Project 043 Noise–Power–Distance Reevaluation

Georgia Institute of Technology

Project Lead Investigator
Dimitri Mavris
Regents Professor
School of Aerospace Engineering
Georgia Institute of Technology
Mail Stop 0150
Atlanta, GA 30332-0150
404-894-1557
dimitri.mavris@ae.gatech.edu

University Participants

Georgia Institute of Technology (GT)
- P.I.s: Dr. Dimitri Mavris (P.I.) and Dr. Michelle Kirby (co-P.I.)
- FAA Award Number: 13-C-AJFE-GIT-075 and 095
- Period of Performance: August 11, 2020 to December 31, 2022
- Tasks:
    1. Development and testing of the noise–power–distance+ configuration ((NPD+C) correction function (CF)
    2. Engagement with Original Equipment Manufacturers (OEMs) for Validation of the NPD+C Approach with Real Data
    3. Noise Validation Efforts with Noise Monitoring Data at the San Francisco Airport
    4. Rescoping of the Problem to Focus on NPD Corrections at Low-Thrust Values

Project Funding Level
This project is funded at the following levels: GT, $200,000. In addition, $200,000 in matching funds has been provided through in-kind contributions from a major airline. This total includes salaries for the project director, research engineers, and graduate research assistants, as well as funding for computing, and financial and administrative support, including meeting arrangements. The institute has also agreed to provide tuition remission for students whose tuition is paid via state funds.

Investigation Team
- Dimitri Mavris, P.I., GT
- Michelle Kirby, Co-Investigator, GT
- Dushhyanth Rajaram, Research Faculty, GT
- Ameya Behere, Graduate Student, GT

Project Overview
The standard technique for evaluating fleet noise is to estimate the flight procedure source noise by using noise–power–distance (NPD) curves. Noise calculations within the Aviation Environmental Design Tool (AEDT) rely on NPD curves provided by aircraft manufacturers. This dataset reflects representative aircraft categories at set power levels and aircraft configurations. Noise levels are obtained as a function of slant distance via spherical spreading through a standard atmosphere, and other correction factors are applied to obtain the desired sound field metrics at the location of the receiver. The current NPD model does not consider the aircraft configuration (e.g., flap settings) or alternative flight procedures being implemented. These factors are important, because the noise characteristics of an aircraft depend on the thrust, aircraft speed, and airframe configuration, among other contributing factors such as ambient conditions. The outcome of this

research is an approach based on the suggested NPD+C format, which will enable more accurate noise predictions because of its inclusion of aircraft configuration and speed changes.

Task 1 - Refinement of the Final NPD+C Correction Functions

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Objectives

The objective of this task is to create a CF to correct the baseline NPD for an aircraft class to match a given flight configuration, incorporating flight velocity (FV), flap deflection angle (FDA), and gear setting (gear).

Research Approach

Overview

Before a CF was created, several categories of commercial transportation aircraft were identified according to their payload capacity. Ultimately, four categories were identified: 50, 150, 210, and 300 passenger (pax) categories. Fitting the NPD CF involved four steps. The first was the aircraft class definition, in which the bypass ratios, overall pressure ratios, and rated thrusts (i.e., sea-level static thrust) were collected for a given aircraft class. Next, these values were used to create a series of engine variants for the aircraft class and were evaluated with the EDS software to generate engine state tables for use in the Aircraft Noise Prediction Program (ANOPP). The final step of this process was to fit a model to these data, so that the difference between a given configuration and a baseline condition could be predicted. The model itself would be a function of both engine parameters and aircraft configuration, i.e., *fcn* (bypass ratio, overall pressure ratio, sea-level static thrust, FDA, FV, gear). This process is shown in the left column of Figure 1. A general form of the CF equation can be found in which *a, b, c, d,* and *e* are constants, and the remaining terms are cross-products, raised to powers (up to the fifth power) and multiplied by constants.

