Dearborn, Michigan
NOISE-CON 2008
2008 July 28-30

Functional Description of the FAA's Aviation Environmental Design Tool's Aircraft Acoustics Module

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ABSTRACT

This paper presents architectural and functional descriptions of the Aircraft Acoustics Module (AAM) in the Federal Aviation Administration's Aviation Environmental Design Tool (AEDT) for modeling aircraft noise in the vicinity of airports. While the overall functionality of the AAM was based on the FAA's current Integrated Noise Model (INM), the development of the AAM as a module in AEDT has led to distinct architectural differences relative to INM. In order to highlight the new features of AEDT and its AAM, the INM will be discussed in this paper as a reference. Following this description, the role of the AAM in noise impact analyses is discussed, including the use of AAM output to generate a variety of different noise metrics with AEDT.

1. INTRODUCTION

The Federal Aviation Administration's Integrated Noise Model (INM) has been the primary software tool for federally-funded, aircraft noise modeling projects in the United States since 1978. It is also used by over 1,000 users in more than 30 countries. INM is a Federal Aviation Administration Office of Environment and Energy (FAA AEE) tool and is most often used for modeling aircraft noise in the vicinity of an airport, including the prediction of noise impacts from fleet, flight path and runway configuration changes.

Currently under development is the FAA's Aviation Environmental Design Tool (AEDT), a software tool to integrate the combined noise and air quality modeling on the flight, airport, regional and global scales. AEDT will allow for the interdependencies between aviation-related noise and emissions impacts to be assessed. In 2011, an AEDT version for local and regional aviation environmental analysis is scheduled to be released to the general public. The complete AEDT suite will replace FAA AEE's current environmental modeling tools, which includes INM, the Emissions and Dispersion Modeling System (EDMS), the Model for Assessing Global Exposure to the Noise of Transport Aircraft (MAGENTA) and the System for assessing Aviation's Global Emissions (SAGE). It is also planned that AEDT will include all the functionality of FAA's Noise Integrated Routing System (NIRS), currently used for regional airspace noise analysis.

The aircraft noise modeling capabilities in AEDT reside in the Aircraft Acoustics Module (AAM). The acoustics computation methodology in the AAM is based on existing methodology in the INM. However, the development of the AAM as a module in AEDT has led to distinct architectural differences from INM, where the combination of several AEDT modules is used for

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aircraft noise and performance modeling similar to INM instead of just the AEDT's AAM. These architectural differences also manifest themselves in the manner the INM and the AEDT's AAM are used for noise impact analyses.

This paper is organized into two sections. First, functional and architectural descriptions of both INM and the AEDT's AAM are presented (see Section 2). The functional description focuses on the similarities between the acoustic computation methodologies between the INM and AEDT's AAM, as well as pinpointing where they differ. Given the similar predictive capabilities between INM and AEDT's AAM, the architectural description focuses on the benefits of the overall AEDT architecture and enhanced noise modeling capabilities, relative to INM. Second, the use of the AEDT for noise impact analyses is discussed, including the use of AAM output to generate a variety of different noise metrics (see Section 3).

2. DESCRIPTION OF AEDT'S AAM RELATIVE TO INM

A. Functionality

Both INM and AEDT's AAM are implementations of integrated, empirical aircraft noise modeling methodologies. Both use aircraft noise and performance data, based on empirical data collected during aircraft noise measurements and processed according to SAE-AIR-1845 "Procedure for the Computation of Airplane Noise in the Vicinity of Airports,[1]" to calculate noise levels associated with one or more flight paths. While INM has both aircraft noise and performance modeling capabilities, aircraft performance is modeled in AEDT by the Aircraft Performance Module (APM) and those results become inputs to the AAM.

