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13. ABSTRACT (Maximum 200 words)
The Federal Aviation Administration, Office of Environment and Energy (FAA-AEE) has developed the Aviation Environmental Design Tool (AEDT) version 2a software system with the support of the following development team: FAA, National Aeronautics and Space Administration (NASA), U.S. DOT Volpe National Transportation Systems Center (Volpe Center), ATAC Corporation, Metron Aviation, Wyle Laboratories, CSSI, Inc., Foliage, MIT, and Georgia Tech. AEDT 2a is designed to dynamically model aircraft performance in space and time to compute aircraft noise, emissions, and fuel burn. This document is the AEDT 2a Service Pack 2 Uncertainty Quantification Supplemental Report, which compares changes between AEDT 2a and Service Pack 2 based on verification and validation and capability demonstrations of the software's methodologies and performance in comparison with legacy models.

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1 Introduction

The inaugural version of the Federal Aviation Administration (FAA) Aviation Environmental Design Tool Version 2a (AEDT 2a) was released in March 2012. The companion AEDT 2a Uncertainty Quantification Report documents the methodologies used in AEDT 2a as well as a thorough expert review, verification and validation, capability demonstration, parametric uncertainty/sensitivity analysis and other relevant testing conducted during the development of AEDT 2a.

Since the initial release, two Service Pack updates to AEDT 2a have been released. The intent of this report is to document the motivations of each Service Pack and to supplement the original Uncertainty Quantification Report by documenting and comparing changes in the uncertainty quantification (UQ) analysis of AEDT 2a Service Pack 2.

The AEDT 2a Service Pack 1 (SP1) was released on June 29, 2012. This service pack was driven by the need to address issues affecting aircraft performance, emissions reports, and weather. The issues fixed in this service pack occurred in specific use cases and did not warrant an update to the Uncertainty Quantification Report. A summary of changes in SP1 are included in Section 1.1.

The AEDT 2a Service Pack 2 (SP2), released on February 15, 2014, was motivated by a combination of AEDT optimization improvements and user feedback. The update addresses issues affecting altitude control, AEDT standard input file (ASIF), and terrain processing as well as the computational speed of AEDT 2a for the Optimization of Airspace & Procedures in the Metroplex (OAPM) use case. A supplemental UQ effort was performed to build confidence in the tool's capability, fidelity, and connection to the precedent of the legacy tool it replaces. The UQ effort for this service pack consists of verification and validation (V&V) and capability demonstrations of the software's methodologies and performance in comparison with legacy models. It does not include expert review as issues were identified through use of AEDT2a by experts. It does not include parametric uncertainty/sensitivity analysis because the changes in SP2 due not impact the original analyses. A summary of changes in SP2 are included in Section 1.2.

1.1 Changes in AEDT 2a SP1

The following changes are included in SP1. A full list of changes is included in the SP1 release notes.

- Resolved an issue with "Use Single Airport Weather" option.
- Resolved issues with emissions report and added volatile organic compounds (VOC), total organic gases (TOG), and non-methane hydrocarbons (NMHC) in emissions report.
- Resolved an issue with impact evaluation where it did not include operation count in detailed noise SEL.
- Resolved an issue in Change Analysis Report not using annualization weightings for each individual case.
- Resolved flight performance issues.
- Resolved an issue with stage "M" profiles not assigned appropriate distance for calculating default cruise altitude.

1.2 Changes in AEDT 2a SP2

The following changes are included in SP2. A full list of changes is included in the SP2 release notes.

- Resolved issues with Legacy altitude control flight performance algorithms that could result in infinite loops.
- Resolved an altitude control error that disallowed input altitude control values above BADA-defined maximums even when the control type was AtOrBelow.
- Resolved an issue where flights with altitude controls in a study with a user specified cut-off altitude previously required at least one control point to be below the cut-off altitude in order to be processed.
- Resolved an issue in ASIF import where altitude control codes were being overwritten.
- Updated the ASIF import process to greatly reduce import times for large studies.
- Removed errant final procedure steps in cases where AEDT abandoned the standard procedure for the flight during altitude control processing that resulted in misleading error messages.
- Fixed invalid level procedure steps used to reach altitude controls that resulted in misleading error messages.
- Resolved an error that allowed results that did not conform to the specified altitude controls due to incorrect tolerance checking.
- Revised error message reporting for flights with altitude controls that are unachievable for the assigned aircraft; the revised messages are easier to interpret.
- Changed noise-power-distance (NPD) operational mode assignment rules for sensor path operations to be consistent with all other 2a operation types, using departure NPD data for all flight path segments with altitudes above 10,000 ft. above field elevation (AFE).
- Revised the expiration date for airport records in STUDY_NIRS.
- Improved error message reporting for studies run using terrain; error messages now attempt to guide the user to the cause of their problem.
- Resolved stability issues in the terrain module that compromised the ability to produce acoustic results for a study run using terrain.
- Includes an updated user guide with recommendations for fixing flights that fail to fly in AEDT.

2 Validation and Verification

The AEDT 2a Uncertainty Quantification Report[1] provided a section on Validation and Verification (V&V). The section consisted of a set of activities that examined how well AEDT 2a met its design objectives.

The V&V section for this supplemental UQ report examines aircraft flight performance issues addressed in SP2 and a detailed noise comparison of SP2 and NIRS.

2.1 Aircraft Flight Performance Issues Addressed in AEDT 2a SP2

This section addresses aircraft flight performance calculation issues from AEDT 2a (2a) that were addressed in AEDT 2a SP2 (SP2). Each issue is described along with an explanation of the fix and a description of the testing done to demonstrate that the issue is fixed. All of the issues described rarely

[1] Aviation Environmental Design Tool (AEDT) 2a Uncertainty Quantification Report, February 2014, DOT/FAA/AEE/2013-03

occur in AEDT, and were only discovered through testing and analysis utilizing studies not available prior to the 2a release. The majority of the issues were discovered when running a test study derived from an FAA Optimization of Airspace and Procedures in the Metroplex (OAPM) environmental analysis. Therefore a majority of the fixes for these issues were validated using selected flights from that OAPM test study which exhibited the specific issues in AEDT.

2.1.1 Departure flights with a single "at or below" altitude control at the end may fail

Departure flights with a single "at or below" altitude control, defined at the very last track point, may produce error messages during flight performance calculations in 2a. In theory, these types of flights should not produce errors in AEDT – the flight performance calculations should always be able to generate a departure trajectory that is below a single specified altitude at a single specified geographic location. There are three different causes of such flight failures in 2a, which are each addressed separately below.

2.1.1.1 En-Route weather validation failures

Departure flights with a single "at or below" altitude control, defined at the very last track point with an altitude value greater than 10,000 ft. Above Field Elevation (AFE), may produce error messages during weather validation in 2a. This occurs in 2a due to a unit conversion problem which causes 2a to attempt to obtain weather data at an unrealistic altitude, which correctly fails. SP2 corrects this unit conversion issue and eliminates these instances of weather validation failures.

Verification testing for this issue was performed using 21 flight operations from the OAPM test study. In 2a, all 21 of these flights fail due to the weather validation issue. These flights all run correctly without errors in SP2.

2.1.1.2 En-Route maximum attainable altitude failures

Departure flights with a single "at or below" altitude control, defined at the very last track point with an altitude value greater than 10,000 ft. AFE, may produce error messages during maximum attainable altitude calculations in 2a. This occurs in 2a due to remnants of the Noise Integrated Routing System (NIRS) legacy software code that were retained but not directly used to calculate portions of flight trajectories above 10,000 ft. AFE. This code, using the ECAC Doc 29 performance model, occasionally calculates trajectory points at altitudes considered unattainable within the BADA performance model. Improper retention of this trajectory information in 2a causes flight failures during the BADA calculation process. Removal of this Legacy code dependence for altitude control calculations at altitudes above 10,000 ft. AFE in SP2 eliminates this problem.

Verification testing for this issue was performed using 8 flight operations from the OAPM test study. In 2a, all 8 of these flights fail during maximum attainable altitude calculations. These flights all run correctly without errors in SP2.

2.1.1.3 Terminal Area "not enough thrust to climb" failures

Departure flights with a single "at or below" altitude control, defined at the very last track point with an altitude value less than 10,000 ft. AFE, may fail in 2a because they cannot reach a terminal-area (i.e. altitude value below 10,000 ft. AFE) "at or below" altitude control. 2a flight calculation logic requires the use of a climb procedure step, with a minimum of a half a degree climb angle, to be used to calculate trajectory segments starting at altitudes below and attempting to satisfy "at or below" altitude controls. Therefore, 2a flights fail in these instances with an “at or below” altitude control set at an altitude higher than the ECAC Doc 29 performance model determines the aircraft can fly, but still below 10,000 ft AFE. It is rare that an aircraft in AEDT cannot fly to an altitude greater than 10,000 ft. AFE, however certain aircraft types, most notably the 1900D, are susceptible to this issue. SP2 addresses this issue by allowing flights to maintain a constant altitude rather than climb in order to meet the intent of the specified “at or below” altitude control.

Verification testing for this issue was performed using 11 flight operations from the OAPM test study. In 2a, all 11 of these flights fail with a “not enough thrust to climb” error. These flights all run correctly without errors in SP2.

Figure 1 shows altitude versus ground track distance values, as well as the “at or below” altitude control, for a test flight using aircraft type 1900D where SP2 allows the flight to level-off rather than force it to climb to meet the altitude control constraint.

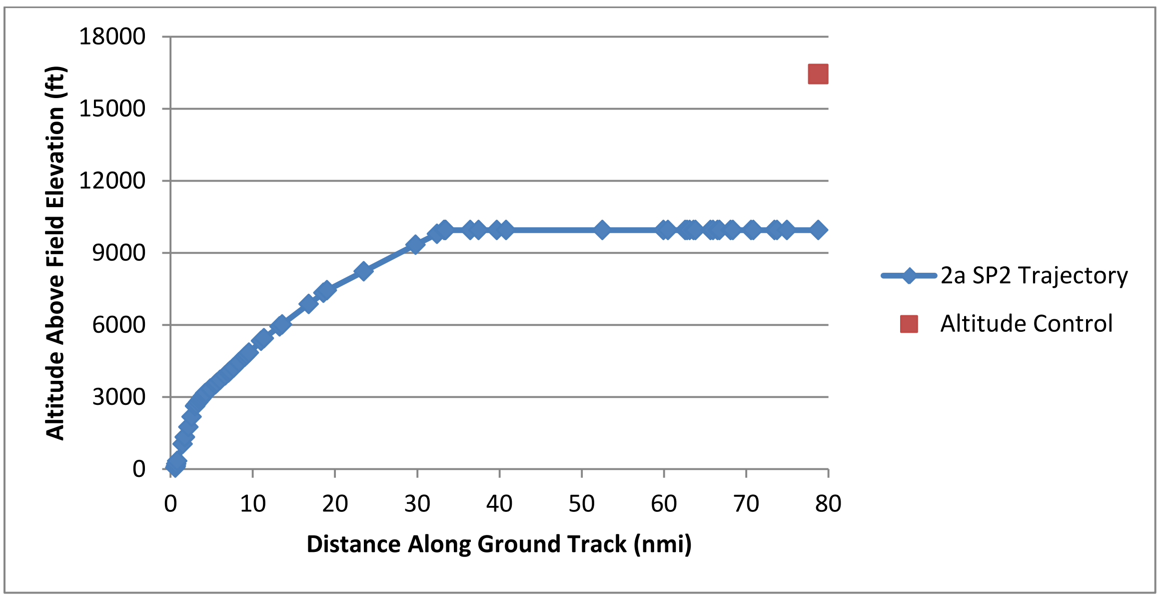


Figure 1 AEDT 2a SP2 Test Flight of Aircraft Type 1900D

2.1.2 Altitude control tolerances violated

2a can calculate flight trajectories that are more than the specified altitude tolerance away from the defined altitude control value. For example, it can produce a warning message like: “For Event 100000 on track 1, the aircraft failed to meet altitude control 'AtOrBelow' at the altitude 27,193 ft, however obtaining an altitude of 30,665.2003509166 ft, it remained within the allowable altitude tolerance of (300 ft). The flight will continue to be processed.” In this example the trajectory misses the altitude control value by over 3,000 feet while the allowable tolerance is only 300 feet, yet the flight is successfully processed. SP2 corrects the values so that flights either meet their altitude constraints within the specified tolerances or produce an error message.

