Project 011(B) Rapid Fleet-Wide Environmental Assessment Capabilities

Georgia Institute of Technology

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University Participants

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- Period of Performance: August 1, 2015 to January 31, 2017

Project Funding Level

FAA funded amount is $50,000 for the period of performance of August 1, 2015 to January 31, 2017. The Georgia Institute of Technology has agreed to a total of $50,000 in matching funds. This total includes salaries for the project director, research engineers, graduate research assistants and computing, financial and administrative support. The institute has also agreed to provide equipment funds as well as tuition remission for the students paid for by state funds.

Investigation Team

Prof. Dimitri Mavris, Dr. Michelle Kirby, Dr. Don Lim, Dr. Yongchang Li, Dr. Holger Pfaender, and Dr. Matthew Levine. Graduate Students: Jung (Andy) Hyun, Evanthia Kallou. Undergraduates: Emily Glover and Jacob Jacob

Project Overview

This project focuses on continued development of ASDL's rapid fleet-wide environmental assessment capabilities that complement the FAA's Aviation Environmental Design Tool (AEDT) with a lower fidelity screening tool that allows for consideration of a large number of technology scenarios. These technology scenarios can be quickly analyzed and reduced to a manageable set of scenarios for more focused, high fidelity analysis in the environmental tools suite. The Global and Regional Environmental Assessment Tradeoff (GREAT) tool has been developed, validated, and utilized on several FAA and

NASA projects in the past that have assessed fleet-level fuel burn and emissions over time. This tool links official forecasts, origin-destination pair route scaling, and replacement schedules to comparatively evaluate multiple technology and policy scenarios. In recent years, GREAT has been linked to ASDL's Airport Noise Grid Integration Method (ANGIM) tool to automatically generate baseline and future year airport schedules. While ANGIM has been validated against the FAA's INM tool and the method has been peer reviewed and published in AIAA's Journal of Aircraft, ANGIM had never been formally validated against AEDT and official inventory studies. The goal of this project was to validate ANGIM against AEDT using the 2012 Goals and Target Benefit Assessment (GATBA) and determine possible improvements to the linked GREAT-ANGIM tool based on the results of this comparative study. After implementing these improvements, the GREAT-ANGIM tool shall be used to analyze a series of noise goal scenarios defined by FAA.

Task 1 – Validating ANGIM against AEDT using GATBA study

Objective(s)

Validate ANGIM's capability to measure contour area and population exposure for DNL-55dB, 60dB, and 65dB by comparing against an AEDT study that included three study scenarios: a 2012 baseline, a 2030 evolutionary technology scenario, and a 2030 aggressive technology scenario. It should be noted that these future technology scenarios use an equivalency approach to scale operations rather than considering specific technologies and unique Noise-Power-Distance curves for future aircraft types.

Research Approach

This task consisted of three primary subtasks. The first task focused on acquiring the GATBA scenarios from the FAA and executing them in AEDT. The second task required queries from the AEDT study databases to prepare input files of consistent schedules and vehicles for ANGIM. The first two tasks enabled the same scenarios to be executed in ANGIM in order to evaluate the uncertainty introduced by ANGIM's simplifying assumptions.

AEDT Runs of GATBA Scenarios

While the GATBA studies had been previously run by Volpe, Georgia Tech had to acquire these studies from Volpe and re-run them in AEDT 2b FP1, as the studies were incompatible with any other version of AEDT. For each study, Georgia Tech ran 3 different atmospheric absorption models (SAE-AIR-1845, SAE-ARP-866A, and SAE-ARP-5534) at a subset of five airports (KATL, KJFK, KMIA, KMDW, and KSAN). For all of these cases, the SAE-ARP-866A contours were greater than the SAE-AIR-1845 contours, and the SAE-ARP-5534 contours were slightly larger than the SAE-ARP-866A contours. This is a significant finding, because ANGIM assumes standard day conditions with the SAE-AIR-1845 atmospheric model. The standard day atmosphere assumption allows the aircraft level grids to be pre-computed for ANGIM, which is the most significant enabler of ANGIM's rapid formulation. The ANGIM-AEDT comparisons that followed were only compared for the SAE-AIR-1845 model. An additional 33 airports were run in AEDT using the SAE-AIR-1845 model.

