Project 053 Validation of Low Exposure Noise Modeling by Open-Source Data Management and Visualization Systems Integrated with AEDT

Stanford University

Project Lead Investigator

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University Participants

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- P.I.(s): Prof. Juan J. Alonso
- FAA Award Number: 13-C-AJFE-SU-022
- Period of Performance: October 1, 2024, to September 30, 2025
- Tasks
    1. Complete prototype of Metroplex Overflight Noise Analysis (MONA), including Aviation Environmental Design Tool (AEDT) integration. **Complete.**
    2. Validation and verification of AEDT noise predictions in day-night average sound level (DNL) 55-65 dB areas. Completed study (for arrivals into San Francisco International Airport [SFO] 28L/R only) and submitted journal paper, which was published in March 2024.
    3. Data science formats and scientific computing for large-scale airspace analyses. **Complete.**
    4. Viable alternative approach routes into the San Francisco Bay Area metroplex. **Pending/de-scoped**.

Project Funding Level

The current expected tasks for this reporting period were placed on hold during fiscal year (FY) 2025 due to a delay in funding. As of November 2025 (at the writing of this report), we have not received information regarding when the funds will become available to complete the tasks we had proposed. For this reason, the remainder of this report simply provides a summary of past accomplishments and a description of the plan to (a) complete the assessment of the accuracy of AEDT's noise predictions including departure operations and (b) prepare the release of the software developed in Project 053 for open-source distribution and use. The total expect funding for FY 2025 was $350,000 to cover all activities described below.

Investigation Team

The investigation team is made up of the faculty, graduate and undergraduate students, and collaborators listed below with their respective areas of expertise/areas of contribution and the period of time their involvement was expected:

Juan J. Alonso (P.I., Stanford Aeronautics & Astronautics): overall responsibility for the project and its technical and administrative elements.

Brian Munguía (Graduate Student, Stanford Aeronautics & Astronautics): AEDT, cloud-based AEDT study execution, AEDT debugging; departures study development and initial debugging. During the period of performance (October 1, 2024, to September 30, 2025) Mr. Munguía was expected to perform tasks in support of the development of departure operations, noise model accuracy assessments, and journal paper submission.

Donald Jackson (Collaborator, software developer): overall MONA project infrastructure (servers, databases, hardware/software monitoring), Geographic Information System (GIS), web-based visualization deployment, technical guidance. During the period of performance, Mr. Jackson was expected to help develop our open-source software and prepare it for release, together with an additional software developer (to be determined). He did continue to maintain our infrastructure database, and to ingest and curate the noise data from our sensors and from those from SFO/EnviroSuite® (October 1, 2024, to September 30, 2025), so as not to lose any data during the hiatus in funding.

Thomas Rindfleisch (Co-P.I., Sr. Research Scientist, Emeritus, Stanford University): noise monitoring and filtering, aircraft trajectory collection/processing, visualization, data analysis. During the period of performance, Mr. Rindfleisch would have worked to analyze results of our calculations and experimental measurements and would have worked to help prepare all the data for our journal submission and to generate the main manuscript in collaboration with Prof. Alonso. (October 1, 2024, to September 30, 2025).

Project Overview

The MONA project was started to provide real-time and objective data, analyses, and reports to key stakeholders and policy makers to mitigate the noise impacts of the deployment of new NextGen procedures. This system (a) collects and archives air traffic data using a network of antennae and automatic dependent surveillance-broadcast (ADS-B) receivers, (b) analyzes noise impacts using a variety of metrics, (c) visualizes resulting large-scale datasets, and (d) uses a network of sound-level monitors (SLM) to validate and enhance the quality of noise predictions. The focus of ASCENT Project 053 is to improve upon the noise predictions of MONA through tighter integration with AEDT. In particular, our work is focused on the following three tasks: (1) integrate and automate AEDT's noise analysis capabilities, (2) validate and verify (V&V) AEDT's noise predictions in DNL 55-65 dB areas, and (3) propose software engineering/architectural choices for future AEDT development to enhance usability in multiple workflows including Application Programming Interface (API) formulation, visualization interfaces, resilient data acquisition and storage, and cloud computing.

