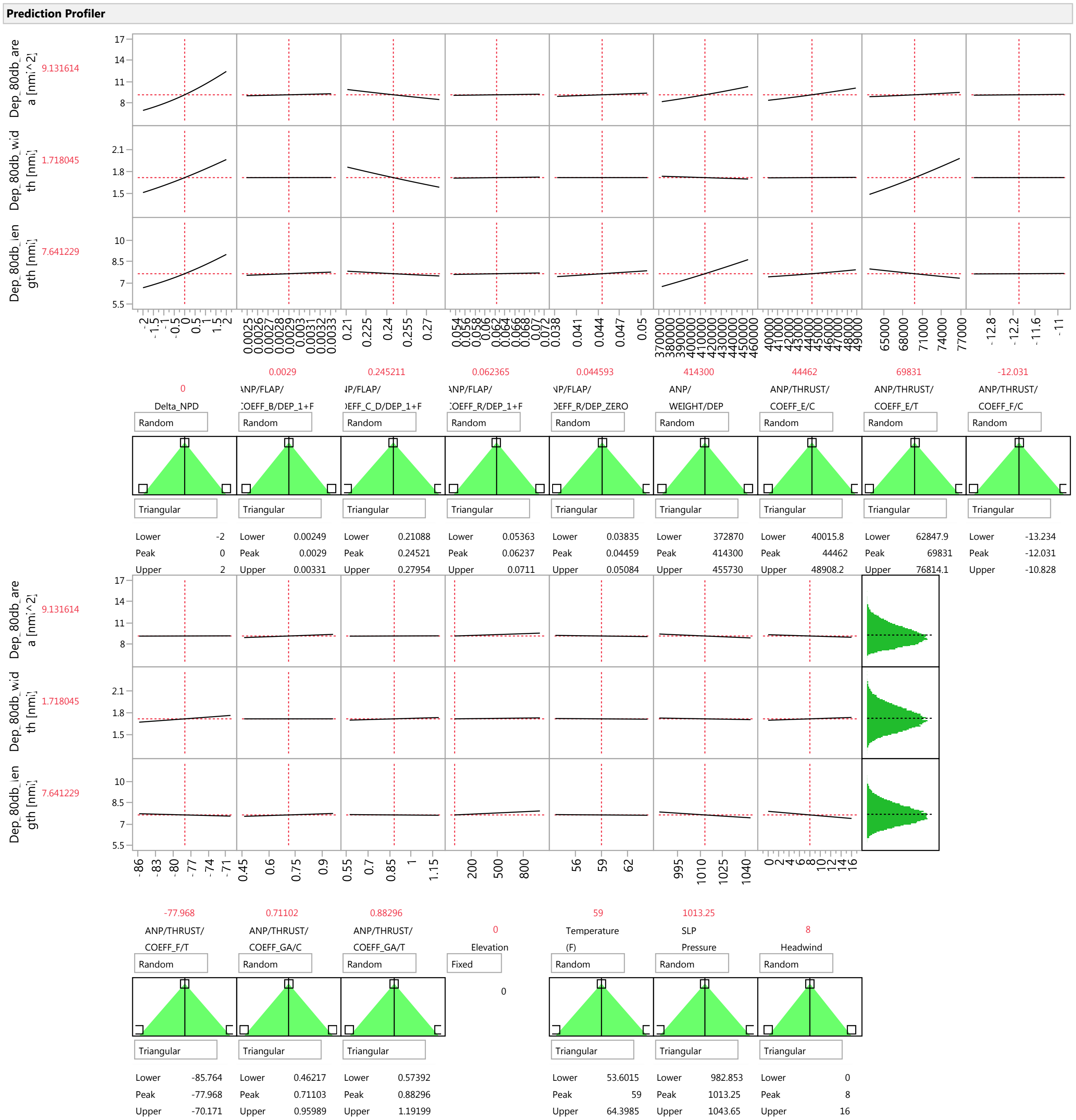
Table D-14. Monte Carlo Simulation Set Up with Triangular Probability Density Functions for Mission Fuel Calculation