For each scenario and each airport, operations by military, small general aviation, and old out of production aircraft with negligible operations were removed from these operational schedules. Georgia Tech also changed the grid dimensions from the original scenario because they were inconsistent from airport to airport, and occasionally the grid resolutions were too coarse. Guidance on acceptable grid resolutions are discussed in ECAC.CEAC Doc29[1], where the balance between interpolation errors introduced by coarse grid spacing and the increased computation time associated with more grid points are addressed. The document cites comparative studies that have shown a *maximum* value of 300 meters, or approximately 0.16-nautical miles, constitutes a good compromise between accuracy of the interpolated noise contours and computational times, yet some cases in the GATBA study used resolutions as coarse as 0.25-nautical miles. Georgia Tech came to similar conclusions years ago when establishing a standard grid resolution for ANGIM, Generic Airports, and Generic Vehicles. Given ANGIM's computational speed relative to AEDT, a finer grid-spacing of 0.08-nautical miles in each direction was chosen, and Georgia Tech has consistently used this resolution on all noise analyses. Thus, Georgia Tech modified the grid resolution in AEDT to match the grid resolution used in ANGIM. This lead to long computer runtimes for each AEDT airport and scenario.

[1] ECAC.CEAC Doc 29, Report on Standard Method of Computing Noise Contours Around Civil Airports, Vol. 2, 3rd ed., Technical Guide, Dec. 2005.

After running these cases in AEDT, contour area measurements and population exposure counts were collected for each scenario. It should be noted that Georgia Tech discovered a bug in AEDT's contouring algorithm that impacted AEDT's contour printing, contour area calculation, and population exposure counts. This bug was reported to Volpe, and once they were fixed the contours were regenerated. The combination of long computer runtimes and bug fixing increased the number of iterations and amount of time it took to complete this subtask.

Queries of AEDT Study Databases and Preparation of ANGIM Input Files

The first part of this subtask required a query to determine the full set of unique aircraft in the GATBA studies. The relevant AEDT coefficients that define each of these aircraft were extracted from the AEDT database version associated with the GATBA study. These collections of coefficients were saved as aircraft XML files to ensure consistency with the GATBA analysis. The aircraft XML files were used as inputs to ASDL's in house tool referred to as the AEDTTester. This tool uses AEDT source code including the Aircraft Performance Module (APM) and Aircraft Acoustics Module (AAM) to generate single aircraft Sound Exposure Level (SEL) grids for each unique departure stage-length and arrival procedure. ASDL has also developed a MATLAB based wrapper around the AEDTTester that allows it to be run in batch mode and collect all the necessary grids for use in ANGIM. The SEL grids generated for this ANGIM analysis assume standard day sea-level atmospheric conditions and straight ground tracks. Each of these assumptions enables pre-computation of aircraft-level half grids. ANGIM mirrors, translates, and rotates these grids into place and performs logarithmic addition to calculate airport-level DNL grids.

Once all of the grids were generated, the schedules for the relevant airports were extracted using SQL queries on the GATBA study database and formatted as necessary to be used with ANGIM. It should be noted that the GATBA studies included specific runway assignments for all operations, and the ANGIM flight schedules match these specific runway assignments.

Comparison of ANGIM and AEDT

Once the ANGIM files were prepared, running all three scenarios took less than one hour, compared to greater than 36 days to run similar cases in AEDT. Under the assumption of SAE-AIR-1845 atmospheric model and matching runway assignments, comparison of contour areas showed good agreement between ANGIM and AEDT, with most contour area comparisons within 5%. A few airports with extreme track divergence, particularly airports in the New York Metroplex (KEWR, KJFK, and KLGA) had larger contour area differences. These results suggest that the straight track assumption used by ANGIM is a good assumption at most airports, but a suggested improvement for ANGIM is an ability to include curved tracks at a select few airports. Depending on the number of track designs included, it may be feasible to add unique curved tracks for these few airports, although half-grids cannot be used for these turning tracks because the SEL noise grids will no longer be symmetric about the runway centerline.