Given aircraft-receiver geometry and aircraft flight performance characteristics, noise is generated in both INM and AEDT's AAM by applying a series of noise level adjustments to the aircraft noise source data. These adjustments take into account atmospheric effects, aircraft speed and performance, study geometry, terrain shielding, and various aircraft type- and operation-specific adjustments. The methodology used to calculate aircraft noise in INM is documented in the "Integrated Noise Model (INM) Version 7.0 Technical Manual[2]", and is based on international guidance.[1,3,4]

For sound exposure metrics, the sound exposure ratio due to a single-flight path segment of a flight operation for a fixed wing aircraft is provided below.

$$E_{seg} = 10^{\frac{[L_{E,P,d} + N_{ADJ}]}{10}} \tag{1}$$

where

- E_{seg} sound exposure ratio at an observer location due to a single-flight path segment of a flight operation,
- $L_{E.P,d}$ noise exposure level at a specific slant distance and power setting for a given aircraft, in dB, and
- N_{ADJ} noise level adjustments, in dB.

The sound exposure ratio is then weighted by number of operations and time period specific weighting factors and the cumulative sound exposure ratio over the flight path is computed.

$$E_{wt,flt} = \sum_{i=1}^{n_{seg}} [W_{d(i)} * N_{d(i)} + W_{e(i)} * N_{e(i)} + W_{n(i)} * N_{n(i)}] * E_{seg(i)} \tag{2}$$

where

- $N_{d(i),\, e(i),\, n(i)}$ number of user-specified operations over a given time period (day, evening or night) on the i-th segment,
- $W_{d(i),\, e(i),\, n(i)}$ weighting factor for a given time period on the i-th segment, and

n_{seg} number of segments in the three-dimensional flight path.

If INM were to calculate noise from a single flight path (or a single event), then the sound exposure ratio over the flight path would be

$$L_{E,wt,flt} = 10 * \log_{10}\left[\frac{E_{wt,flt}}{N_T}\right] \quad (3)$$

where

$L_{E,wt,flt}$ sound exposure level at an observer location due to a single flight path, and

N_T metric-specific time-averaging constant.

A variation on this methodology is used to calculate maximum noise level and time-based metrics in INM.

The same methodology is used in the AEDT's AAM on a single event basis. However, INM and AEDT's AAM begin to differ when cumulative noise metrics over a series of flight operations are considered. Cumulative metrics are calculated in INM by summing over all of the flight paths in a given airport study; effectively replacing the sound exposure ratio over a flight path with the sound exposure ratio over a given airport study (see Equation 3). AEDT's AAM performs single event noise calculations, and does not calculate cumulative noise metrics. Instead, cumulative noise metrics are calculated using a combination of several AEDT modules in conjunction with the AEDT's AAM.

The AAM was designed as a single event noise calculation module, in order to improve its modularity within the AEDT system. This modularity allows for: (a) parallel processing over a network; (b) module updates, bug fixes and revisions without modifying the entire tool; (c) insertion of alternate modules or sub-modules into AEDT, in order to test or use new and expanded functionality; (d) increased transparency of the entire calculation process; and (e) additional, enhanced noise computation capabilities. Once single event noise has been calculated, cumulative noise metrics are calculated through a series of different modules in AEDT, taking advantage of the architectural differences between INM and AEDT.

B. Architecture

INM has been under continuous development since 1978 and has undergone multiple releases on several different software platforms. This history has locked INM into a fairly rigid structure, where flight tracks and aircraft performance are determined by one module (the flight module) and then passed to another module (the noise compute module) for terrain processing and noise computations.

The design and development of AEDT has allowed for a more open software architecture, where multiple modules are used in conjunction with the AAM to compute aircraft noise (see Figure 1).[5] Instead of all of the noise computations being handled by a single module in series, the AAM is called by the Taskmaster (TM) on a single event basis to process aircraft performance data generated by the Aircraft Performance Module (APM) and corresponding noise data stored in the AEDT databases and retrieved by the Database Access Module (DAM). The noise results calculated by the AAM are then stored in a database. Once all of the flight operations have been run through the AAM, the Event Based Methodology Engine (EBME) accumulates the corresponding noise grids, calling on the TM to call the AAM to generate any additional noise grids not already computed. The EBME then calls on the Acoustics Metrics Module (AMM) to calculate the appropriate noise metrics, compiles the cumulative noise results and feeds the results back to the TM for output.

