Aviation Environmental Design Tool (AEDT)

NOx Modeling Demonstration

Presented to: TRB AEDT/APMT Workshop #4

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Introduction

- **Objectives**
  - Advance AEDT development toward modeling noise and emissions trades and interdependencies
  - Demonstrate ability to model global emissions using aircraft fleet data and performance algorithms common to noise and emissions calculations

- **The NOx Modeling Demonstration was selected as the first demonstration of the initial development of the FAA's Aviation Environmental Design Tool (AEDT) for the following reasons:**
  - Directly supported International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection 7th meeting (CAEP/7) goal to "limit or reduce the impact of aviation emissions on local air quality"
  - Results could be compared with analysis conducted for CAEP/6 as reported in Information Paper 13 (IP-13)
  - AEDT modules used for the demonstration were mature

What was Done?

- **Three modeling rounds:**
  - Round 1 – One month of data using Emissions and Dispersion Modeling System (EDMS) and System for assessing Aviation's Global Emissions (SAGE)
  - Round 2 – Full year of data using EDMS and SAGE
  - Round 3 – Full year of data using emissions, fuel burn, performance and delay modules that are common to AEDT

  - Emissions inventory for the global fleet
    - NO_x, CO_2, H_2O
    - 2002, 2006, 2008, 2012, 2016, 2020
    - 5 – 30% NO_x stringencies
    - 3,000 feet and below, 10,000 feet and below, total flight

How was it Done?

- **Derived schedule of operations**
- **Developed replacements database**
- **Compiled an airport database**
- **New software to**
  - Model delays
  - Model aircraft performance
  - Model aircraft emissions
  - Generate reports

Operations

- **Modified AEDT/ Model for Assessing Global Exposure to the Noise of Transport Aircraft (MAGENTA) forecasting module to support:**
  - Use of FAA's Enhanced Traffic Management System (ETMS) and International Official Airline Guide (IOAG) schedule data
  - Application of the ICAO/CAEP Forecasting and Economic Sub Group (FESG) forecast to grow the schedule
- **Most current FESG forecast (2002) used**
- **Resulted in a <u>schedule</u> of operations**
- **Origin and Destination airport information preserved**
- **Takeoff weight estimated based on trip length**

Operations (continued)

- **Commercially available registration database (Campbell-Hill) data used to determine distribution of airframe/engine combinations based on generic ETMS/IOAG types**
  - Example: American Airlines B752 =
    11% B757-200 with PW2037 engines
    2% B757-200 with PW2040 engines
    87% B757-200 with RB211-535E4-B engines

Operations (concluded)

- **Aircraft/engine combinations used for calculating emissions and aircraft performance**
- **Since ETMS data were used,**
  - Unscheduled flights were included
  - Fleet mix reflected smaller aircraft, not just the commercial jets included in registration databases (BACK or Campbell-Hill)
- **Resulted in a more comprehensive global operations database**
- **All emissions were applied to origin airport (and its ICAO Region) per United Nations Framework Convention on Climate Change (UNFCCC)**

Replacements Database

- **For future scenarios, aircraft age from Campbell-Hill was used to retire older aircraft and apply a replacements database**
- **ICAO/CAEP does not currently produce a replacements database for emissions, so one was developed**
  - Based on FESG best practice replacement database "Jet-9", which was designed for modeling fleet changes due to noise standards
  - Added ICAO/CAEP "Production" Technology Level (TL) information (for emissions)
    - 1 – A minor change which does not require a complete engine recertification
    - 2 – A major change with a scaled proven technology
    - 5A – New technology using current industry best practice
    - 5B – New technology (beyond current best)

Airport Database

- **Airport database developed with global coverage (32,000+ airports)**
  - Key parameters for NOx Modelling Demonstration
    - Airport elevation
    - Average annual temperature
    - Average annual pressure
    - Average annual humidity
  - Supports the performance module
  - Input to BFFM2 for emissions

Airport database (continued)