Factor	Current value	Setting	Distribution	Lower	Peak	Upper
ANP/FLAP/ COEFF_B/DEP_1+F	0.002897	Random	Triangular	0.00249	0.0029	0.00331
NP/FLAP/ DEFF_C_D/DEP_1+F	0.24573	Random	Triangular	0.21088	0.24521	0.27954
NP/FLAP/COEFF_R/ P_FULL_D	0.101929	Random	Triangular	0.08774	0.10202	0.1163
NP/FLAP/ DEFF_R/DEP_ZERO	0.044567	Random	Triangular	0.03835	0.04459	0.05084
BADA/ CL_CAS2	310.316	Random	Triangular	294.5	310	325.5
BADA/ CL_MACH	0.819681	Random	Triangular	0.7995	0.82	0.8405
BADA/ CR_MACH	0.820478	Random	Triangular	0.779	0.82	0.861
BADA/ DE_CAS2	300.081	Random	Triangular	285	300	315
BADA/ DE_MACH	0.82007	Random	Triangular	0.779	0.82	0.861
BADA/ COEFF_CD0	0.0189329	Random	Triangular	0.01801	0.01895	0.0199
BADA/ COEFF_CD2	0.0329537	Random	Triangular	0.03132	0.03297	0.03461
BADA/ FUEL/CF1	0.593473	Random	Triangular	0.56455	0.59426	0.62397

Factor	Current value	Setting	Distribution / Value	Lower	Peak	Upper
BADA/ FUEL/CF2	867.61	Random	Triangular	412.92	825.84	1238.76
BADA/ FUEL/CF3	25.8976	Random	Triangular	24.6022	25.897	27.1919
BADA/ FUEL/CFCR	0.95422	Fixed	0.95422			
BADA/ THRUST/TDH	0.070873	Random	Triangular	0.03892	0.07077	0.10262
BADA/ THRUST/TDL	0.04954	Random	Triangular	-0.0641	0.06405	0.19215
BADA/ MASS_REF	190	Fixed	190			
BADA/ WING_AREA	361.6	Fixed	361.6			
Elevation	0	Fixed	0			
Temperature (F)	58.877	Random	Triangular	53.6015	59	64.3985
BADA/ THRUST/TC1	369984	Random	Triangular	351453	369950	388448
EN/ NOX_REI_TO	34.306	Random	Triangular	26.1288	34.38	42.6312

Table D-15. Monte Carlo Simulation Set Up with Triangular Probability Density Functions for Departure Noise Calculation



	Delta_NPD	ANP/FLAP/ OEFF_B/DEP_1+F	P/FLAP/ EFF_C_D/DEP_1+F	ANP/FLAP/ OEFF_R/DEP_1+F	NP/FLAP/ EFF_R/DEP_ZERO	ANP/ WEIGHT/DEP	ANP/THRUST/ COEFF_E/C	ANP/THRUST/ COEFF_E/T	ANP/THRUST/ COEFF_F/C
	0	0.0029	0.245211	0.062365	0.044593	414300	44462	69831	-12.031
	Random	Random	Random	Random	Random	Random	Random	Random	Random
	Triangular	Triangular	Triangular	Triangular	Triangular	Triangular	Triangular	Triangular	Triangular
Lower	-2	0.00249	0.21088	0.05363	0.03835	372870	40015.8	62847.9	-13.234
Peak	0	0.0029	0.24521	0.06237	0.04459	414300	44462	69831	-12.031
Upper	2	0.00331	0.27954	0.0711	0.05084	455730	48908.2	76814.1	-10.828

	ANP/THRUST/ COEFF_F/T	ANP/THRUST/ COEFF_GA/C	ANP/THRUST/ COEFF_GA/T	Elevation	Temperature (F)	SLP Pressure	Headwind
	-77.968	0.71102	0.88296	0	59	1013.25	8
	Random	Random	Random	Fixed	Random	Random	Random
	Triangular	Triangular	Triangular	0	Triangular	Triangular	Triangular
Lower	-85.764	0.46217	0.57392		53.6015	982.853	0
Peak	-77.968	0.71103	0.88296		59	1013.25	8
Upper	-70.171	0.95989	1.19199		64.3985	1043.65	16

