Project 044 Aircraft Noise Abatement Procedure Modeling and Validation

Massachusetts Institute of Technology

Project Lead Investigator

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University Participants

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- FAA Award Number: 13-C-AJFE-MIT, Amendment Nos. 050, 057, and 073
- Period of Performance: September 1, 2018 to August 31, 2021
- Tasks:
    1. Evaluate general approaches to aircraft noise validation
    2. Develop validation approach options
    3. Develop flight test plans
    4. Initial experimental runs on targets of opportunity
    5. Evaluate experimental results and implications for advanced operational flight procedure noise modeling and low-noise procedures

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

- PI: Jacqueline Huynh
- Award Number: MIT Subaward Purchase Order No. S5171 – PO 523807
- Period of Performance: September 1, 2020 to August 31, 2021
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Project Funding Level

FAA provided $720,000 in funding. A total of $720,000 in matching funds were provided: approximately $125,000 from MIT and $595,000 from the Massachusetts Port Authority.

Investigation Team

- Professor R. John Hansman (PI), MIT
- Professor Jacqueline Huynh (PI), UCI

- Clement Li (graduate student), MIT
- Sandro Salgueiro (graduate student), MIT
- Madeleine Jansson (graduate student), MIT
- Ara Mahseredjian (graduate student), MIT

Project Overview

This project utilizes empirical noise data to develop validation methods from noise and flight surveillance datasets and 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 have traditionally been attributed to factors such as varied power settings, aircraft configuration differences, and propagation effects. Recent analyses in 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 and other sources such as 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 the 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 developing strategies for noise mitigation, through either new aircraft technologies or operational changes. Furthermore, improved noise modeling capabilities would 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. As 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 - Evaluate General Approaches to Aircraft Noise Validation

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Objective(s)

This goal of this task is to evaluate the different options for validation of the Aircraft Noise Prediction Program (ANOPP) source component models and to confirm noise reductions from proposed low-noise procedures. Approaches to experimental design were considered, including dedicated engineering flight trials that involve parametric sweeps of velocity and aircraft configuration at various power conditions. This process would involve collaborating with airline operators, who would need to be willing to fly trials of procedures, and air traffic control (ATC), which would need to approve the procedures. A ground measurement system would need to be in place under the departure tracks.

Potential monitoring approaches will also be considered, including distributed microphone arrays or single microphone installations, as well as potential phased-array microphone configurations. In addition, alternative flight data sources will be obtained, either through airline sources or through available surveillance data. Sources of noise data from existing and emerging noise monitoring systems will be identified. Boston Logan International Airport (BOS) has agreed to provide data, and additional airports will be approached to participate in the effort. Emerging open source and community noise monitoring systems such as those being developed under ASCENT Project 53 will also be investigated. Opportunities for collaboration will be explored, with a focus on providing correlated flight data and noise datasets.

This task will use a systems approach and will explore options with potential collaborators on experimental opportunities to validate research concepts.

Research Approach

- Evaluate the different options for validation of the ANOPP source component models and confirm any noise reductions from proposed procedures
- Identify potential existing data sources for noise validation
- Model aircraft flight profiles by using existing surveillance (e.g., ADS-B or ASDE-X) data to generate noise estimates (Readily available surveillance data are easier and less expensive to acquire than Flight Data Recorder (FDR) data and dedicated flight tests.)
- Evaluate flight profiles to understand why some procedures are quieter than others

Major Accomplishments

- Flight radar and noise monitoring data were collected at BOS. ADS-B and noise monitoring data were collected at Seattle–Tacoma International Airport (SEA).
- A framework was developed to generate flight profiles by using raw ADS-B and atmospheric data. Noise monitor recordings were correlated with ADS-B data.
- Flight profiles were generated for various approaches to landing at BOS and SEA. Flight profiles were used to model aircraft noise at various monitor locations, and noise estimates were compared with monitor recordings.
- Quieter flyover cases were analyzed, and trends in aircraft altitude, airspeed, and lateral position were identified.
- Sources of weather data as a function of altitude were identified to make atmospheric absorption corrections for noise modeling validation.

Task 2 - Develop Validation Approach Options

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Objective(s)

On the basis of the results of Task 1 and initial discussions with potential collaborators (measurement experts, model developers, manufacturers, operators, and test locations), one or more validation options will be identified. Targets of opportunity will be explored in which noise measurements may supplement other planned flight trials. For each option, the potential advantages and disadvantages will be identified, and preliminary flight test plans will be developed in coordination with the identified collaborators and in consultation with subject-matter experts such as NASA. Potential advantages include the willingness of operators or collaborators to participate and provide test resources, including aircraft and measurement systems. Other factors include measurement system resolution and the discrimination of noise sources. Timing and location may also be considered. On the basis of this analysis, recommendations for the next steps will be made.

