Project 045 Takeoff/Climb Analysis to Support AEDT APM Development

Georgia Institute of Technology

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- Tasks:
    - Task 1: NADP library investigation
    - Task 2: Arrival profile modeling
    - Task 3: Integrated impact assessment of inaccuracies from thrust, weight, procedures, and NPD curves

Project Funding Level

The project is funded at the following levels: GT ($175,000). Cost-share details are below:

GT has agreed to a total of $175,000 in matching funds. This total includes salaries for the project director; research engineers; graduate research assistants; and computing, financial and administrative support, including meeting arrangements. The institute has also agreed to provide tuition remission for the students, paid for by state funds.

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Project Overview

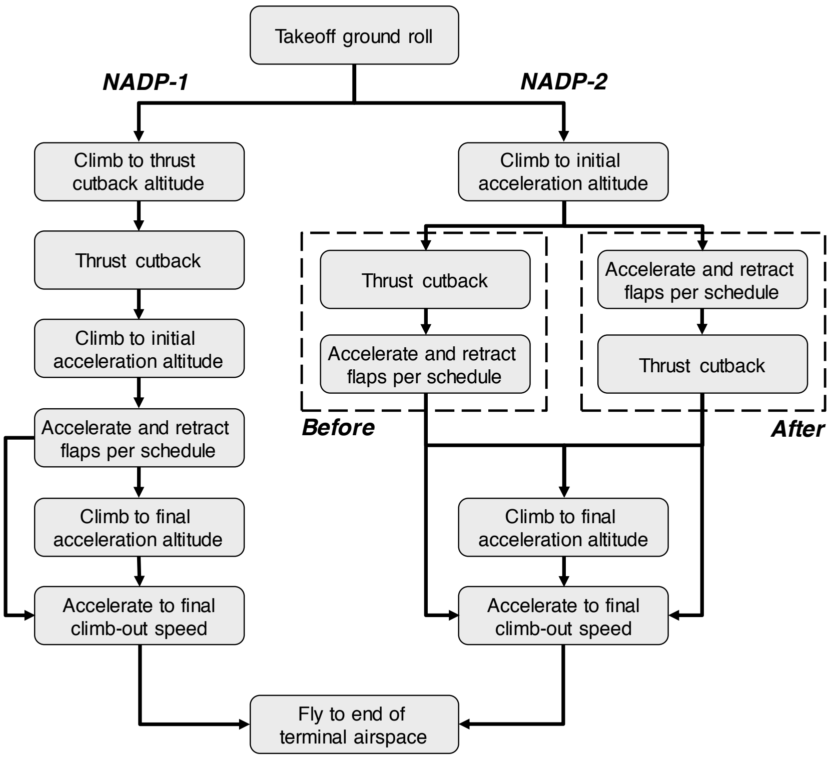
Accurate modeling of aircraft performance is a key factor in estimating aircraft noise, emissions, and fuel burn. Within the Aviation Environmental Design Tool (AEDT), many assumptions are made for aircraft performance modeling with respect to aircraft weight and departure procedure, coupled with aircraft departure typically being modeled by assuming that full rated takeoff power/thrust is used. As operations around airports continue to evolve, there is a need to examine those assumptions and to improve the modeling accuracy with flight data. In recent years, flight data are increasingly being used to enhance models and bring model estimation even closer to reality. Research is needed to build on prior work with a view to develop a robust set of recommendations for improved estimation processes for takeoff weight, reduced thrust takeoffs, and departure profiles within AEDT.

Task 1 - NADP Library Investigation

Georgia Institute of Technology

Objective(s)

Previous research efforts under Project 45 led to the development of the NADP Library, a set of noise abatement departure profiles (NADPs) that are defined as procedural profiles in AEDT. The library is generic and can be applied to any aircraft or airport. Each such profile is based on the combination of three parameters: thrust cutback, initial acceleration, and final acceleration. The complete flowchart is described in Figure **1**. The distinction between the two NADP-2 profile types comes from the thrust cutback initiation. Profiles following the “before” track use climb thrust to accelerate through the flap schedule, and those following the “after” track use takeoff thrust instead, NADP-1 profiles differ from “before” NADP-2 profiles because of the use of a constant speed climb step between the cutback and initiation of acceleration.



Terminology

- Thrust cutback – Throttle setting changed from "takeoff" mode to "climb" mode
- Initial acceleration altitude – altitude at which aircraft will pitch over and start increasing speed to retract flaps
- Final acceleration altitude – altitude at which aircraft will accelerate to final climb-out speed (usually 250 KCAS)

Figure 1. Description of generic NADP within NADP Library.

Research Approach

There are 6 NADP-1 profiles and 13 NADP-2 defined in the library. Even more modeling options are possible when the possibilities of alternate weight and reduced thrust are considered. Including such a high number of profiles as modeling options in future versions of AEDT is undesirable. Therefore, a grouping of profiles within NADP Library is required so that a subset of these 19 profiles can be selected. A single profile within each group can then be chosen to represent the all other profiles within the group.

Any grouping must reproduce the high variability in modeling options present in the original library, while simultaneously minimizing the error arising from the substitution of profiles within a group. Such a process requires clustering algorithms that can be applied to different comparison metrics. Because the similarity between profiles is to be judged between their environmental impacts, the following comparison metrics were identified for preliminary analysis:

1. Performance-based comparison metrics
   a. Trajectory root mean square (RMS)
   b. Speed RMS
   c. Thrust RMS
2. Noise-based comparison metrics
   a. RMS of sound exposure level (SEL) grid difference
   b. Differences in contour area, length, and width
3. Emissions-based comparison metrics
   a. Difference in fuel burn up to 1,000 ft, 3,000 ft and the complete profile
   b. Difference in NOx emissions up to 1,000 ft, 3,000 ft and the complete profile

All comparison metrics are calculated pairwise for all profiles. The 6 NADP-1 and 13 NADP-2 profiles are not compared to one another. Thus, for the complete set of 19 NADP profiles, a 6 × 6 and 13 × 13 matrix of each calculated similarity metric is obtained. The computation process for calculating the performance-based comparison metrics is outlined below.

