Project 044 Aircraft Noise Abatement Procedure Modeling and Validation

Massachusetts Institute of Technology

Project Lead Investigator

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University Participants

Massachusetts Institute of Technology (MIT)

- P.I.: Prof. R. John Hansman
- FAA Award Number: 13-C-AJFE-MIT, Amendment Nos. 050, 057, 073, 084, 105, 109, 115, 126, 133, and 143
- Period of Performance: September 1, 2018, to August 31, 2027
- Tasks:
    1. Review and identify relevant machine learning and data-mining techniques
    2. Apply data-mining techniques to relevant noise monitor, aircraft, operator, and flight dynamics data
    3. Expand approach to the analysis of additional airports and aircraft types
    4. Identify operational factors which influence the community noise at specific locations
    5. Assess implications of results to the design of noise abatement procedures

University of California - Irvine (via sub-award from MIT)

- P.I.(s): Prof. Jacqueline Huynh
- Award Number: MIT Subaward Purchase Order No. 523807
- Period of Performance: September 1, 2020, to September 30, 2026
- Tasks:
    1. Review and identify relevant machine learning and data-mining techniques
    2. Apply data-mining techniques to relevant noise monitor, aircraft, operator, and flight dynamics data
    3. Expand approach to the analysis of additional airports and aircraft types
    4. Identify operational factors which influence the community noise at specific locations
    5. Assess implications of results to the design of noise abatement procedures

Project Funding Level

$995,000 Federal Aviation Administration (FAA) funding and $995,000 matching funds. Sources of match are approximately $201,300 from MIT and $793,700 from Massachusetts Port Authority.

Investigation Team

Massachusetts Institute of Technology

Prof. R. John Hansman, (P.I.), Tasks 1-5
Brandon Hadfield, (graduate student), Tasks 1-5
Sandro Salgueiro, (graduate student, graduated), Tasks 1-5
Merek Homola, (graduate student), Tasks 1-5
Clement Li, (Postdoc), Tasks 1-5

Phillip Hood, (undergraduate student), Tasks 1-5

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Project Overview

This project uses empirical noise data to develop validation methods from noise and flight surveillance datasets and to improve existing noise models. Field measurements of aircraft noise on approach and departure have historically shown significant variation (on the order of 10 dB), which has traditionally been attributed to factors such as varied power settings, aircraft configuration differences, and propagation effects. Recent analyses of this and other ASCENT projects have attempted to account for these factors but have been constrained by limited detailed flight data. This project explores approaches to combine emerging sources of flight data from flight data recorders (FDR) and other sources such as Automatic Dependent Surveillance-Broadcast (ADS-B) with current and emerging networks of ground noise monitors, to validate or improve aircraft noise models and to validate proposed noise abatement procedures. The rise of data-mining techniques has substantially enabled new insights and modeling capabilities based on the use of large datasets without requiring full a priori knowledge of all relevant physics. The development of advanced data-mining approaches applied to noise modeling is expected to provide insight into aircraft noise prediction for refining or validating noise models and for developing strategies for noise mitigation, through either new aircraft technologies or operational changes. Furthermore, improved noise modeling capabilities are expected to enable more informed decision making for stakeholders considering the options and consequences of operational or technological changes, thus facilitating the minimization of noise impacts on communities. Because noise is becoming an increasingly important factor in operational decisions regarding airports in the National Airspace System, an accurate understanding of noise impacts is necessary to minimize unnecessary disruptions to, or inefficiencies in, National Airspace System operations.

Task 1 – Review and Identify Relevant Machine Learning and Data Mining Techniques

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Objectives

Machine learning and data-mining techniques appropriate for evaluating relationships between noise monitor, aircraft, operator, and flight dynamics data will be reviewed and identified. These may include, but are not limited to, supervised machine learning on monitor-by-monitor basis, clustering and correlating resulting clusters to noise levels, identification of features/states relevant to observed noise, and intermonitor correlation analysis to investigate trajectory-level effects.

Research Approach

- Identify potential existing data sources for noise validation.
- Develop model of aircraft flight profiles by using existing surveillance (e.g., ADS-B or Airport Surface Detection Equipment, Model-X) data to generate noise estimates (readily available surveillance data are easier and less expensive to acquire than FDR data and data from dedicated flight tests).
- Evaluate flight profiles to understand why some procedures are quieter than others.

Milestones

- Identified Seattle Tacoma International Airport (SEA) noise monitor networks as potential sources of noise data for assessments.
- Identified the OpenSky database as a source of flight procedure data for noise assessments.
- Identified relevant machine learning techniques beyond simple linear regressions to correlate noise levels to operational factors.

