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16. Abstract

The mitigation of aviation environmental effects is one of the key enablers to sustainable aviation growth. In order to perform mitigation efforts, however, it is required that the effects themselves be modeled with a high level of accuracy. The Aviation Environmental Design Tool (AEDT) offers the capability to model aircraft performance, fuel burn, emissions, and noise. Efforts are ongoing for improving the fidelity of modeling accuracy of AEDT by improving the assumptions used within AEDT to model various real-world effects. In this paper, the overall sensitivity of noise metric predictions to varying assumptions within AEDT is explored and quantified. This is achieved with the utilization of multiple types of real-world data including detailed flight performance characteristics from airline flight data records, noise monitoring data obtained from stations around one specific airport, and historicalweather data. The paper provides a quantification of the overall accuracy of AEDT at its highest level of fidelity and also the sensitivity of noise predictions to various assumptions. The outcomes are expected to provide best practice recommendations and help users prioritize and more accurately quantify community noise exposure using AEDT.

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Noise Model Validation using Real World Operations Data

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The mitigation of aviation environmental effects is one of the key enablers to sustainable aviation growth. In order to perform mitigation efforts, however, it is required that the effects themselves be modeled with a high level of accuracy. The Aviation Environmental Design Tool (AEDT) offers the capability to model aircraft performance, fuel burn, emissions, and noise. Efforts are ongoing for improving the fidelity of modeling accuracy of AEDT by improving the assumptions used within AEDT to model various real-world effects. In this paper, the overall sensitivity of noise metric predictions to varying assumptions within AEDT is explored and quantified. This is achieved with the utilization of multiple types of real-world data including detailed flight performance characteristics from airline flight data records, noise monitoring data obtained from stations around one specific airport, and historical weather data. The paper provides a quantification of the overall accuracy of AEDT at its highest level of fidelity and also the sensitivity of noise predictions to various assumptions. The outcomes are expected to provide best practice recommendations and help users prioritize and more accurately quantify community noise exposure using AEDT.

I. Introduction and Background

The aviation industry has been undergoing steady long-term growth over the past few years. This trend of growth has been observed in both the domestic aviation market in the US and also in global markets. Because of this anticipated growth, it is expected that the amount of noise exposure that surrounding airport communities experience might increase. In order to perform mitigation of these effects, it is required that the effects themselves be modeled with a high level of accuracy. This involves the use of modeling and simulation capabilities for both aircraft operations, and the computation of the associated environmental metrics. One of the most advanced capabilities to this effect, is offered by the FAA's Aviation Environmental Design Tool (AEDT)**. AEDT is a software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality consequences. AEDT's primary objective is to facilitate the environmental review of Federal actions associated with changes to airport, airspace, and other applicable aviation activity.

There have been several efforts in the past related to improvement of modeled procedures in AEDT or comparing AEDT capabilities with real-world operational data. The Noise Abatement Departure Procedures (NADPs) are commonly used for mitigation of community noise either closer to the airport or further afield. In prior work by Lim et al. [1] users are provided with a set of 20 different NADP profiles which are suitable for modeling a large variety of operations that are typically observed in the real world. Other efforts have meanwhile focused on quantifying impacts of such NADP profiles on noise modeling and identifying most representative NADP profiles [2, 3]. AEDT has been used in a wide variety of research applications including creation of alternate rapid noise modeling tools [4, 5], comparing aviation environmental impact mitigation strategies [6], and various other community noise quantification studies [7–9]. Other efforts have also focused on using large amounts of real-world data to produce reduced order models for rapid computation of noise impacts [10] or for estimating the impact of average types of operations at different airports [11].

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**Federal Aviation Administration Aviation Environmental Design Tool (AEDT): https://aedt.faa.gov/

In terms of validation efforts for noise modeling, prior studies related to noise model validation date back to AEDT's predecessor, the Integrated Noise Model (INM). Several prior efforts have focused on validation of AEDT or INM in order to quantify the level of agreement between model prediction and data recorded from actual operations. In a study conducted by Page et al. in 2000 [12], an investigation of data from Denver International Airport (KDEN) in 1997 was performed in order to determine how different thrust prediction methods affected INM's prediction accuracy. They found that manufacturer's F_n/δ curves, look-up values of normalized thrust which take into account that thrust changes as a function of density, were the most accurate and then used this information to improve the utilized Noise Power Distance (NPD) curves in INM from historical manufacturer data. In 2006, Forsyth and Follet [13] utilized the same 1997 KDEN data with an interest in updating INM's database; however, an emphasis on higher altitudes was used. As a result, spectral classes were created to correct the NPD information with respect to SAE AIR-1845 atmospheric absorption standards. Another study performed with the same 1997 KDEN data was conducted by Plotkin et al. [14]. The focus of this study was to compare KDEN data to the latest version of noise modeling capability and to study options to further enhance the modeling capability by accounting for effects from weather and terrain.

After AEDT was introduced by the FAA in 2015, verification and validation studies shifted to using AEDT. Hobbs et al. [15] proposed an easily implementable method for including terrain and ground cover effects to noise propagation calculations by using algorithms originally implemented in the Advanced Acoustic Model (AAM) [12]. These algorithms use optical straight-ray theory as adapted for acoustics to model noise propagation in addition to the Fresnel ellipse method. After using data from Portland International Airport (PDX), San Francisco International Airport (SFO), and Oakland International Airport (OAK), it was determined that this improved noise propagation calculations when compared to empirical data. This functionality is expected in future versions of AEDT.

Continuing the research conducted in the previous study, Downing et al. [16] investigated a method for including man-made structural effects in AEDT's noise propagation calculations in 2019. Three separate models were evaluated with respect to their ability to accurately predict how buildings and barriers affect aircraft noise: Traffic Noise Model (TNM) [17], SoundPLAN 7.4 (which uses ISO 9613-2), and the National Cooperative Highway Research Program's Reflection Screening Tool. After validation using data from Los Angeles International Airport (LAX) and Long Beach Airport (LGB), TNM was chosen as the best option due to its noise calculations having similar variability and consistency when compared to AEDT's baseline calculations. As a result, a stand alone tool based on the TNM methodology is being considered for now that may later be integrated into AEDT.

Research Objective: This paper presents an automated framework for validation of noise modeling capabilities within the Aviation Environmental Design Tool (AEDT) using real-world flight operations and noise monitoring data.

II. Noise Modeling in AEDT

System-level noise modeling is performed using AEDT in this paper. There are two important elements to this modeling that are described in detail in this section – A) The data sources utilized during modeling and B) The modeling assumptions and alternatives available for each assumption.

A. Data Sources Utilized

There are several data sources of different fidelity that can be utilized for noise modeling. They can range from simple ground-based radar observations to more sophisticated data fusion from multiple sensors on an aircraft itself. The two main datasets that are relevant for this paper are described below –

1) **Flight Operational Quality Assurance (FOQA)** data consists of data recorded by the airline operating the flight. The basis for the FOQA program is laid by the FAA Advisory Circular 120-82 which states "The value of FOQA programs is the early identification of adverse safety trends that, if uncorrected, could lead to accidents" [18]. To this effect, FOQA systems record large amounts of data at one recording per second, i.e. 1 Hz, with these data having been used for a number of safety related applications in prior work [19, 20]. The important elements of the FOQA data for this paper relate to the detailed time history of parameters such as altitude, speed, thrust, weight, configuration (flaps, gear), etc. for each flight that is modeled in AEDT.
2) **Noise Monitoring Data** data contains 5 key parameters: A unique flight ID, noise monitor locations, class of noise reading, SEL, and L_{max} metrics of associated noise events. The flight ID in the noise monitor data allows

flights to be matched to the appropriate flight from FOQA data thereby matching the aircraft configuration and the time of the noise event with the noise metric value. The class of the noise reading identifies the confidence with which the noise reading has been matched with the flight ID corresponding to it. The highest confidence is marked as a class 1 reading. These locations (except for their altitude) is used in flight modeling discussed in subsequent sections. The noise monitor data is used as a benchmark comparison for the noise results that are calculated by AEDT.