The performance data and trajectories of different profiles are compared with an RMS-based methodology. The performance results from an AEDT simulation consist of a table, with each row representing a particular point in space-time reported by altitude, cumulative distance traveled, speed, and thrust, among other parameters. Because different profiles result in different performance data, the points in these tables are not expected to match in any parameter. For the calculation of comparison metrics, it is desirable for a single parameter to be specified for consistent sampling. To solve this problem, an independent set of data points is generated by using linear interpolation on each NADP profile. The interpolated profiles shown in Figure **2** are similar to the raw profiles except the interpolated profile points that define the curve share the same altitudes.

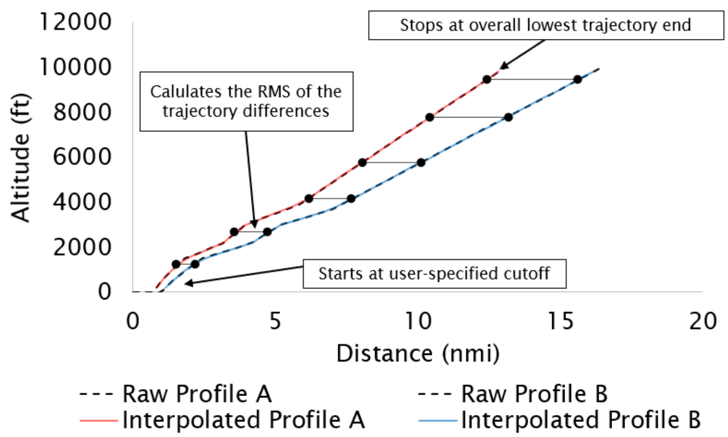


Figure 2. Trajectory comparison method visualization.

Given that the interpolated profiles are the same size and share the same step size, the differences between distance, speed, and thrust may be calculated. In Figure **2**, these differences are represented by horizontal lines linked at discrete points along the red and blue lines. Samples are represented by filled black circles. Sampling currently takes place every 200 feet, starting at a user-specified point and ending at the lowest altitude between the two profiles.

The set of differences is then squared and summed, as shown in equation 1, where *n* represents the number of samples in the set. The variable *x* represents the trajectory state being analyzed (e.g., cumulative distance traveled). The calculated result provides an overall measure of discrepancy between the two profiles in terms of distance.

$$x_{rms} = \sqrt{\frac{x_1^2 + x_2^2 + \cdots + x_n^2}{n}} \quad (1)$$

For example, if x_{rms} equals 2.07 nmi, on average, profiles A and B are approximately 2.07 nmi apart. The average value is calculated in the sense of RMS. Many alternative methods exist to calculate averages, such as taking a simple mean of the absolute value of differences. If more than two profiles are being analyzed, this methodology is used with each possible pair, constructing a matrix of resulting combinatory RMS values. Given the sheer volume of information, results are better visualized with conditional formatting, creating a heat map matrix, as listed in Table **1**, Table **2**, and Table **3** for the same NADP1 profile set in terms of velocity, distance, and thrust, respectively.

Table 1. Sample RMS heat map matrix comparing profile velocities.

RMS Speed(kts)	NADP1_1-3	NADP1_2-3	NADP1_3-3	NADP1_4-3	NADP1_6-3	NADP1_7-3
NADP1_1-3	0.00	13.81	20.92	13.81	20.93	20.93
NADP1_2-3	13.81	0.00	10.78	0.00	10.78	10.78
NADP1_3-3	20.92	10.78	0.00	10.78	0.00	0.01
NADP1_4-3	13.81	0.00	10.78	0.00	10.78	10.78
NADP1_6-3	20.93	10.78	0.00	10.78	0.00	0.01
NADP1_7-3	20.93	10.78	0.01	10.78	0.01	0.00

Symmetric

Table 2. Sample RMS heat map matrix comparing profile cumulative distance.

RMS Distance(nmi)	NADP1_1-3	NADP1_2-3	NADP1_3-3	NADP1_4-3	NADP1_6-3	NADP1_7-3
NADP1_1-3	0.00	0.27	0.43	0.29	0.46	0.52
NADP1_2-3	0.27	0.00	0.23	0.04	0.26	0.32
NADP1_3-3	0.43	0.23	0.00	0.22	0.04	0.13
NADP1_4-3	0.29	0.04	0.22	0.00	0.23	0.29
NADP1_6-3	0.46	0.26	0.04	0.23	0.00	0.09
NADP1_7-3	0.52	0.32	0.13	0.29	0.09	0.00

Symmetric

Table 3. Sample RMS heat map matrix comparing profile total thrust.

RMS Thrust(lb)	NADP1_1-3	NADP1_2-3	NADP1_3-3	NADP1_4-3	NADP1_6-3	NADP1_7-3
NADP1_1-3	0.00	354.42	532.81	545.74	675.09	938.66
NADP1_2-3	354.42	0.00	273.88	415.61	497.53	820.54
NADP1_3-3	532.81	273.88	0.00	497.75	415.39	774.04
NADP1_4-3	545.74	415.61	497.75	0.00	273.85	690.14
NADP1_6-3	675.09	497.53	415.39	273.85	0.00	633.88
NADP1_7-3	938.66	820.54	774.04	690.14	633.88	0.00

Symmetric

The last number in the NADP profile label represents the stage length. In Table **1**, the stage length is 3. Of note, the matrix shown is symmetric, because directionality does not matter. To read Table **1**, start at a row containing the profile of interest, and then move right until encountering the column of the second profile of interest. The number presented is the RMS value comparing these two profiles.