More important than accuracy per airport is the ability of ANGIM to capture the trends for future scenarios relative to the baseline scenario. When evaluating the change in ANGIM contours per scenario versus the change in AEDT contours per scenario, the cumulative contour changes across all 38 airports in ANGIM was within 2.5% of the cumulative contour changes in AEDT.

When evaluating population exposure, a similar conclusion was reached. ANGIM was reasonably accurate compared to AEDT, but the few airports with significant diverging ground tracks were also associated with high density population dispersion around the airports. However, when 4 of the 38 airports (KEWR, KJFK, KLGA, and PHNL) were removed from the population comparison study, the cumulative population exposure counts were very close, as shown in Table 1. Similar results were observed for the two 2030 scenarios. This once again supports the conclusion that the straight track assumption is good for most airports, but modeling diverging tracks at a few airports could improve ANGIM's assessment capability.

The full validation study was compiled into a single Powerpoint presentation and provided to the FAA. The presentation includes AEDT-ANGIM contour overlay plots, contour area measurements, and population exposure counts for all 38 airports at every scenario.

Table 1. ANGIM-AEDT Cumulative Population Comparison for GATBA 2012 Scenario

AEDT	ANGIM

	Contour	Option 1	Option 1		
		Population Count	Population Count	Diff	Pct Diff
34 Airports	55	2405839.694	2534627.436	128788	5.35%
	60	679404.4952	740265.7896	60861	8.96%
	65	126028.5925	128587.242	2559	2.03%

Task 2 – Enhancement of ANGIM, AEDTTester, and GREAT Capabilities

Objective(s)

The lessons learned from the GATBA study have guided the recent enhancement of ASDL's complementary tools. This section is divided into three subsections, each focused on one of the following three tools: ANGIM, AEDTTester, and GREAT. Developments for each are currently ongoing.

Research Approach

While the validation of ANGIM was performed using a GATBA 2012 analysis, Georgia Tech and the FAA agreed that GREAT should use data from the FAA's most recent inventory analysis based on 2015 data. This dataset was acquired from the FAA and is currently being used to update Georgia Tech's tools.

Enhancements of ANGIM

One of the most significant lessons learned from the GATBA Analysis concerned the actual utilization of airport runways at each airport. Georgia Tech learned that many airports feature departure threshold displacements such that brake release points do not coincide with runway endpoints. ANGIM's runway configurations did not capture this threshold displacement, which resulted in a mismatch of AEDT and ANGIM contours. To accommodate these threshold displacements, Georgia Tech modified the runway configuration files and added a convention for enabling displacement thresholds.

Additionally, ANGIM contains a utilization factor method for distributing operations across the different runway endpoints in the event that runway assignments are not known a priori. In the past, Georgia Tech did not have knowledge or data of actual airport utilization, and so an equal utilization assumption was often used. The example GATBA studies and the more recently acquired 2015 noise inventory have shed much light on actual runway usage and shown that equal utilization is not a good assumption. In fact, many runways are used preferentially in one direction due to prevailing winds and traffic flows. Some runways are used preferentially as departure runways or approach runways. In response to this observation, ANGIM was enhanced to include unique approach and departure utilization factors. The values for these utilization factors were determined from queries on the airport schedules in the 2015 noise inventory, and a verification study was run at five representative airports (KMSP, KLAX, KORD, KSAN, and KSDF). This verification study compared ANGIM schedule with specific runway assignments versus the same ANGIM schedule using no specific runway assignments and instead leveraging the utilization factors. For most of the airports, this comparison was nearly exact. Slight runway preferences for certain aircraft types can lead to slight inaccuracies, but even in these cases the utilization factors greatly improve accuracy compare to the equal utilization assumption.

In response to this modification of the ANGIM method, new runway configuration files were created for all of the MAGENTA 95 airports using the 2015 noise inventory as the reference point. A team of undergraduate students conducting research for course credits were assigned the task of analyzing flight schedules to determine runway utilization factors for each runway endpoint, including threshold displacements. This enhancement will improve the ability to generate more accurate contours, area measurements, and population exposure counts for ANGIM schedules automatically generated by GREAT, which lacks information on specific runway assignments of projected future operations.