It is noted here that the framework for modeling and automation developed in this paper is independent of the data source used and will only need to be modified to account for the availability of parameters in case other data sources are used. In this work, the data used is obtained from flight operations at San Francisco International Airport (KSFO) and noise monitoring readings obtained from the SFO airport noise program*.

B. Modeling Assumptions and AEDT Capabilities

Modeling in AEDT offers users multiple settings for critical assumptions related to the modeling of performance and noise. A systematic breakdown of these settings is shown in Figure 1. The options highlighted in gold color in the matrix are the ones that have been explored in this paper. The options that are highlighted in light grey are additional modeling capabilities being explored by the authors for future research and may not be available directly in AEDT.

Departure					
Assumption	AEDT Default	Option 2	Option 3	Option 4	Option 5
Thrust	Full	RT15	FOQA	*RT5*	*RT10*
Weight	AEDT	Alt Weight	FOQA		
Ground Track	Airport Default	FOQA			
Procedure	STANDARD	NADP1_1	NADP2_11	FOQA	
Weather	AEDT Standard	FOQA	High-Fidelity	ASOS	
Surface	Soft	~~Hard~~			
Terrain	None	*Actual*			
Flaps	AEDT	*FOQA*			
Gear	AEDT	*FOQA*			
NPD	AEDT	*NPD+C Corr Function*			

Arrival					
Assumption	AEDT Default	Option 2	Option 3	Option 4	Option 5
Thrust	AEDT	FOQA			
Weight	AEDT	FOQA			
Ground Track	Airport Default	FOQA			
Procedure	STANDARD	FOQA			
Weather	AEDT Standard	FOQA	High-Fidelity	ASOS	
Surface	Soft	~~Hard~~			
Terrain	None	*Actual*			
Flaps	AEDT	*FOQA*			
Gear	AEDT	*FOQA*			
NPD	AEDT	*NPD+C Corr Function*			

Fig. 1 Modeling Options of Highest Noise Prediction Impact.

Beginning a new study in AEDT poses the question of the airport for investigation. The SFO airport is selected for the present work since the research team has access to real-world noise monitoring data from there. Another setting that the user must fulfill is the airframe used for modeling. In this study, the research team has FOQA data available for multiple airframes, however the down-selected flights use the Airbus 320-200, the Boeing 737-800 and the Boeing 757-200. The following section will detail the other settings that were not held constant by available data but rather by the availability within the AEDT software itself. There are a number of settings available under every assumption (row) of Figure 1 which can affect the performance and noise for each flight operation. This section aims to provide detailed

*https://webtrak.emsbk.com/sfo13

descriptions of each option and an idea of how it might affect the calculations. For further details, readers are referred to the AEDT technical manual [21].

1) **Thrust Settings**: The options for thrust in AEDT can be seen through some of the procedures in the FLEET database. AEDT is comprised of multiple databases that allow the program to draw the information it needs to perform its calculations. Using the B737-800 as an example, the FLEET database has the following procedures available: STANDARD, "MODIFIED_RT05", "MODIFIED_RT10", and "MODIFIED_RT15". The corresponding amount of thrust upon takeoff for each of these procedures is 100%, 95%, 90%, and 85%. Thrust settings upon takeoff and cutback were investigated in ASCENT Project 45 which concluded that other thrust options should be included in AEDT as operators usually use 15% reduced thrust in real world operation. It has also been shown that this decrease in takeoff and cutback thrust results in a 30% decrease in area of the 80 dB Sound Exposure Level contour for a single aisle aircraft [22]. These thrust options can be changed by using these different procedures; however, they can also be changed by defining procedures themselves and using identifiers for 5%, 10%, and 15% reduced thrust. The final thrust option that is available is the actual thrust from the flight given in the FOQA data.

2) **Procedure and Fixed Point Profiles**: The FLEET database has two types of profiles that can be used: procedural profiles and fixed point profiles (FPPs). Procedural profiles define an aircraft's thrust, speed and trajectory in a series of steps. FPPs are profiles which fully define the location and state of the aircraft in the sky as well as its state: thrust and speed. FPPs are used to model the FOQA data within AEDT since they can include the speed and thrust from flight data.

3) **Weight**: Aircraft weight can also be altered within AEDT. This can be done by uploading a new profile to the FLEET database with the corresponding weight field filled with the data necessary. Another method would be to use different procedures that are available within the FLEET database that consider alternate weights. These procedures include "MODIFIED_AW", "MODIFIED_AW_RT05", "MODIFIED_AW_RT10", and "MODIFIED_AW_RT15". The option of FOQA weight can be used within AEDT while employing FPPs. This way the information regarding weight, thrust, and speed can be used in one FPP for each flight modeled.

4) **Ground Track**: The ground track is the latitude and longitude points on the ground of the aircraft during its flight. The default AEDT modeling for ground tracks are straight into the airport, parallel with whichever runway the aircraft is using upon arrival, or straight out of the airport upon departure. In addition to this setting is the use of the ground track from the FOQA data which accounts for turns aircraft make on their way into airports or leaving airports.

5) **Weather**: The default weather settings that are used in AEDT studies are located in the AIRPORT database. The values needed for the performance and acoustic calculations from this database are: Temperature, Relative Humidity, Wind Speed, Sea Level Pressure, and Dew Point. The wind direction is always assumed to be a headwind direction. The AEDT GUI and the SQL tables have the ability to change the values in the AIRPORT database for these properties. For the present work, in addition to the default weather, these values were changed with weather data from the Automated Surface Observing System (ASOS).

   One of the major differences between AEDT and INM is that AEDT has the capability to use high-fidelity weather data in multiple formats. This is external data that is provided by giving AEDT an additional file path to the location of the file. AEDT can use high-fidelity weather in multiple formats: MERRA-2, Rapid Update Cycle (RUC), Rapid Refresh (RAP) and more. High-fidelity weather data does not effect the acoustic calculations in AEDT but rather the performance calculations. This then affects the acoustics, making it an indirect effect on the noise caused during the operation.

6) **Surface and Terrain**: The surface options within AEDT are available for propeller aircraft. There is a hard surface and a soft surface option that affect the ground reflection and other properties in noise calculations.

7) **Flaps and Landing Gear**: The flap and gear schedule for modeling in AEDT have two options: the schedules that are provided with each of the procedures, or the flap schedule defined in the FOQA data.

8) **Noise Power Distance (NPD) Curves**: Noise calculations in AEDT rely on NPD curves derived from aircraft certification data. Noise levels are obtained as a function of observer distance via spherical spreading through a standard atmosphere. Other correction factors are applied to obtain the desired sound field metrics at the location of the receiver. NPD + configuration (NPD+C) curves which may enable more accurate noise prediction due to aircraft configuration and speed changes are under research [23].