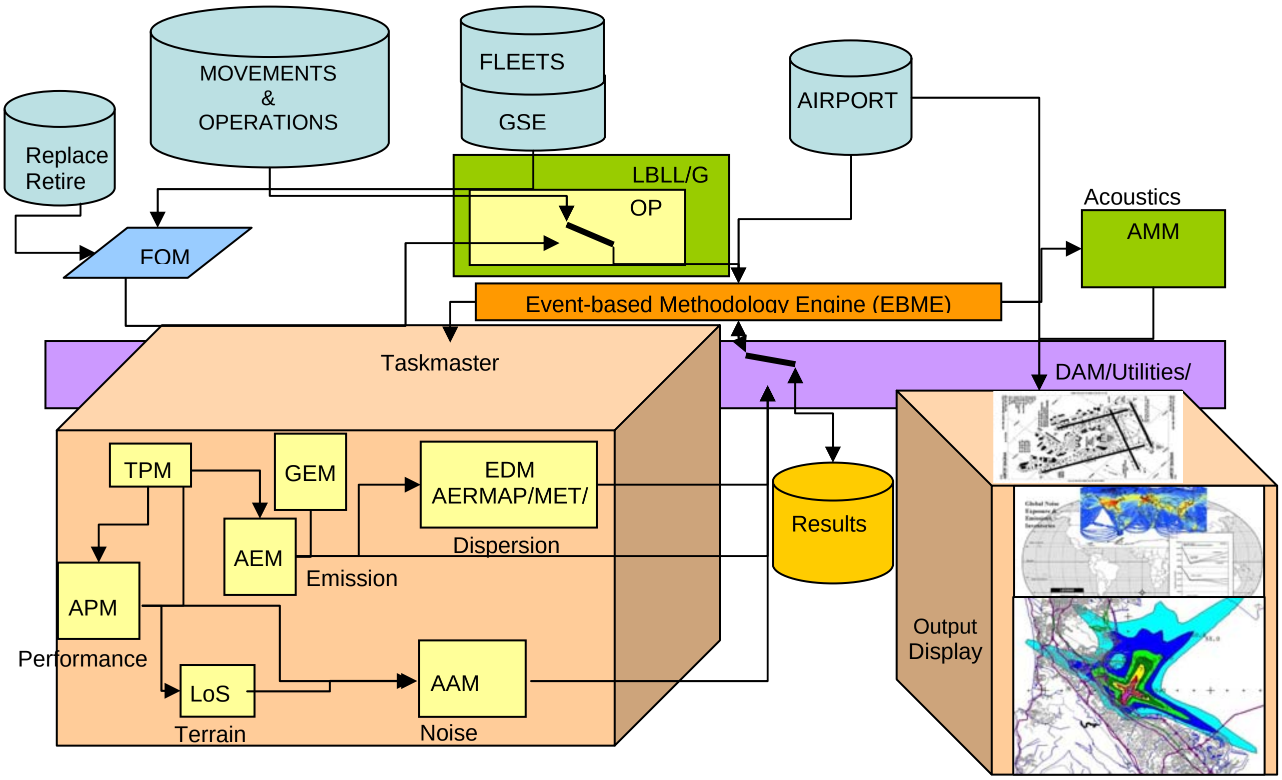

Figure 1: Flowchart of Noise and Emissions Computations in AEDT.

The AEDT architecture allows for a greater level of flexibility than the INM architecture in terms of modularity, functionality and scalability. Because the software is modular and run on a single event basis, many of the modules may be run in parallel (as well as multiple instances of the same module across a network of processors), instead of waiting for one module to complete processing on the entire study before another can begin (as was the case in INM). This modularity also easily allows for module updates and revisions without modifying the entire tool, including acoustic enhancements. Sub-modules with expanded functionality could be inserted into the processing stream, such as a module accounting for advanced meteorological effects. Furthermore, modules with alternate or improved noise calculation algorithms could be dropped in to replace or enhance the AAM. One such possibility could be the introduction of a simulation noise module, provided that the supporting database and scheduling infrastructure were available and made compatible with other system data. As part of AEDT development, the assessment of the variability associated with module inputs and outputs plays a significant role in understanding the tool's overall robustness and targeting areas for potential future improvement. A comprehensive assessment effort, initially focused on core computational modules, is being undertaken throughout the development of AEDT. This effort will both quantify the uncertainty associated with the algorithms and databases within the tool and better inform the use of development resources towards improving the accuracy of AEDT.