Figure 2 contains altitude versus ground track distance values for an example MD82 flight that produced the warning message above, along with its “at or below” altitude controls. In this example, 2a flies to the target altitude of the final altitude control early on, and then continues to climb, thereby violating the intent of the altitude control. SP2 correctly stays at altitude values below the final "at or below" altitude control.

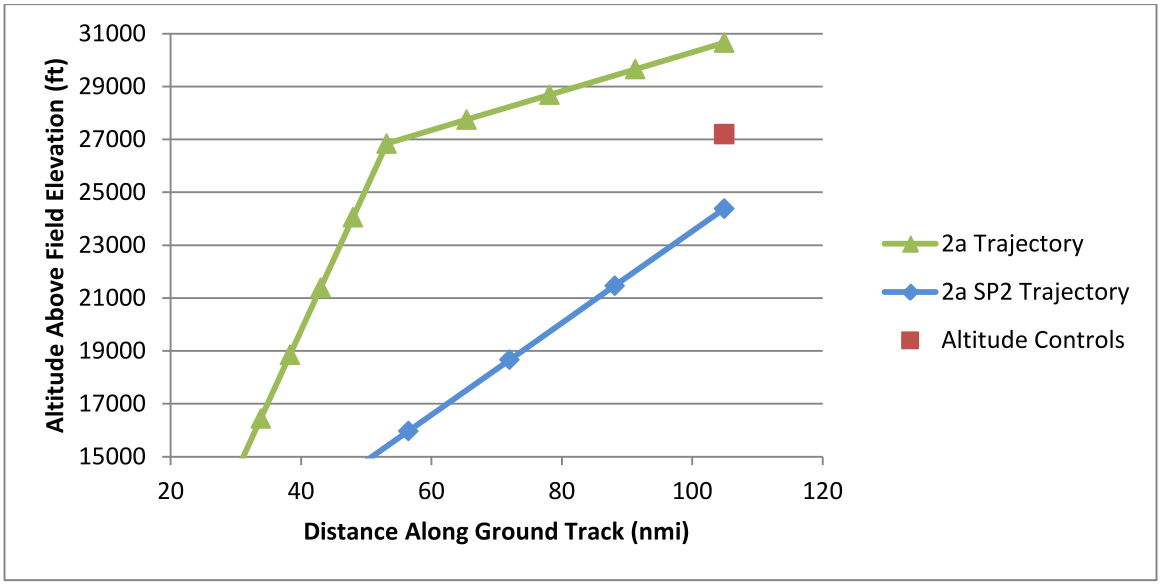


Figure 2 Comparison of 2a and SP2 Test Flights of Aircraft Type MD82

2.1.3 Flight performance calculations may encounter infinite loops

In 2a, the flight performance calculation process may continue indefinitely when calculating flights using altitude controls. This is the same issue that was encountered in the NIRS legacy tool after the 2a release, and occurs in the same source code. To date, it has only been encountered in a small number of OAPM test study flights in either NIRS or 2a despite their extensive use. As was done in NIRS to correct the issue, counters were added in SP2 that trigger exits from flight performance calculations when iterative loops are unable to converge. Flights that hit any of these triggers will result in error messages stating "Too many iterations" followed by the location of the occurrence during the calculation process.

Verification testing for this issue was performed using 4 flight operations from the OAPM test study. In 2a, each of the 4 flights encounters the issue and runs indefinitely. These flights all produce a "Too many iterations" error message in SP2. When this error is encountered, the altitude control definitions for each affected flight must be modified in order to be successfully processed in SP2.

2.1.4 Flights containing "at or below" altitude control values above BADA-defined maximums fail

Flights that include an "at or below" altitude control value above the BADA-defined maximum altitude for the specified aircraft type produce error messages in 2a. This should not be the case as "at or below" dictates that the calculated trajectory can remain below BADA-defined maximum altitude and still satisfy the constraint. 2a incorrectly filters these flights out along with similar flights using "at" or "at or above" altitude controls rather than trying to calculate trajectories that meet the constraints in the "at or below" case. In SP2, "at or below" altitude control values are allowed to be above BADA-defined maximums.

Figure 3 shows the modified SP2 behavior using a sample OAPM test study flight using the GASEPF aircraft type. In 2a this flight fails with the message, “The altitude control at 12560 ft is higher than the BADA maximum operating altitude of 12000 ft.” SP2 does not apply this check for “at or below” altitude controls and produces the trajectory shown.

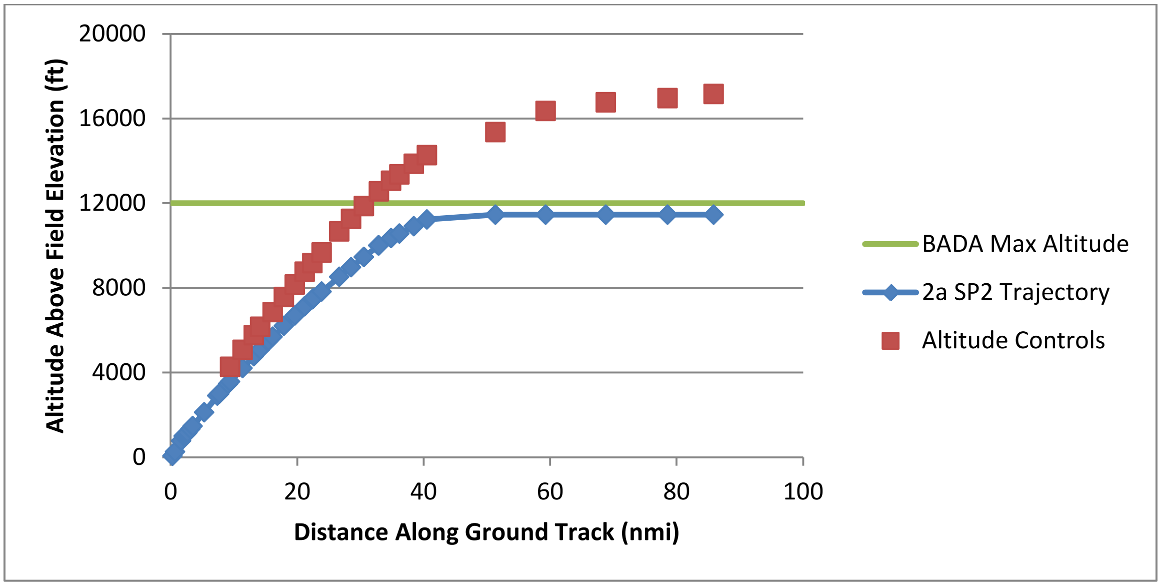


Figure 3 AEDT 2a SP2 Test Flight of Aircraft Type GASEPF

2.1.5 Flights with altitude controls fail when none of the altitude controls are below the altitude cutoff

2a incorrectly requires altitude control flights to have at least one altitude control defined below the specified altitude cutoff value. This limitation is not required and has been removed for SP2.

Figure 4 shows the modified SP2 behavior using a sample OAPM test study flight using the A300-622R aircraft type. In 2a this flight produces the error message “There must be a minimum of one altitude control node between 500 ft AFE and the 18000 ft (MSL) study cutoff altitude”. SP2 does not apply this check and produces the trajectory shown.

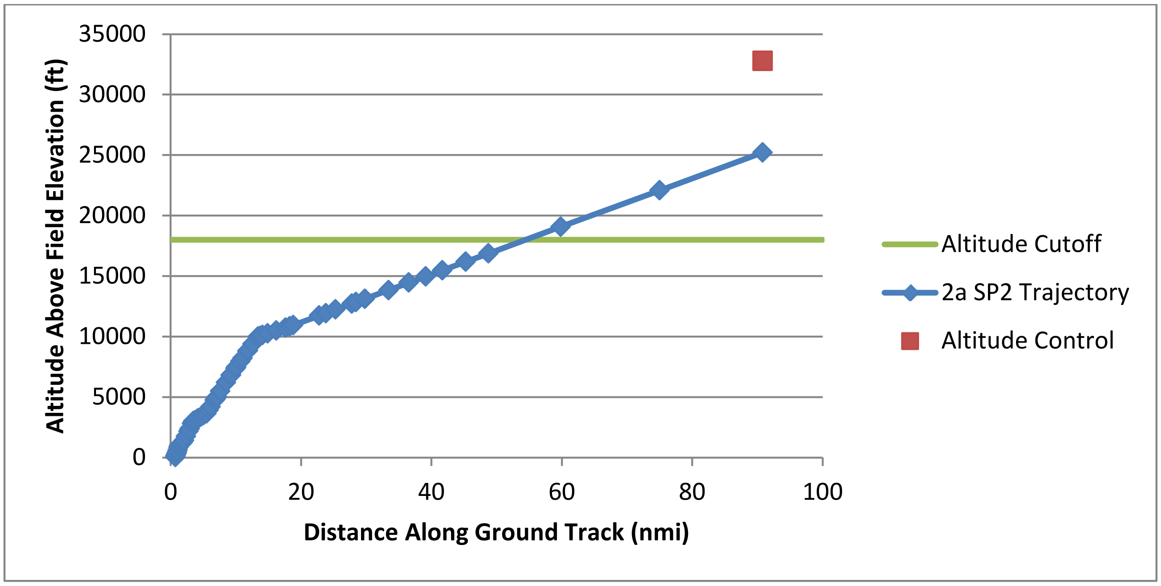


Figure 4 AEDT 2a SP2 Test Flight of Aircraft Type A300-622R

2.1.6 Error messages difficult to interpret

Some 2a error messages are difficult to interpret; especially error messages that are produced by flights with altitude controls that are unachievable for the assigned aircraft type. SP2 includes revised error messages that are easier to interpret. The revised error messages, along with their triggers, are described in detail in Appendix K of the AEDT 2a SP2 User's Guide.

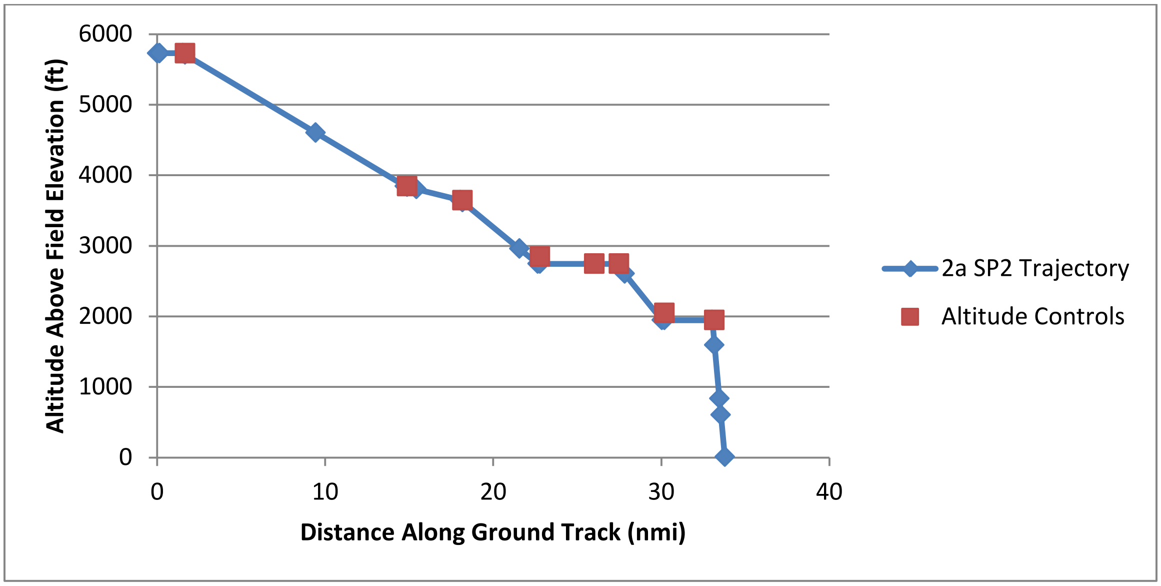
2.1.7 Invalid procedure steps may result in flight failures and misleading error messages

While calculating flights with altitude controls, 2a continues to calculate STANDARD profile procedure steps even after it has abandoned the STANDARD procedure to meet altitude control constraints that the STANDARD procedure cannot meet. This behavior, while consistent with the NIRS Legacy tool, can result in calculated states that are incompatible with the rest of the trajectory, thereby producing flight failures and error messages. There are two different resultant issues in 2a which are each addressed separately below.