C. Compatibility of Settings

Of the settings discussed previously, the ones that are varied in this study include the procedures and profiles, thrust, weight, and weather. It is important to note that not all of these variations are compatible with each other. For example, when using a fixed point profile, it is not logical to also use 95%, 90% and 85% of the thrust used. In another example, it is not physically possible to include FOQA thrust values in a procedural profile. This is because the thrust values from the FOQA will be numerical thrust values in pounds but the procedural profiles require thrust type and step type definitions rather than actual thrust values since the thrust is calculated by AEDT rather than given in the profile definition. This leads to the creation of a compatibility matrix yielding the actual number of combinations for one flight to be modeled. There are 4608 combinations for all possible modeling options with departure procedural profiles. When using fixed point profiles, the combinations become 768 when taking into account different settings that are no longer feasible. Arrival has less combinations of modeling settings because it has less modeling settings in general. For example, the only profiles available for arrival are the STANDARD and the FPP from the FOQA data. Thrust only offers one option. This yields 512 combinations for both FPPs and procedural profiles: 1024 total combinations.

The settings varied in this study were not as lengthy as the entire combination matrix provides. The settings used for departure were: Fixed Point Profiles, the STANDARD procedural profiles, AEDT default weight, Alternate Weight, FOQA weight, Full Thrust, Reduced Thrust 15%, FOQA Thrust, ASOS weather and the AEDT Default weather. This yielded 18 different jobs within AEDT. On the arrival modeling, the settings used were: the STANDARD procedural profile, Fixed Point Profile, AEDT default weather and ASOS weather. This yielded 12 different jobs. With a total of 30 cases to define in AEDT, an opportunity to automate AEDT using SQL presented itself. This is discussed in the following section.

D. Automation Capabilities

An automation capability was developed in order to handle these combinations in a more time-efficient manner. It consists of using 9 SQL automation scripts as are shown in Figure 2. The user specifies the profiles to be modeled (either procedural or FPP), the ground tracks and a combination matrix. This matrix maps Profile IDs and Ground Track IDs together along with runway specifications to model the correct combinations from the matrix options in Figure 1. These scripts use the different databases behind AEDT as well as an empty database created by the user and a new study database in order to set up the studies. Once scripts 0a through 4b have been executed, script 5 can be executed which gathers all of the information from the previous scripts and sets up the metric results within the new study. The user can then open the AEDT GUI to click "Run All" and allow AEDT to perform the calculations. The AEDT Report Extraction Executable outputs a folder of reports including performance, emissions and noise. This allows 4 reports for each case in the test matrix to be acquired, which can be conveniently accessed for post-study data processing.

The inputted information to these scripts is the flight profile names of interest: GT786-D-FPP, GT1043-D-FPP, GT528-D-FPP, GT457-D-FPP, GT506-D-FPP, GT1090-D-FPP MODIFIED_AW_RT15, STANDARD, and stage length information. The stage lengths for certain flights will differ depending on their origin-destination airports. For example, GT 786 and GT 528 were both stage length 4 departures of a 737-800 and GT 1043 was a stage length 2 A320-200 departure. The Modified Alternate Weight Reduced Thrust 15% procedures were also included for these aircraft. This information is kept in the Profiles csv. The track information for all of these is included in the Tracks csv. Associating a track, profile, and runway is accomplished in the Profile/Track Combination Matrix csv.

III. Results and Discussion

The modeling framework is implemented on three departing and three arriving flights at San Francisco International Airport (KSFO) using AEDT version 3c. These flights have been provided arbitrary flight IDs (GT-xxx) to anonymize the real world flight details. In this section, detailed results are provided for a selection of three flights departing from and three flights arriving at KSFO. Two dashboards that combine important metadata related to all available flight

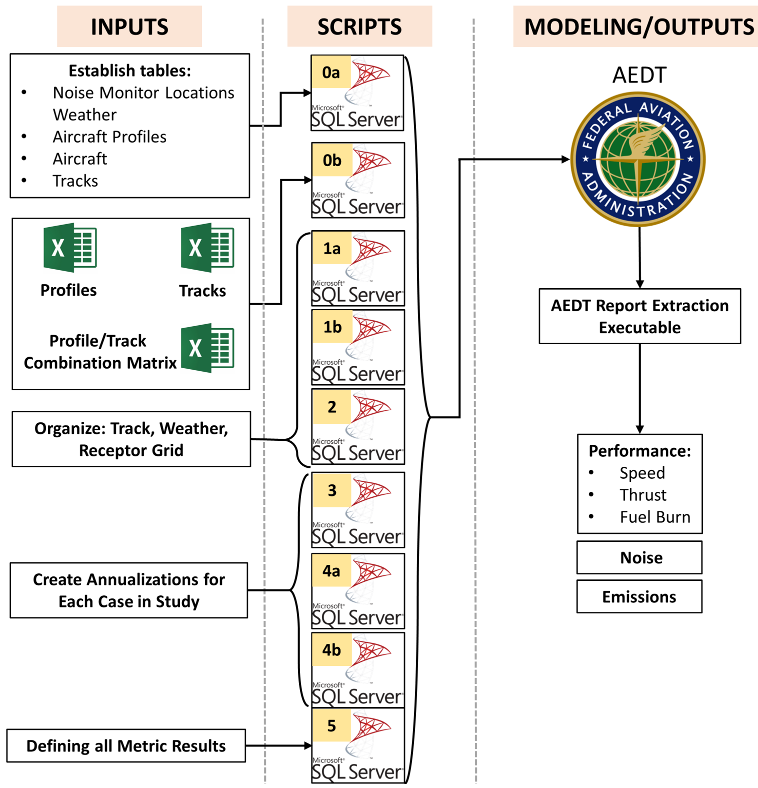

Fig. 2 Noise Modeling Process Automation Steps.

operations are built in Tableau software to help down-selection of flights to be modeled. A snapshot of the dashboards are shown in Figure 3 (Departure) and Figure 4 (Arrival). These dashboards contain high-level information about the flights such as airframe and engine type, number of noise monitors that were triggered by this flight, etc. These metadata parameters help researchers down-select specific flights to model with different assumptions. While using the detailed flight track and trajectory will yield the aircraft performance that was closest to the actual performance, it is not necessarily always available to users such as airport personnel. Therefore, investigating how close AEDT results are to the actual recorded noise under various modeling options within AEDT is important from a usability perspective. The individual flight modeling results are elaborated in the following subsections.