Research Approach

- Identify methods to correct variations in modeled noise due to flap setting, aircraft weight, and ambient atmospheric conditions; apply these methods to approaches at BOS and SEA
- Acquire ADS-B data from the OpenSky Network and atmospheric data from NOAA High-Resolution Rapid Refresh; use these data to estimate weight from true airspeed and atmospheric attenuation from relative humidity
- Model noise at various flap configurations to identify the noise impact of high-lift devices

Major Accomplishments

- Demonstrated the impacts of aircraft configuration and relative humidity on modeled and measured noise over noise monitors of interest at the BOS and SEA
- Presented noise modeling methodology and results at the 2021 InterNoise and American Institute of Aeronautics and Astronautics (AIAA) Aviation conferences, respectively
- Demonstrated the noise benefit of delayed-deceleration approaches using empirical data; analyzed flyovers of various monitors at BOS and SEA, and demonstrated a correlation between the fastest flyovers, flying at indicated airspeeds consistent with clean or almost-clean flap configurations, and the quietest noise monitor recordings

Task 3 - Develop Flight Test Plans

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Objective(s)

For the recommended validation options identified in Task 2, detailed flight test plans will be developed. Flight test plans for dedicated engineering flights would involve detailed planning of the speed, configuration, and thrust of each trial. Test plans for flight trials in collaboration with airline operators would focus on documenting the flown profiles to analyze the associated data measurements. Opportunity exists in both of these types of trials to validate not only the expected effects of aircraft speed versus noise in the analysis models, but also the expected noise impacts of procedures including delayed deceleration approaches, steeper approaches, and continuous approaches.

Research Approach

- Develop flight test plans where appropriate for the validation of low-noise procedures
- Collaborate with airline operators and industry to determine appropriate data collection for trial flight tests

Major Accomplishments

- Modeled noise from flight tests that were conducted during the ecoDemonstrator flight demonstration in the previous period was compared with identified noise monitoring data collected at SEA.
- Determined that validation for low-noise flight procedures such as the delayed deceleration approach can be performed by using available surveillance and noise monitoring data, if reasonable assumptions regarding the weight, flap and slat configuration, and atmospheric attenuation are made. Partnerships with operators for FDR data were sought, but MIT was unable to obtain FDR data because of operator restrictions on the sharing of flight data.

Task 4 - Initial Experimental Runs on Targets of Opportunity

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Objective

If targets of opportunity are identified in Task 2 that would occur within the period of performance of this proposed research, initial experimental runs will be conducted after consultation with the FAA Office of Environment and Energy and other relevant parties.

Research Approach

- Document procedural recommendations to enable flight trials
- Meet with airline technical pilots and representatives from aircraft manufacturers to discuss operational constraints and test opportunities
- Develop test plans and protocols for potential flight trials
- Develop test plans and protocols for potential noise measurement campaigns
    - Specific flight test locations
    - Operational field measurements

Major Accomplishments

- Flight data collected from an aircraft performing a conventional deceleration approach during the ecoDemonstrator tests that were flown in the previous cycle were used to model the noise impacts of the procedure, and those impacts were compared with noise data collected by the Port of Seattle.
- Additional conventional and delayed deceleration approach procedures were observed in surveillance data at BOS and SEA and were identified for noise analysis.
- Instead of using dedicated flight test plans, flights from this surveillance data were grouped by altitude and analyzed with varied speed, configuration, and thrust. The noise monitor readings from these flights were then compared. This approach removed flyover altitude as a variable and enabled a direct comparison between the noise levels and the speed, configuration, and thrust levels of the flights.
- Flights for which the speeds were more likely to have been in the clean configuration when they flew over the monitors were shown to correlate with lower recorded noise levels than flights that were more likely to have been in a dirty configuration when they flew over the monitors.

Task 5 - Evaluate Experimental Results and Implications for Advanced Operational Flight Procedure Noise Modeling and Low-Noise Procedures

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Objective(s)

Contingent on data availability from Task 4 or other data identified as part of the experimental approach and discussions with collaborators, this task, in coordination with NASA, will involve the following:

- Evaluating the Advanced Operational Flight Procedure Noise Modeling relative to experimental results
- Identifying discrepancies requiring correction
- Determining whether the results and data are sufficient to improve discrepancies or whether continued validation and testing are required

The implications for Advanced Operational Flight Procedure Noise Modeling from the data will be evaluated.

Validation of procedures, such as delayed deceleration approaches, will also create opportunities for the development of further low-noise procedures.

Research Approach

- Treat noise monitoring data from SEA and BOS as experimental data, which could serve as a benchmark for comparison against ANOPP component-based noise models
- Model departure noise for various departures from SEA, and identify the characteristics of the quietest departures; determine whether learning can be applied to future departure noise abatement procedure designs

Major Accomplishments

- Noise models demonstrated similar trends to monitor recordings for approach procedures when proper assumptions regarding flap configuration were made. Both speed and configuration were shown to impact the noise model results.
- Aircraft weight and thrust levels were shown to impact the noise modeling results for approach procedures.