Major Accomplishments

- Identified multilinear regression, clustering, airline grouping, XGBOOST and residual analysis as data-based modeling approaches to understand changes in noise as a function of operational and weather factors.

Publications

None.

Outreach Efforts

The ASCENT Project 044 team participated in the following outreach efforts:

- Collaborated with Port of Seattle to obtain noise data for arrivals and departures over 3 years.
- Participated in weekly teleconferences and meetings with FAA Technical Monitors.
- Performed outreach and collaboration with Massport, an operator at Boston Logan International Airport (BOS), and ASCENT Advisory Board members.
- Presented at the biannual ASCENT Advisory Board meetings.

Awards

None.

Student Involvement

Graduate and undergraduate students have been involved in all aspects of this research in terms of analysis, documentation, and presentation.

Plans for Next Period

Techniques to complete residuals analysis to understand factors contributing to noisy versus quiet airframes will be pursued, along with discussions with airlines about related possible sources of noise.

Task 2 – Apply Data Mining Techniques to Relevant Noise Monitor, Aircraft, Operator, and Flight Dynamics Data

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University of California, Irvine

Objectives

Machine learning and data-mining techniques identified in Task 1 will be applied to relevant noise monitor, aircraft, operator, and flight dynamics data. The process will begin with SEA noise and OpenSky surveillance data for several aircraft types. Additional data inferred data states, such as flight operation type, will also be considered. From this analysis, the trends or features relevant to the observed noise will be assessed, along with the identification of possible correlations between datasets.

Research Approach

- Identify methods to correct variations in modeled noise due to flap setting, aircraft weight, and ambient atmospheric conditions; apply these methods to departures and approaches at SEA.
- Acquire ADS-B data from the OpenSky Network and atmospheric data from the National Oceanic and Atmospheric Administration’s High-Resolution Rapid Refresh; use these data to estimate weight from true airspeed and atmospheric attenuation from relative humidity and temperature.

Milestones

- Developed a method to relate OpenSky surveillance operational data to atmospheric data and noise monitor data at particular time stamps.
- Developed a departure and approach weight estimation method based on ADS-B speed profiles, presented at American Institute of Aeronautics and Astronautics (AIAA) AVIATION 2025.
- Developed a method to assign flap deployment based on speed for each aircraft.

Major Accomplishments

- Developed a data-driven approach for assessing departure noise as a function of various operational, weather, and carrier factors, presented at AIAA SciTech 2025.
- Identified contributing noise factors for departure and arrival procedures of Boeing 737-800 aircraft at SEA from 3 years of noise monitor recordings, presented at AIAA SciTech 2025
- Demonstrated the impacts of aircraft operation and weather on modeled and measured noise over noise monitors of interest at SEA for both approaches and departures.
- Multivariate linear regressions and XGBOOST analysis resulted in moderate R^2 values for single monitor events.
- Airline grouping was found to provide more insight into the full procedural impact on multiple noise monitors.

Publications

Published Conference Proceedings

Lepe, M., Homola, M., Li, C., Lee, T., Hood, P., Huynh, J. L., & Hansman, R. J. (2025, January). Multifactor Analysis of Operational Factors Contributing to Aircraft Overflight Noise Variation. AIAA 2025-2004. AIAA SciTech 2025 Forum. https://doi.org/10.2514/6.2025-2004

Homola, M., Lepe, M., Trávník, M., Huynh, J. L., & Hansman, R. J. (2025, July). *Take-Off and Landing Weight Estimation From ADS-B Airspeed Profiles*. AIAA 2025-3309. AIAA AVIATION Forum and ASCEND 2025. https://doi.org/10.2514/6.2025-3309

Outreach Efforts

- Participated in weekly teleconferences and meetings with FAA Technical Monitors.
- Performed outreach and collaboration with Massport, an operator at BOS, and ASCENT Advisory Board members.
- Presented at the biannual ASCENT Advisory Board meetings.
- Presented to the major United States Airlines.

Awards

None.

Student Involvement

Graduate and undergraduate students have been involved in all aspects of this research in terms of analysis, documentation, and presentation.

Plans for Next Period

The additional data-mining techniques, such as residual analysis on loud and quiet airframes will be applied on approach and departure radar, weather, and noise monitor data for multiple aircraft types.

Task 3 – Expand Approach to the Analysis of Additional Airports and Aircraft Types

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Objectives

The data-mining approaches and analysis process from Task 2 will be expanded to additional airports and aircraft types. The modeling approach will be applied to gather data for the additional aircraft and locations. Potential trends or features relevant to the observed noise will be assessed for the larger dataset.

Research Approach

- Examine relevant noise monitor networks at different airports.
- Outreach to different airports to obtain noise monitor data.
- Expand approach to the analysis of additional airports and aircraft types.