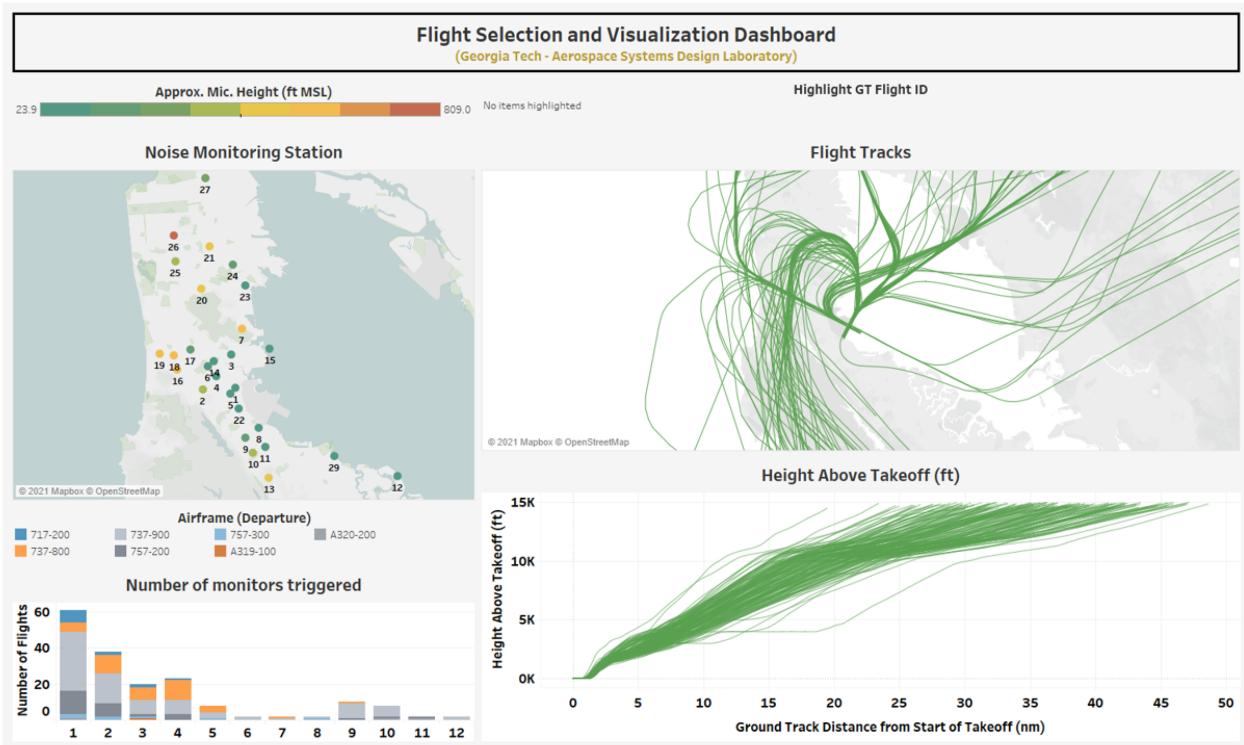

Fig. 3 Visualization dashboard for downselecting departing flights to model in AEDT.

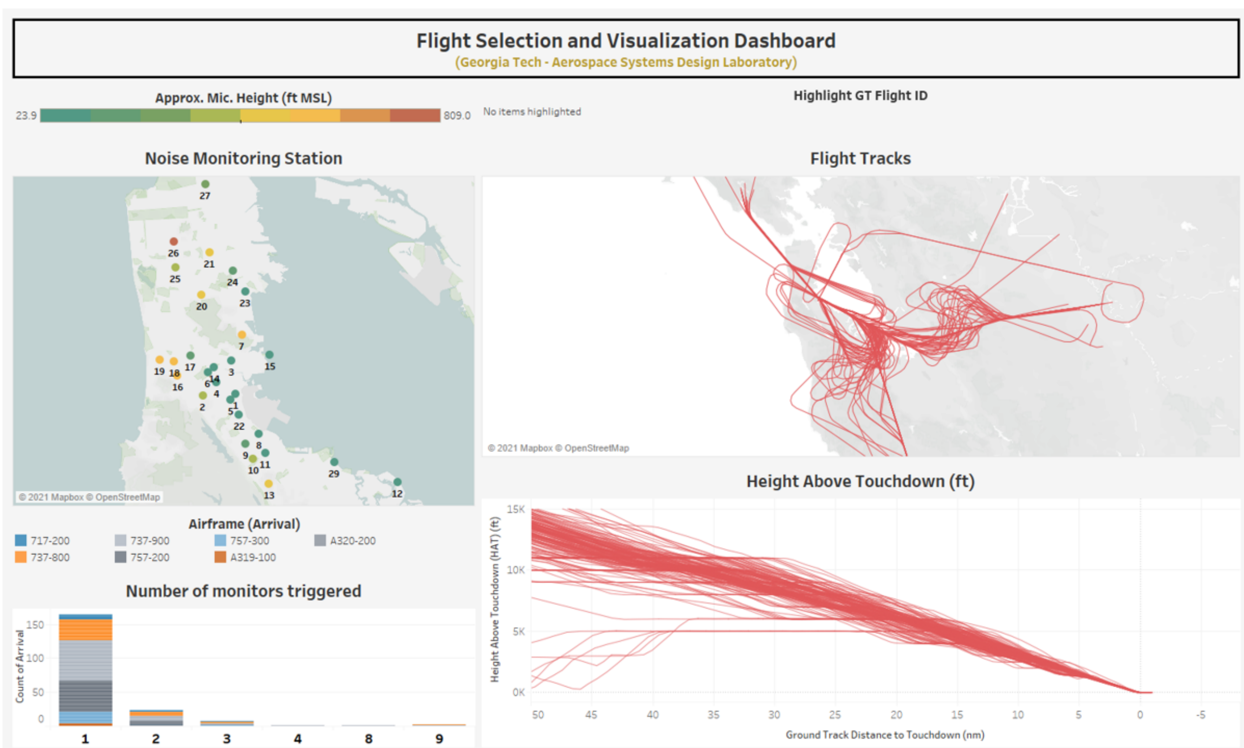

Fig. 4 Visualization dashboard for downselecting arriving flights to model in AEDT.

A. Departures

Table 2 provides a comparison between the AEDT default weather parameters and the ASOS weather for the three departing flights considered in the present work.

Table 1 Weather condition comparison for departure flights GT 528, GT 786, and GT 1043.

Weather Option	Temp [F]	SLP [mb]	DP [F]	RH [%]	Wind Speed [kts]	Wind Dir [°]
AEDT Default	57	1016.7	49.2	76.2	9.2	N/A
ASOS_786	62.1	1014.3	54	74.8	18	260
ASOS_1043	62.1	1014.3	54	74.8	15	260
ASOS_528	62.1	1014.2	55	77.5	10	320

1. Flight Number: ***GT 528***

Flight GT 528 was a Boeing 737-900ER with an origin-destination pair (OD Pair) of SFO-CVG making this a stage length 4 aircraft. Because the B737-900ER does not exist as an ANP airframe in the FLEET database used by AEDT, the Boeing 737-800 is used as a proxy instead. The real-world flight data gives the gross weight at takeoff as 165,435 lbs, 8,735 pounds heavier than the default weight used to model a 737-800 aircraft's performance. The monitors triggered by this flight as well as the ground track can be seen in Figure 5.

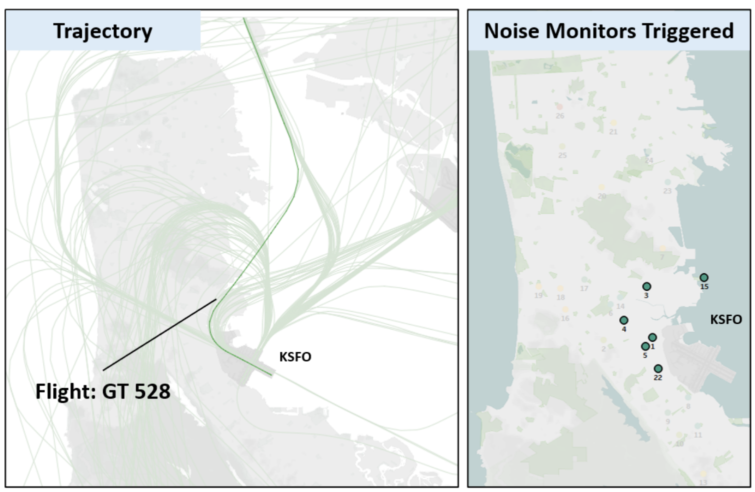

Fig. 5 Trajectory and Monitors Triggered for Flight GT 528.

Figure 6 shows the performance plots for flight GT 528. This is part of the data that is extracted from AEDT using the AEDT Report Extraction Executable. It is important to note that the lines on the plots representing the FPPs will lie on top of one another. This is because the FPPs strictly define the aircraft state (thrust, speed and altitude) at different points in its profile. Therefore, a change in weather will not affect the aircraft's performance. However, in the procedural profiles such as the STANDARD and MODIFIED_AW_RT15, the aircraft's performance will change since the procedure *steps* are defined and AEDT performs the calculations for thrust and speed.

