Project 036 Parametric Uncertainty Assessment for the Aviation Environmental Design Tool (AEDT)

Georgia Institute of Technology

Project Lead Investigator

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University Participants

Georgia Institute of Technology (GT)

- FAA Award Number: 13-C-AJFE-GIT, Amendments 19, 29, 30, 40, and 49
- Period of Performance: October 1, 2019 to September 30, 2020
- Task: AEDT uncertainty quantification (UQ) reports development.

Project Funding Level

The current funding for this project is based on amendments 30, 40, and 49 for a total of $300,000 from May 31, 2019 to May 30, 2020. The Georgia Institute of Technology has agreed to a total of $300,000 in matching funds.

Investigation Team

- Prof. Dimitri Mavris (PI), Georgia Institute of Technology, oversees the entire project.
- Dr. Yongchang Li (Co-PI, project lead), Georgia Institute of Technology, leads the research team in performing capability demonstrations and tests and in validating various functionalities of different AEDT versions.
- Dr. Michelle Kirby (Co-PI), Georgia Institute of Technology, oversees the entire project and supports all of the research activities.
- Bogdan Dorca (graduate student), Georgia Institute of Technology, conducts AEDT capability demonstration, feature evaluation, and system testing.
- Zhenyu Gao (graduate student), Georgia Institute of Technology, conducts parametric uncertainty quantification analyses for the BADA4 model, created the AEDT study, and performed a sensitivity analysis for this study.
- Santusht Sairam (graduate student), Georgia Institute of Technology, conducts AEDT capability demonstration, feature evaluation, and system testing.
- Dr. Holger Pfaender (research staff) provides consultation and support.

Project Overview

The FAA's Office of Environment and Energy (AEE) has developed a comprehensive suite of software tools that allow for a thorough assessment of the environmental effects of aviation, particularly for assessments of interdependencies among aviation-related noise, emissions, performance, and cost. As the heart of this tool suite, the high-fidelity Aviation Environmental Design Tool (AEDT) is a software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality impacts. This software has been developed by the FAA AEE for public release as the next-generation FAA environmental consequence tool. AEDT enables evaluations of interdependencies among aircraft-related fuel consumption, emissions, and noise. AEDT 2 was released in four phases. The first version, AEDT 2a, was released in March 2012 (US FAA, AEDT 2a Uncertainty Quantification Report, 2014; US FAA, AEDT 2a SP2 UQ Supplemental Report, 2014) and the second version, AEDT 2b, was released in May 2015 (US FAA, AEDT 2b UQ Report, 2016). The third and fourth versions, AEDT 2c and AEDT 2d, respectively, were released in September 2016 and September 2017. A new version, AEDT 3b, was released in September 2019 with major updates, including the inclusion of the Base of Aircraft Data family 4 (BADA4) performance model for fuel consumption, emissions, and noise and the implementation of reduced thrust and alternative weight profiles for departure operations.

The uncertainty quantification (UQ) applied in this project comprehensively assesses the accuracy, functionality, and capabilities of AEDT during the development process. The major purposes of this effort are as follows:

- Contribute to the external understanding of AEDT.
- Demonstrate and evaluate AEDT's capability and fidelity (ability to represent reality).
- Help AEDT users to understand the sensitivities of output responses to variations in input parameters/assumptions.
- Identify gaps in functionality.
- Identify high-priority areas for further research and development.

The UQ consists of verification and validation, capability demonstrations, and parametric uncertainty/sensitivity analysis.

Task 1 – AEDT UQ Reports Development

Georgia Institute of Technology

Objectives

In order to provide the best possible environmental impacts modeling capabilities in AEDT, the FAA/AEE continues to develop AEDT, improving existing modeling methods and data and adding new functionalities. The AEDT development team has been exercising an agile development process, where minor updates are released in new Sprint versions every three weeks, and major updates and/or new functionalities are incorporated as new versions of AEDT. The FAA/AEE seeks an independent effort in system testing to evaluate the accuracy, functionality, and capabilities of AEDT and support the future development process. Thus, the objective of this effort is to provide FAA with high-quality UQ analysis of AEDT and its future releases to evaluate AEDT's capability, while identifying gaps in the tool's functionality and areas for further development.