- **Multiple identifiers for the same airport**
  - IOAG uses International Air Transport Association (IATA) (non-unique) identifier + country
  - ETMS uses ICAO, FAA, and IATA
- **Airport database was needed to resolve airport ambiguities**

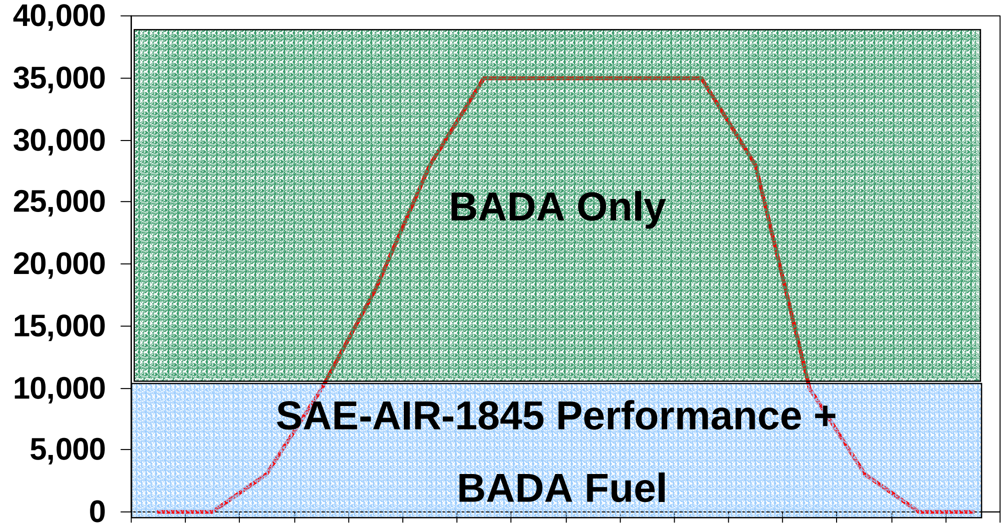
Airport Database (concluded)

- **Contains data useful for AEDT in the future**
  - Runway coordinates
  - Runway gradient
  - ILS glide slope angle
- **Combines multiple data sources**
- **Significant improvement over previous databases**

Delay Modeling

- Where airport capacity data were available, taxi-in/out times were calculated in 1-hour increments, aggregated to annual average values. Airborne arrival delays were also computed
- Modeled using WWLMINET
- When airport capacity data were not available, ICAO default taxi time in mode (TIM) were used

Aircraft Performance



Emissions Calculations

- **Emissions were modeled gate-to-gate**
- **Boeing Fuel Flow Method 2 was used for computing emissions**
- **TL5B fuel burn penalty modeled**
  - Since fuel flow was computed, it was possible to model a 2% fuel burn penalty for TL5B engines
    - Introduced to account for uncertainty associated with new technologies
  - This also enabled modeling CO_2 and H_2O which are directly proportional to fuel consumption

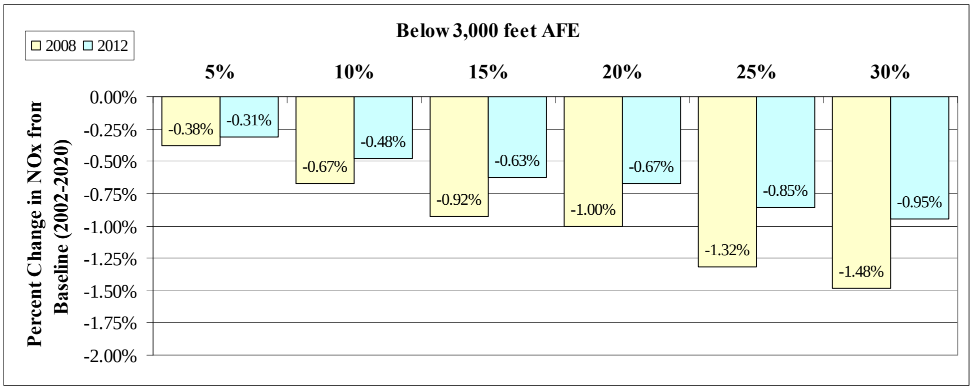
Generate Reports

- A reporting module was developed to automate the report generation process
- Implemented in EDMS
- Accepts emissions results from SAGE and aggregates with EDMS
- Output is HTML that can be copied into Excel for plotting results