The introduction of the EBME and the database structure in AEDT allows for better data storage and data compilation capabilities, allowing for generation of noise results for various flight scenarios or airport configurations without rerunning the entire study. This also allows for an airport study to be run piecewise, if several new flight tracks are added to an existing airport study, which would drastically decrease overall computation time and effort. Similarly, multiple metrics may also be calculated without rerunning the entire study (provided that the metrics are within the same weighting class, i.e. all A weighted metrics).

The AEDT architecture also allows for greater study scalability. While INM calculates cumulative noise metrics over multiple events, all of those events are tied to a single airport study. Under this paradigm, regional and global analyses are handled by additional software tools; NIRS and MAGENTA respectively. Because the AEDT's AAM is a single event module, its use is scalable for regional and global analyses[6]. This scalability, coupled with the increased data storage and grid compilation capabilities in AEDT, will lead to run time improvements as output databases are populated with single event grids.

3. NOISE IMPACT ANALYSES IN AEDT

An important role of AEDT is to conduct noise impact analyses for either Federal Aviation Regulation (FAR) Part 150 noise compatibility planning or FAA Order 1050 environmental assessments or environmental impact statements in the United States, as well a regional and global noise analyses. Such analyses may include assessing current airport (or airports) noise impacts or changes in noise impact due to changes in runway configurations, fleet mix or operational procedures.

The modularity, scalability and improved functionality associated with the AEDT architecture directly benefit noise impact analyses in AEDT. The improved data storage and results compilation capabilities in AEDT will allow for the mixing and matching of various different runway configurations, fleet mixes and operational procedures, in order to present results for a variety of different scenarios without significantly increasing software runtime. The modularity associated with bringing the cumulative noise metric calculations outside of the main noise computation module allow for the calculation of various different noise metrics (including user defined metrics) on the same set of events without rerunning the entire study (provided that the metrics are within the same weighting class, i.e. all A weighted metrics). The scalability in the AEDT architecture allows for noise contributions from additional events (such as future events, or regional operations) to be taken into consideration without rerunning the entire noise impact analyses.

AEDT explicitly accommodates impact assessments involving the interdependencies between noise and emissions[7]. Common aircraft performance and flight data may be used for both noise and emissions, in the AAM and Aircraft Emissions Module (AEM) respectively. This structure improves model usability and decreases study setup time, since the aircraft and airport information only need to be defined for the common input. Another benefit of the AEDT structure is that it allows for noise and emissions impacts to be evaluated together and potential tradeoffs may be assessed; e.g., performance changes resulting in a minor decrease in noise level but a large decrease in emissions.

4. CONCLUSIONS

While the core noise calculations in INM and AEDT's AAM are based off of the same methodologies, the added flexibility and modularity in the AEDT architecture allows for significant improvement in model functionality and capabilities over INM. These changes to software architecture allow for: (a) easier implementation of module updates and revisions without modifying the entire tool; (b) insertion of alternate noise computation modules or sub-modules with new and expanded functionality into AEDT; (c) improved software runtime through parallel processing over a network and improved data storage and results compilation capabilities; (d) increased transparency of the entire calculation process; and (e) greater scalability for regional and global analyses. These improved capabilities directly benefit noise impact analyses in AEDT, and help facilitate noise/emissions interdependency studies.

ACKNOWLEDGEMENTS

This work was funded by the Federal Aviation Administration's Office of Environment and Energy. The authors would like to acknowledge the support of the Lourdes Maurice, Raquel Girvin, Ralph Iovinelli, Hua He and Becky Cointin of the FAA Office of Environment and Energy in Washington, D.C. for their contributions to this effort.

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