GT has been conducting UQ on AEDT's releases since 2015 and recently completed UQ analysis on the BADA4 model, reduced thrust profiles, and other new features for AEDT 3b. All the work was concluded in 2019 and GT has been focusing on developing AEDT reports including AEDT 3b UQ report and the ASCENT Project 36 final report. Project 36 was officially closed out on May 30, 2020 and the work that has been performed under the project was transitioned to ASCENT Project 54.

Research Approach

GT developed the final report summarizing the work that has been accomplished before ASCENT Project 36 was officially closed out. In addition, the AEDT 3b UQ report was also created to document the UQ effort on AEDT 3b to inform and educate the user regarding the methodologies used in AEDT 3b, as well as the thorough verification and validation (V&V), capability demonstration, and parametric uncertainty/sensitivity analysis of AEDT using the BADA4 aircraft performance model. The report consists of four analyses which were designed as the V&V of the newly implemented capabilities in AEDT 3b. Within the analyses, all of the relevant functionality specific to a given algorithm was evaluated to determine if it functioned as intended. In addition, test cases were designed to conduct further analysis to ensure the functionality was implemented properly.

- **Analysis 1—Reduced Thrust Profile V&V Analysis**: A V&V analysis of AEDT 3b's new feature to model aircraft performance and environmental impact using alternative weight and reduced thrust profiles. A comprehensive study was conducted to analyze the performance, fuel burn, emissions, and noise impacts of these new modified profiles. The analysis showed that the results produced by the alternative weight and reduced thrust profiles were reasonable and as expected.
- **Analysis 2—BADA4 V&V Analyses**: A comparison of BADA4 model and Aircraft Noise and Performance (ANP) model at aircraft and fleet level. Three levels of analysis at flight segment, single flight, and fleet level were conducted to ensure that the BADA4 algorithm and associated data are properly implemented into AEDT 3b. Further V&V analyses were done by comparing the results produced by BADA4 and ANP at the fleet level. Analysis results implied that BADA4 provides more accurate and unified results in aircraft performance modeling.
- **Analysis 3—AEDT 3c Features V&V Analyses**: This analysis consists of two comprehensive studies: (1) The ANP performance comparison between AEDT 3b and AEDT 3c to investigate the effects of new speed limit, and (2) BADA4 versus ANP comparison within AEDT 3c. It was identified that the speed limit change generally increases fuel burn and NOx emissions, which is expected. The results of the AEDT 3c verification and validation analyses display reasonable general trends of the new AEDT implementations.
- **Analysis 4—Parametric UQ on BADA4**: This parametric uncertainty/sensitivity analysis on BADA4 strives to quantify and identify how the algorithms and methodologies of BADA4 performance model respond to variations in inputs. Major contributors that have big effects on the outputs were identified. These analyses serve to inform the user as to the expected variation of BADA4 performance resulting from the variation of input parameters, as well as future data collection and tool development.

An inventory of UQ analysis was also compiled to summarize the UQ analysis that has been conducted for AEDT 3b. In addition, the bugs and issues found during the UQ analysis were listed, and the status of each bug were discussed as well.

Milestones

Milestone	Due Date	Estimated Completion Date	Actual Completion Date	Status
A36 Kickoff Meeting	5/3/2016	5/3/2016	5/3/2016	Completed
Quarterly Report (Aug)	7/31/2016	7/31/2016	7/31/2016	Completed
ASCENT Meeting	9/27-28/2016	9/27-28/2016	9/27-28/2016	Completed
Quarterly Report (Nov)	10/31/2016	10/31/2016	10/31/2016	Completed
Annual Report	1/18/2017	1/18/2017	1/13/2017	Completed
Quarterly Report (Jan)	1/31/2017	1/31/2017	1/27/2017	Completed
Quarterly Report (Mar)	3/31/2017	3/31/2017	3/31/2017	Completed
ASCENT Meeting	4/18/2017	4/18/2017	4/18/2017	Completed
Quarterly Report (Jun)	6/30/2017	6/30/2017	6/30/2017	Completed
ASCENT Meeting	9/26/2017	9/26/2017	9/26/2017	Completed
Quarterly Report (Oct)	10/30/2017	10/30/2017	10/30/2017	Completed
Annual Report	11/30/2017	11/30/2017	11/30/2017	Completed
Quarterly Report (Jan)	1/31/2018	1/31/2018	1/31/2018	Completed
Quarterly Report (Mar)	3/31/2018	3/31/2018	3/31/2018	Completed
ASCENT Meeting	4/3-4/2018	4/3-4/2018	4/3-4/2018	Completed
Quarterly Report (Jun)	6/30/2018	6/30/2018	6/30/2018	Completed
ASCENT Meeting	10/9-10/2018	10/9-10/2018	10/9-10/2018	Completed
Quarterly Report (Oct)	10/30/2018	10/30/2018	10/30/2018	Completed
Annual Report	11/30/2018	11/30/2018	11/30/2018	Completed
Quarterly Report (Jan)	1/31/2019	1/31/2019	1/31/2019	Completed
ASCENT Meeting	4/18-19/2019	4/18-19/2019	4/18-19/2019	Completed
Quarterly Report (Apr)	4/30/2019	4/30/2019	4/30/2019	Completed
Quarterly Report (Jul)	7/31/2019	7/31/2019	7/31/2019	Completed
ASCENT Meeting	10/22-23/2019	10/22-23/2019	10/22-23/2019	Completed
Quarterly Report (Oct)	10/31/2019	10/31/2019	10/31/2019	Completed
Annual Report	11/30/2019	11/30/2019	11/30/2019	Completed
Quarterly Report (Dec)	12/31/2019	12/31/2019	12/31/2019	Completed
Quarterly Report (Mar)	3/31/2020	3/31/2020	3/31/2020	Completed