Table D-16. Correlation Matrix for Mission Fuel MCS with Copulas Functions

Mission Fuel	BADA/COEFF_CD0	BADA/COEFF_CD2	BADA/FUEL/CF1	BADA/FUEL/CF2	BADA/THRUST/TC1	BADA/THRUST/TDH	BADA/THRUST/TDL	BADA/MASS_REF	BADA/WING_AREA	EN/NOX_REI_TO
BADA/COEFF_CD0	1	0.008	-0.3628	-0.3926	0.5354	-0.668	-0.6947	0.6867	-0.5419	-0.1098
BADA/COEFF_CD2	0.008	1	0.0106	0.0063	0.0289	-0.0121	-0.0153	0.0138	-0.0489	-0.0322
BADA/FUEL/CF1	-0.3628	0.0106	1	0.9526	0.2176	0.803	0.806	-0.1748	-0.0064	-0.1019
BADA/FUEL/CF2	-0.3926	0.0063	0.9526	1	0.1606	0.8755	0.8742	-0.2195	-0.0098	0.1038
BADA/THRUST/TC1	0.5354	0.0289	0.2176	0.1606	1	-0.1452	-0.1657	0.8595	0.0168	-0.0901
BADA/THRUST/TDH	-0.668	-0.0121	0.803	0.8755	-0.1452	1	0.9844	-0.5286	0.146	0.2669
BADA/THRUST/TDL	-0.6947	-0.0153	0.806	0.8742	-0.1657	0.9844	1	-0.5534	0.16	0.2618
BADA/MASS_REF	0.6867	0.0138	-0.1748	-0.2195	0.8595	-0.5286	-0.5534	1	0.0501	-0.1246
BADA/WING_AREA	-0.5419	-0.0489	-0.0064	-0.0098	0.0168	0.146	0.16	0.0501	1	-0.0266
EN/NOX_REI_TO	-0.1098	-0.0322	-0.1019	0.1038	-0.0901	0.2669	0.2618	-0.1246	-0.0266	1

Table D-17. Correlation Matrix for Mission NOx MCS with Copulas Functions

Mission NOx	ANP/THRUST/COEFF_E/C	ANP/THRUST/COEFF_E/T	BADA/COEFF_CD0	BADA/COEFF_CD2	BADA/FUEL/CF1	BADA/FUEL/CF2	BADA/THRUST/TC1	BADA/THRUST/TC2	BADA/THRUST/TDH	BADA/THRUST/TDL	EN/NOX_REI_AP	EN/NOX_REI_CO	EN/NOX_REI_ID	EN/NOX_REI_TO	EN/UA_RWF_AP	EN/UA_RWF_CO
ANP/THRUST/COEFF_E/C	1	0.9987	0.6724	0.0259	-0.0845	-0.1228	0.9465	-0.0595	-0.4138	-0.4374	0	0	0	0	0	0
ANP/THRUST/COEFF_E/T	0.9987	1	0.6736	0.0253	-0.0828	-0.1227	0.9455	-0.0603	-0.4157	-0.4389	0	0	0	0	0	0
BADA/COEFF_CD0	0.6724	0.6736	1	0.008	-0.3628	-0.3926	0.5354	0.1285	-0.668	-0.6947	0	0	0	0	0	0
BADA/COEFF_CD2	0.0259	0.0253	0.008	1	0.0106	0.0063	0.0289	0.0171	-0.0121	-0.0153	0	0	0	0	0	0
BADA/FUEL/CF1	-0.0845	-0.0828	-0.3628	0.0106	1	0.9526	0.2176	-0.4794	0.803	0.806	0	0	0	0	0	0
BADA/FUEL/CF2	-0.1228	-0.1227	-0.3926	0.0063	0.9526	1	0.1606	-0.3783	0.8755	0.8742	0	0	0	0	0	0
BADA/THRUST/TC1	0.9465	0.9455	0.5354	0.0289	0.2176	0.1606	1	-0.2722	-0.1452	-0.1657	0	0	0	0	0	0
BADA/THRUST/TC2	-0.0595	-0.0603	0.1285	0.0171	-0.4794	-0.3783	-0.2722	1	-0.3464	-0.3359	0	0	0	0	0	0
BADA/THRUST/TDH	-0.4138	-0.4157	-0.668	-0.0121	0.803	0.8755	-0.1452	-0.3464	1	0.9844	0	0	0	0	0	0
BADA/THRUST/TDL	-0.4374	-0.4389	-0.6947	-0.0153	0.806	0.8742	-0.1657	-0.3359	0.9844	1	0	0	0	0	0	0
EN/NOX_REI_AP	0	0	0	0	0	0	0	0	0	0	1	0.962	0.9802	0.9555	-0.2367	-0.2056
EN/NOX_REI_CO	0	0	0	0	0	0	0	0	0	0	0.962	1	0.9335	0.9981	-0.1922	-0.1633
EN/NOX_REI_ID	0	0	0	0	0	0	0	0	0	0	0.9802	0.9335	1	0.9208	-0.2614	-0.2463
EN/NOX_REI_TO	0	0	0	0	0	0	0	0	0	0	0.9555	0.9981	0.9208	1	-0.1689	-0.1373
EN/UA_RWF_AP	0	0	0	0	0	0	0	0	0	0	-0.2367	-0.1922	-0.2614	-0.1689	1	0.992
EN/UA_RWF_CO	0	0	0	0	0	0	0	0	0	0	-0.2056	-0.1633	-0.2463	-0.1373	0.992	1