2.1.7.1 Invalid descend step failures

In some instances, the errant calculation of extra STANDARD arrival procedure steps in 2a results in misleading error messages during descent step calculations. In these instances, a descent segment calculation starts at an altitude lower than it should, lower even than the target descent altitude. This produces a situation where AEDT is forced to calculate a descend procedure step with increasing altitude, yielding flight failures and misleading error messages such as “Next altitude 1500 must be higher than descend start altitude of 1686.4.”

SP2 removes the errant final procedure steps where AEDT abandons the STANDARD procedure and this issue no longer occurs. Figure 5 (two plots below) shows the altitude controls and resultant calculated trajectory from SP2 for the same flight that produced the descend step error message above in 2a. The flight is a BEC58P arrival. The first covers the entire flight; the second zooms in on the segment that caused the error in 2a.



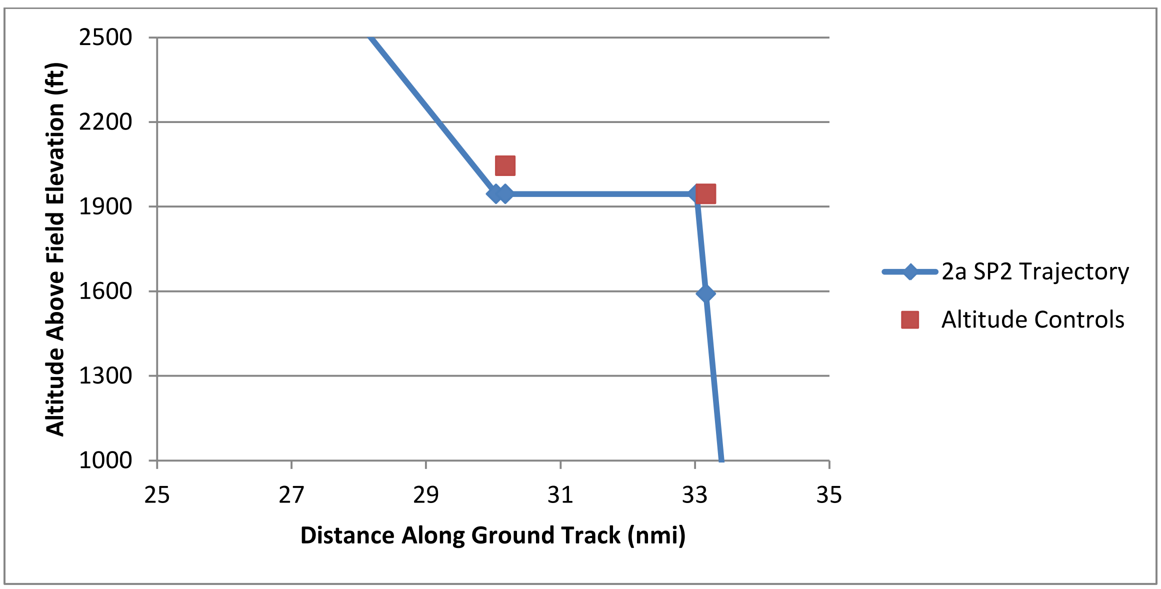


Figure 5 AEDT 2a SP2 Test Arrival of Aircraft Type BEC58P; entire flight (top), zoomed (bottom)

2.1.7.2 Invalid level step failures

The errant calculation of extra STANDARD arrival procedure steps in 2a also results in flight failures and misleading error messages during level step calculations. In these instances, an extra level step from the STANDARD arrival procedure gets calculated starting at an altitude that differs from the procedure definition, but using the target ending altitude from the procedure definition. This produces a situation where AEDT is forced to calculate a level procedure step with a change in altitude, yielding misleading error messages such as “Next altitude 3000 must equal level start altitude 3122.40023803711.”

SP2 removes the errant final procedure steps where AEDT abandons the STANDARD procedure and this issue no longer occurs. Figure 6 shows the altitude controls and resultant calculated trajectory from SP2 for the same flight that produced the level step error message in 2a. The flight is an A320-232A arrival. The first covers the entire flight; the second zooms in on the segment that caused the error in 2a.

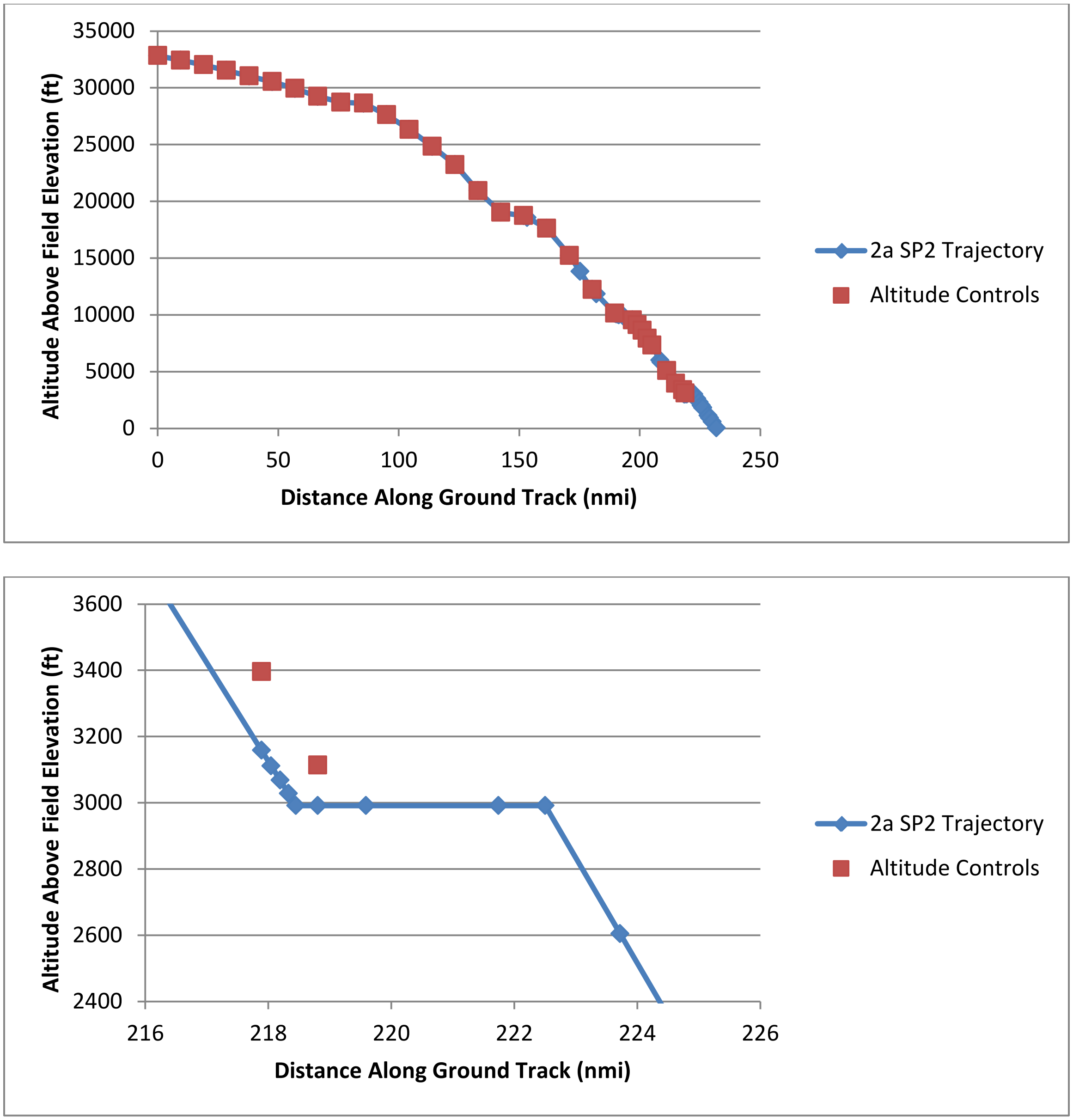


Figure 6 AEDT 2a SP2 Test Arrival of Aircraft Type A320-232A; entire flight (top), zoomed (bottom)

2.1.8 Flights fail when defined with trip distances not available within the AEDT system database

2a does not allow a flight to be processed when the defined trip distance is inconsistent with the trip distances available for the specified aircraft type within the AEDT system database. When a flight operation is defined using an Origin/Destination airport pair rather than a directly specified stage length, 2a calculates the Great Circle distance between the two airports to determine the trip distance. It then attempts to find an available flight profile with a stage length matching that calculated trip distance. If a matching stage length is not available, it attempts to find a flight profile at the next lowest stage length. If that stage length is also not available, then 2a produces an error message.

SP2 has relaxed constraints on finding and assigning stage length assignments relative to 2a, matching the behavior of the NIRS legacy tool. Rather than producing an error message if a stage length within one stage length increment of the calculated trip distance cannot be found, SP2 will continue to search for sequentially decreasing stage length values until one is found. When this occurs, a warning message is given and the flight is processed.

Verification testing for this issue was performed using 10 flight operations defined with Origin/Destination airport pairs that yield calculated trip distances greater than that matching the highest available stage length for the defined aircraft types. In 2a, each of the 10 flights produces an error message and is not processed. In SP2, these flights all produce a warning message but are successfully processed. As an example, a flight between KIAD and KBUR yielding a 1,980 nmi trip distance corresponding with stage length 4 and using an IA1125 in 2a produces the error message "Attempted to use a stage: 3 profile for air operation: 17. This profile does not exist for aircraft id:IA1125, Stage length: 3, and operation type: D." In SP2, this same flight produces the warning message "The stage length for the profile for air operation: 17 for aircraft id:IA1125, was changed to, Stage length: 1 (from original Stage 4), but event will still be processed."

2.1.9 Conclusion

Several flight performance calculation issues from AEDT 2a that were discovered using newly developed test studies were addressed in AEDT 2a SP2. Relative to 2a, SP2 successfully runs flights that previously incorrectly produced error messages, calculates trajectories that better match altitude control definitions, allows for greater flexibility in stage length definitions, and provides more detailed information to users on how they can address valid flight performance failures.

2.2 Detailed Noise Comparison of AEDT 2a SP2 and NIRS

This section documents the results from carrying out the detailed comparison of noise between AEDT 2a SP2and NIRS. Some of the same detailed comparisons of noise between 2a and NIRS for the original UQ were also performed between SP2 and NIRS to examine any differences in the comparative results and provide explanations for those differences. Note that the intent was not to exhaustively reproduce all the comparisons that were performed in the 2a UQ report, but instead select a test for comparison that will exercise the components of both tools to highlight potential changes in flight performance and noise computation between 2a and SP2 in relation to the baseline legacy tool.

The changes implemented in SP1 and SP2 that could have potentially affected the outcomes of this particular comparison are:

- Resolution of an altitude control error that disallowed input altitude control values above BADA-defined maximums even when the control type was AtOrBelow
- Resolution of an issue where flights with altitude controls in a study with a user specified cut-off altitude previously required at least one control point to be below the cut-off altitude in order to be processed
- Resolution of an issue with stage "M" profiles not assigned appropriate distance for calculating default cruise altitude
- Resolution of an issue in ASIF import where altitude control codes were being overwritten

- Resolution of an error that allowed results that did not conform to the specified altitude controls due to incorrect tolerance checking
- Resolution of stability issues in the terrain module that compromised the ability to produce acoustic results for a study run using terrain

2.2.1 Methodology and Results

Table 1: Description of Detailed Tests details the set of five different tests carried out originally with 2a and NIRS and now, for the purposes of this supplemental report, with SP2 and NIRS. The table also details the different project test conditions used for each test. In order to affect valid comparisons, the input data, project settings, and initial conditions were identical in all cases. For complete details on the tests and the parameters employed, please refer to the AEDT 2a Uncertainty Quantification Report.