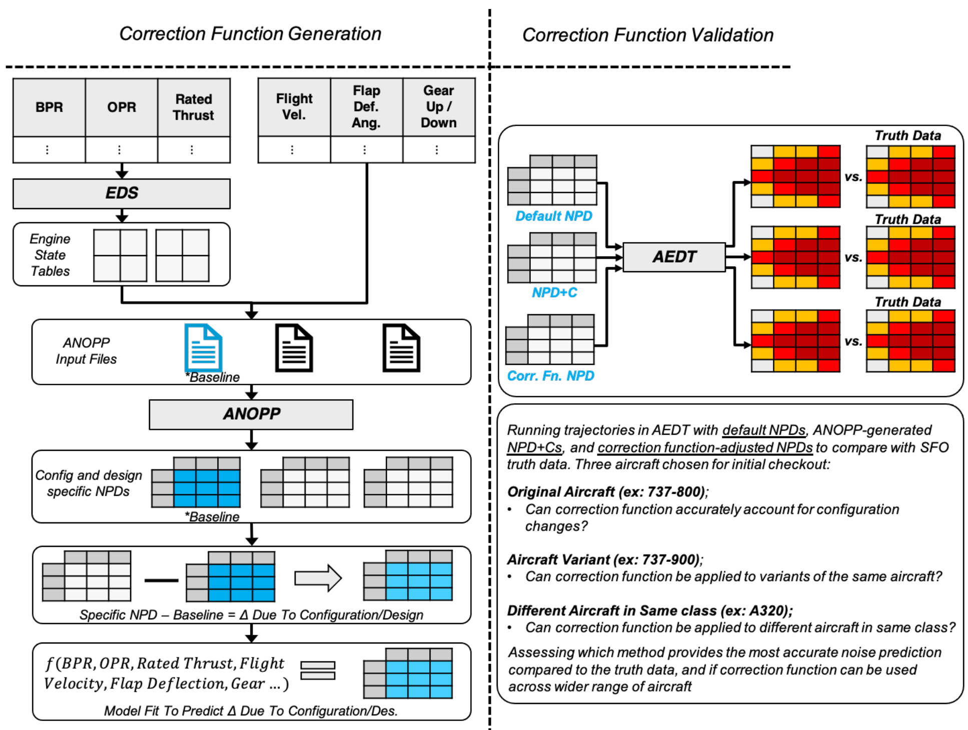

Figure 1. CF generation and validation processes.

Milestone(s)
None.

Major Accomplishments
None.

Publications
None.

Outreach Efforts
None.

Awards
None.

Student Involvement
Ameya Behere

Plans for Next Period
Continue efforts of task under Project 54.

Task 2 - Engagement with Original Equipment Manufacturers (OEMs) for Validation of the NPD+C Approach with Real Data
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Objectives
The objective of this task is to engage with OEMs to potentially validate GT's CF approach to correcting the baseline NPD by using real aircraft data. Given a specific aircraft, the idea is to have an OEM provide NPD data for a variety of flight configurations, incorporating FV, FDA, and gear, and to compare the trends in the real data against predictions made by GT's correction functions.

Research Approach
Boeing agreed to engage with GT to provide limited NPD+C data for a variety of configurations for a Boeing 737-8 type aircraft. Subsequently, GT invoked the CFs for a 737-8 type aircraft by fixing the engine-level parameters to the baselines of the 737-8, as confirmed by Boeing for a specific engine–airframe combination. Values of NPD+C were computed for the exact configurations for which Boeing provided data. Subsequently, a one-to-one comparison was made between NPD corrections predicted by the CFs and the data provided by Boeing. Broadly, the trends did not unequivocally match across the entire dataset. On further investigation, we found that the potential reasons for the mismatch were likely to be due to differences in the underlying truth model (ANOPP by GT and an in-house proprietary program by Boeing) used to generate the NPD data. Moreover, Boeing noted that, because they are not typically required to generate NPD+C data for a large variety of aircraft configurations, they rely on many simplifying assumptions to speed up the analysis and decrease the computational cost. The high-fidelity analyses and actual noise measurements are exclusively relied upon to meet certification requirements. Consequently, any validation effort with GT's approach would not be likely to scale to entire fleets of aircraft.