Noise is compared by using RMS in a different manner, as shown in Table 4. In this case, *n* in equation 1 represents the total number of grid points in one profile. As long as the number of grid points and the latitude/longitude coordinates match between two profiles, then the difference in noise at every grid point is calculated and root-mean-squared. This procedure provides a single metric to assess the overall discrepancy between two profiles. Of note, the noise contours in Table 4 are taken at sea level in this particular case.

Table 4. Sample RMS heat map matrix comparing profile noise.

RMS Sound(db)	NADP1_1-3	NADP1_2-3	NADP1_3-3	NADP1_4-3	NADP1_6-3	NADP1_7-3
NADP1_1-3	0.00	0.35	0.57	0.36	0.58	0.66
NADP1_2-3	0.35	0.00	0.25	0.09	0.26	0.40
NADP1_3-3	0.57	0.25	0.00	0.27	0.09	0.31
NADP1_4-3	0.36	0.09	0.27	0.00	0.25	0.33
NADP1_6-3	0.58	[illegible]	[illegible]	0.25	0.00	0.23
NADP1_7-3	0.66	0.40	0.31	0.33	0.23	0.00

Symmetric

For example, NADP1_1-3 and NADP1_7-3 differ on average by 0.66 dB in the upper-right-hand corner. Notably, NADP1_1-3 has the least in common with the rest of the profiles in terms of overall average noise level. Further analysis on the actual shape of the noise contours is required to determine why.

Emissions analysis presents an exception to the rule. Instead of calculating an RMS value between profiles, a simple difference in total fuel burn and NO_x emissions is calculated between two profiles. The results are organized into a heat map matrix for easy visualization in Table **5**. NOx emissions are shown for the climb up to mixing height, which is 3,000 ft above field elevation in this situation. For example, between NADP1_3-3 and NADP1_4-3, total NO_x emissions differ by 0.107 kilograms. The sign of the difference is removed for the entire matrix, so which profile results in greater NO_x emission cannot be inferred.

Table 5. Sample RMS heat map matrix comparing profile NOx emissions up to 3,000 ft mixing height.

Diff NOx(kg)	NADP1_1-3	NADP1_2-3	NADP1_3-3	NADP1_4-3	NADP1_6-3	NADP1_7-3
NADP1_1-3	0.000	0.099	0.416	0.089	0.407	0.381
NADP1_2-3	0.099	0.000	0.318	0.010	0.308	0.283
NADP1_3-3	0.416	0.318	0.000	0.328	0.010	0.035
NADP1_4-3	0.089	0.010	0.328	0.000	0.318	0.293
NADP1_6-3	0.407	[illegible]	[illegible]	0.318	0.000	0.025
NADP1_7-3	0.381	0.283	0.035	0.293	0.025	0.000

Symmetric

Various clustering methods can be used to transform heat maps into clusters. However, at this stage, there are multiple comparison metrics to consider without any relative priority scaling. Moreover, the comparison metrics have different units and ranges of typical values, thus further adding complexity to the clustering process. Therefore, a normalization scheme is needed that can compute each comparison metric on the same relative scale, thus enabling relative comparison. Several normalization schemes will be considered:

1. Performing RMS over relative differences instead of absolute differences
2. RMS scaled by mean of values
3. RMS scaled by range of values
4. RMS scaled by standard deviation
5. RMS scaled by interquartile range

The complete flowchart of the grouping process is shown in Figure **3**. The objective of the grouping process is to start with the complete NADP Library and end with a Reduced NADP Library that contains fewer profile definitions while retaining the variability of the original profile set. Any grouping must hold true across different operating conditions, thus necessitating the involvement of different test conditions in the grouping process. The currently identified parameters are aircraft size, airport altitude, and stage length. The selected airports correspond to a large variation in airport altitude and aid in assessing the effects of airport altitude on the profiles, and are also synergistic with Project 43 research. After a combination of these parameters has been compiled into a test matrix, a set of automation tools are used to generate results for each test case. The results relevant to grouping are the performance, noise, and emissions. Next, comparison metrics are computed between results for profile pairs, as previously described in detail. The comparison metrics are stored as heat map matrices, which will be used as inputs to the final step of clustering/grouping. In this step, heat maps are converted into clusters by using techniques that preserve variability with a minimum number of groups/clusters. Different techniques are being explored, and the most suitable will be implemented. After the grouping is complete, the Reduced NADP Library will be obtained.