The expected benefits of this project mirror the tasks mentioned above, including (a) ability to automate complex noise analyses in metroplexes so they are available in near-real time after the preceding 24-hr period, (b) a better understanding of the accuracy of AEDT's current noise models in high- (DNL >65 dB) and low-noise (DNL 55-65 dB) areas and the reasons for the discrepancies (if any) in existing predictions, and (c) recommendations to software developers on flexible architectures and APIs for AEDT so that the tool is more versatile and generally applicable. AEDT predictions are built around the policy context of an average annual day. The majority of the V&V results produced and shared by the MONA team have focused on a cumulative daily basis for which flight track data are directly collected. The project thus far has managed to automate the cloud-based analysis (using many parallel instances of AEDT) of *every flight into SFO for a period of an entire year (July 1, 2021-June 30, 2022)* and, therefore, some of our results, included in the March 2024 journal publication, now contain DNL levels based on the flight operations collected through MONA system. The focus of the work we have done so far is on arrivals into SFO with main attention paid to arrivals on runways 28L/R. Having created the entire framework and having generated data for a full year of arrivals operations, the effort during this past year focused exclusively on creating, submitting, and providing reviews for a journal publication including all of our results to date. The final journal publication in *The Journal of the Acoustical Society of America* (JASA) was made available online and published in Volume 155, Issue 3 in March 2024. The full citation for this work, which includes all of our results to date is:

Rindfleisch, T. C., Alonso, J. J., Jackson, D. C., Munguia, B. C., & Bowman, N. W. (2024). A Large-Scale Validation Study of AEDT Noise Modeling for Aircraft Arrivals. *The Journal of the Acoustical Society of America, 155(*3), 1928-1949. https://doi.org/10.1121/10.0025276

Background and Previous Accomplishments

The MONA project started approximately 7 years ago with the main objective of providing real-time and objective data, analysis, and reports to key stakeholders and policy makers to help in mitigating the noise impacts of the deployment of new NextGen procedures. Since then, we have put together and deployed a system that (a) collects, archives, and makes available air traffic data using a series of networked antennae and ADS-B receivers 24/7, (b) analyzes noise impacts using a variety of metrics (based on both a MONA-developed noise prediction tool and the noise prediction tools within AEDT), (c) visualizes resulting large-scale datasets in a simple, user-friendly fashion using both a bespoke website and Uber®'s

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kepler.gl and deck.gl large-scale data visualization toolboxes, and (d) has deployed a small network of low-cost, Stanford-owned, sound-level monitors scattered across the South Bay part of the Bay Area and has included the data from the noise monitors deployed by SFO to cross-calibrate measurements by MONA and SFO monitors, collect noise measurements more widely geographically, and enhance noise predictions so they describe exactly the actual noise levels experienced.

The longer-term objectives of the MONA project are to (a) ensure the validation and verification of all noise predictions provided (by AEDT or other tools) in both areas near the airport and in other areas further away from the airport, (b) achieve full automation of complex noise analyses in regions around airports in the US, including AEDT-based noise predictions, (c) make all results web-accessible for in-depth interpretations of historical and proposed changes, (d) eventually study potential alternative traffic patterns in complex airspace to mitigate aviation environmental impacts, and (e) export the proven/validated MONA technology to other airport regions via open-source software/hardware.

The MONA system has matured considerably over the past few years to the point that a full-system prototype has now been operational for some time. In fact, for all arrival operations into SFO, we consider the system to be fully operational. To recall the main elements of the system, the MONA team has deployed a small network of ADS-B/multilateration (MLAT) antennae and has completed the software necessary to merge the data streams from all of these antennae including de-duplication of sightings, identification of aircraft equipment and routes flown, physical interpolation of data missing from the joint observations, and archiving (in appropriate database formats) of the information collected for successive analysis. Moreover, for arrival operations, we have spent considerable time and effort understanding the best ways to utilize the AEDT (by understanding the ways to most accurately model aircraft trajectories, aircraft equipment, and aircraft noise) so that any comparisons between experimental data and the results obtained from AEDT may be affected as little as possible by confounding variables. In fact, we have spent time in using AEDT in multiple ways including the standard version of AEDT that is approved for regulatory use in the U.S. and an improved version that leverages higher-fidelity aircraft performance models (BADA 4) and detailed descriptions of individual aircraft trajectories (using the so-called altitude and speed controls that result from the ADS-B data and their post-processing).