ASCENT Meeting	3/31-4/1/2020	3/31-4/1/2020	3/31-4/1/2020	Completed
Quarterly Report (Jun)	6/30/2020	6/30/2020	6/30/2020	Completed
Final Report	8/31/2020	8/31/2020	8/31/2020	Completed
Annual Report	11/30/2020	11/30/2020	11/30/2020	Completed

Major Accomplishments

As of May 2020, all new AEDT Sprint releases, including Sprints 124-138, have been tested. Fifteen AEDT Sprints have been tested, focusing on new features and added capabilities. Some of the new features/capabilities were minor updates to the GUI, bug fixes, or data updates. Major updates included modified weight and reduced thrust profile, BADA4 performance model, and user-defined profile editor. To understand the background of new AEDT features, all relevant documents were reviewed, including software requirement documents, database design documents, AEDT Sprint release notes, updated technical manuals, user manuals, and research papers/reports. Basic tests of all new AEDT versions were completed to confirm their functionality, and issues were reported to the FAA and the development team via biweekly ASCENT project teleconferences and weekly AEDT development-lead calls. Identified issues and follow-up actions taken by the developers were documented and shared through the Team Foundation Server (TFS) online system. The TFS also allows for reporting of any potential areas of improvements in AEDT algorithms and user friendliness.

Finally, two reports were developed including a final project report and AEDT 3b UQ report which documented the UQ efforts on AEDT 3b. Though the project officially ended on May 30, 2020, the work that has been conducted under this project will be continued under ASCENT Project 54.

Publications

Written reports

ASCENT quarterly reports (Jan. 2019; Apr. 2019; Jul. 2019, Oct. 2019)
ASCENT annual report (Nov. 2018)

Peer-reviewed journal publications

Gao, Z., Behere, A., Li, Y., Lim, D., Kirby, M., & Mavris, D.M. Quantitative assessment of the new departure profiles with improved weight and thrust modeling. Approved for publication, Journal of Aircraft.

Outreach Efforts

N/A

Awards

None

Student Involvement

Bogdan Dorca is a third year PhD student at Georgia Institute of Technology. Mr. Dorca conducted AEDT capability demonstration, feature evaluation and system testing. Mr. Dorca is being trained on related tools such as INM, AEDT Tester, AEDT 2e, and AEDT 3b.

Zhenyu Gao is a fourth year PhD student at Georgia Institute of Technology. Mr. Gao conducted parametric uncertainty quantification analyses for the BADA4 model, created the AEDT study, and performed a sensitivity analysis for this study. Mr. Gao is being trained on related tools such as INM, AEDT Tester, AEDT 2e, and AEDT 3b.

Santusht Sairam is a second year Master student at Georgia Institute of Technology. Mr. Sairam conducted AEDT capability demonstration, feature evaluation and system testing. Mr. Sairam is being trained on related tools such as INM, AEDT Tester, AEDT 2e, and AEDT 3b.

Plans for Next Period

This project officially closed out on May 30, 2020; however, some of the tasks performed by GT will be continued under the new ASCENT Project 54. GT will perform the system testing, validation, and verification tasks for the new versions of AEDT 3d and beyond to identify any issues that should be addressed by the development team.