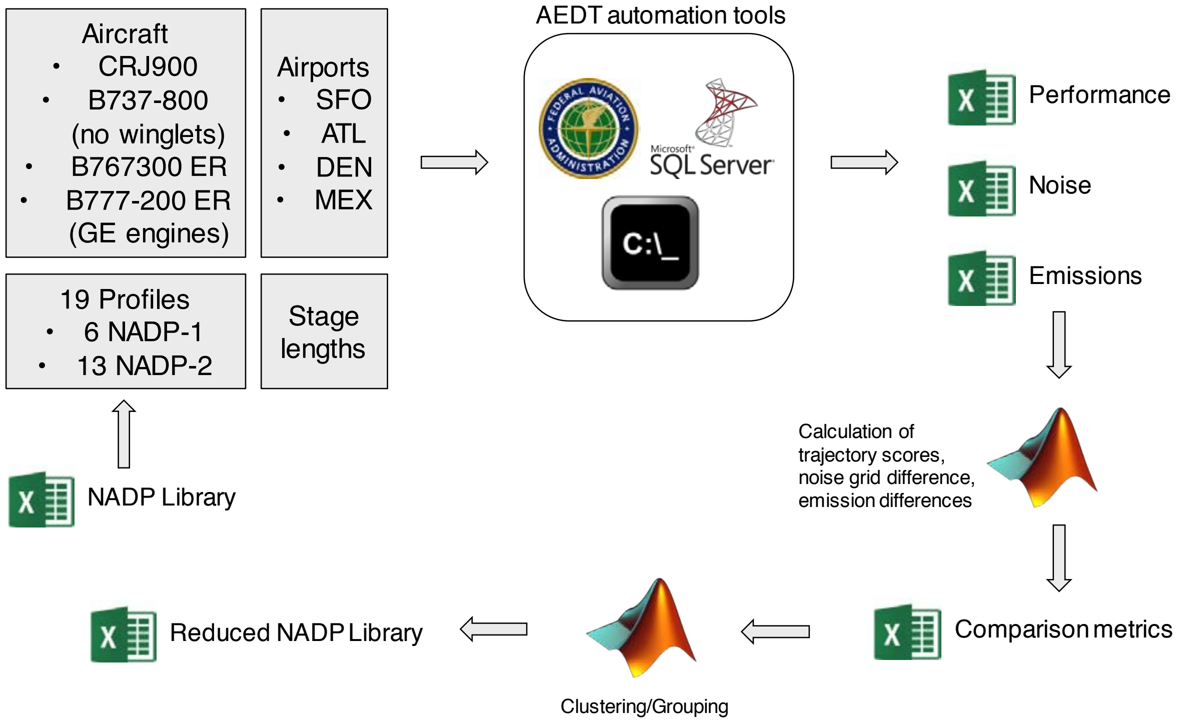


Figure 3. Process of NADP Library grouping.

Milestone

The objective of this task is to provide recommendations for the implementation of NADPs in AEDT. To accomplish this, the NADP Library is being analyzed to shortlist three to five different profiles that are representative of the variability among NADPs.

Major Accomplishments

- Development and implementation of metrics to numerically compare NADP library profiles by using MATLAB scripts
- Automation of processes to enable analysis of numerous combinations of aircraft, airports, profiles, and takeoff weights

Publications

N/A

Outreach Efforts

Bi-weekly calls with the FAA, Volpe, and ATAC. Bi-annual ASCENT meetings.

Awards

None.

Student Involvement

Ameya Behere and Loren Isakson, Graduate Research Assistants, Georgia Institute of Technology

Plans for Next Period

- Implement normalization techniques for same scale assessment of comparison metrics
- Implement clustering algorithms for grouping of NADP library profiles
- Develop the reduced NADP library as options for future implementation into AEDT
- Compare the reduced NADP library to real-world flight data to inform the selection process for implementation into AEDT

Task 2 - NextGen Arrival Profile Modeling

Georgia Institute of Technology

Objective(s)

Previous research has extensively investigated the difference between departure procedures in AEDT and the actual departure procedures observed by using data types such as radar data, Flight Operational Quality Assurance (FOQA) data, and airline and airport documentation, thus resulting in a library of departure procedures. A similar study is to take place for arrival procedures. The use of FOQA data from one airline will be utilized to assess the accuracy of AEDT arrival procedures for 14 airframes. The FOQA data will be used to find different arrival characteristics such as level off altitude, velocity, gear setting and flap setting. These different characteristics will then be compared to what is currently prescribed in AEDT. If a significant difference is found, new arrival profiles will be proposed.

Research Approach

Recent research conducted under ACRP 02-55 has developed methods to model advanced NextGen profiles in AEDT. The project is now complete, and the final deliverables included a report and technical guidance for selecting appropriate aircraft approach and departure profiles, which are available to the public. The GT team has conducted a thorough review of the work conducted in ACRP 02-55 and has created an actionable plan to incorporate the findings.

The ACRP 02-55 objective was to capture and represent arrival procedures used in the real world. This was done by creating additional standard or default procedures that are not currently within AEDT. The researchers working on this study had access to Performance Data Analysis and Reporting System (PDARS) data for more than 274,000 arrival procedures. The data was taken from 30 airports throughout the United States for 68 different aircraft types. From this, the flights were grouped according to the level off length, level off altitude and aircraft class. An example of this grouping would be "A-LJ-1-3000-40to49-5to14." This signifies an approach operation for a large jet with a stage length of 1, which has a level off at 3,000 ft, for a distance between 40 and 49 nmi, ending with 5 to 14 nmi from the airport. The flights were then modeled to fly out of one airport, KATL, to make the trajectories comparable. Level off "bins" for flights were created every 1,000 ft.

An averaged trajectory for these grouped flights was then created and compared to their analogous baseline trajectories, which were STANDARD AEDT approach procedures found in AEDT2a service pack 2. The method used to average the flights was not explicitly defined within the airport. A trajectory score was computed for the average trajectories of the different groups with the following formula:

$$TrajScore = \frac{\sum_{i=1}^{N} \left| H_{avg,i} - H_{BL,i} \right|}{N}$$

where H_{avg} is the altitude from the averaged trajectory, and H_{BL} is the altitude of the baseline from AEDT. These were then normalized to the number of samples taken. Samples were taken every 1 nautical mile in ground track distance. After the grouping process and the calculation of trajectory scores, the worst six profiles for six aircraft classes were chosen to create AEDT procedures by using AEDT's altitude controls functionality. Then 36 approach profiles were generated for six different aircraft classes.

