Project 044 Aircraft Noise Abatement Procedure Modeling and Validation

Massachusetts Institute of Technology

Project Lead Investigator

R. John Hansman
T. Wilson Professor of Aeronautics & Astronautics
Department of Aeronautics & Astronautics
Massachusetts Institute of Technology
Room 33-303
77 Massachusetts Ave
Cambridge, MA 02139
617-253-2271
rjhans@mit.edu

University Participants

Massachusetts Institute of Technology (MIT)

- PI: R. John Hansman
- FAA Award Number: 13-C-AJFE-MIT, Amendment Nos. 050, 057, and 073
- Period of Performance: Sept. 1, 2018 to Aug. 31, 2021
- Tasks: [to be added by project team]

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

- PI: Jacqueline Thomas
- Award Number: MIT Subaward Purchase Order No. TBD
- Period of Performance: Sept. 1, 2020 to Aug. 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 Aircraft Noise Prediction Program (ANOPP) and Aviation Environmental Design Tool (AEDT) and Low-Noise Procedures

Project Funding Level

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

Investigation Team

- Prof R. John Hansman (PI)
- Jacqueline Thomas (PI)
- Clement Li (graduate student)
- Sandro Salgueiro (graduate student)
- Madeleine Jansson (graduate student)
- Ara Mahseredjian (graduate student)

Project Overview

This project will utilize empirical noise data to develop data-based/learned noise models and validate 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 analysis under this and other ASCENT projects have attempted to account for these factors but are constrained by limited detailed flight data. This project will explore 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 also validate proposed noise abatement procedures. The rise of data mining and machine learning techniques has enabled significant insight and modeling capabilities based on the use of large datasets and 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, either through new aircraft technologies or operational changes. Furthermore, improved noise modeling capabilities would enable more informed decision-making for stakeholders when considering options and consequences of operational or technological changes, facilitating the minimization of noise impacts on communities. As noise is becoming an increasingly large factor in operational decisions around airports in the National Airspace System (NAS), an accurate understanding of noise impacts is necessary to minimize unnecessary disruptions or inefficiencies to NAS operations.

Task 1 – Evaluate General Approaches to Aircraft Noise Validation

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Objectives

This goal of this Task is to evaluate the different options for validation of the ANOPP source component models and to confirm noise reductions from proposed low-noise procedures. Approaches to experimental design will be considered, which may include 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), who would have 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 as well as confirmation of any noise reductions from proposed procedures.
- Identify potential existing data sources for noise validation.
- Collaborate with industry and operators to determine who would be willing to fly procedures.
- Evaluate potential challenges associated with flight testing and taking measurements.

Major Accomplishments

- Flight radar and noise monitor data collected at Boston Logan International Airport and Seattle-Tacoma International Airport (SEA) was identified as a data source that can be used for noise model validation.
- Data from flight demonstrations conducted by Boeing was examined to validate flight procedure modeling methods and the feasibility of the flight procedure.

- 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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Objectives

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 discrimination of noise sources. Timing and location may also be considered. On the basis of this analysis, recommendations for next steps will be made.

Research Approach

- Explore targets of opportunity for noise measurements or flight testing.
- Identify sources of data that can be used for validation from industry or other entities.

Major Accomplishments

- Worked with a research team at Stanford University to identify noise monitor data of high-lift devices that could be used to validate noise of flight procedures with significant airframe noise contributors.
- Target of opportunity to fly a low-noise approach procedure in Boeing ecoDemonstrator tests were identified.
- Flight radar and noise monitor data collected at Boston Logan International Airport were identified as useful for evaluating noise of low-noise procedures like the delayed deceleration approaches when atmospheric absorption as a function of historical weather is properly taken into account.

Task 3 – Develop Flight Test Plans

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Objectives

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 trails in collaboration with airline operators would focus more heavily 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 for validation of low-noise procedures.
- Collaborate with airline operators and industry to determine appropriate data collection for trial flight tests.

Major Accomplishments

- Assisted in flight plan design for the delayed deceleration approach procedure and how to communicate the approach to pilots.
- Developed assessment methods to examine which attributes of the procedure contribute to which noise impacts.
- Developed assessment methods to model the noise impacts of flight profiles from radar data for comparison with noise 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 would be conducted after consultation with AEE and other relevant parties.

Research Approach

- Document procedure recommendations so that flight trials are possible.
- 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

- The delayed deceleration approach concept was identified as a noise abatement flight procedure as a candidate for flight test demonstration.
- A delayed deceleration approach combined with steeper approach were assessed for feasibility and noise reduction impacts by the MIT team and the Boeing team.
- Weekly meetings and discussions with industry were held to determine the feasibility of flying delayed deceleration approaches and steeper approaches.
- A delayed deceleration approach procedure was flight tested for operational demonstration.
- Flight data collected from operational demonstration was used to model procedure noise impacts.