Table 1: Description of Detailed Tests

Test #	Purpose of Test	Project Test Conditions
1	Environmental Parameters Test: Analyze environmental effects of temperature, pressure, humidity, altitude, and runway elevation on flight performance and noise exposure.	A single procedure-step aircraft, one which uses procedure-steps for profile generation, is flown from a low elevation New-England hub (NENG) and a high elevation Mountain hub (WEST).
2	Runway Parameters Test: Analyze and isolate runway elevation effects on flight profile performance generation.	A single procedure-step aircraft departs and arrives at three runways, above, at, and below airport elevation using a straight in/out track set.
3	Profile Generation Test: Test flight performance logic for default, custom, and overflight profiles.	All aircraft fly both straight in/out and U-shaped tracks for default, custom, hold down, climbing, and overflight profiles.
4	Terrain Test: Test terrain effects on noise exposure.	A single procedure-step aircraft arrives and departs using both a straight in/out track and U-shaped track from an airport using a custom terrain map which consists of exaggerated cliffs and valleys.
5	Noise Metric Test: Test noise exposure over all available metrics: LAMAX, LAEQN, SEL, DNL, LAEQ, CNEL, LAEQD, TALA, PNLTM, WECPNL, EPNL, TAPNL, NEF, CEXP, TALC, and LCMAX[2].	A set of representative aircraft are flown with arrival and departure operations with a straight in/out track.

In the following section we present comparisons of test results from each of the five individual tests. Specifically we provide results from comparisons of NIRS 7.0b3 with both 2a and SP2 and note any differences.

[2] Federal Aviation Administration, Office of Environment and Energy, *Integrated Noise Model (INM) Version 7.0 Technical Manual*. 2008.

Test 1: Environmental Parameters Test
This test consists of a single 737300 light commercial jet using procedure- step profiles. This aircraft test is used to test the effects of model parameters (such as environmental factors, elevations, and noise computations) which lie outside of the individual profile state parameters (distance, altitude, speed, and thrust). The aircraft was flown using STANDARD departure and arrival profiles at both Boston (elevation 20' MSL) and Denver (elevation 2431' MSL). Departures were flown to 10,000 ft. AFE and arrivals from 6,000 ft. AFE. The results from the SP2 comparison showed no changes in differences with NIRS in either flight performance or the computed noise when compared to the earlier results from AEDT 2a.

Test 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 used to check that runway elevations are correctly considered for flight performance. In the comparison of NIRS with 2a, the profiles differed by less than 162 feet on average for departures and less than 5 feet on average for arrivals over the default profile sections for the test aircraft. In the comparison of NIRS with SP2, the profiles differed by less than 158 feet on average for departures and less than 5 feet on average for arrivals. The maximum altitude differences as percentages were also nearly identical at about 10%.

Test 3: Profile Generation Test
In this test, different aircraft profile types were used to test flight performance results and confirm that the profile types are appropriately modeled similarly in both AEDT and NIRS. The different kinds of profiles tested were standard profiles, custom (hold-down & climbing) profiles, and overflight profiles. The profile generation test used all of the aircraft in the NIRS database 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. Standard profiles were tested with the 1900D and 737-300 aircraft types, custom profiles were tested with the A300-622R aircraft type, and overflight profiles were tested with the 737-300 and A320-211 aircraft types. The tables below provide comparisons of the average altitude difference seen in the 2a comparisons versus the 2a SP2 comparisons.

Table 2: Profile Generation Test – Standard Profiles

Aircraft Type	Profile Type	Average Altitude Difference (feet)	
		2a vs. NIRS	2a SP2 vs. NIRS
1900D	ARR DEFAULT-1	0	0
	DEP DEFAULT-1	68	59
	DEP DEFAULT-2	65	55
737-300	ARR DEFAULT-1	0	0
	DEP DEFAULT-1	67	63
	DEP DEFAULT-2	68	64
	DEP DEFAULT-3	65	61
	DEP DEFAULT-4	70	66
	DEP ICAO_A-1	70	67
	DEP ICAO_A-2	71	67
	DEP ICAO_A-3	68	64
	DEP ICAO_A-4	71	67
	DEP ICAO_B-1	67	63
	DEP ICAO_B-2	68	64
	DEP ICAO_B-3	65	61
	DEP ICAO_B-4	70	66

Table 3: Profile Generation Test – Custom Profiles

Aircraft Type	Profile Type	Average Altitude Difference (feet)	
		2a vs. NIRS	2a SP2 vs. NIRS
A300-622R	ARR Hold-Down	308	305
	ARR Descend	3	3
	DEP Hold-Down	23	24
	DEP Descend	49	45

Table 4: Profile Generation Test – Overflight Profiles

Aircraft Type	Profile Type	Average Altitude Difference (feet)	
		2a vs. NIRS	2a SP2 vs. NIRS
737700	Climb	653	666
	Descend	692	679
A320-211	Climb	653	666
	Descend	692	679

These comparisons show that the average altitude differences have not changed significantly. It can be expected that the profiles generated by 2a are therefore going to be very similar, if not identical, to those generated by SP2.

Test 4: Terrain Test

The terrain test was designed to evaluate the effects of terrain on the noise computed by AEDT versus that computed by NIRS. This test utilized a custom built set of terrain maps designed to demonstrate and highlight the effects of terrain on noise exposure computations. The terrain maps consist of exaggerated cliffs and valleys that aim to make clear, delineated boundaries between elevation levels in resulting noise exposure maps. The features of this custom terrain are documented in detail in the AEDT 2a Uncertainty Quantification Report. The terrain test used a single procedural-step aircraft, the A320-211, arriving and departing from the 01C runway over a grid set that is covered by the terrain files. Both a straight track and "U" shaped track were analyzed. The test compared the trends in the SEL noise exposure data using the custom terrain.

The following figures present the noise exposure difference-histograms for the comparisons of 2a and SP2 with NIRS. The first figure shows the comparisons of the difference-histograms for the straight departure track and the second figure shows the comparisons for the curved or "U" shaped departure track.

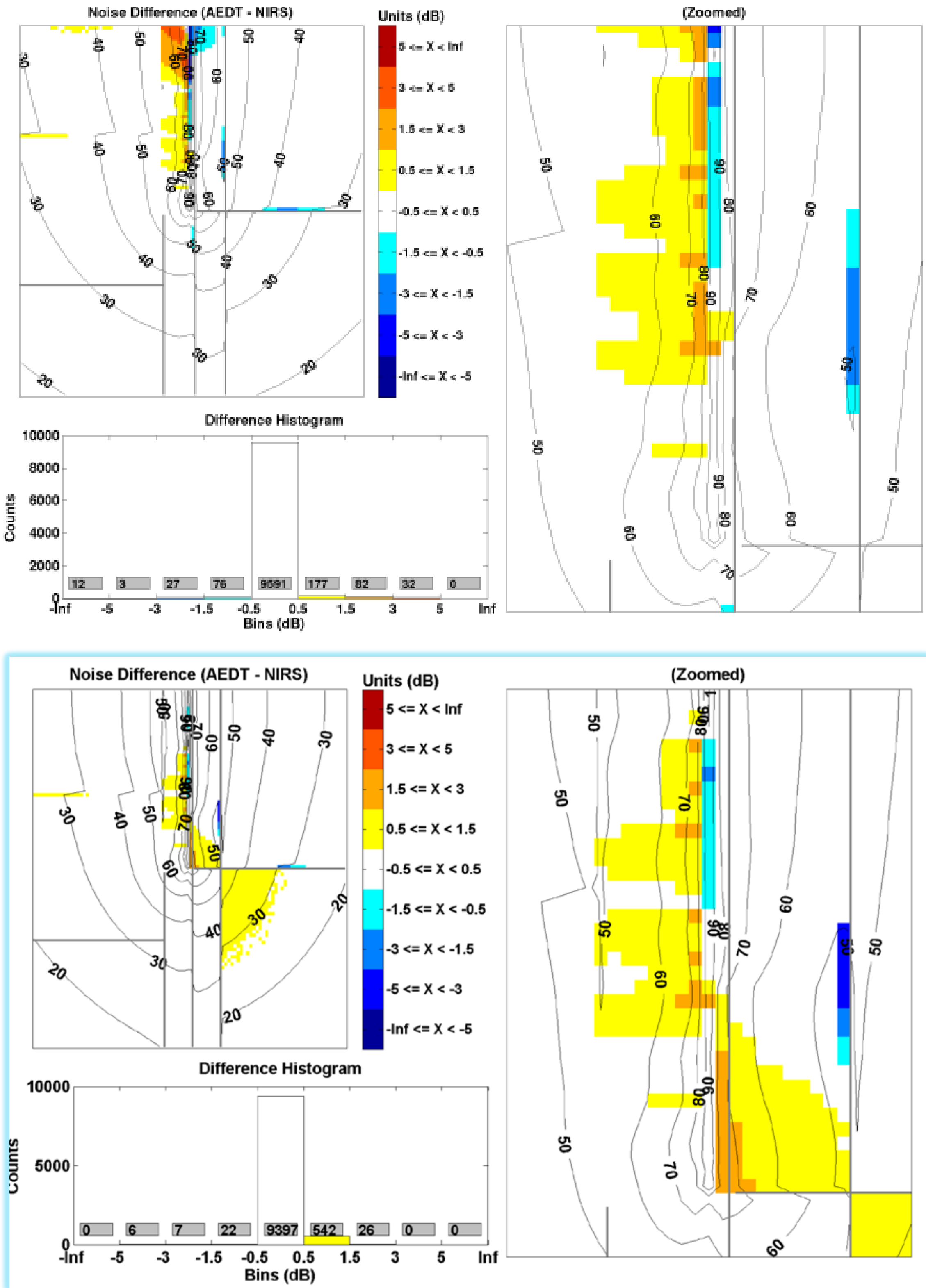


Figure 7: AEDT vs. NIRS Straight Departure Differences with Terrain – 2a (top) vs. SP2 (bottom)

