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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- PI(s): R. John Hansman
- FAA Award Number: 13-C-AJFE-MIT, Amendment Nos. 050 and 057
- Period of Performance: September 1, 2018 to August 31, 2020 (via no-cost extension)
- Task(s):
    1. Evaluate general approaches to aircraft noise validation
    2. Develop validation approach options
    3. Develop detailed flight test plans
    4. Perform initial experimental runs on targets of opportunity
    5. Evaluate experimental results and implications for ANOPP and AEDT and low-noise procedures

Project Funding Level

Project Funding Level: $350,000 FAA funding and $350,000 matching funds. Sources of match are approximately $79,000 from Massachusetts Institute of Technology (MIT) and $271,000 from the Massachusetts Port Authority.

Investigation Team

- Prof R. John Hansman (PI)
- Jacqueline Thomas (graduate student)
- Clement Li (graduate student)
- Sandro Salgueiro (graduate student)
- Rachel Price (graduate student)
- Annick Dewald (graduate student)
- Alison Yu (graduate student)

Project Overview

This project will develop an approach to validating advanced operational flight procedures that incorporate modified configurations and speeds. Noise analysis developed at MIT under ASCENT Project 23 shows opportunities to reduce community noise under flight tracks through configuration and speed changes. Analysis results indicate that flight speed can significantly impact noise population exposure. There is a question as to whether one of the models used for these results—the FINK airframe noise model from ANOPP, which was developed from flight tests in the 1970s—might still be valid for modern aircraft. Thus, this project will utilize discussions with industry experts to determine the validity of the

modeled noise impacts of advanced operational procedure concepts. This project will also evaluate potential opportunities for aircraft noise validation.

Task 1 - Evaluate General Approaches to Aircraft Noise Validation

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Objective(s)

This task will be to evaluate the different options for improved validation of the ANOPP source component models as well as confirmation of any noise reductions from proposed low-noise procedures. Approaches to experimental design will be considered, including dedicated engineering flight trials, which would include parametric sweeps of velocity and aircraft configuration at various power conditions potentially including engine shutdown or more likely idle thrust. Another approach would be to monitor preliminary operational trials of reduced speed departures. This process would involve collaborating with airline operators, who would need to be willing to fly trials of procedures, and 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. The most effective microphone configuration will depend on the experimental approach. For example, the phased array microphones may provide benefits in isolating aerodynamic noise from engine noise if the engine shutdown condition is not feasible (as is likely to be the case). A distributed array much further out on the departure trajectory than traditional noise monitoring locations may be effective for monitoring climb noise variations with speed and configuration.

This task will use a systems approach and will explore options with potential collaborators on experimental opportunities to identify options for experimental validation. This will include consulting experts who have previously performed noise measurement campaigns or experts in noise monitoring to understand options and best practices.

Research Approach

- Evaluate the different options for improved validation of the ANOPP source component models as well as confirmation of any noise reductions from proposed procedures
- 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

- Communication was established between the team and ANOPP noise experts at NASA to determine whether data might already exist on the airframe noise of modern aircraft and might be used to determine the noise impacts of reduced speed departure concepts.
- We examined flight procedure data from simulator and flight demonstrations to validate flight procedure modeling methods and the feasibility of the flight procedure.
- We modeled the possible noise variations as a result of atmospheric changes throughout a standard year to show what amount of variation in monitored noise would be expected if flight trials were conducted to determine the noise impacts of procedures with speed and configuration variations.

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 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

- Several meetings and discussions with ANOPP noise experts at NASA were held to determine the validity of ANOPP airframe noise models for modern aircraft.
- We worked with industry to uncover data on clean airframe noise of modern aircraft.
- We worked with a research team at Stanford to identify noise monitor data of high-lift devices that could be used to validate noise of flight procedures with significant airframe noise contributors.
- We identified a target of opportunity to fly a low-noise approach procedure via industry sponsored tests.

Task 3 - Develop Detailed 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 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 operations and low-noise procedures
- Collaborate with airline operators and industry to determine appropriate data collection for trail flight tests

Major Accomplishments

- We assisted in flight plan design for the delayed deceleration approach procedure and how to communicate the approach to pilots.
- We developed assessment methods to examine which noise benefits of the procedure were attributed to which portions of the procedure.

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 thoroughly and unambiguously so that simulator or 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.
- Potential delayed deceleration approaches combined with steeper approaches were assessed for feasibility and noise reduction impacts between the MIT team and the industry team.
- Weekly meetings and discussions with industry were held to determine the feasibility of delayed deceleration approaches and steeper approaches.
- Simulator flight tests were conducted for the proposed delayed deceleration and steeper approach concept.
- A delayed deceleration approach procedure was flight tested for operational demonstration.

Task 5 - Evaluate Experimental Results and Implications for ANOPP and AEDT 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:

- Evaluate the ANOPP correlations relative to experimental results,
- Identify discrepancies that need to be corrected, and
- 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 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 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 Airport in November of 2019.

Major Accomplishments

- Noise analysis was performed on simulated 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 provided by Stanford on configuration noise.

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

- 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 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 involve continued work with industry on finalizing the delayed deceleration approach noise according to the data from the flight procedure demonstration. The team will continue to evaluate additional airframe noise measurement opportunities for modeled noise validation. Discussions with the pilots from the flight demonstration of the delayed deceleration approach will be conducted to collect lessons learned that will be necessary to perform this procedure in future operations. Additional operational implications and strategies for overcoming challenges associated with the flight procedures will be researched. Implications for modeling low-noise procedures with AEDT and ANOPP will be determined.