The noise comparison for flight GT 528 given in Figure 7 shows both under predictions and over predictions of the noise created at the noise monitor locations. For most of the monitors, AEDT under-predicts the noise except for some modeling variants at two of the locations – 1 and 15. The level of agreement is variable between the measurement and model with better agreement at some noise monitors than others. Noise monitor 22 is a sideline monitor which has the largest variation.

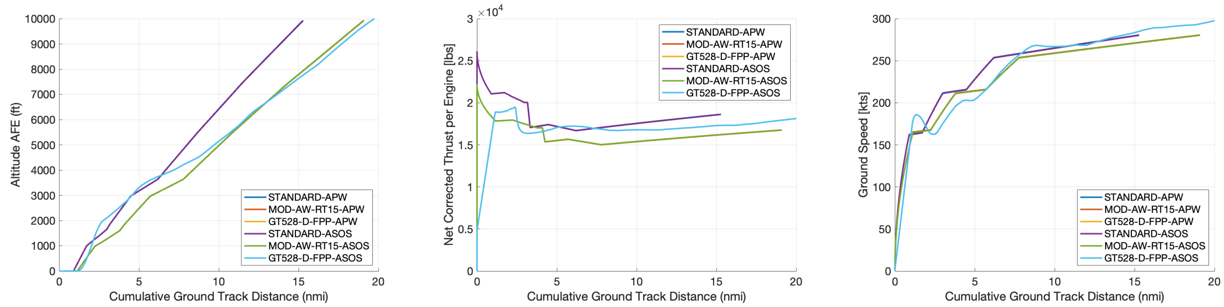

Fig. 6 Trajectory, Thrust, and Ground Speed Performance for Flight GT 528.

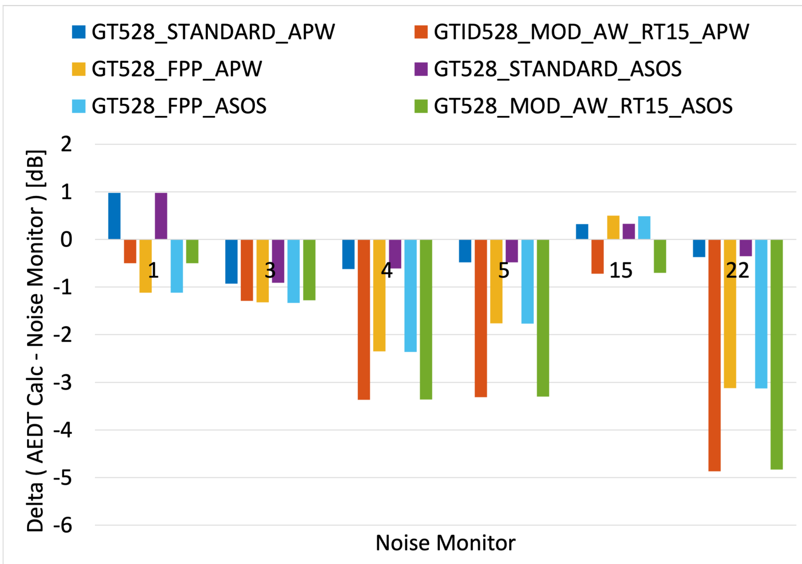

Fig. 7 Acoustic Results using AEDT Default Weather and ASOS for Flight GT 528.

2. Flight Number: ***GT 786***

Flight GT 786 was a departure flight with an OD pair SFO-ATL. It was a Boeing 737-900ER with gross weight of 180,605 lbs upon takeoff, 23,905 pounds heavier than the default AEDT weight. The flight's ground track is shown in Fig. 8 as well as the monitors that were triggered by the flight.

As described previously, the results obtained from the automation scripts include performance results as well. These are visualized in the form of the aircraft trajectory, ground speed, and thrust in Figure 9. The figure indicates differences in altitude profile, thrust and speed between the various modeling options as expected due to the varying assumptions.

AEDT's calculated noise results are shown in Fig. 10. Similar to the first flight, the deltas between AEDT and the real-world recorded data are plotted. Overall, there is a good agreement between all AEDT modeling options and the recordings, with no clear bias towards under– or over– prediction by AEDT. It can be seen that the largest difference is for sideline monitor 22 which could be for a number of reasons that need to be investigated in further studies. Among all other monitors, the differences between AEDT and measurements are within 2.5 dB for this flight. The results for noise monitor 8 are under review as this monitor is very close to highway 101, making the data recorded more complex and indistinguishable.

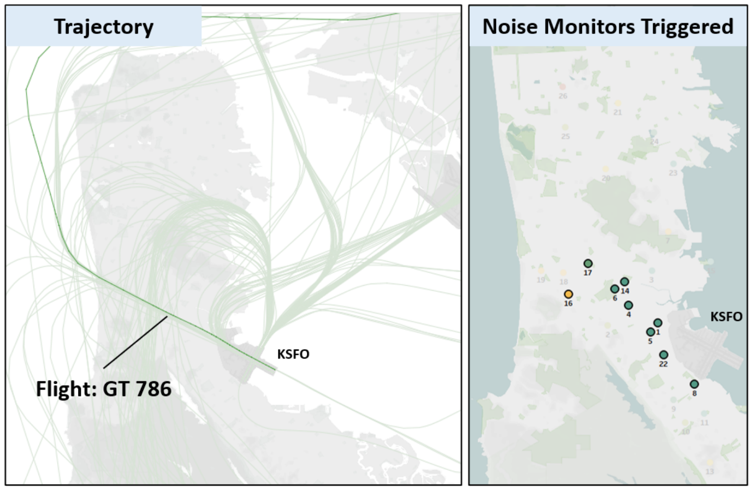

Fig. 8 Trajectory and Monitors Triggered for Flight GT 786.

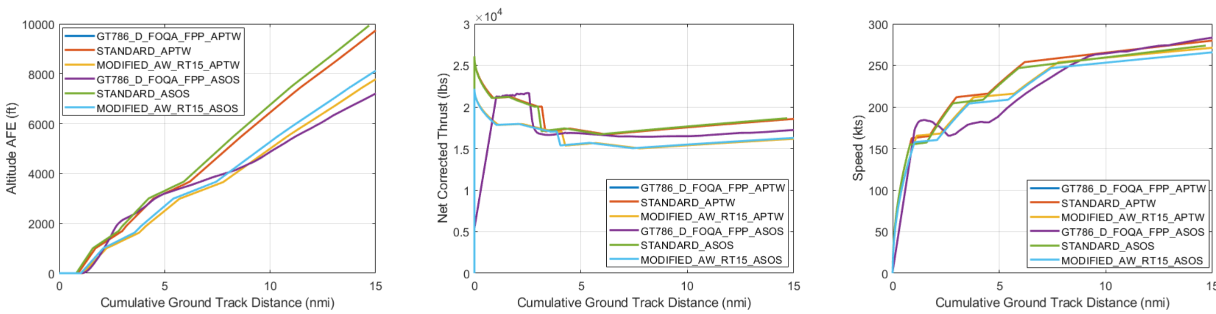

Fig. 9 Trajectory, Thrust, and Ground Speed Performance for Flight GT 786.

Fig. 10 Acoustic Results using AEDT Default Weather and ASOS for Flight GT 786.