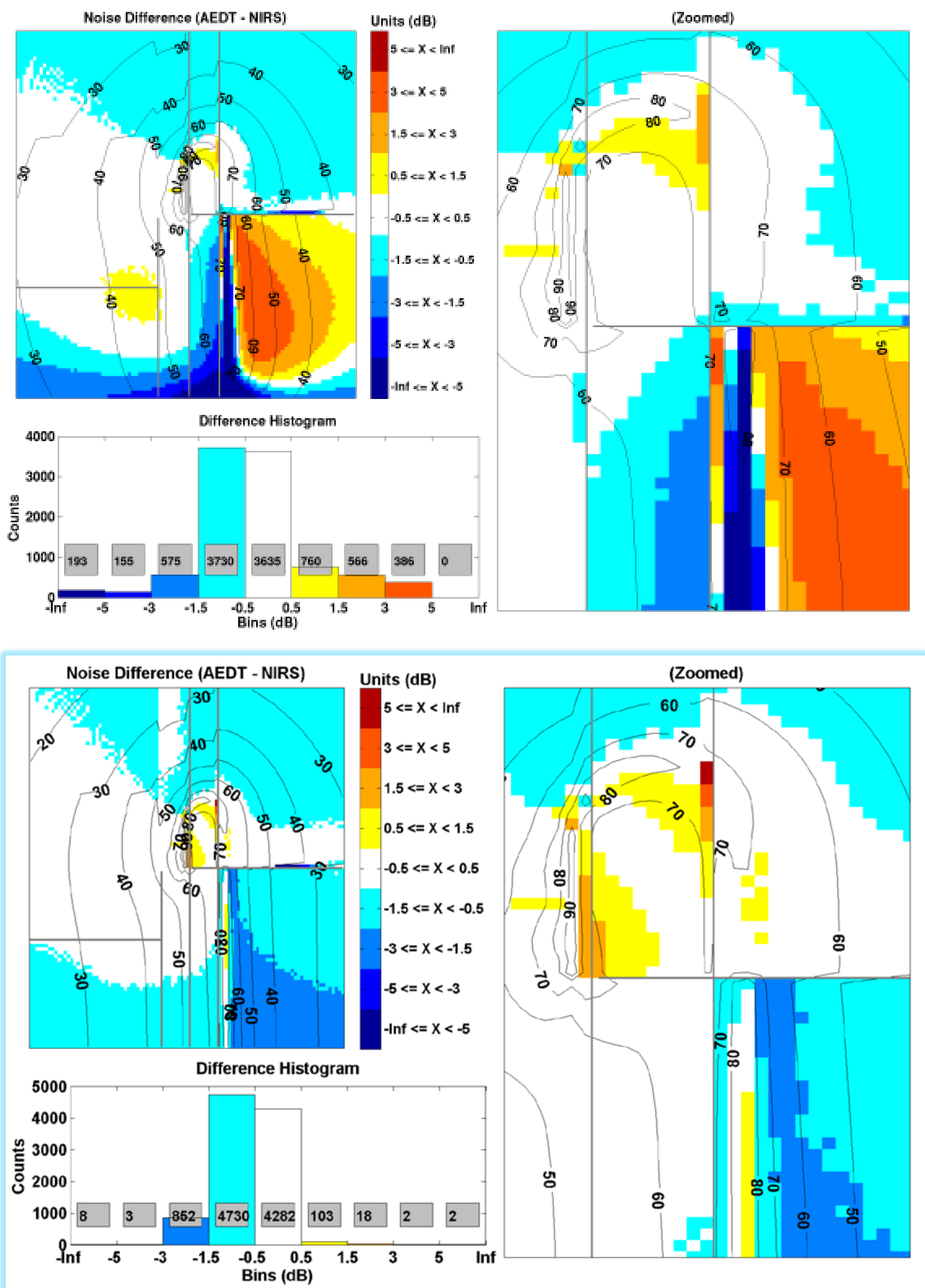


Figure 8: AEDT vs. NIRS Curved Departure Differences with Terrain – 2a (top) vs. SP2 (bottom)

It is expected that differences in noise exposure will be observed between NIRS and AEDT when terrain is applied. This stems from the fact that AEDT and NIRS use different algorithms for interpolating elevations from the terrain map. NIRS computes the elevation at the point of interest by interpolating the terrain elevation at the four corners of the terrain cell into which the point of interest falls. AEDT computes the elevation at the point of interest using the ESRI GIS system, which uses the elevation of the closest terrain point to the point of interest. However, flight and noise modeling differences will also account for differences in noise exposure. In a comparison of the differences observed with 2a compared with NIRS and the differences observed with SP2 compared with NIRS, it can be seen that there are small changes in noise for the straight track. However, with SP2 the curved track sees a greater reduction in the magnitude of differences. It is also possible that improvements to the terrain and acoustic module are a factor in the improvement seen in concurrence of noise results.

Test 5: Noise Metric Test

In the noise metric test, all 16 noise metrics available in both NIRS and AEDT were compared to ensure that no invalid results were produced and that any differences in results were due to intentional differences between the two tools. The metric tests consisted of noise computed on a regular grid for an arrival and departure operation for each of the aircraft in a representative set of 15 aircraft types. The departure operations were simulated at night, giving a penalty for some metrics where the impact of night operations is more heavily weighted. The arrival operations were simulated during the day. Both operations occur on a single runway. The test examined the noise values for each metric supported by both NIRS and AEDT. No flight performance results were analyzed for this test. The original UQ report presented a comparison of the noise contours from 2a and NIRS for selected aircraft types for each of the 16 noise metrics. In addition, noise difference-histograms were computed and shown for the DNL metric for 15 different aircraft types – 1900D, 737-300, 767-300, A320-211, A330-301, CNA441, COMJET, DC3, DC1010, ECLIPSE500, EMB145, GASEPF, PA30, PA31, and SD330.

The following figures depict the noise exposure difference-histograms for comparisons of AEDT with NIRS for selected aircraft types for different noise metrics computed on straight arrival and departure tracks. In each case, the image on the top represents the difference-histogram for 2a with NIRS and the image on the bottom represents the difference-histogram for SP2 with NIRS.

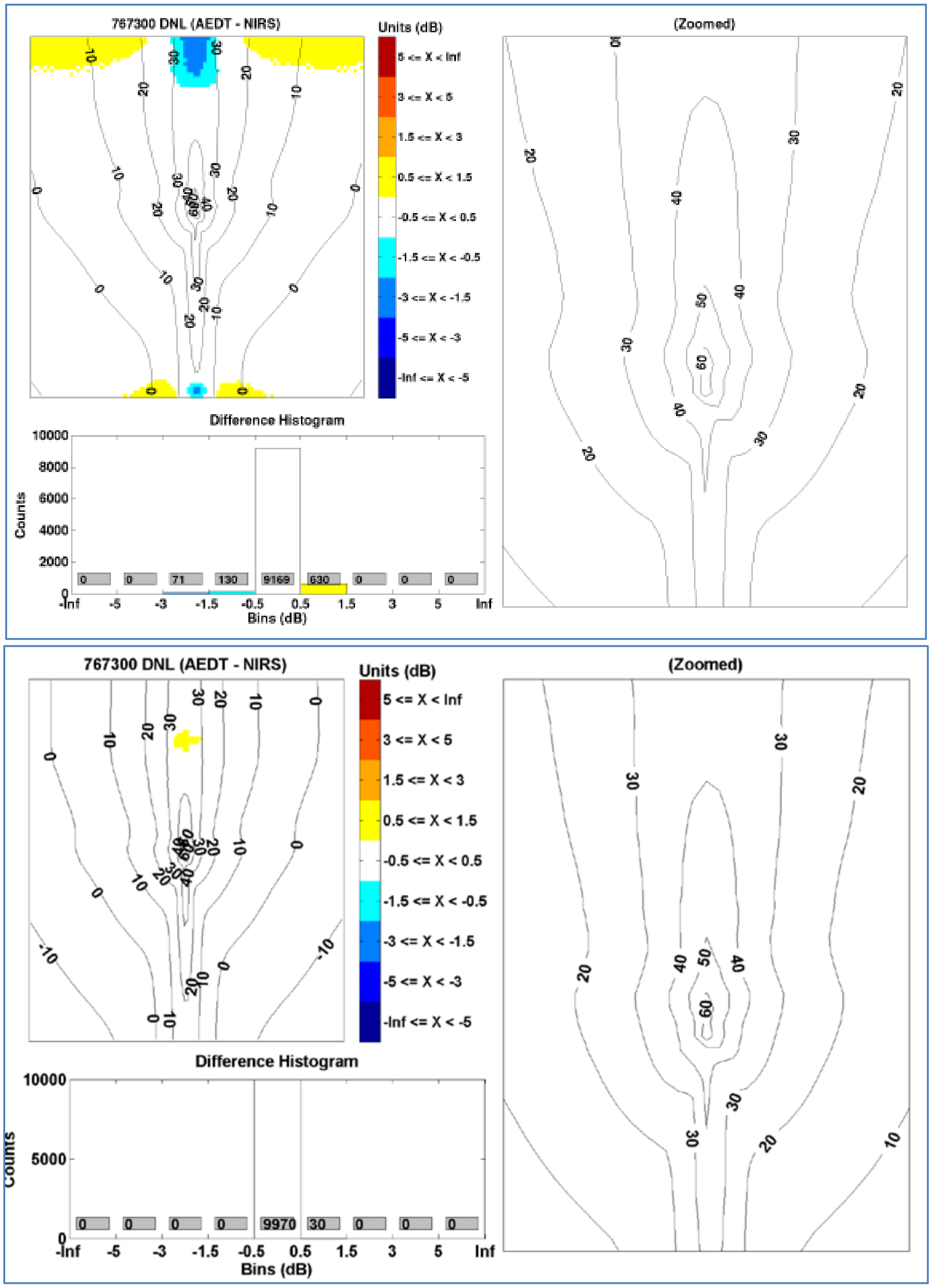


Figure 9: AEDT vs. NIRS 767300 DNL Difference-Histograms – 2a (top) vs. SP2 (bottom)

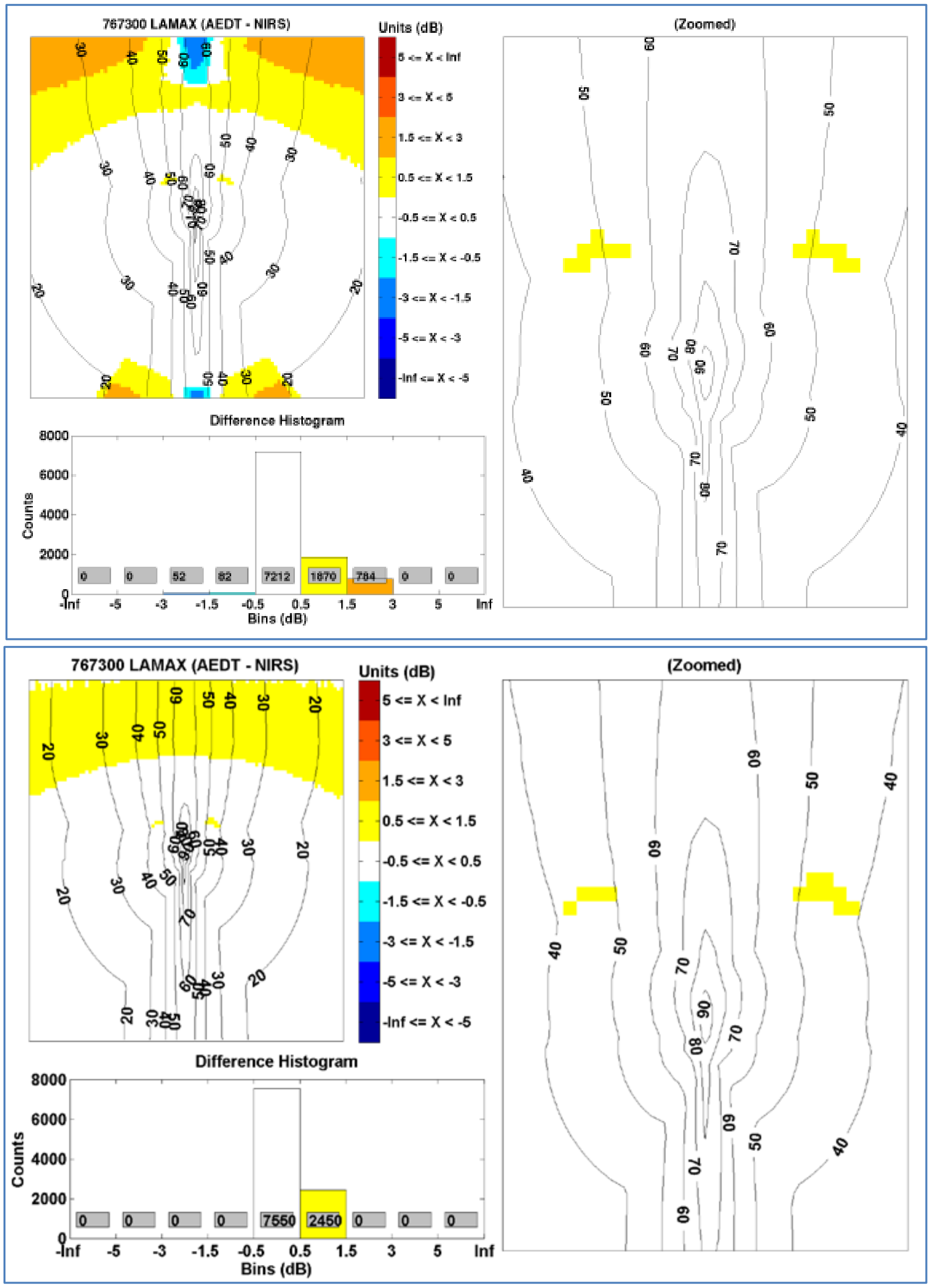


Figure 10: AEDT vs. NIRS 767300 LAMAX Difference-Histograms – 2a (top) vs. SP2 (bottom)