Milestone

- Identified and reached out to obtain noise monitor date for analysis from BOS and John Wayne Airport (SNA).

Major Accomplishments

- Collected 3 years of approach and departure noise data at BOS and SNA for analysis.
- Collected 3 years of flap settings and weight data at SNA.
- Expanded analysis to Boeing 737-700 and Airbus A320 aircraft.

Publications

Student Thesis

Lee, T. (2025). A Data-Driven Approach to Aircraft Noise Variation and Operational Efficiency Analysis. *UC Irvine Masters Thesis*. ProQuest ID: Lee_uci_0030M_19549. Merritt ID: ark:/13030/m5mt5fxm. Retrieved from https://escholarship.org/uc/item/6tf709kc

Outreach Efforts

- Participated in weekly teleconferences and meetings with FAA Technical Monitors.
- Performed outreach and collaboration with Massport, an operator at BOS, and ASCENT Advisory Board members.
- Presented at the biannual ASCENT Advisory Board meetings.

Awards

None.

Student Involvement

Graduate and undergraduate students have been involved in all aspects of this research in terms of analysis, documentation, and presentation.

Plans for Next Period

The data-mining approaches and analysis process from Task 2 will be expanded to procedures flown at BOS.

Task 4 – Identify Operational Factors Which Influence the Community Noise at Specific Locations

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University of California, Irvine

Objective

Operational factors from the large dataset and applied data-mining techniques in Task 3 will be used to identify any operational factors which influence the community noise. Any observed differences in monitors, airport, and aircraft type will be identified to highlight location- or vehicle-specific trends.

Research Approach

- Use data-mining techniques and big data to assess factors with the highest influences on noise levels.

Milestones

- Observed and identified a variety of departure and approach procedures in surveillance data at SEA and SNA.
- Used different data-mining approaches such as multivariate correlations, clustering, and machine learning applied to the data at SEA to examine trends in variables affecting aircraft noise, including those due to aircraft weight, thrust, distance to the monitor, airspeed, ambient atmospheric conditions, and compounding factors

Major Accomplishments

- Measured noise levels versus weight, thrust, speed, altitude, weather factors, and airline were examined through a multivariate approach for departures and arrivals.

- Airline grouping approach was found to give the most insight between operational strategy and noise levels at multiple noise monitors. Example results are shown in Figure 1.
- Identified the correlation of between weight and climb rate and thrust strategy for departure procedures.
- For approach procedures, speed and weight correlated more closely to noise levels, whereas thrust did not correlate well with noise.
- The data-mining approaches and analysis process from Task 2 were expanded to SNA which has a unique and aggressive noise abatement procedure in place, giving observably into maneuvers not normally flown at other airports.