3. *Flight Number:* ***GT 1043***

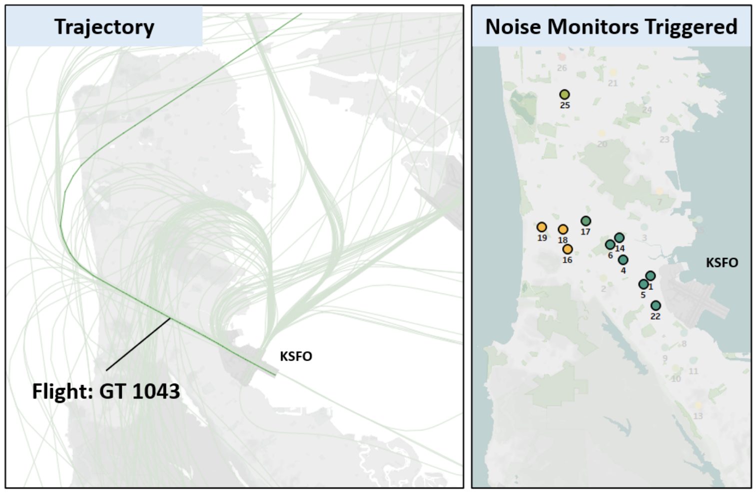

Fig. 11 Trajectory and Monitors Triggered for Flight GT 1043.

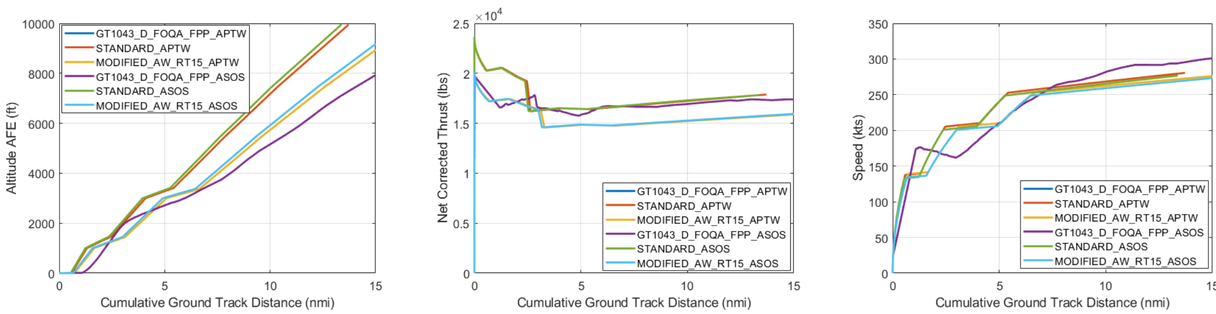

Fig. 12 Trajectory, Thrust, and Ground Speed Performance for Flight GT 1043.

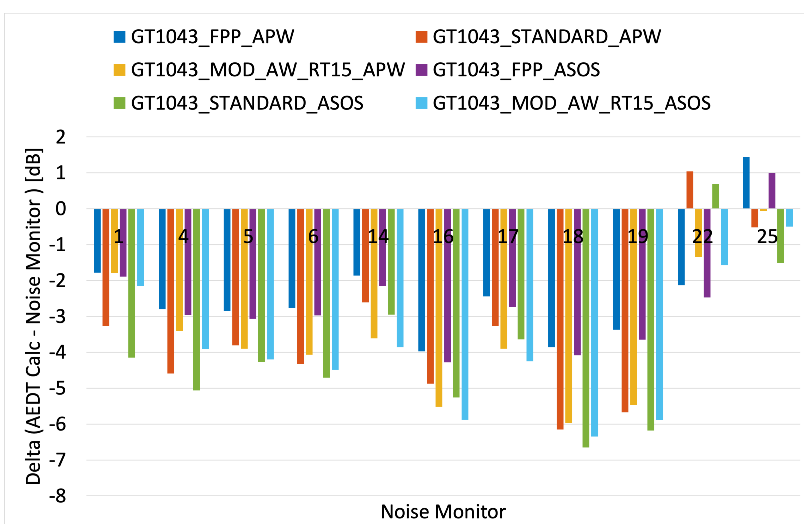

Fig. 13 Acoustic Results using AEDT Default Weather and ASOS for Flight GT 1043.

The third departure flight investigated is Flight GT 1043 with an OD pair of SFO-SLC making it a stage length 2 aircraft. The airframe was an A320-200. It's gross weight at takeoff was 142,908 lbs, 3,700 pounds heavier than the default weight for this airframe.

The weather conditions for this flight are very similar to those for flight GT 786 as these flights took off within 15 minutes of each other, except for a slight change in wind speed. The flight ground track is shown in Fig. 11 with the monitors that were triggered by the flight. The performance plots in Figure 12 indicate that the actual flight profile was close to the AEDT model options in terms of ground speed, but differed in terms of the altitude profile with a lower altitude than AEDT options at the same cumulative ground track distance. Similarly, the actual flight had a higher net corrected thrust at takeoff than AEDT options, which indicates that the AEDT modeling options that have reduced thrust might under-predict the noise.

Figure 13 shows that AEDT mostly under predicts the noise during this event. This could be due to a number of factors: the flight trajectory, the amount of thrust calculated versus the thrust that was actually used during the flight. It can be seen that the darker blue bar in Fig. 13 representing the noise for the FPP, has a lower residual in comparison to the other profiles at noise monitors 1, 4, 5, 6, 14, 16, 17, 18, and 19. The residuals for several modeling options for this flight are higher than the previous flight at multiple noise monitor locations.

B. Arrivals

Table 2 provides a comparison between the AEDT default weather parameters and the ASOS weather for the three arrival flights considered in the present work.

Table 2 Weather condition comparison for arrival flights GT 457, GT 506, and GT 1090.

Weather Option	Temp [F]	SLP [mb]	DP [F]	RH [%]	Wind Speed [kts]	Wind Dir [°]
AEDT Default	57	1016.7	49.2	76.2	9.2	N/A
ASOS_457	70	1016.2	53.1	54.9	14	300
ASOS_506	61.0	1018.0	53.1	75.2	9	270
ASOS_1090	66.9	1013.9	57.0	70.5	3	290

1. Flight Number: ***GT 457***

The first arrival flight investigated is Flight GT 457 with an OD pair of SEA-SFO. All arrival aircraft are modeled as stage length 1 so as to use the stage length with the least weight. This takes into account aircraft burning fuel during the flight and arriving at the airport at their lowest weight. The airframe was an A320-200. Its weight at touchdown was 140,635 lbs, 9,500 pounds heavier than the default weight for this airframe. The flight ground track is shown in Fig. 14 with the monitors that were triggered by the flight.

The performance plots in Figure 15 show the difference between an arrival profile using a constant descent approach (CDA) or an arrival that has a level segment. The AEDT procedure has a level segment at 3000 feet; This is seen as the flat segment in the trajectory (the left-most plot in the performance plots). The fixed point profile shows a CDA being used. There have been other ASCENT projects investigating the impact of these different arrival procedures on noise prediction [24].

Arriving flights being much quieter in general trigger fewer noise monitors as compared to departures. For GT 457, only two noise monitors are triggered (with high confidence) as can be seen in Fig. 16. Monitor 12 is near the water (a hard surface close to a soft surface) and monitor 1 is at the end of the runway. While monitor 1 was triggered, it is being investigated further due to issues related to the timing of the trigger. The results of these investigations will be provided in future work.