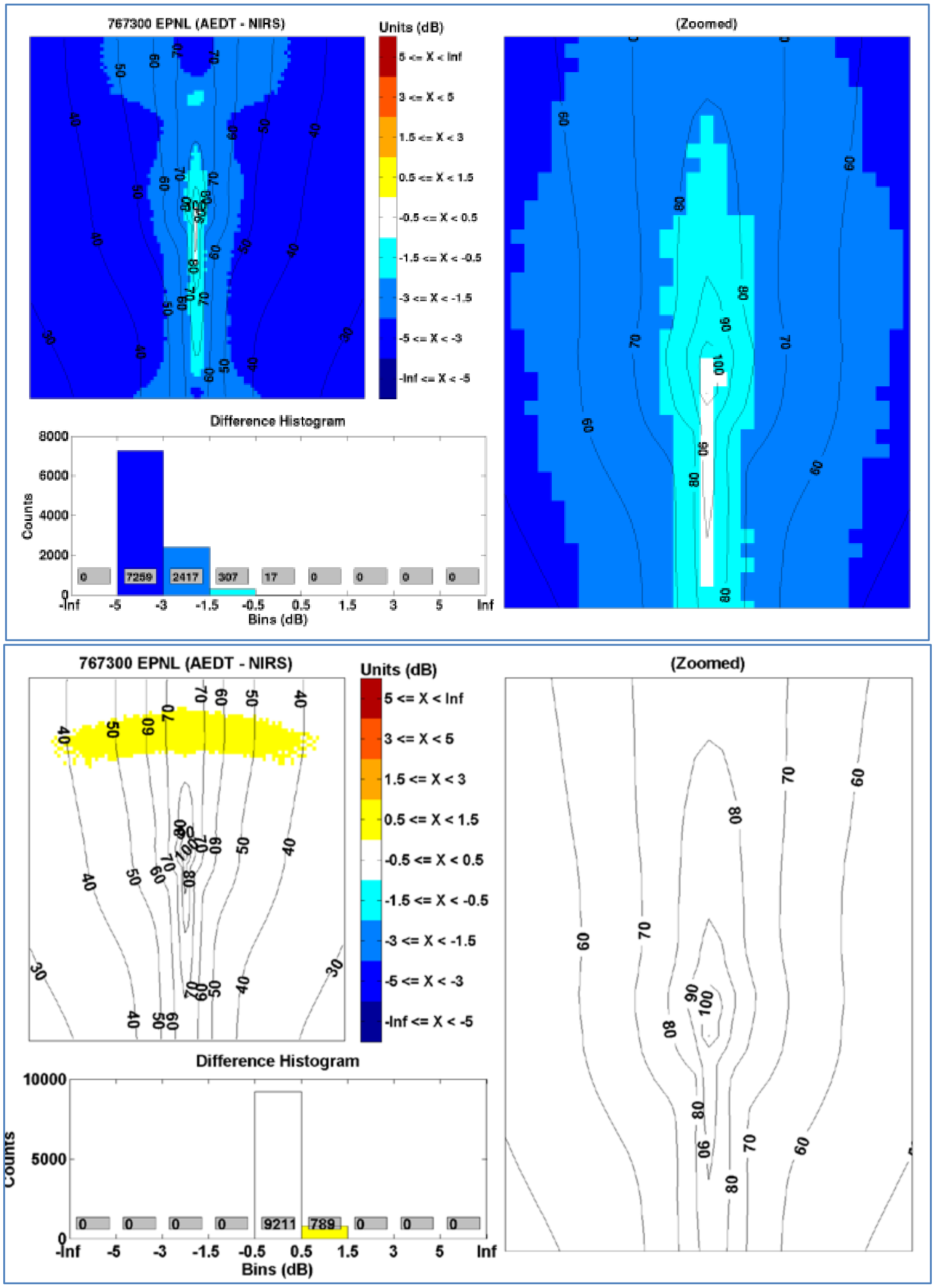


Figure 11: AEDT vs. NIRS 767300 EPNL Difference-Histograms – 2a (top) vs. SP2 (bottom)

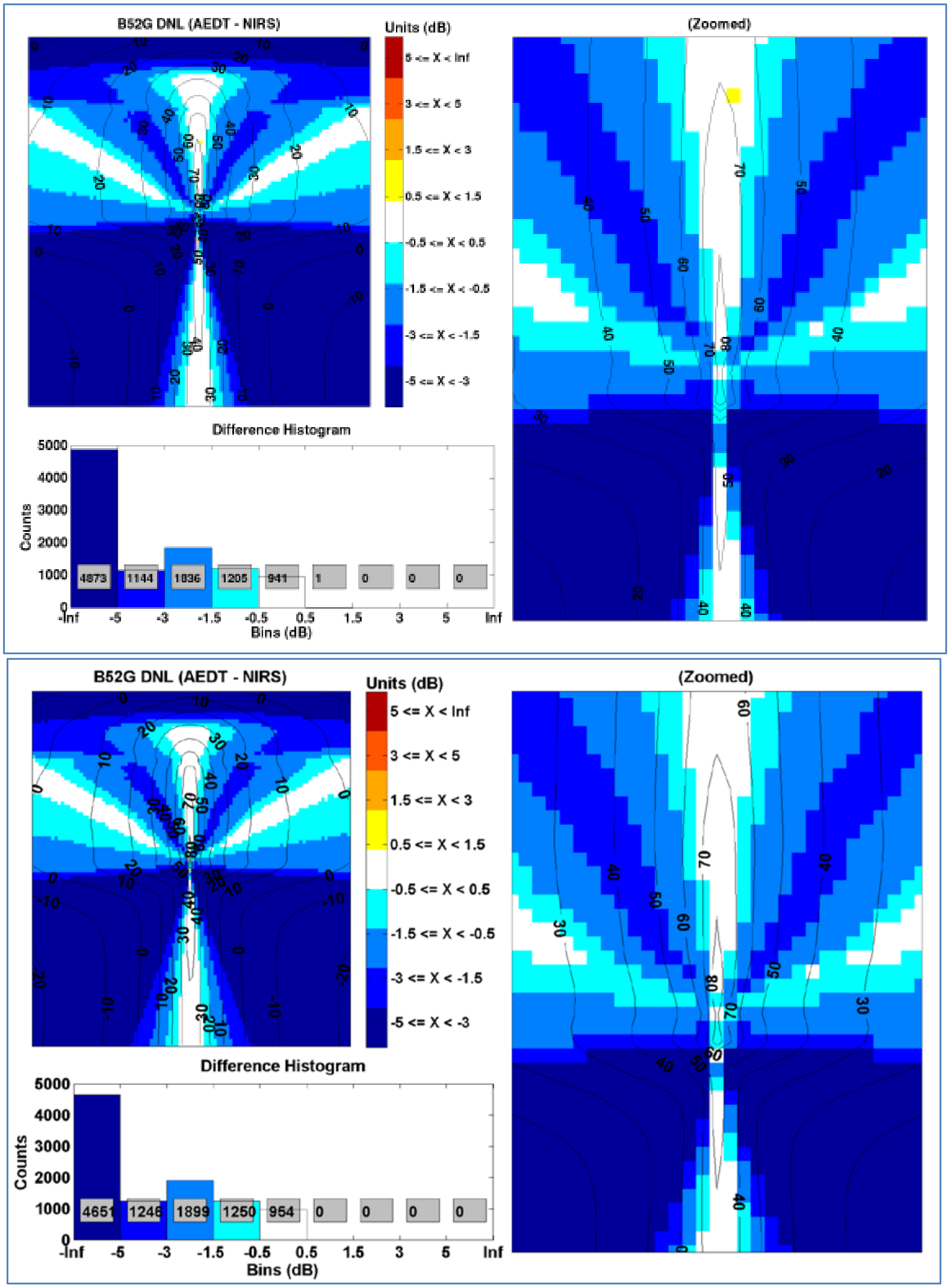


Figure 12: AEDT vs. NIRS B52G DNL Difference-Histograms - 2a (top) vs. SP2 (bottom)

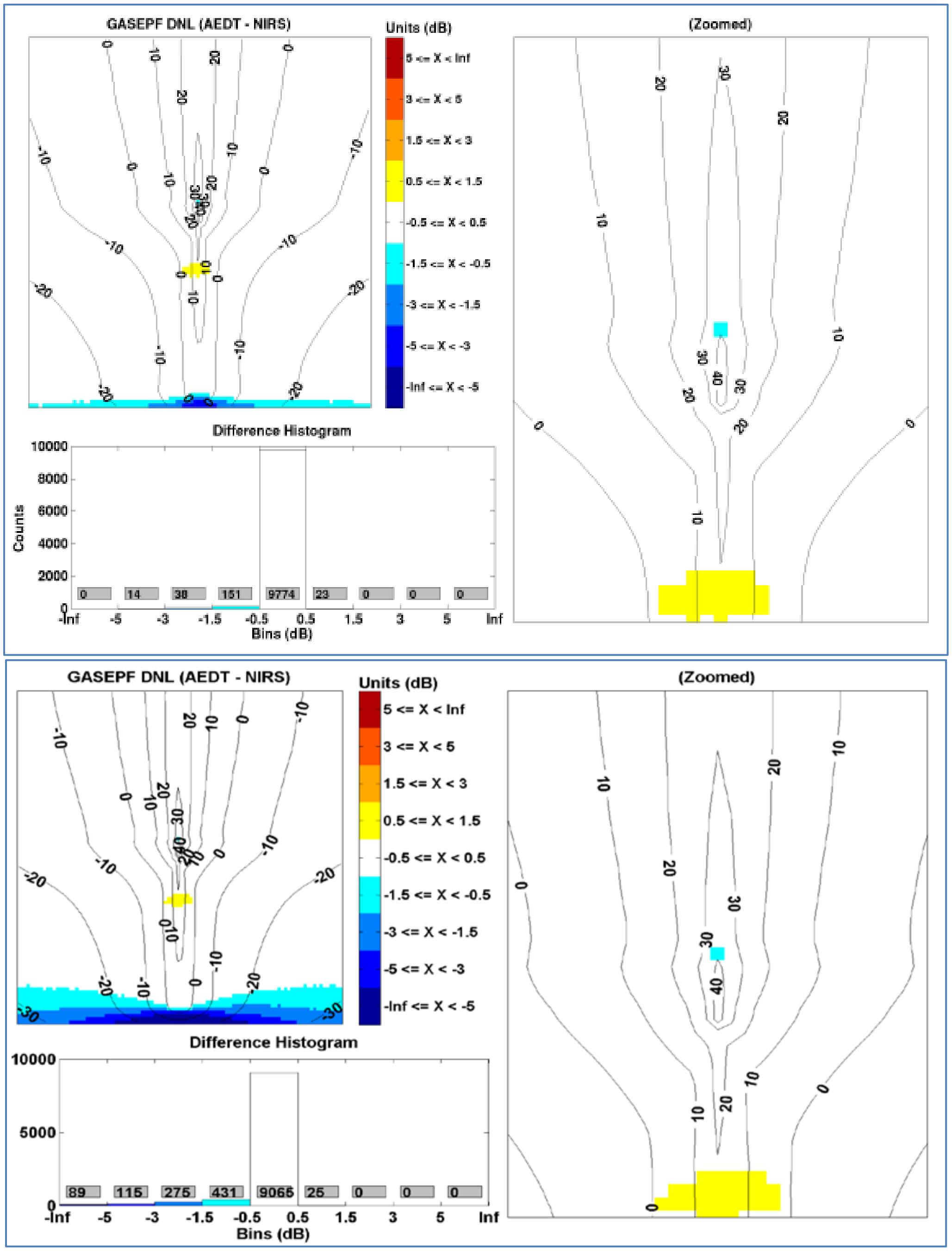


Figure 13: AEDT vs. NIRS GASEPF DNL Difference-Histograms - 2a (top) vs. SP2 (bottom)