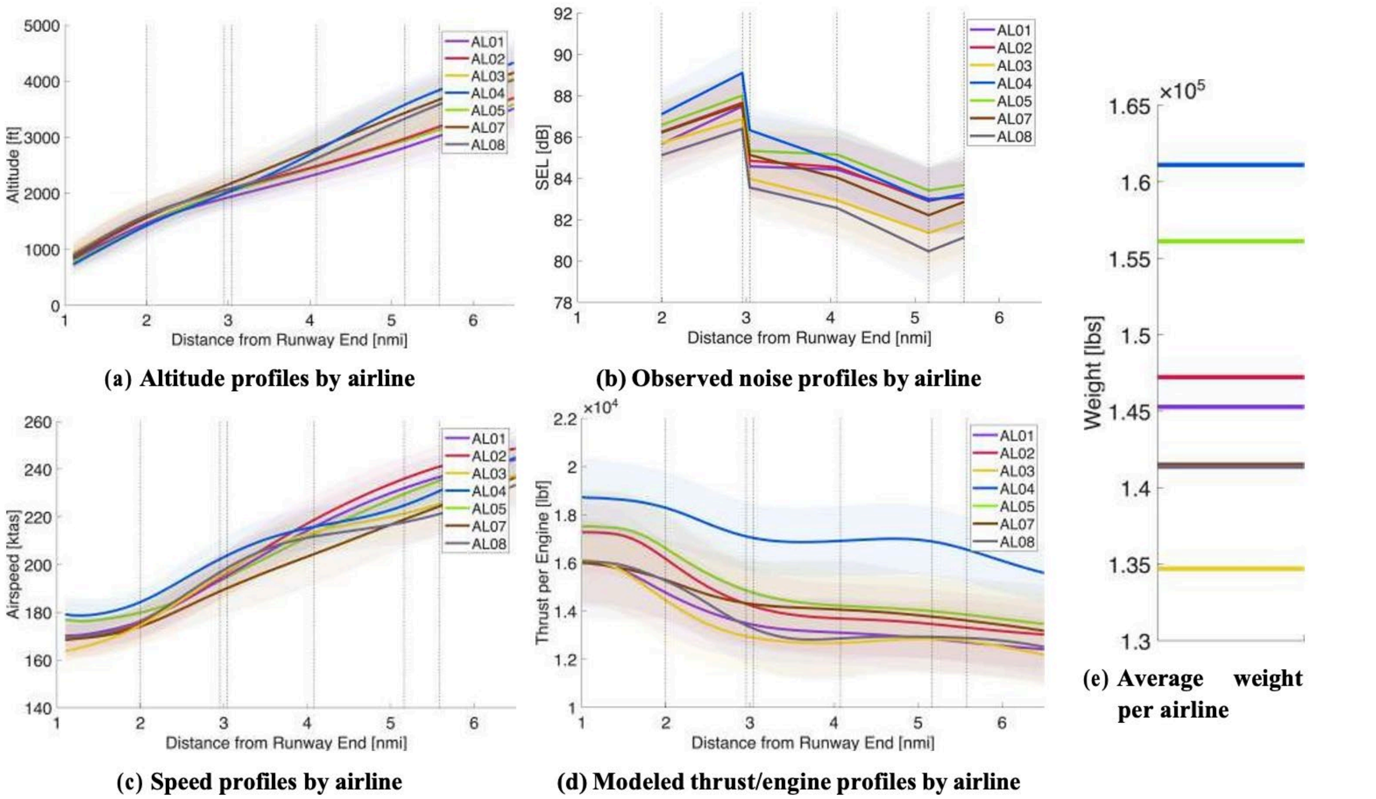

Figure 1. Boeing 737-800 southbound departure profiles for 3 years of operations at SEA for different airlines. Bold lines represent averages, and shaded areas represent region within one standard deviation.

Publications
None.

Outreach Efforts
- Participated in weekly teleconferences and meetings with FAA Technical Monitors.
- Performed outreach and collaboration with Massport, an operator at BOS, and ASCENT Advisory Board members.
- Presented at the biannual ASCENT Advisory Board meetings.

Awards
None.

Student Involvement
Graduate and undergraduate students have been involved in all aspects of this research in terms of analysis, documentation, and presentation.

Plans for Next Period
Any observed differences in monitors, airport, and aircraft type will be identified to highlight location- or vehicle-specific trends. In particular, the differences in analysis for procedures at BOS, SEA, and SNA will be examined to evaluate the effectiveness of these noise abatement procedures by a direct comparison.

Task 5 – Assess Implications of Results to the Design of Noise Abatement Procedures
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University of California, Irvine

Objectives
Implications from Task 4 will be considered in the design of noise abatement arrival and departure procedures. Different flight operations will be explored and may include cockpit procedures, published procedures, and air traffic control procedures. Results may influence recommended noise abatement techniques and opportunities to improve existing procedures and noise modeling methods.

Research Approach
- Treat noise monitoring data from different airports as experimental data, which could serve as a benchmark for comparing loud versus quiet flights.
- Determine whether learnings can be applied to future departure and approach noise abatement procedure designs.

Milestone
- Performed initial examination of quiet versus loud departure and arrival procedures from 3 years of SEA and SNA data.

Major Accomplishments
- Identified weather factors such as relative humidity, temperature, and wind magnitude and direction to have some correlations, albeit weaker, with the measured noise levels on departure.
- Found aircraft altitude and thrust levels to have the strongest correlations with measured noise for the departure procedures examined, whereas velocity and weight had stronger correlations on arrivals.
- A new, low-noise procedure that was implemented for BOS runway 22L arrivals started to be flown, with preliminary flight trajectory analysis showing utilization of the new procedure.

Publications
Cezairli, M., Salgueiro, S., & Hansman, R. J. (2024). Implementation Analysis of Low-Noise Performance-Based Navigation Flight Procedures at Boston Logan Airport. *Journal of Air Transportation, 33*(3), 274-284. https://doi.org/10.2514/1.D0475

Outreach Efforts
- Participated in weekly teleconferences and meetings with FAA Technical Monitors.
- Performed outreach and collaboration with Massport, an operator at BOS, and ASCENT Advisory Board members.
- Presented at the biannual ASCENT Advisory Board meetings.

Awards
None.

Student Involvement

Graduate and undergraduate students have been involved in all aspects of this research in terms of analysis, documentation, and presentation.

Plans for Next Period

The next phase of this project will evaluate how additional variables identified in the previous tasks influence aircraft noise and will inform the design of future advanced flight procedures intended to reduce aircraft noise.