Table D-18. Correlation Matrix for Terminal NOx MCS with Copulas Functions

Terminal NOx	ANP/THR_STATIC	ANP/THRUST/COEFF_E/C	ANP/THRUST/COEFF_E/T	BADA/COEFF_CD0	BADA/FUEL/CF1	BADA/FUEL/CF2	EN/NOX_REI_AP	EN/NOX_REI_CO	EN/NOX_REI_ID	EN/NOX_REI_TO	EN/UA_RWF_AP	EN/UA_RWF_CO	EN/UA_RWF_ID	EN/UA_RWF_TO
ANP/THR_STATIC	1	1	0.9987	0.6724	-0.0845	-0.1228	0	0	0	0	0	0	0	0
ANP/THRUST/COEFF_E/C	1	1	0.9987	0.6724	-0.0845	-0.1228	0	0	0	0	0	0	0	0
ANP/THRUST/COEFF_E/T	0.9987	0.9987	1	0.6736	-0.0828	-0.1227	0	0	0	0	0	0	0	0
BADA/COEFF_CD0	0.6724	0.6724	0.6736	1	-0.3628	-0.3926	0	0	0	0	0	0	0	0
BADA/FUEL/CF1	-0.0845	-0.0845	-0.0828	-0.3628	1	0.9526	0	0	0	0	0	0	0	0
BADA/FUEL/CF2	-0.1228	-0.1228	-0.1227	-0.3926	0.9526	1	0	0	0	0	0	0	0	0
EN/NOX_REI_AP	0	0	0	0	0	0	1	0.962	0.9802	0.9555	-0.2367	-0.2056	-0.3828	-0.1782
EN/NOX_REI_CO	0	0	0	0	0	0	0.962	1	0.9335	0.9981	-0.1922	-0.1633	-0.3371	-0.1352
EN/NOX_REI_ID	0	0	0	0	0	0	0.9802	0.9335	1	0.9208	-0.2614	-0.2463	-0.3523	-0.2284
EN/NOX_REI_TO	0	0	0	0	0	0	0.9555	0.9981	0.9208	1	-0.1689	-0.1373	-0.3212	-0.106
EN/UA_RWF_AP	0	0	0	0	0	0	-0.2367	-0.1922	-0.2614	-0.1689	1	0.992	0.9436	0.9803
EN/UA_RWF_CO	0	0	0	0	0	0	-0.2056	-0.1633	-0.2463	-0.1373	0.992	1	0.9102	0.9963
EN/UA_RWF_ID	0	0	0	0	0	0	-0.3828	-0.3371	-0.3523	-0.3212	0.9436	0.9102	1	0.8851
EN/UA_RWF_TO	0	0	0	0	0	0	-0.1782	-0.1352	-0.2284	-0.106	0.9803	0.9963	0.8851	1