Enhancements of AEDTTester

The original AEDTTester code was developed simultaneously with AEDT 2a. The code essentially mimics AEDT's database query methods by reading in user XML aircraft and flights files instead. The AEDTTester then calls actual AEDT methods including the APM and AAM models that are necessary for generating SEL noise grids. This code was not synced to changes and updates to AEDT, which is constantly releasing new versions and updates as it continues to be developed. In conjunction with other ASCENT projects being conducted at ASDL, Georgia Tech was given access to AEDT developer's source code through the TFS. The AEDTTester required updates to accommodate new updates that have been made since AEDT 2a. The current version of the AEDTTester is synced to the AEDT 2c official release.

One previous convention that was built into the AEDTTester was a straight ground track assumption for terminal area procedures. This coincided with the ANGIM assumption of straight ground tracks, and thus diverging tracks were not previously considered. The results of the GATBA comparison determined the need to include diverging ground tracks for a select subset of airports in order to improve accuracy. A derivative version of the AEDTTester was thus developed to allow for diverging ground tracks. This version of the AEDTTester will be used to expand ANGIM's library of pre-computed SEL grids for airport analysis to improve accuracy at a select few major airports.

Enhancements of GREAT

Each of the improvements to ANGIM and AEDTTester will enhance the integrated GREAT-ANGIM tool. Additionally, the linkage between GREAT and ANGIM has been enhanced to include out-of-production operations. This capability was requested by the FAA in order to perform scenario analyses to evaluate the noise implications of of various retirement rates. Initially, the GREAT enhancement was only designed to use representative vehicles for all out of production aircraft, similar to the generic vehicles used for in-production vehicles, which have been shown to provide good accuracy. The representative out-of-production vehicles, however, did not well approximate the fleet-level noise contributed by out of production vehicles. Modeling generic out-of-production vehicles is not worth the effort because there is no goal of improving these vehicles through technology infusion. Rather these vehicles will be phased out as they age or new policy restrictions are implemented. Efforts are ongoing to include all out of production vehicle grids for every airport in the MAGENTA 95 subset, but it is unclear how these additional grids may impact the integrated GREAT-ANGIM runtime.

Milestone(s)

GATBA Analysis comparing ANGIM and AEDT was completed and a detailed documentation of all airport comparisons was provided to the FAA. (Completed August 2016)

Integration of Enhancements to ANGIM, AEDTTester, and GREAT. (Targeted completion mid-January 2017)

Sample Noise Scenario and Transfer of Tool to FAA. (Targeted completion end of January 2017)

Major Accomplishments

Validated ANGIM against AEDT and showed straight ground track assumption is typically reasonable.

Updated airport configurations and utilization factors at all MAGENTA 95 airports.

Updated ANGIM to enable departure threshold displacements and unique approach/departure utilization factors.

Compiled an updated AEDTTester synced to AEDT 2c release and enabled diverging ground tracks for terminal procedures.

Publications

N/A

Outreach Efforts

Presentations at Spring and Fall ASCENT meetings.

Presentations of Results on Tools Teleconference in March and August.

Prepared detailed comparisons of every airport in GATBA analysis in Powerpoint file, available upon request.

Awards

N/A

Student Involvement

Jung (Andy) Hyun Kim – Graduate Research Assistant, Georgia Institute of Technology

- Aided SQL queries and airport schedule generation for ANGIM analysis

Evanthia Kallou – Graduate Research Assistant, Georgia Institute of Technology

- Trained on AEDT and helped collect AEDT GATBA contour areas and population exposure counts

Emily Glover – Undergraduate Research Assistant, Georgia Institute of Technology

- Analyzed airport schedules and collected runway utilization factors

Jacob Jacob – Undergraduate Research Assistant, Georgia Institute of Technology

- Analyzed airport schedules and collected runway utilization factors

<u>Plans for Next Period</u>

Task 1 – Validating ANGIM against AEDT using GATBA study

This task is complete, and no other action is necessary.

Task 2 – Enhancement of ANGIM, AEDTTester, and GREAT Capabilities

Enhancements to ANGIM and AEDTTester shall be integrated into GREAT. All out-of-production grids shall be added to the GREAT-ANGIM integrated tool, and a sample noise goal analysis shall be conducted.