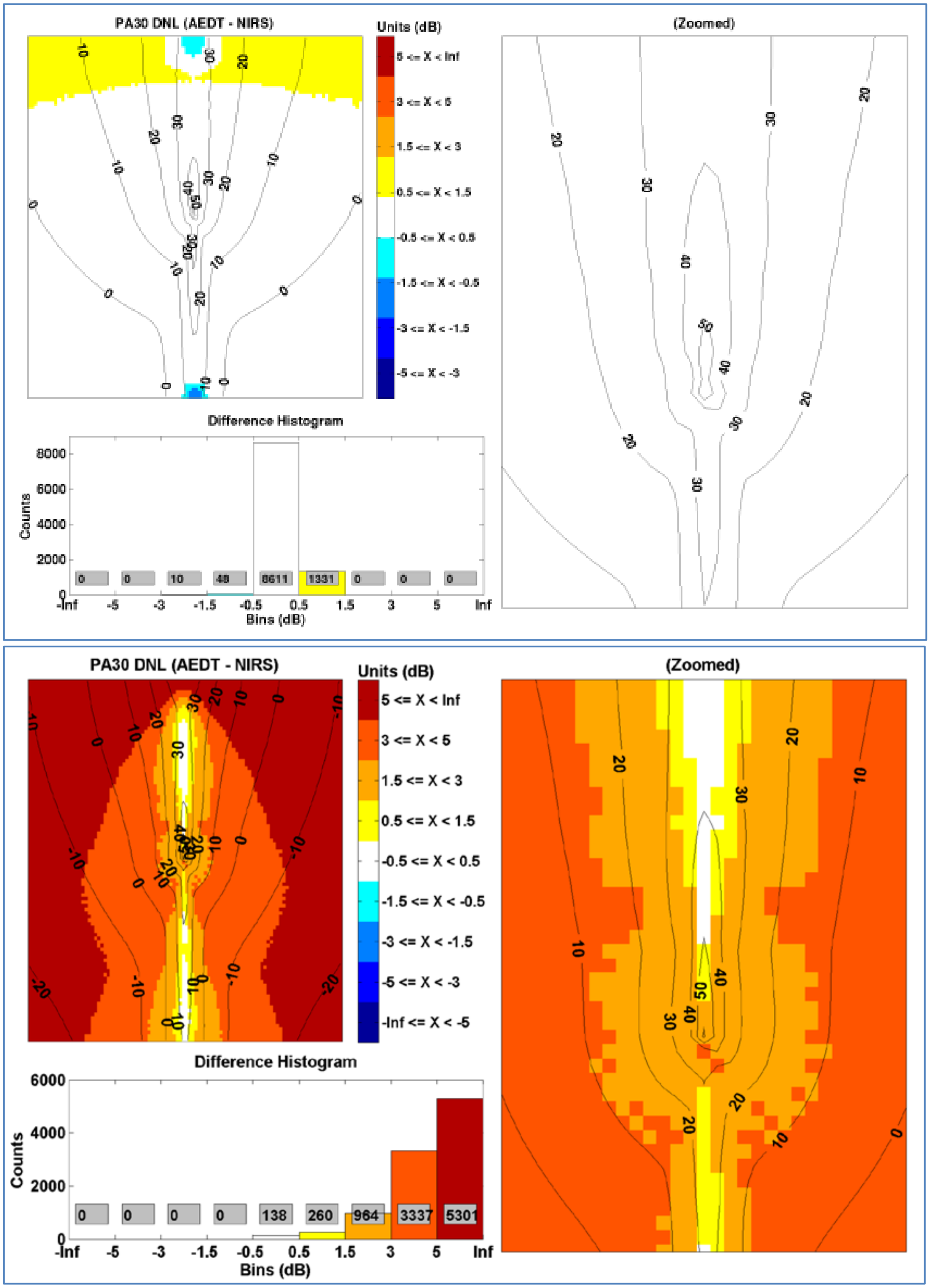


Figure 14: AEDT vs. NIRS PA30 DNL Difference-Histograms - 2a (top) vs. SP2 (bottom)

These comparisons of the differences show that there are changes between 2a and SP2 that result in differences in the computed noise exposure for individual aircraft types in or near the runway environment. These changes range from minimal (e.g. GASEPF DNL) to fairly significant (e.g. 767300 EPNL or PA30 DNL). In most cases they show that the concurrence between AEDT and NIRS is better in SP2. Further investigation into some of the differences in results indicates they were partly caused by differences in flight performance modeling between 2a and AEDT 2a SP2. An example for the modeled flight trajectory for the PA30 with 2a and SP2 is shown below.

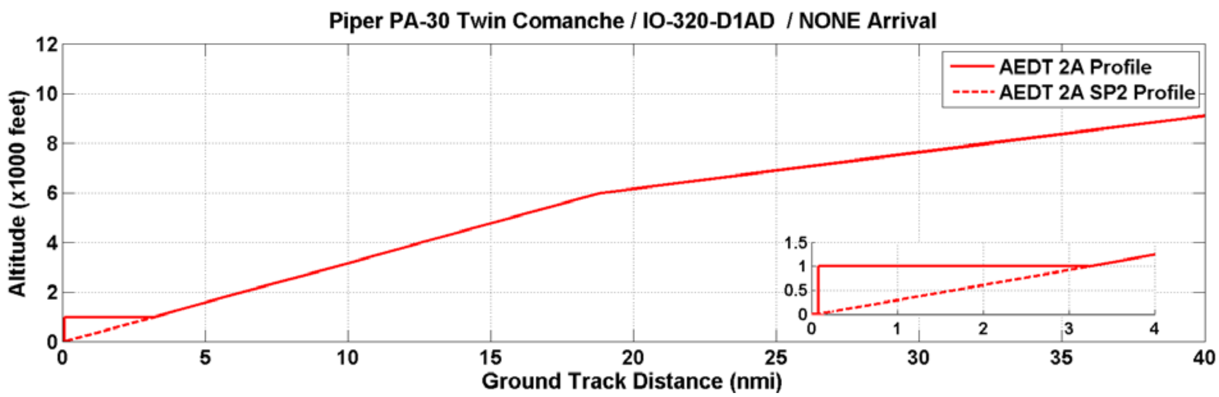


Figure 15: AEDT 2a vs. SP2 PA30 Arrival Profile Comparison

It can be seen that the computed arrival profile for the PA30 under SP2 is more accurate and realistic. A similar example for the Shorts 330-200 Series is shown below.

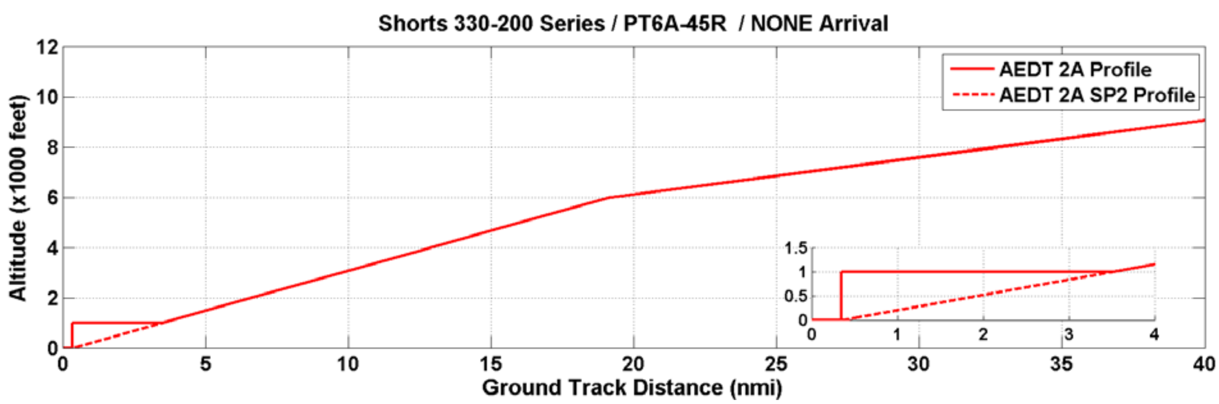


Figure 16: AEDT 2a vs. SP2 SHORT 330 Arrival Profile Comparison

In addition, examples of aircraft types that passed flight performance modeling in 2a but failed in SP2 were identified. An example of this is the Cessna 441, where both the departure and arrival operations passed in 2a but only the departure operation passed in SP2. This difference can be attributed to better error checking in the SP2 flight performance module, especially when altitude control codes are employed.

2.2.2 Conclusion

Driven by the fact that AEDT implements different advanced algorithms and methods, particularly in flight performance calculations that affect noise exposure calculations, as well as in updates to aircraft performance data, we expect to see differences between AEDT and the legacy tool NIRS. However, these comparisons show that the gap between those differences has decreased and result in overall better concurrence between SP2 and NIRS. These results also show that in comparing individual aircraft differences between 2a and SP2, SP2 should generate results that are more accurate than those of 2a. This improved accuracy originates with improvements to the acoustics, terrain, and flight performance models. However, given that the most noticeable differences occur for a fairly small number of aircraft, it should be expected that the comparative results from a large study, encompassing a mix of aircraft types and operations, should be very similar between 2a and SP2.

3 Capability Demonstration

The AEDT 2a Uncertainty Quantification Report[3] provided a section on Capability Demonstrations. The section illustrated AEDT 2a's capability for performing calculations to support a National Environmental Policy Act (NEPA) study for an applicable airspace redesign study.

The Capability Demonstration section for this supplemental UQ report examines noise impact results for a subset of one of the example airspace redesign studies to compare changes in AEDT 2a SP2.

3.1 AEDT-NIRS Compatibility Demonstration

As part of the AEDT 2a uncertainty quantification effort, analyses derived from two applicable legacy airspace studies were run in both NIRS and AEDT 2a. The legacy studies that were utilized for these analyses were the Cleveland and Detroit Environmental Assessment (part of an applicable airspace analysis known as the Midwest AirSpace Enhancement (MASE) project) and the New York/New Jersey/Philadelphia Metropolitan Airspace Redesign. The goal was to demonstrate that AEDT 2a was capable of running large-scale applicable noise studies, and to also demonstrate that AEDT 2a and NIRS produced comparable noise impact results. In both cases, to ensure an "apples-to-apples" comparison of the noise impacts, the scenarios as modeled in both AEDT and NIRS had the following common parameters:

- Identical receptor sets
- A common set of flight operations that successfully passed flight performance in both applications
- The total weight count of flight operations
- Similar or matching weather and terrain
- Identical annualization trees

After all the results were collected, the impacts graphs were compared. Intentional differences between the two tools did produce differences in the results that were deemed acceptable, as explained in the pertinent section of the AEDT 2a Uncertainty Quantification Report.

For the SP2 comparison, a subset of one study that was directly impacted by SP2 changes was analyzed. The following sections describe the methodology, results and conclusions of the supplemental analysis.

[3] Aviation Environmental Design Tool (AEDT) 2a Uncertainty Quantification Report, February 2014, DOT/FAA/AEE/2013-03

3.1.1 Methodology and Results

For the purposes of this supplemental report, the Cleveland-only scenario was rerun in SP2 and compared with the same results obtained previously from 2a. The chosen study contained operations and tracks at Cleveland with noise computed for a receptor set named 4f6f containing about 17,000 population points, including special interest location points. The study area also included a region of special-use airspace. Figure 17: Cleveland 4f6f Receptor Set Centroids and Lake Erie depicts the locations of the receptor points in reference to the study area. The Baseline scenario for this comparison contained 142,207 air operations and 4,517,524 flight trajectory segments, while the Alternative scenario contained 175,482 air operations and 5,235,957 flight trajectory segments.