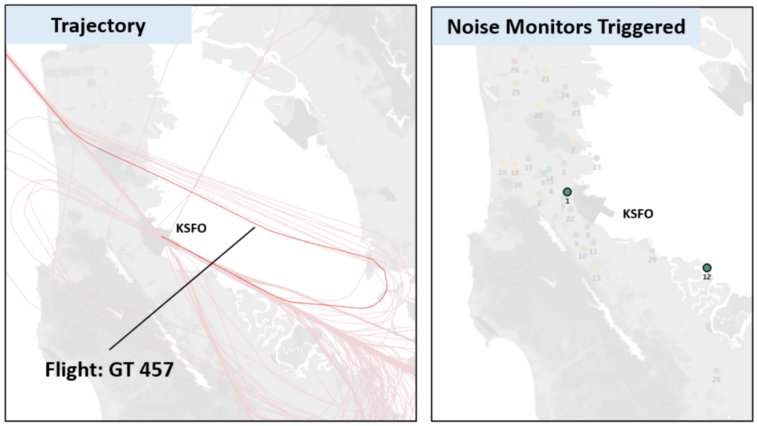

Fig. 14 Trajectory and Monitors Triggered for Flight GT 457.

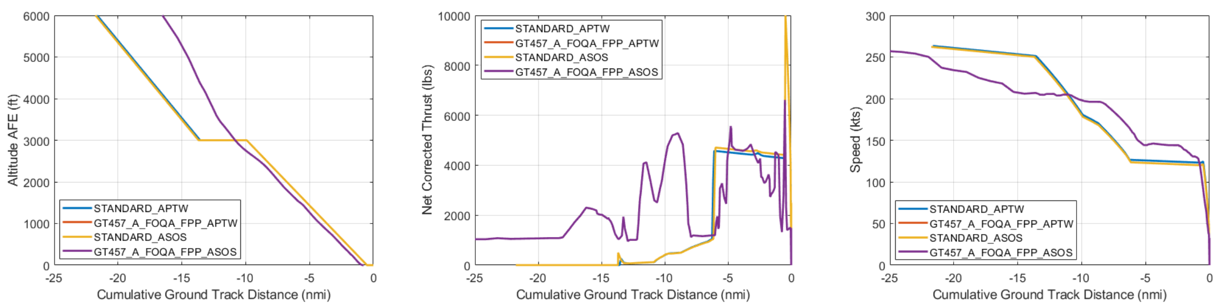

Fig. 15 Trajectory, Thrust, and Ground Speed Performance for Flight GT 457.

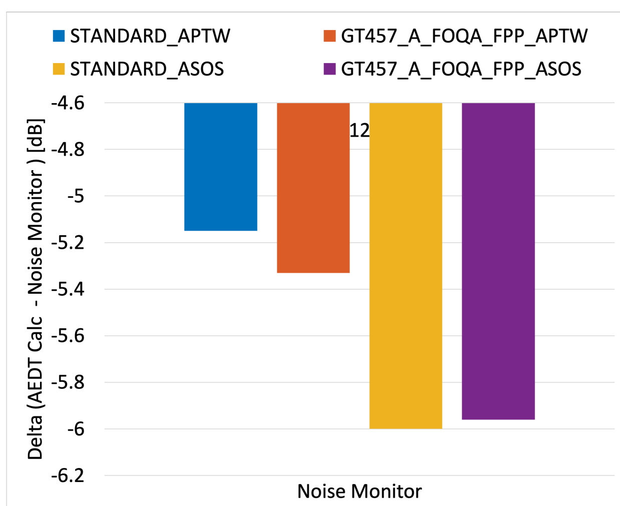

Fig. 16 Acoustic Results using AEDT Default Weather and ASOS for Flight GT 457.

2. Flight Number: ***GT 506***

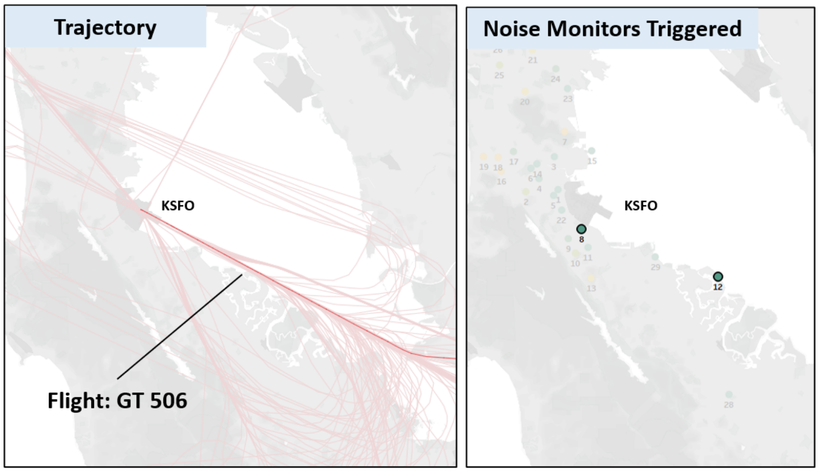

Fig. 17 Trajectory and Monitors Triggered for Flight GT 506.

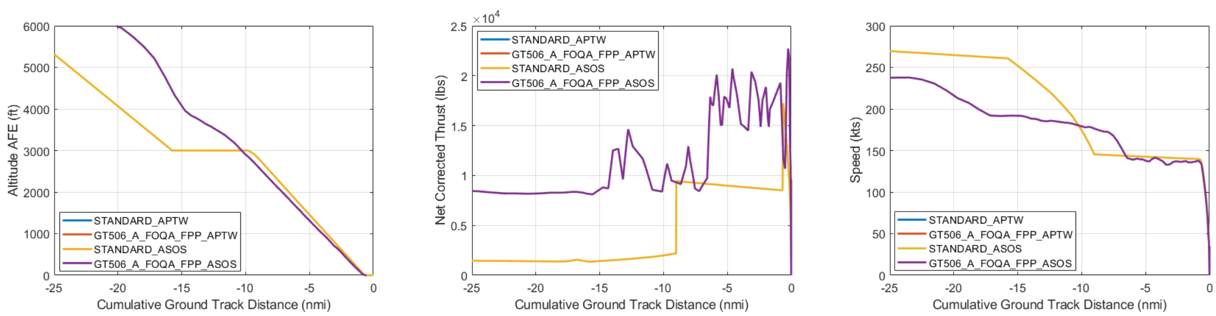

Fig. 18 Trajectory, Thrust, and Ground Speed Performance for Flight GT 506.

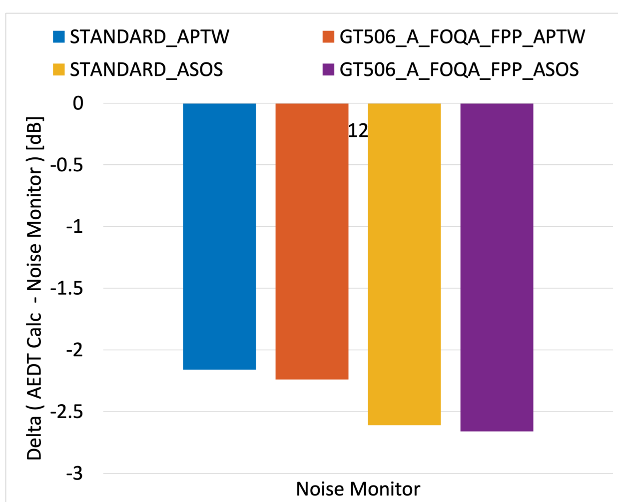

Fig. 19 Acoustic Results using AEDT Default Weather and ASOS for Flight GT 506.

The second arrival flight investigated is Flight GT 506 with an OD pair of ATL-SFO. Again this will be a stage length 1 aircraft. The airframe was an B757-300 and its weight at touchdown was 210,199 lbs, 8,600 pounds heavier than the default weight for this airframe.