Task 5 – Evaluate Experimental Results and Implications for ANOPP and AEDT and Low-Noise Procedures

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Objectives

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:

- Evaluate the ANOPP correlations relative to experimental results.
- Identify discrepancies that need to be corrected.
- Determine whether the results and data are sufficient to improve discrepancies or whether continued validation and testing are required.

The implications for AEDT from the data will be evaluated. The results of the flight tests, data exploration, and ASCENT Project 44 may create opportunities to continue to improve the noise-power-distance and configuration curves in AEDT. Validating the noise component modules in ANOPP would also allow for potential component corrections within the noise models of AEDT. The implications for AEDT will allow future research teams to continue to develop the AEDT noise models upon the results of the data analysis and flight tests from this project.

Implications for the development of low-noise procedures will also be evaluated. Validation and improvement of the noise models ANOPP and AEDT will allow for higher-fidelity development of low-noise procedures. Validation of procedures such as delayed deceleration approaches will also create opportunity for the development of further low-noise procedures.

Research Approach

- Evaluate implications for modeling low-noise procedures with ANOPP and AEDT.
- Evaluate implications for the development of low-noise procedures.

Milestone

The delayed deceleration approach was flown as an operational flight demonstration on the Boeing ecoDemonstrator at Atlantic City International Airport in November of 2019. Evaluation of the data from the Boeing ecoDemonstrator test and noise monitor data from Boston Logan International Airport were used to evaluate the modeling of low-noise procedures.

Major Accomplishments

- Noise analysis was performed on ecoDemonstrator flight tests to show the impacts of different decisions made for actual flight test implementation, such as when and where the delayed deceleration would occur.
- Noise results were compared with data gathered at Boston Logan International Airport to predict flap deflection schedules for low-noise procedure modeling.

Publications

Jensen, L. & Hansman, R.J. (2018) Data-driven flight procedure simulation and noise analysis in a large-scale air MIT

Jensen, L., O'Neill, G., Thomas, J., Yu, A., & Hansman, R.J. (2018). Block 1 procedure recommendations for Logan Airport community noise reduction. MIT ICAT Report

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

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

Thomas, J. & Hansman, R.J. (2020). Evaluation of the impact of transport jet aircraft approach and departure speed on community noise. MIT ICAT Report

Thomas, J. & Hansman, R.J. (2020). Modeling and assessment of delayed deceleration approaches for community noise reduction. AIAA Aviation

Thomas, J. & Hansman, R.J. (2019). Framework for analyzing aircraft community noise impacts of advanced operational flight procedures. Journal of Aircraft, Volume 6, Issue 4. https://doi.org/10.2514/1.C035100

Thomas, J. & Hansman, R.J. (2017). Modeling performance and noise of advanced operational procedures for current and future aircraft. MIT International Center for Air Transportation

Thomas, J., Jensen, l., Brooks, C., Brenner, M., & Hansman, R.J. (2017). Investigation of aircraft approach and departure velocity profiles on community noise. AIAA Aviation Forum, p. 1–12

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

Thomas, J., Yu, A., Li., C., Maddens Toscano, P., & Hansman, R.J. (2019). Advanced operational procedure design concepts for noise abatement. USA/Europe ATM R&D Seminar

Yu, A. & Hansman, R.J. (2019). Aircraft noise modeling of dispersed flight tracks and metrics for assessing impacts. MIT ICAT Report

Yu, A. & Hansman, R.J. (2019). Approach for representing the aircraft noise impacts of concentrated flight tracks. AIAA Aviation Forum 2019, Dallas, Texas. https://doi.org/10.2514/6.2019-3186

Outreach Efforts

- September 30,2020: Presentation to the ASCENT Advisory Board.
- October 15,2019: Presentation to the ASCENT Advisory Board.
- November 8, 2019: Presentation to NASA.
- November 12, 2019: Presentation to Airline Industry Consortium.
- Weekly meetings with industry.
- Biweekly teleconferences and meetings with FAA Technical Monitors.
- In-person outreach and collaboration with Massport, operator of Boston Logan International Airport and ASCENT Advisory Board member.

Awards

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 include noise modeling validation of approach procedures using radar flights and noise measurements for several aircraft types, such as Boeing 737-800, Airbus A320, and Embraer E190. Noise monitor readings from Seattle-Tacoma International Airport have also been identified as a source for additional validation and will be included. The implications of the validation, including how data can be used to inform flight profile assumptions when assessing operational flights, as well as potential benefits and operational implications from advanced flight procedures such as the delayed deceleration approach will also be examined.