This document was helpful in providing a method to group different flight trajectories. The GT team will create their own algorithm for averaging a particular group of flights according to characteristics that will be discussed later. The averaging and grouping findings will then be compared to the findings in the ACRP 02-55 document to assess whether there is a correlation between the two.

A similar study will be conducted by the GT team with a new set of airline data acquired from one airline. FOQA data from 21,146 flights and 14 airframes will be used to assemble trajectories into groups. The data include information about altitude, ground track distance, thrust, velocity, gear position, flap position, etc.; the data are more thorough than the PDARS data that the ACRP 02-55 research used. Popular arrival settings for each of the previously described parameters will be heavily inspected to find common departure modes.

A systematic parsing of the data must first be conducted, because these data include the entire flight trajectory from taxi and takeoff to landing and taxi again. For the purposes of this task, the GT team will be investigating only the altitude from 6,000 ft until touchdown, because this is the same altitude range that AEDT uses in its definition of approach. The data will then be entered into visualization software. This software allows users to easily manipulate the data to see trends; an example of this software is shown in Figure 4. This dashboard allows users to see popular modes of flight for approach. The parameters that will be investigated are altitude, ground track distance, thrust, velocity, gear position, and flap position, because these are the parameters that most affect the noise generated by the aircraft. A demonstrational study with 100 flights of data is shown below. This will be expanded to include all the flights for all the airframes.

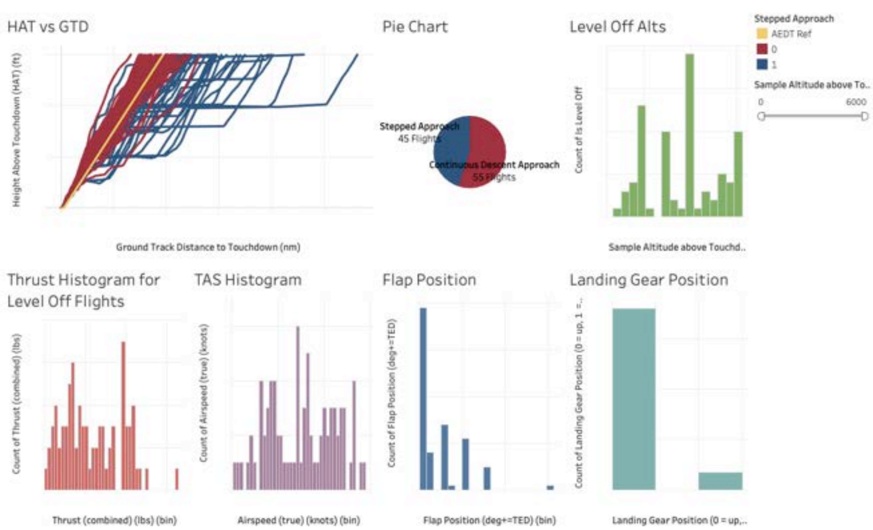


Figure 4. Dashboard with key flight characteristics during arrival for a single-aisle passenger aircraft.

Trends are already observable in the level off altitude, thrust setting, airspeed, flap setting, and landing gear position in the data from 100 flights alone. For example, approximately half the flights have level off segments, which can be seen in the pie chart and the color coding of the plotted flight trajectories. Of these flights categorized as level off, there is an obvious popular altitude for level offs, which can be seen in the "Level Off Alts" chart.

Approach profile and performance variation from the STANDARD AEDT procedure has the potential to change the noise and emissions outputted from an aircraft during this operation. To accurately capture these products, the AEDT procedures must be representative of real aircraft operations. The above approach will allow our team to make proper comparisons and suggestions for improvement to current AEDT procedures. This research will continue into the next period, with examination of different airports and aircraft types with a comparison to the AEDT approach profiles. Initial assessments of real-world flight data indicate differences with respect to the AEDT profile that are dependent on the airport of choice.

Milestone

The objective of this task is to provide insight into how accurately the current AEDT approach profile represents how real-world flight trajectories are performed and, if it does not, to propose new profiles for use.

Major Accomplishments

- Obtained real-world FOQA performance data from airline partner for 13 airframes
- Created a parsing algorithm that observes only the approach phase of flight
- Created an algorithm that detects level segments during the approach phase
- Used this algorithm to create a detailed statistical analysis of the FOQA data to observe common approach procedural patterns

Publications

N/A

Outreach Efforts

Bi-weekly calls with the FAA, Volpe, and ATAC. Bi-annual ASCENT meetings.

Awards

None.

Student Involvement

Ameya Behere and Loren Isakson, Graduate Research Assistants, Georgia Institute of Technology

Plans for Next Period

- Analyze the results of this algorithm and compare the characteristics of real approach procedures to that prescribed in AEDT, to suggest better methods of modeling arrival procedures

Task 3 - Integrated Impact Assessment of Inaccuracies from Thrust, Weight, Procedures, and NPD Curves

Georgia Institute of Technology

Objective

Assess the total impact of proposed improvement in accuracy in modeling assumptions from thrust, weight, procedures, and noise-power-distance (NPD) curves in AEDT vs. real-world settings. The final comparisons will be among standard baseline AEDT modeling assumptions, improved AEDT modeling assumptions (based on real-world data), and actual real-world noise contours.

Research Approach

The research approach is presented in Figure **5**. The initial focus of this task was the departure phase of flight.