Table D-19. Correlation Matrix for Departure Noise MCS with Copulas Functions

Departure Noise	ANP/WEIGHT/DEP	ANP/THRUST/COEFF_E/C	ANP/THRUST/COEFF_E/T	ANP/THRUST/COEFF_F/C	ANP/THRUST/COEFF_F/T	ANP/THRUST/COEFF_GA/C	ANP/THRUST/COEFF_GA/T
ANP/WEIGHT/DEP	1	0.9454	0.9464	-0.7823	-0.7899	0.4447	0.7827
ANP/THRUST/COEFF_E/C	0.9454	1	0.9987	-0.8293	-0.8345	0.4816	0.8256
ANP/THRUST/COEFF_E/T	0.9464	0.9987	1	-0.8276	-0.8356	0.4795	0.8253
ANP/THRUST/COEFF_F/C	-0.7823	-0.8293	-0.8276	1	0.9731	-0.4362	-0.9335
ANP/THRUST/COEFF_F/T	-0.7899	-0.8345	-0.8356	0.9731	1	-0.363	-0.9019
ANP/THRUST/COEFF_GA/C	0.4447	0.4816	0.4795	-0.4362	-0.363	1	0.4912
ANP/THRUST/COEFF_GA/T	0.7827	0.8256	0.8253	-0.9335	-0.9019	0.4912	1

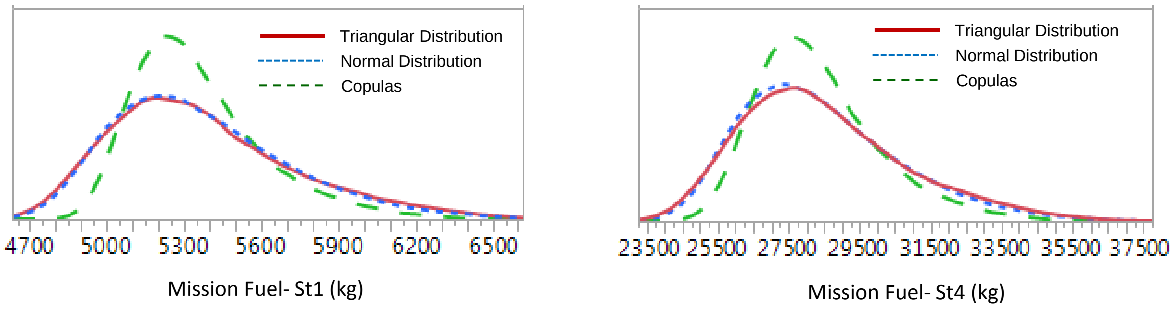


Figure D-1. Comparison of Histograms of Mission Fuel

Table D-20. MCS Results for Mission Fuel

	Fuel Burn - St1 (kg)			Fuel Burn - St4 (kg)		
Summary Statistics	Triangular	Gaussian	Copulas	Triangular	Gaussian	Copulas
Mean	5372.4531	5364.8604	5355.842	28470.167	28392.336	28329.288
Std Dev	365.83298	348.29853	257.15008	2352.1928	2252.6341	1749.4615
Change in Std Dev due to Correlation	NA	DATUM	-26%	NA	DATUM	-22%