The MONA system has achieved a level of integration with FAA's AEDT software that enables fully-automatic processing of noise exposure at arbitrary receptor locations for arrival routes into the San Francisco Bay Area airports. The JASA publication includes our published and most accurate and comprehensive assessment of the comparison between AEDT predictions and noise-monitoring stations created to date, with an entire year of flights observed at multiple locations. In total, more than 200,000 datapoints give statistical significance to the results that we have obtained, that are presented here, and that we submitted for peer-reviewed publication.

Again, direct research efforts were halted during this past year of performance. Because of this, we do not report on any progress but include the description of the tasks that would have been pursued, for reference, in the section titled "Plans for Next Period"

Task 2 - AEDT Noise Prediction Assessment in DNL 55-65 and DNL > 65 dB Areas

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Our team has previously reported on the development of the MONA system, the data that it acquires, the information processing (both to prepare and post-process AEDT simulations and to filter and curate experimental noise data) that is necessary to V&V the predictions, and the preliminary observations from all the data collected and produced. Our FY 2024 report, in particular, focused on the statistically-significant characterization of the discrepancies between the measured noise at two different noise-monitoring stations and the predictions using AEDT in various ways with increasing levels of modeling fidelity. The reader is referred to the report for more details. By *statistically significant* we mean that the observations and conclusions are based on large amounts of data that are deemed to have converged probability distributions and statistical moments (e.g., expected value/mean and standard deviations). In other words, we do not attempt to draw conclusions about the predictive qualities of AEDT noise models based on 5 to 10 flights (as has been common in the literature) but that, rather, we focus on large-enough numbers of observations: at least 10,000 flights/datapoints for the main aircraft types and over 200,000 flights, over a 12-month period, for our entire study.

Moreover, the actual data we drew conclusions from were highly curated to eliminate any noise events that are unlikely to be the result of aircraft overflights alone, as well as other situations where multiple aircraft may have passed over a noise-monitoring station nearly simultaneously. This is to say that we feel confident that the data presented in prior publications (both the JASA paper and previous annual reports) are of the highest quality possible. The data presented and the associated conclusions/observations, with the obvious limitations that they apply to SFO and to arrival operations at SFO, were peer reviewed and approved for publication.

Outreach Efforts

No specific outreach efforts were pursued during the period of performance due to the delay in funding.

Awards

None.

Student Involvement

Due to the delay in funding, no student involvement took place this past year. The main PhD Candidate in the project, Mr. Brian Munguía shifted his contributions to other active projects.

Plans for Next Period

Our future efforts in ASCENT Project 053, assuming the availability of funds, will focus on completing the full study, including arrivals (discussed in the FY 2024 report) and departures (to be completed) to develop a complete picture of the areas where AEDT-R and AEDT-AE can and cannot provide the required accuracy in the noise predictions and to more effectively pinpoint areas of potential noise modeling improvements that may be undertaken by AEDT developers to continuously improve the quality of the predictions and, therefore, the quality of proposed new routes accounting for noise impacts on the ground. The outcome of such studies is expected to be more efficient arrivals and departure routes that minimize the noise radiated to the overflown communities. We will also carry out a number of studies to further improve the accuracy of modeling using the AEDT, including terrain and ground effects. Finally, we will continue to improve, modularize, and document key elements of our MONA system software so that it can be used more effectively for our own studies, but so it can also be shared with other researchers to conduct similar studies at different institutions and airports. A second journal paper is expected to be prepared detailing the entire set of results but focusing on the departure routes. We expect the predictions for departure routes, which are dominated by engine noise, to produce better results than those that we have achieved for arrivals.