Process FOQA data

The objective of this step was to obtain the FOQA data and extract relevant phases of flight and parameters. Approximately 21,000 flights from 14 different airframes were obtained. For the initial iteration to test the methodology presented in Figure **5**, the analysis focused on a single-aisle passenger aircraft, for which there were approximately 4,500 flight records. Scripts were created to automate the data extraction from the raw FOQA files, such that only the relevant segments and parameters were extracted. For this analysis, the departure segment was defined as the start of ground roll until 15,000 ft above runway elevation. The extracted parameters were airspeed (true), airspeed (calibrated), thrust, landing gear position, flap position, gross weight, altitude, ground track distance, and time.

Determine departure modes

The primary focus of this step was to determine common departure modes flown by real-world aircraft by using the extracted FOQA data. Departure modes refer to combinations of airspeed, thrust, and configuration (flap and landing gear) for a given aircraft and stage length. There are two main ways in which this will be accomplished: a visualization dashboard and statistical analysis. For the visualization, dashboards were created in Tableau to visualize the parameter distributions at certain altitudes (Figure **6**) and statistical box plots of specific parameters for a range of altitudes (Figure **7**). These dashboards help users find common departure modes for the relevant parameters at key altitudes. For the statistical analysis, a script was created that calculates statistical quantities (e.g., mode, median, mean, and standard deviation) for all parameters of interest at different altitude and stage length combinations. Thus, users can easily identify statistically representative values for parameters and create common departure modes. This stage of the approach is currently in progress.

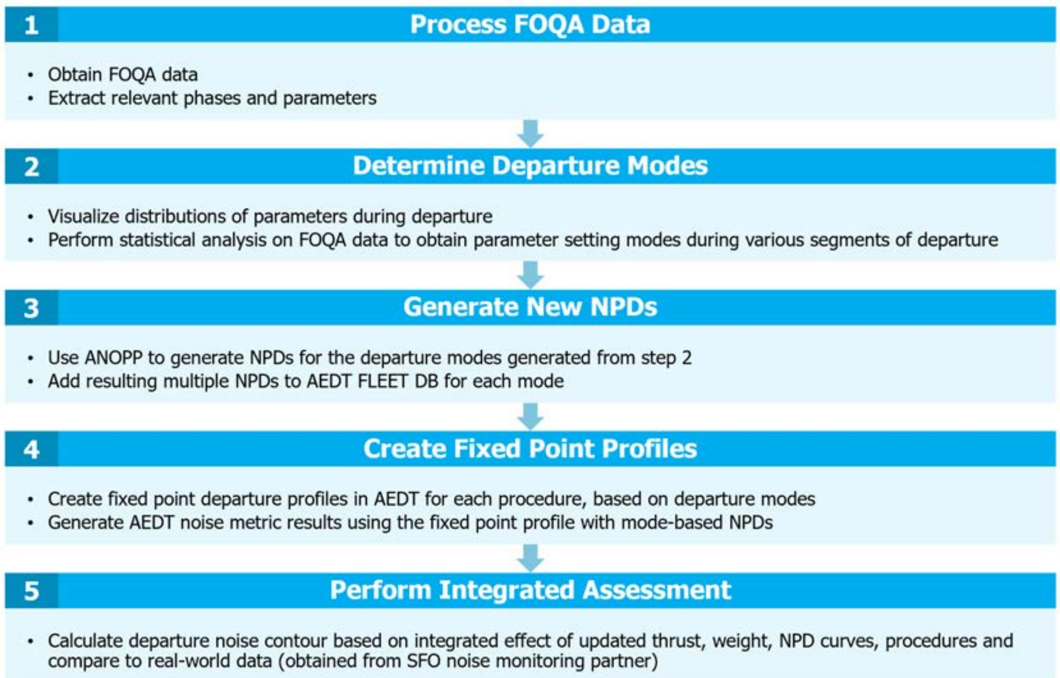


Figure 5. Task 3 research approach.

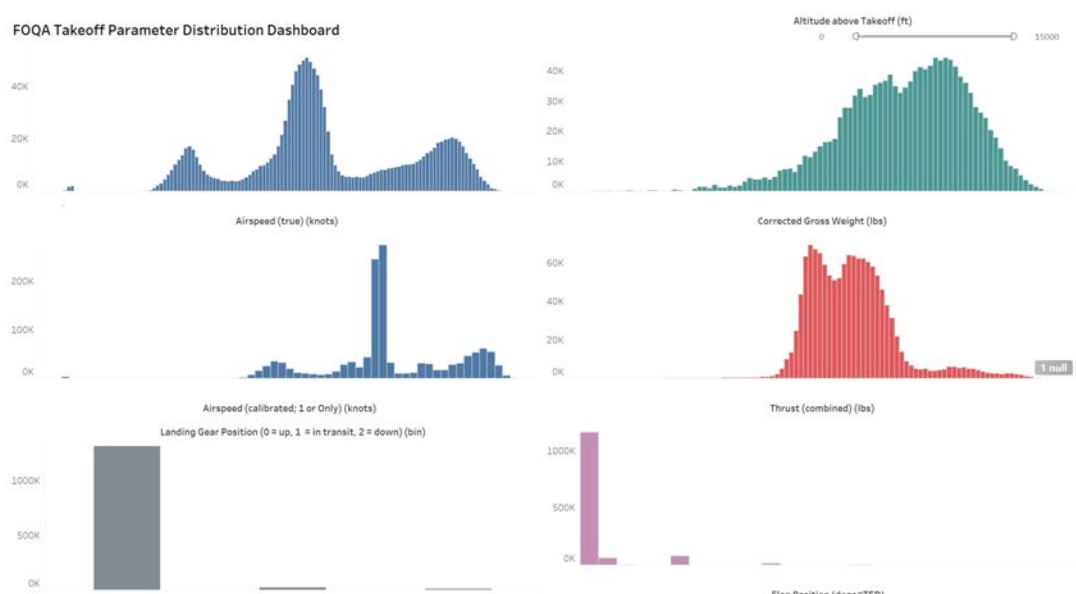


Figure 6. Representative FOQA parameter distribution dashboard.