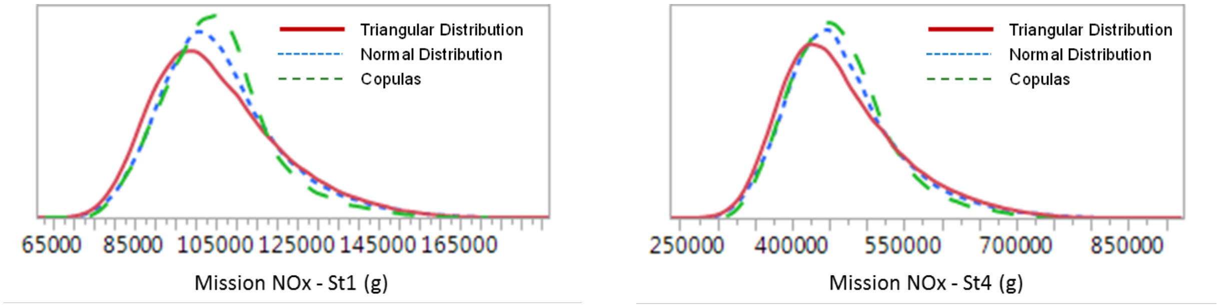


Figure D-2. Comparison of Histograms of Mission NOx

Table D-21. MCS Results for Mission NOx

	Mission NOx - St1 (g)			Mission NOx - St4 (g)		
Summary Statistics	Triangular	Gaussian	Copulas	Triangular	Gaussian	Copulas
Mean	105150.24	105834.42	104867.21	465931.31	467825.75	463925.63
Std Dev	15793.695	14905.87	12981.991	80225.189	76158.887	67081.142
Change in Std Dev due to Correlation	NA	DATUM	-13%	NA	DATUM	-12%

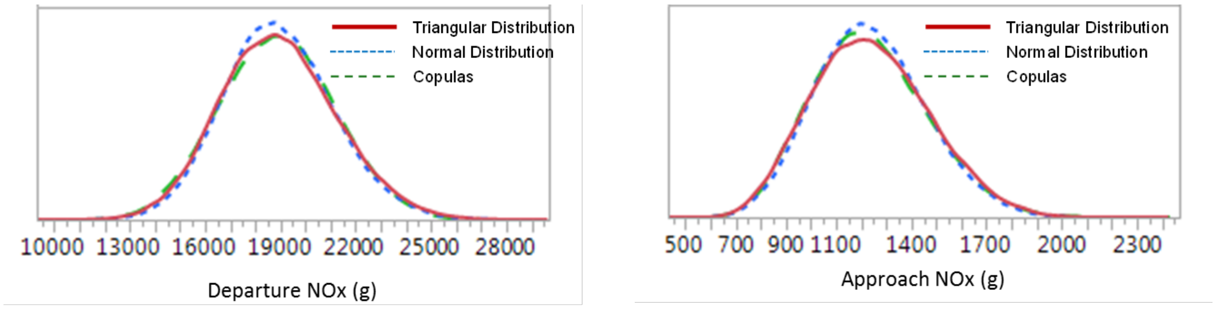


Figure D-3. Comparison of Histograms of Terminal NOx

Table D-22. MCS Results for Terminal NOx

	Departure NOx (g)			Approach NOx (g)		
Summary Statistics	Triangular	Gaussian	Copulas	Triangular	Gaussian	Copulas
Mean	18924.919	18933.22	18878.787	1239.8046	1238.2941	1235.8474
Std Dev	2337.3185	2212.9304	2292.2649	233.69805	220.786	230.26084
Change in Std Dev due to Correlation	NA	DATUM	4%	NA	DATUM	4%

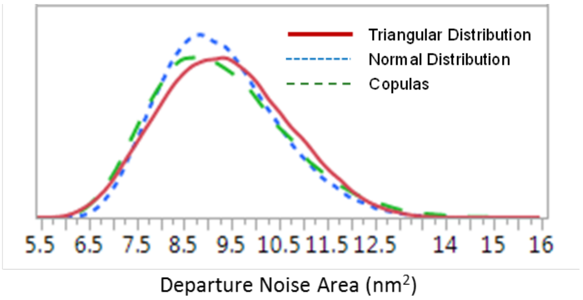


Figure D-4. Comparison of Histograms of Departure Noise

Table D-23. MCS Results for Departure Noise 80dB Contour Area

	Departure Noise Area (nm^2)		
Summary Statistics	Triangular	Gaussian	Copulas
Mean	9.3555372	9.2503272	9.2639181
Std Dev	1.3298128	1.2338656	1.3927785
Change in Std Dev due to Correlation	NA	DATUM	13%