Milestones
1. Noted that differences in underlying assumptions between truth models are likely to lead to mismatches in trends when data from OEMs are compared with predictions from GT's NPD+C correction functions
2. Noted that, given how OEMs generate limited data for varying aircraft configurations, the validation efforts will be difficult to scale across multiple aircraft

Major Accomplishments

1. Successfully engaged with Boeing in validating the NPD+C approach

Publications

None.

Outreach Efforts

Engagement of airframe manufacturers

Awards

None.

Student Involvement

Ameya Behere

Plans for Next Period

None.

Task 3 - Noise Validation Efforts with Noise Monitoring Data at the San Francisco Airport

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Objective

The objective of this task is to validate the NPD+C approach by comparing modeled noise metric values to a real-world data source. The real-world data in this case come from two sources: the San Francisco airport (SFO) noise monitoring program and GT's airline partner.

Research Approach

The data from SFO consist of noise values, along with metadata including date and time, measured at several noise monitor locations. The airline data consist of flight operational quality assurance (FOQA) parameters recorded at a high sampling frequency. These two data sources were correlated so that each flight could be linked to its observed noise impact. After down-selecting flights to be modeled at the SFO airport, we developed four modeling cases for each flight. Across all four modeling cases, the ground track from the FOQA data was used. Additionally, the airport-averaged weather was used for all four cases. These cases differed in their use of the flight profiles and whether they used the default NPD in AEDT or the NPD+C approach:

1. AEDT standard arrival profile with default NPD
2. FOQA fixed-point profile with default NPD
3. AEDT standard arrival profile with NPD+C
4. FOQA fixed-point profile with NPD+C

The modeled noise metrics for all four cases were obtained and compared with the measured noise values from SFO's noise monitoring program. This comparison should indicate the accuracy of using the NPD+C instead of the default NPD. Because the NPD+C is currently being re-scoped and re-developed, this task is currently paused.

Major Accomplishments

1. Development of a process to model NPD+C in AEDT
2. Preliminary analysis of NPD+C modeled noise results from AEDT and comparison to real-world noise monitoring data

Publications

None.

Outreach Efforts
None.

Awards
None.

Student Involvement
Ameya Behere

Plans for Next Period
None.

Task 4 - Rescoping of the Problem to Focus on NPD Corrections at Low-Thrust Values
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Objectives
1. Setup of ANOPP to run at low-thrust values, i.e., lower than the typical 7% thrust
2. Generation of NPD data for three aircraft in the low-thrust regime for a variety of configurations

Research Approach
The learning from the validation efforts with Boeing made GT re-focus its approach to NPD+C corrections at low-thrust values to enhance AEDT's interpolation capabilities, specifically at low-thrust values during approach. GT will continue to seek validation data, which are very challenging to find.

GT recently successfully generated new sets of NPD data for three specific aircraft, one each in the regional jet, single aisle, and twin aisle classes. Of note, the engine-level parameters were set to the baseline values for the respective aircraft. Subsequently, NPD data were generated through ANOPP with the process outlined above under Task 1 for thrust fractions, i.e., thrust levels of 3%, 7%, 9%, and 11% for a range of flap deflection angles, approach speeds, and landing gear configurations. Of note, having the engine cycle converge at thrust values lower than 7% was challenging. GT devoted substantial effort to setting up ANOPP to run at thrust values as low as 3%. Below 3% thrust, the engine cycle did not converge.

GT is currently in the process of generating the NPD+C correction functions for these low-thrust cases.

Milestones
- Developed correction functions across vehicle classes
- Validated the approach with OEM data and any potential sources of noise monitoring data

Major Accomplishments
Correction factors were refined and finalized for a range of vehicle classes and compared with OEM data and real-world noise monitoring data.

Publications
None.

Outreach Efforts
A21
Manufacturers

Awards
None.

Student Involvement

Ameya Behere

Plans for Next Period

- ASCENT Project 43 has been sunset, and all further efforts will be rolled under the Project 54 umbrella, specifically:
  - Continue engagement of the manufacturers to obtain "fit-for-purpose" application of the correction function within AEDT
  - Compare noise contours against "truth data" in the form of real-world noise observations for aircraft of the same class
  - Finalize implementation plan to AEDT
  - Complete an airport-level study to determine the impact on the day–night average sound level contours

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