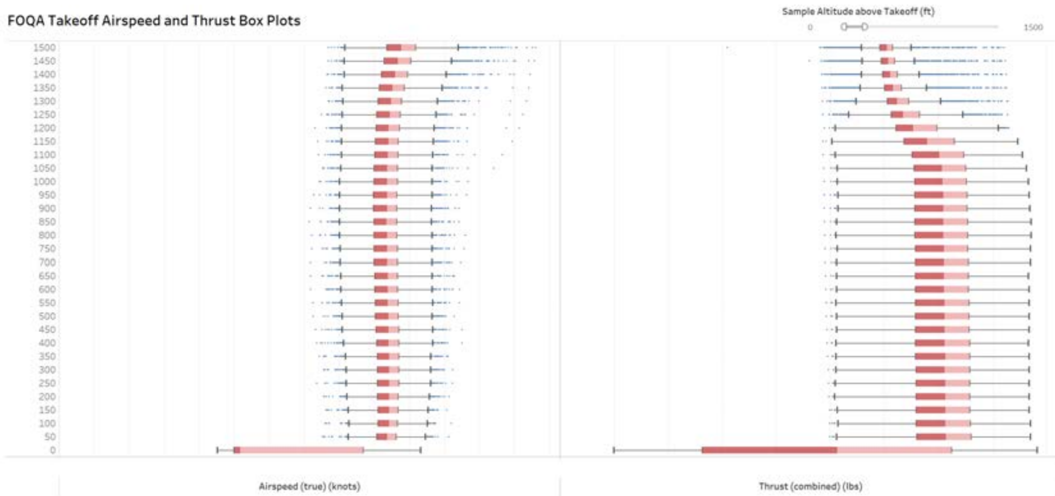


Figure 7. Representative FOQA parameter box plot analysis dashboard.

Generate new NPDs

The departure modes generated from the FOQA analysis will be used to generate a set of new NPD curves for the fleet. The tool used to generate the NPDs will be Aircraft Noise Prediction Program (ANOPP), a noise calculation tool developed by NASA. These new NPDs will have characteristics of real-world flights and are expected to separately consider the noise from the engine and the airframe, which are configuration dependent. Because these NPDs are mode based, multiple NPDs could exist for the same thrust setting, owing to different flap and landing gear configurations. Therefore, a substantial portion of the research will be focused on incorporating multiple NPDs for the same thrust setting into the AEDT fleet database. This work is not the primary focus of this project; instead, the work from ASCENT Project 43 will be leveraged as much as possible to aid in this specific subtask. This phase of the research approach is still in progress.

Create fixed point profiles

The focus of this step is to generate fixed point profiles in AEDT for the aircraft in this study. Fixed point profiles will be used because the thrust setting is already known for the departure modes based on the FOQA data. This phase of the research is still in progress.

Perform integrated assessment

The final step is performing integrated assessment by calculating departure noise contours based on the integrated effect of updated thrust, weight, NPD curves, and procedures. The resulting contours will be compared to real-world noise contours. The comparisons will be across standard AEDT contours, new AEDT contours with updated modeling assumptions and departure modes, and real-world noise contours. This phase of the research is still in progress.

Representative results – departure modes

This section presents preliminary results for departure modes for a single-aisle passenger aircraft, according to the analysis from Step 2 of the approach in Figure **5**. The results are shown for an altitude above takeoff of 1,000 ft. The statistical analysis code was applied to the 4,500 flights for this airframe, and the results are presented in Table 6.

Table 6. Statistical analysis results of select parameters for a single-aisle passenger departures at 1,000 ft above takeoff.

Stage Length	Corrected Gross Weight (lb)		Thrust (combined) (lb)		Airspeed (true) (knots)		Flap Position (degrees)	Landing Gear Position (0 = up, 1 = in transit, 2 = down)
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mode	Mode
1	148,324	8,962	31,796	3,076	186.7	11.6	1	0
2	154,937	7,789	33,857	3,209	182.9	10.7	5	0
3	165,394	6,395	36,132	2,360	186.5	9.2	5	0
4	172,123	6,457	37,467	2,476	189.7	9.0	5	0
All	162,051	11,373	35,263	3,414	186.6	10.2	5	0

This statistical analysis was supplemented with visualization of the parameters by using the dashboard created to confirm the shapes of the distributions and gain additional insights. Consider the results for stage length 1 as an example. The parameter distribution for stage length 1 at 1,000 ft above takeoff is shown in
Figure **8**. The distribution for true airspeed is reasonably normally distributed, and a mean of 187 knots seems appropriate. The distribution for the corrected gross weight has a mean of 148,324 lb, and the figure shows that it is negatively skewed; i.e., the median is greater than the mean (the median corrected gross weight is 150,300 lb). The distribution for the combined thrust has a mean of 31,796 lb with a slight positive skew; i.e., the median is less than the mean (the median combined thrust is 31,234 lb). However, there is no evidence of any multi-modal distributions for these continuous parameters, thus suggesting that the mean values from the statistical analysis are appropriate to describe the parameter states at this altitude. Additionally, the figure confirms the mode value of 0 for landing gear position; in fact, all flights had the landing gear up by 1,000 ft. The figure also confirms the mode value of 1° for flap position. However, a flap position of 5° is also fairly common for these flights.