The flight ground track is shown in Fig. 17 with the monitors that were triggered by the flight, monitors 8 and 12. The performance plot in Fig. 18 has a similar trend with flight GT 457. The altitude profile shows the difference in using a level segment in the arrival versus a CDA. During this portion of the flight for the STANDARD profile, the speed decreases significantly. Additionally, the FPP also shows a higher thrust setting during its descent at approximately 7,500 pounds of thrust for 15 miles of its operation. CDAs have been shown to generate less noise during their procedures, this difference in thrust could be a reason for this [25]. Similar to the prediction of flight GT 457, AEDT under-predicts at noise monitor 12 which can be seen in Fig. 19. The results for noise monitor 8 are presently under additional investigation for reasons stated previously.

3. Flight Number: ***GT 1090***

The final arrival flight investigated is Flight GT 1090 with an OD pair of LAX-SFO. The airframe was an B737-800 and its weight at touchdown was 119,966 lbs, 11,700 pounds lighter than the default weight for this airframe.

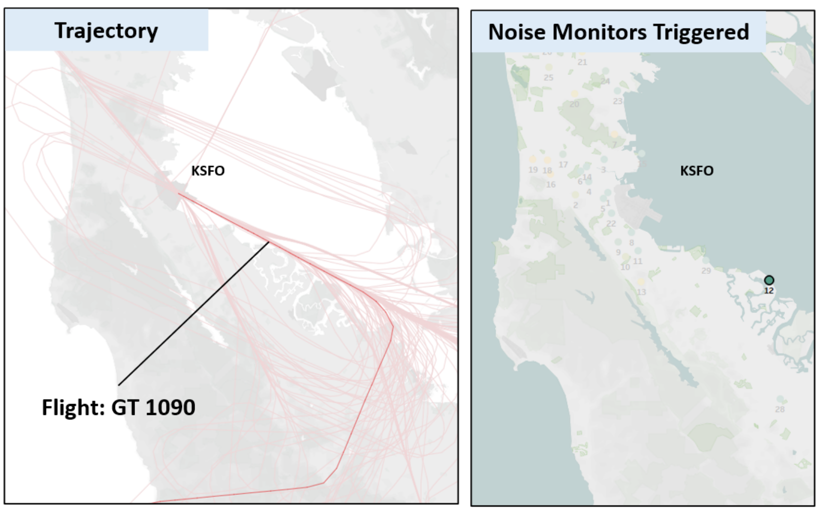

Fig. 20 Trajectory and Monitors Triggered for Flight GT 1090.

The flight ground track is shown in Fig. 20 with the monitor triggered, monitor 12. There is a trend of CDAs versus level segment arrivals between the real-world data and the STANDARD procedures in AEDT. Again this is the case seen between the FPPs and the default within AEDT. The variation in thrust and speed is more similar in this comparison relative to Flight GT 506 and can be seen in Fig. 21. The AEDT under prediction for noise monitor 12 is shown in Fig. 22.

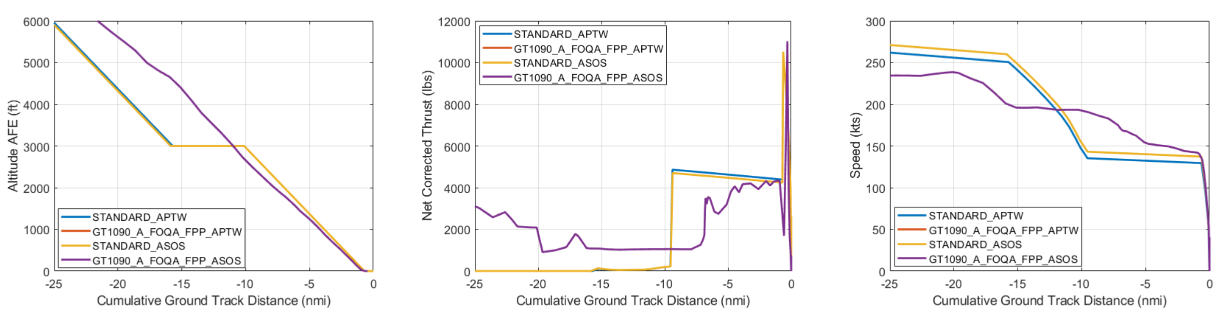

Fig. 21 Trajectory, Thrust, and Ground Speed Performance for Flight GT 1090.

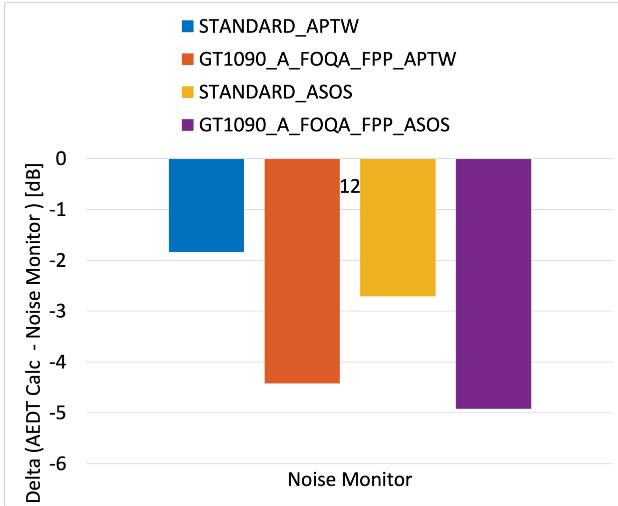

Fig. 22 Acoustic Results using AEDT Default Weather and ASOS for Flight GT 1090.

C. Summary of Results and Discussion

In conclusion, departure noise prediction and propagation by AEDT varies. There are some noise monitors which are highlighted frequently by the results. Sideline noise monitor 22 has larger discrepancies in its predictions than the rest of its counterparts for flights GT 786 and GT 528.

The discrepancies for monitor 12 which was triggered by incoming arrival flights is relatively lower than the sideline monitor predictions. This can be explained by the accompanying performance plots. For the last five miles of the trajectory, the aircraft are roughly at the same altitude. However, for both of the profiles used in arrival modeling, the profile using the default airport weather has smaller deltas. This is true for departing flight GT 1043 as well for noise monitors 1, 4, 5, 6, 14, 16, 17, 18, and 19. Sideline noise monitor 22 and noise monitor 25 have larger variation. Noise monitor 25 is located such that it is triggered by aircraft that are at a higher altitude.

More direct flyover noise prediction performs the best in AEDT noise calculations. The deltas are the smallest for flight GT 786 where the aircraft flies more directly over noise monitors 1, 4, 5, 6, 14, 16, and 17. Determining the flight modeling combination which is most similar to the noise monitoring recordings is difficult as this varies from monitor to monitor. In flight GT 1043, the combination which has the smallest deltas for the flyover monitors is the FPP using AEDT's default weather (APW).

The results and observations indicate that for a majority of noise monitor readings among the modeled flights, there is a good overall match between AEDT and real-world observations. These findings are however, preliminary, and additional flight modeling for statistically significant results need to be obtained in order to further quantify the accuracy of the system-level noise modeling capabilities in AEDT.

IV. Conclusion and Future Work

This paper provided a structured and repeatable framework for noise model validation using real-world operations data. In future studies different settings in the test matrix can be used in order to understand which information in the modeling process can assist with noise prediction to match noise monitoring data more closely. Additionally, more information regarding the monitors can also be added to the modeling framework. Currently, the monitors are all assumed to be at the same altitude as the airport. Some actual altitudes can vary by hundreds of feet which can affect the amount that the noise would have to propagate in reality. Details like these can make an impact on the noise calculated and will be investigated in future efforts.

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