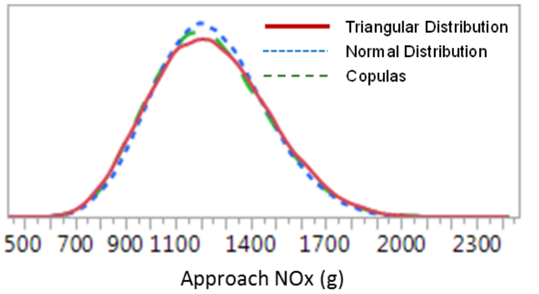


Figure D-5. Comparison of Histograms of Approach Noise 80dB Contour Area

Table D-24. MCS Results for Approach Noise

	Approach Noise Area (nm^2)	
Summary Statistics	Triangular	Gaussian
Mean	5.2354923	5.2359414
Std Dev	0.5772261	0.5521621

D.7 Total Sensitivity Analysis Results of a Small Twin Aisle Aircraft

Table D-25. TSI for Mission Fuel at Stage Length 1

Input Parameter	Total_FB [kg]_St1	
	Main Effect	Total Effect
BADA/FUEL/CF2	0.679	0.855
BADA/FUEL/CF1	0.035	0.074
BADA/FUEL/CFCR	0.023	0.048
BADA/COEFF_CD0	0.015	0.03
BADA/WING_AREA	0.014	0.03
BADA/CR_MACH	0.013	0.028
BADA/CL_MACH	0.009	0.018
BADA/THRUST/TDL	0.005	0.011
ANP/FLAP/COEFF_C_D/DEP_1+F	0.005	0.01
BADA/COEFF_CD2	0.005	0.01

Table D-26. TSI for Mission Fuel at Stage Length 4

Input Parameter	Total_FB [kg]_St4	
	Main Effect	Total Effect
BADA/FUEL/CF2	0.663	0.81
BADA/CR_MACH	0.029	0.061
BADA/FUEL/CF1	0.027	0.055
BADA/FUEL/CFCR	0.025	0.052
BADA/CL_MACH	0.019	0.041
BADA/COEFF_CD0	0.014	0.029
BADA/WING_AREA	0.012	0.026
BADA/COEFF_CD2	0.005	0.009

Table D-27. TSI for Mission NOx at Stage Length 1

Input Parameter	Total_NOx [g]_St1	
	Main Effect	Total Effect
BADA/FUEL/CF2	0.616	0.71
EN/NOX_REI_CO	0.096	0.16
BADA/FUEL/CF1	0.025	0.049
BADA/FUEL/CFCR	0.015	0.031
BADA/CL_MACH	0.008	0.016
EN/NOX_REI_AP	0.008	0.016
BADA/CR_MACH	0.007	0.015
BADA/WING_AREA	0.006	0.013
Temperature (F)	0.006	0.012
BADA/COEFF_CD0	0.005	0.011
EN/NOX_REI_TO	0.004	0.009

Table D-28. TSI for Mission NOx at Stage Length 4

Input Parameter	Total_NOx [g]_St4	
	Main Effect	Total Effect
BADA/FUEL/CF2	0.626	0.711
EN/NOX_REI_CO	0.04	0.076
EN/NOX_REI_AP	0.03	0.056
BADA/CL_MACH	0.021	0.043
BADA/CR_MACH	0.02	0.041
BADA/FUEL/CF1	0.019	0.037
BADA/FUEL/CFCR	0.018	0.036
BADA/COEFF_CD0	0.008	0.016
BADA/WING_AREA	0.008	0.015
Temperature (F)	0.004	0.009

Table D-29. TSI for Departure NOx

Input Parameter	Departure_NOx [g]_St4	
	Main Effect	Total Effect
BADA/FUEL/CF2	0.176	0.291
EN/NOX_REI_TO	0.129	0.252
ANP/FLAP/COEFF_C_D/DEP_1+F	0.095	0.168
EN/NOX_REI_CO	0.06	0.126
BADA/FUEL/CF1	0.046	0.096
ANP/THRUST/COEFF_E/T	0.038	0.094
ANP/FLAP/COEFF_B/DEP_1+F	0.016	0.035
Temperature (F)	0.013	0.029
Headwind	0.01	0.021
EN/UA_RWF_TO	0.008	0.019
EN/UA_RWF_CO	0.006	0.014
SLP Pressure	0.006	0.013
BADA/CR_MACH	0.005	0.012
BADA/COEFF_CD0	0.005	0.01