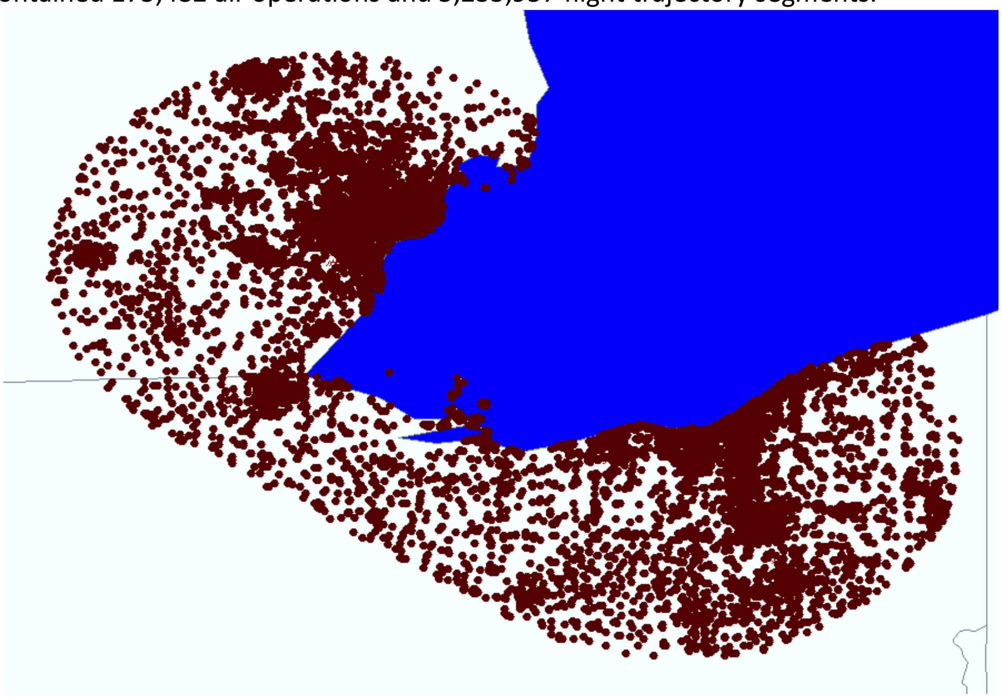


Figure 17: Cleveland 4f6f Receptor Set Centroids and Lake Erie

A normal workflow was conducted to compute noise impacts for the Cleveland-only scenario and to generate the relevant Noise Impact Graphs. Noise Impact Graphs depict *significant* noise impacts – both in the number of centroids affected and in the number of persons affected. Figure 18 and Figure 19 show the noise impact graphs for the Cleveland-only results from 2a and from SP2, respectively.

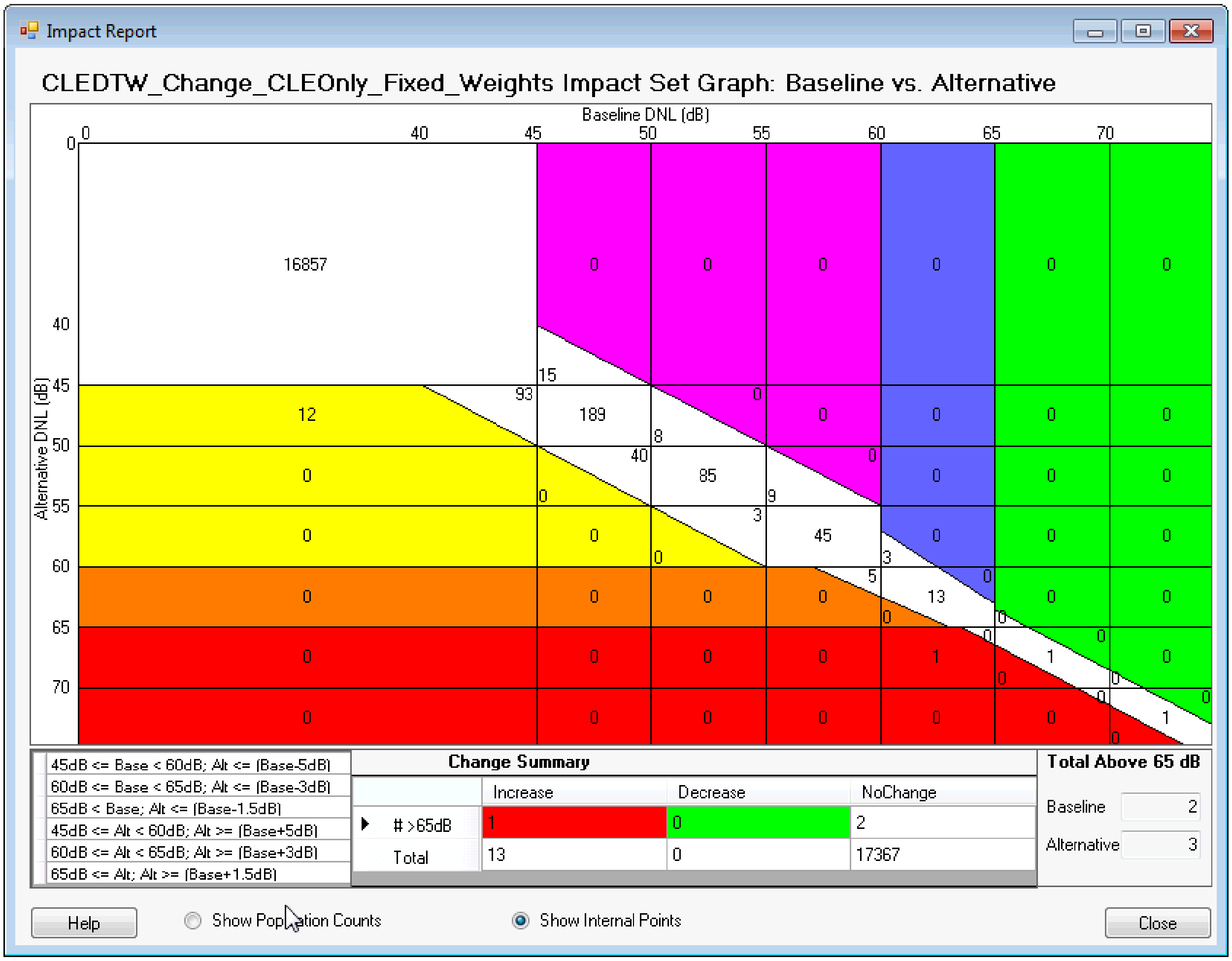


Figure 18: AEDT 2a Noise Impact Graph for Cleveland-Only Scenario – 2a

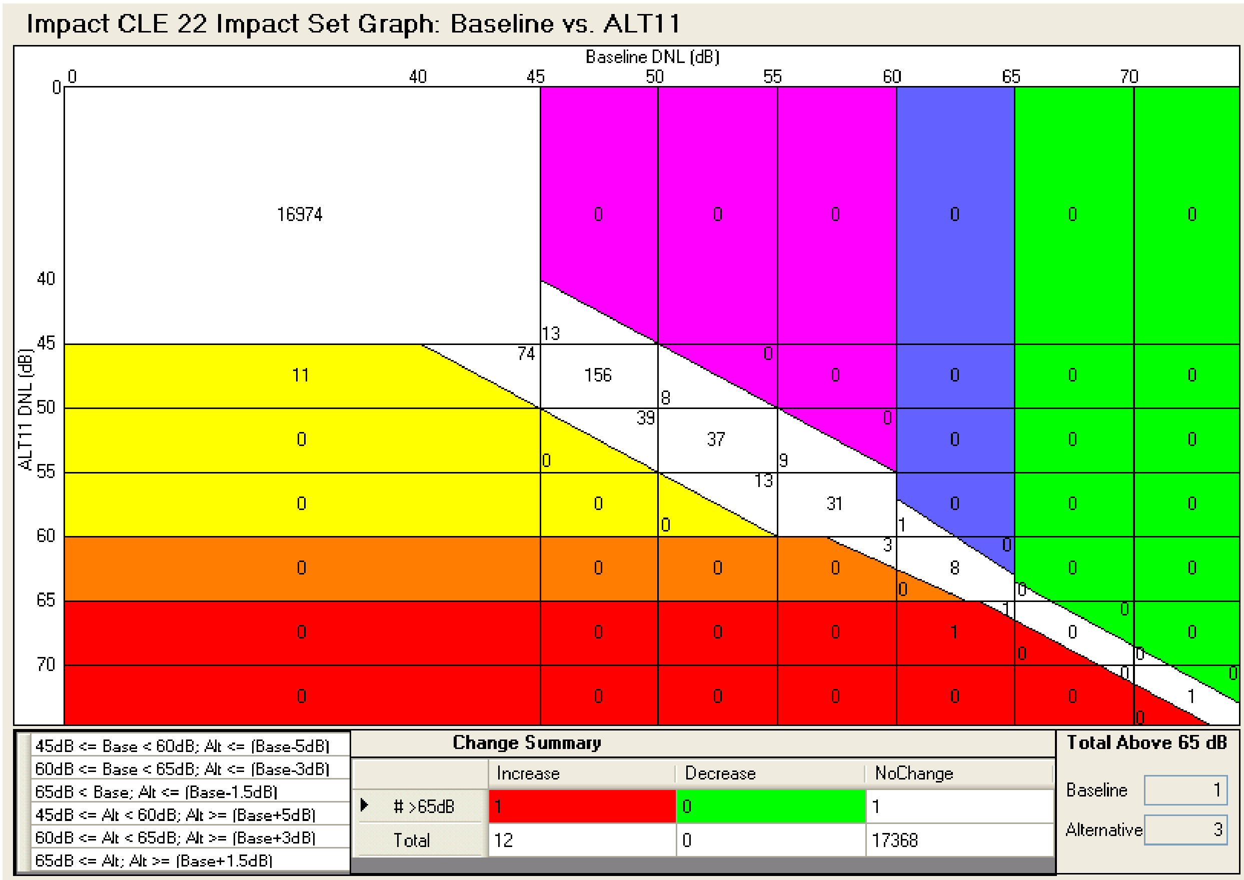


Figure 19: AEDT 2a SP2 Noise Impact Graph for Cleveland Only Scenario

A comparison of the two impact graphs reveals that the only change in *significant* noise impacts was one fewer centroid in the 45-50dB band of the alternative. The number of centroids in all other areas of change deemed *significant* (purple, blue, green, yellow, orange and red zones) remained the same. There was some movement of centroids within existing zones of change (white area) but the changes were not large enough to move any of those centroids into zones of *significant* change.

3.1.2 Conclusion

Section 2 concluded that enhancements to AEDT 2a implemented in SP1 and SP2 are likely to cause differences in computing individual flight trajectories and in the resulting noise impacts. However, results from this large study demonstration suggest that any differences in *significant* noise impacts stemming from aggregate noise impacts are likely to be minimal. The large study demonstration also shows that the expected differences between SP2 and the legacy tool, NIRS, also remain within the bounds of expected differences.

4 Conclusion

The AEDT 2a SP2 update addresses issues identified in AEDT 2a affecting aircraft flight performance, mostly related to altitude controls, as well as ASIF, terrain processing, and computational speed. This supplemental UQ report documents the changes in SP1 and SP2 and the methodology, results, and conclusions from V&V and Capability Demonstration efforts.

Findings from this supplemental report show that, relative to 2a, SP2 successfully runs flights that previously incorrectly produced error messages, calculates trajectories that better match altitude control definitions, allows for greater flexibility in stage length definitions, and provides more detailed information to users on how they can address valid flight performance failures.

As described in the original UQ report, there are expected differences in results when AEDT 2a is compared with the legacy tool NIRS, due to different advanced algorithms, methods, and aircraft performance data. The supplemental UQ V&V analysis found that for several individual aircraft, SP2 should generate results that are both more accurate than those of 2a and in better agreement with NIRS. The capability demonstration of a larger study found that 2a and SP2 differences in *significant* noise impacts are likely to be minimal, as the number of individual aircraft with the most noticeable differences is relatively small. It also found that the differences between SP2 and NIRS remain within the bounds of expected differences.

The AEDT 2a SP2 UQ supplemental analyses showcase confidence in the tool’s capability, fidelity, and connection to the precedent of the legacy tool it replaces.