Project 36
Parametric Uncertainty Quantification of AEDT

ASCENT AVIATION SUSTAINABILITY CENTER

Georgia Tech Aerospace Systems Design Laboratory

Motivation

- AEDT is the heart of the FAA/AEE's environmental tool suites for assessing fleet wide fuel burn, emissions, and noise impacts
- As AEDT sets the global standard for environmental impact analysis, it is under continuous improvements to implement the best modeling methods and data
- FAA is interested in quantifying uncertainties in AEDT output due to uncertainties in input parameters

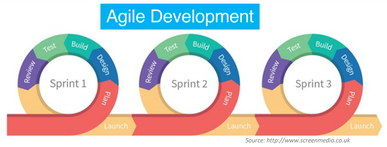
Objectives

- Perform V&V for new methods and functionalities implemented to AEDT sprint releases
- Identify and quantify major contributors to output uncertainties
- Identify gaps in the tools functionality and areas for further development

Project Status

Phase I: August 2015 – January 2016
Parametric Uncertainty Quantification of AEDT 2b
Phase II: April 2016 – March 2017
V&V and Parametric UQ of AEDT 2c
Phase III: April 2017 – August 2018
Finalized AEDT 2b UQ Report for publication
V&V of AEDT 2d and 2e
Phase IV: September 2018 – August 2019
Parametric Uncertainty Quantification of AEDT 3a
V&V of AEDT 3a and 3b

AEDT Development Strategy



Source: http://www.screenmedia.co.uk

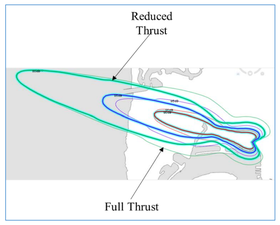
Dates	Milestones
Sep 2017	AEDT 2d Release
Dec 2017	AEDT 2d SP1 Release
Mar 2018	AEDT 2e Release
Sep 2018	AEDT 3a Release

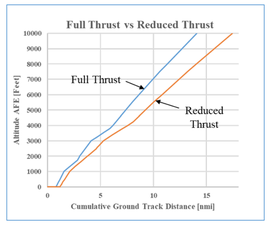
- **New AEDT Functionalities**
  - BADA4 Features
    - BADA4 implementation of procedural departures and arrivals
    - Encryption of BADA 4 data
    - BADA4 with reduced thrust and alternative weight departure procedures
    - BADA4 implementation for sensor-path
    - Climb thrust taper
  - Emissions Analysis Features
    - Enhanced nvPM methods for CAEP nvPM Standard
    - Roadway network designer in AEDT GUI
    - Emission concentration display for non-closing contours
  - Noise Analysis Features
    - Dynamic grid for non-dB metrics
    - Bulk creation of operations
    - Detailed noise results report
  - Other Features
    - Non-closing contours
    - Fixed terminal area wind directions

Reduced Takeoff Thrust Departure Procedures

Capability Enhancements in AEDT

- Airlines use reduced takeoff thrust when possible to save engine maintenance cost
- Reduced thrust departure procedures are implemented in AEDT 3a to model the real world procedures more accurately
  - User can choose between 5%, 10% or 15% thrust reduction level
  - Reduced climb thrust is also implemented which depend on takeoff thrust reduction
- Reduced take off and climb thrust lead to
  - longer ground roll, shallower climb, and increased cumulative track length
  - Increased fuel burn, decreased NOx
  - Decreased noise contour width and areas for all stage lengths and dB levels
  - Increased or decrease contour length depending on dB levels

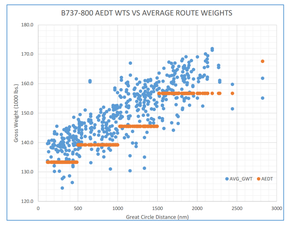


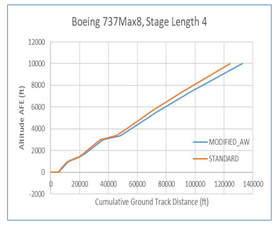


Increased Takeoff Weight Departure Procedures

Capability Enhancements in AEDT

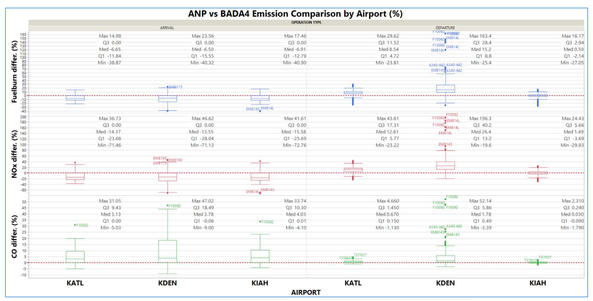
- AEDT estimates aircraft weight via stage lengths and assumes a 65% load factor
- Airline data analysis results from ASCENT Project 35 indicated that these factors led to underestimating the weight consistently across stage lengths
- The alternative (increased) weight departure procedures are implemented in AEDT to better model the takeoff weight
  - New weights are average of current and next stage length
  - The highest SL weight does not exceed MTOW
- The alternative (increased) weight departure procedures lead to
  - Increased contour area and length
  - Increased fuel burn and NOx