Table D-30. TSI for Approach NOx

Input Parameter	Approach_NOx [g]_St4	
	Main Effect	Total Effect
ANP/FLAP/COEFF_R/APP_FULL_D	0.625	0.707
Headwind	0.053	0.094
EN/NOX_REI_ID	0.054	0.093
EN/NOX_REI_AP	0.029	0.062
BADA/FUEL/CF2	0.015	0.031
BADA/FUEL/CF1	0.009	0.019
BADA/CR_MACH	0.005	0.01
BADA/COEFF_CD0	0.004	0.009

Table D-31. TSI for Departure 80dB Contour Area

Dep_80db_area_St4 [nmi^2]		
Input Parameter	**Main Effect**	**Total Effect**
Delta_NPD	0.637	0.74
ANP/WEIGHT/DEP	0.063	0.116
ANP/THRUST/COEFF_E/C	0.041	0.083
ANP/FLAP/COEFF_C_D/DEP_1+F	0.027	0.054
ANP/THRUST/COEFF_E/T	0.007	0.015
SLP Pressure	0.007	0.014
ANP/THRUST/COEFF_GA/C	0.005	0.011
ANP/FLAP/COEFF_R/DEP_ZERO	0.005	0.011

Table D-32. TSI for Departure 80dB Contour Width

Dep_80db_width_St4 [nmi]		
Input Parameter	**Main Effect**	**Total Effect**
ANP/THRUST/COEFF_E/T	0.311	0.459
Delta_NPD	0.248	0.39
ANP/FLAP/COEFF_C_D/DEP_1+F	0.079	0.154
ANP/THRUST/COEFF_F/T	0.014	0.029
Headwind	0.005	0.009
ANP/WEIGHT/DEP	0.004	0.009
ANP/THRUST/COEFF_GA/T	0.004	0.009

Table D-33. TSI for Departure 80dB Contour Length

Dep_80db_length_St4 [nmi]		
Input Parameter	**Main Effect**	**Total Effect**
Delta_NPD	0.373	0.522
ANP/WEIGHT/DEP	0.21	0.338
ANP/THRUST/COEFF_E/T	0.026	0.053
ANP/THRUST/COEFF_E/C	0.02	0.043
Headwind	0.018	0.037
SLP Pressure	0.014	0.029
ANP/FLAP/COEFF_R/DEP_ZERO	0.013	0.027
ANP/FLAP/COEFF_C_D/DEP_1+F	0.012	0.024
Elevation	0.008	0.017
ANP/FLAP/COEFF_B/DEP_1+F	0.007	0.015
ANP/THRUST/COEFF_GA/C	0.006	0.012
ANP/THRUST/COEFF_F/T	0.005	0.009

Table D-34. TSI for Approach 80dB Contour Area

App_80db_area_St4 [nmi^2]		
Input Parameter	**Main Effect**	**Total Effect**
Delta_NPD	0.812	0.929
Headwind	0.02	0.042
SLP Pressure	0.014	0.029
ANP/FLAP/COEFF_R/APP_FULL_D	0.008	0.017
Elevation	0.008	0.016

Table D-35. TSI for Approach 80dB Contour Width

App_80db_width_St4 [nmi]		
Input Parameter	**Main Effect**	**Total Effect**
Delta_NPD	0.719	0.895
Headwind	0.03	0.064
ANP/FLAP/COEFF_R/APP_FULL_D	0.027	0.058
SLP Pressure	0.013	0.027
Elevation	0.009	0.019
ANP/WEIGHT/APP	0.008	0.016

Table D-36. TSI for Approach 80dB Contour Length

App_80db_length_St4 [nmi]		
Input Parameter	**Main Effect**	**Total Effect**
Delta_NPD	0.728	0.97
SLP Pressure	0.021	0.044
Headwind	0.02	0.042
Elevation	0.011	0.024
Temperature (F)	0.005	0.009

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