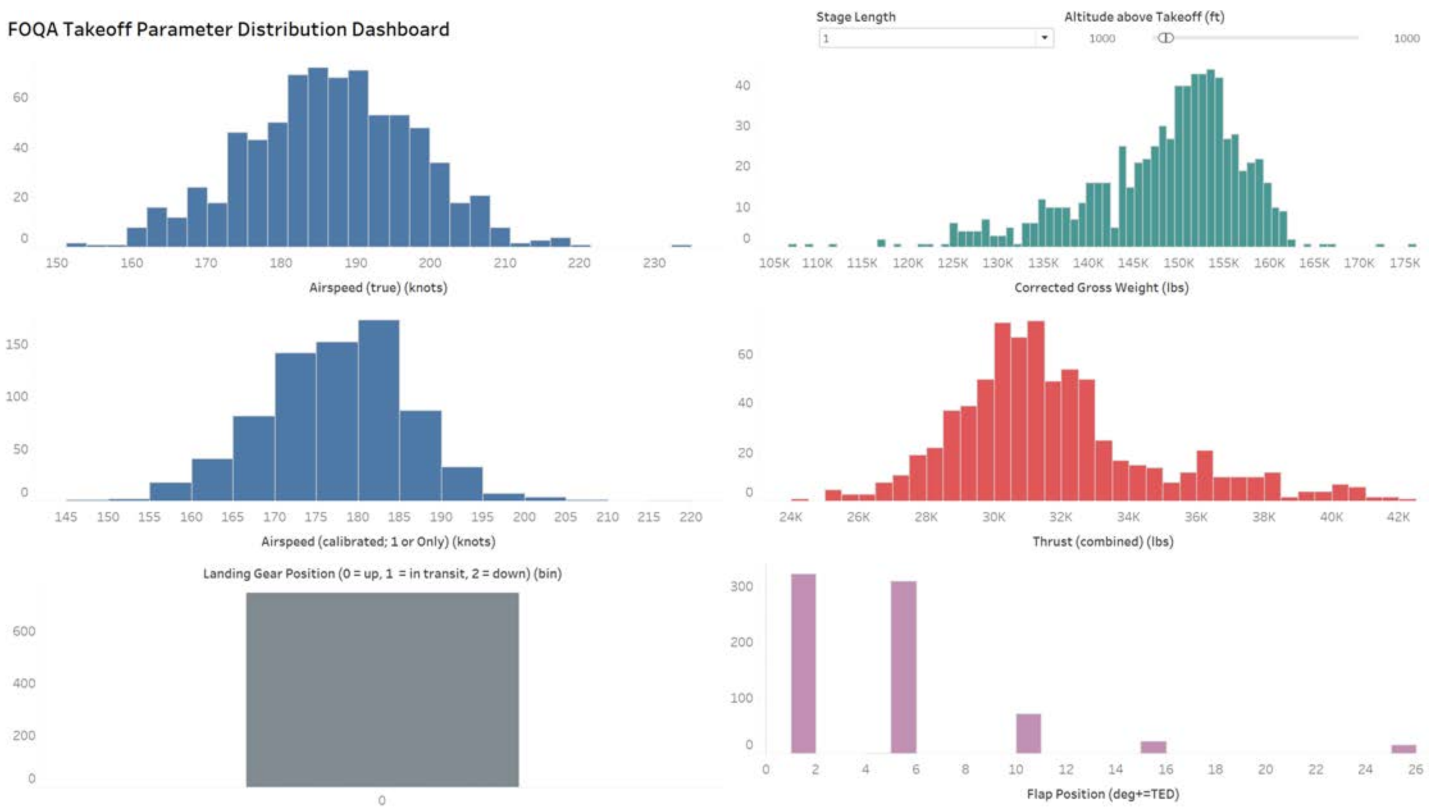


Figure 8. FOQA parameter dashboard result for stage length 1 at 1,000 ft above takeoff.

The combined statistical analysis and visualization dashboard led to the creation of representative departure modes for this aircraft, which are presented in Table 7. These modes are to be used to generate NPD curves for the aircraft.

Table 7. Representative departure modes.

Stage Length	Corrected Gross Weight (lb)	Airspeed (true) (knots)	Thrust (combined) (lb)	Flap Position (degrees)	Landing Gear Position (0 = up, 1 = in transit, 2 = down)
1	148,300	187	31,800	1	0
2	154,900	183	33,900	5	0
3	165,400	186	36,100	5	0
4	172,100	190	37,500	5	0

Milestone(s)

The main objective of this task is to quantify the impact of using each takeoff assumption improvement on the noise predicted by AEDT and compare with real-world noise monitoring data.

Major Accomplishments

- Obtained real-world FOQA performance data from airline partner for 13 airframes
- Identified a process for sampling of FOQA data for modeling in AEDT
- Compared an FOQA profile with the AEDT default profile for assessment of impacts from all assumptions in AEDT APM
- Created visualization dashboards and statistical analysis codes to extract common departure modes based on FOQA data
- Exploring a mode-based methodology for incorporating multiple NPDs for the same thrust setting into the AEDT fleet database

Publications

None.

Outreach Efforts

Bi-weekly calls with the FAA, Volpe, and ATAC. Bi-annual ASCENT meetings.

Awards

N/A

Student Involvement

Dylan Monteiro, Graduate Research Assistant, Georgia Institute of Technology

Plans for Next Period

The primary focus for the next period will be:

- Generate a library of departure modes on the basis of FOQA data, and use these modes to generate NPDs
- Explore different techniques to incorporate multiple NPDs for the same thrust setting into the AEDT fleet database
- Perform integrated assessment to quantify the total impact of inaccuracies from thrust, weight, procedures, and NPD curves