Publications

Jensen, L., Thomas, J., Brooks, C., Brenner, M., & Hansman, R. J. (2017). Analytical approach for quantifying noise from advanced operational procedures [Presentation]. European Air Traffic Management Research and Development Seminar. Seattle, Washington.

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Jensen, L., O'Neill, G., Thomas, J., Yu, A., & Hansman, R. J. (2018). Block 1 procedure recommendations for Logan Airport community noise reduction (Report No. ICAT-2017-08). Massachusetts Institute of Technology, Cambridge, MA.

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Reynolds, T., Sandberg, M., Thomas, J., & Hansman, R. J. (2016). Delayed deceleration approach noise assessment [Presentation]. 16th AIAA Aviation Technology, Integration, and Operations Conference, Washington, DC.

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Thomas, J., & Hansman, R. J. (2017). Modeling performance and noise of advanced operational procedures for current and future aircraft [S. M. thesis, Massachusetts Institute of Technology]. DSPace@MIT. https://dspace.mit.edu/handle/1721.1/108937

Thomas, J., Jensen, l., Brooks, C., Brenner, M., & Hansman, R. J. (2017). Investigation of aircraft approach and departure velocity profiles on community noise [Presentation]. AIAA Aviation 2017 Forum, Grapevine, TX.

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Thomas, J., Yu, A., Li, C., Toscano, P., & Hansman, R. J. (2019). Advanced operational procedure design concepts for noise abatement [Presentation]. 13th USA/Europe Air Traffic Management Research and Development Seminar, Vienna, Austria.

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Thomas, J., & Hansman, R. J. (2020). Evaluation of the impact of transport jet aircraft approach and departure speed on community noise (Report No. ICAT-2020-03). Massachusetts Institute of Technology, Cambridge, MA.

Thomas, J., & Hansman, R. J. (2020). Modeling and assessment of delayed deceleration approaches for community noise reduction [Presentation]. AIAA Aviation Forum, Dallas, TX.
Thomas, J., & Hansman, R. J. (2021). Modeling of delayed deceleration approaches for community noise reduction. Journal of Air Transportation, *29*(3), 127-136. https://doi.org/10.2514/1.D0237
Thomas, J., Mahseredjian, A., & Hansman, R. J. (2021). Delayed deceleration approach procedure noise modeling validation using noise measurements and radar data [Paper presentaiton]. AIAA Aviation 2021 Forum, Virtual Meeting. https://doi.org/10.2514/6.2021-2135.
Yu, A., & Hansman, R. J. (2019). Aircraft noise modeling of dispersed flight tracks and metrics for assessing impacts [S. M. thesis, Massachusetts Institute of Technology]. DSpace@MIT. https://hdl.handle.net/1721.1/122382
Yu, A., & Hansman, R. J. (2019). Approach for representing the aircraft noise impacts of concentrated flight tracks [Presentation]. AIAA Aviation Forum 2019, Dallas, TX. https://doi.org/10.2514/6.2019-3186

Outreach Efforts

- October 28, 2021: presentation to the ASCENT Advisory Board
- September 9,2021: presentation to the Port of Seattle
- April 29, 2021: presentation to the ASCENT Advisory Board
- September 30, 2020: presentation to the ASCENT Advisory Board
- September 9, 2020: presentation to the Port of Seattle
- October 15, 2019: presentation to the ASCENT Advisory Board
- November 8, 2019: presentation to NASA
- November 12, 2019: presentation to the Airline Industry Consortium
- Weekly meetings with industry
- Biweekly teleconferences and meetings with FAA Technical Monitors
- In-person outreach and collaboration with Massport, operator of BOS and ASCENT Advisory Board member

Awards

2021, 2020 AIAA Air Transportation Systems Best Student Paper Award "Modeling, Assessment, and Flight Demonstration of Delayed Deceleration Approaches for Community Noise Reduction" (AIAA-2020-2874) by Jacqueline L. Thomas and R. John Hansman
2018 Department of Transportation/FAA COE Outstanding Student of the Year Award to Jacqueline Thomas.

Student Involvement

Graduate 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 the departure and arrival noise of various aircraft at SEA, starting with the Boeing 737-800 and Airbus A320 and eventually expanding to larger widebody aircraft. A main goal of the upcoming work is to understand the causes of variation in departure noise. Instead of examining and modeling the noise of individual flights of interest, a large number of flights will be analyzed over all monitors in the system. This approach will provide a large dataset for which many quiet and loud cases can be identified over various monitor locations. Flight profiles and noise models will be generated for these cases of interest. Trends in variables affecting aircraft noise, including aircraft weight, thrust, distance to monitor, airspeed, and ambient atmospheric conditions will be identified. Understanding how these variables impact aircraft noise will inform the design of future advanced flight procedures intended to reduce aircraft noise.