BADA4 Vs. ANP

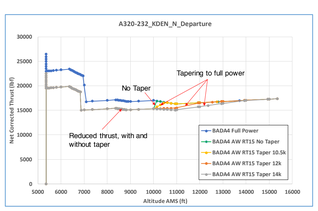
- To test the BADA4 model in AEDT 3a, a study was created to compare BADA4 and ANP with respect to performance, fuel burn, emissions and noise results
- The study consists of 41 aircraft which are major commercial, business jet, and general aviation aircraft and have BADA4 model
- Fuel Burn Results
  - BADA4 departure fuel burn is greater by 12.6% on average which is due to the implementation of the 250 knot limit using 10,000 ft MSL instead of 10,000 ft AFE
  - BADA4 arrival fuel burn is 7.6% less on average
  - BADA4 has better performance model which results in more accurate fuel burn results
- Noise Results
  - For majority of the aircraft studies, the difference in noise results are relatively small
  - Bigger noise differences are observed at high altitude airport and on hot day



Thrust Taper

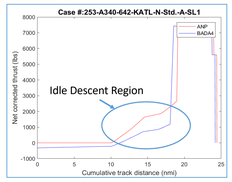
Capability Enhancements in AEDT

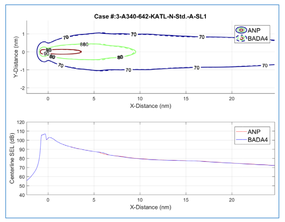
- To avoid an unrealistic jump from the reduced power setting to the full power for BADA4 model, thrust taper was implemented
- This feature would allow the engine to gradually change the thrust from the reduced thrust setting to the full climb setting
- The lower taper is fixed at 10,000 ft, and upper taper limit is adjustable
- This feature is working properly

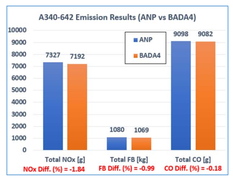


Idle Descent

- For arrival operation, ANP and BADA4 differ mostly in idle descent segment due to different equations/coefficients used in thrust calculations.
- BADA4 model always take into deceleration in the descent segment while ANP does not, thus BADA 4 generates more accurate results
- Through extensive studies, the impact of idle descent segment was found to be relatively small for overall emission and noise results





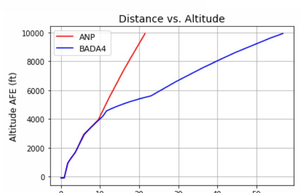


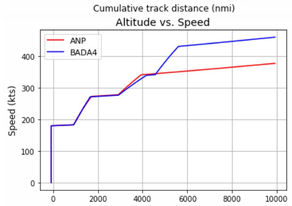
SEL 70 dB Area Diff. (%)	SEL 80 dB Area Diff. (%)	SEL 90 dB Area Diff. (%)
-1.58	-1.43	-2.1

MSL Based Departure Procedures

Capability Enhancements in AEDT

- In AEDT 3a, the 250 knot CAS at 10,000 ft above MSL rule is implemented in BADA4, and ANP uses 250 knot CAS at 10,000 ft AFE
- This implementation results in differences in the performance, fuel burn, emissions and noise results between ANP and BADA4 for operations at airport with high altitude
- For example, at Denver airport (altitude: 5,434 ft) the ANP and BADA4 trajectories and speed plots are very different
- BADA4 has much longer trajectories before reach 10,000 ft AFE, and produces more fuel
- BADA4 follows the 250kt/10ft FAR rule, and its results are closer to the real aircraft operation and more accurate than ANP

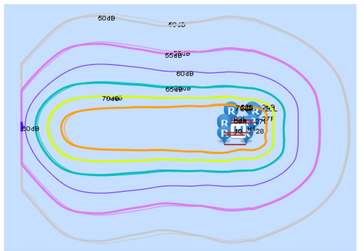




Non-closing Contours

Capability Enhancements in AEDT

- In old AEDT versions, if a contour is not fully covered by a receptor set, it cannot be generated
- In AEDT 2d, the feature of non-closing contour was implemented which allows open noise contour to be generated and displayed
- The attributes of noise/emissions dispersion layer can show if the contour is closed or open for a specific noise level
- The feature was tested and working properly



Summary and Next Steps

- GT team has been working very closely with the AEDT development team to conduct independent V&V of the current and future AEDT versions
- Tested and verified that the AEDT's new capabilities are working properly:
  - ✓ BADA4 Features:
    - BADA4 implementation of procedural departures and arrivals
    - BADA4 with reduced thrust departure profiles
    - Idle decent between ANP and BADA4
    - BADA4 implementation for sensor-path, and thrust taper
  - ✓ Emissions Analysis Features:
    - Enhanced full flight nvPM methods for CAEP nvPM standard
    - Roadway Network Designer in AEDT GUI
  - ✓ Noise Analysis Features:
    - Dynamic grid for non-dB metrics
    - Detailed noise report, and Noise grid import and merging
  - ✓ Other Features:
    - Bulk creation of operations
    - Vector track and track dispersion modeling
    - Non-closing contours for noise and emissions analysis
- **GT has identified some bugs which need fixing→ Most of them have already been addressed by the development team!**
- Documented the findings on TFS for the developers and AEDT UQ reports, and in a conference paper
- The AEDT 2B UQ report has been updated and is published
- Primary next steps on AEDT 3 tests:
  - Continue to support BADA4 implementations for altitude/speed controls
  - Continue the modeling of improved takeoff weight, reduced thrust, and departure procedures
  - Perform independent testing and uncertainty analysis for any newly released features and functionality

Lead investigator: Dr. Dongwook (Don) Lim, Dr. Yongchang Li
Contributors: Yee Chan Jin, Junghyun Kim, Ameya Behere, Zhenyu, Gao, Dylan Thomson, Robert Blickenstaff, Dr. Michelle Kirby, and Dr. Matthew Levine
Project manager: Dr. Mohammed Majeed, FAA

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