Comparison with CAEP/6 IP-13

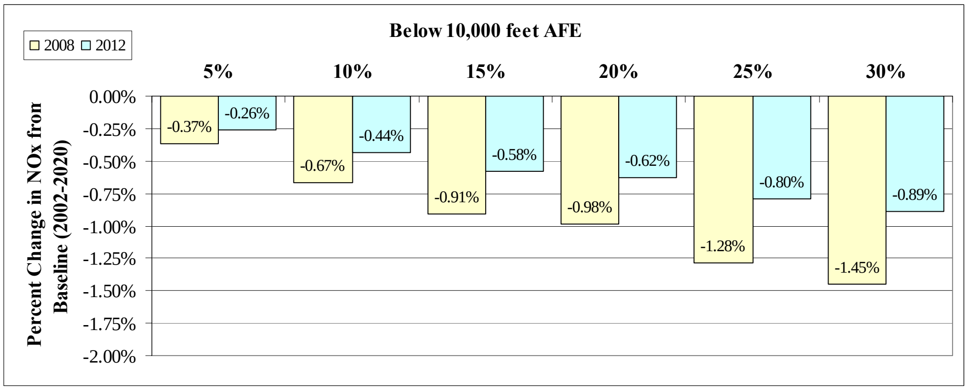
IP-13	NOx Modeling Demonstration
Scope of documentation not intended to be repeated	Completely documented process to allow logical follow-on work
Not intended to be harmonized with noise	Uses the MAGENTA fleet operations module to convert FESG forecast to support NOx Modeling Demonstration
BACK global LTO cycles limited the analysis to looking at the entire world at once.	A complete operations schedule compiled by aircraft type and city pair to allow emissions to be reported by ICAO region
ICAO times in mode ignored aircraft performance variation	Aircraft performance data is used in conjunction with Boeing Fuel Flow Method 2 Taxi/delay times are modeled
Only emissions from the LTO were considered	Gate-to-gate emissions are included
Aggregating the results was tedious, since 80+ files needed to be manually compared.	The report-generation process is automated

Sample Results:
Cumulative change in NOx 2002-2020



Note: These results reflect assumptions that are specific to this analysis. Changes to these assumptions will affect the results.

Sample Results:
Cumulative change in NOx 2002-2020



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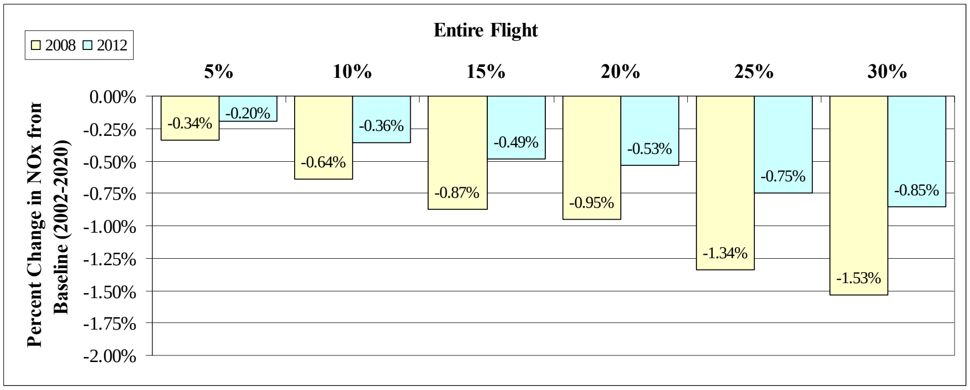
Sample Results:
Cumulative change in NOx 2002-2020



Note: These results reflect assumptions that are specific to this analysis. Changes to these assumptions will affect the results.

Sample Results:
Effects of stringency implementation ranked by amount of total NOx reduction

	Below 3,000 Feet AFE		Below 10,000 Feet AFE	Entire Flight
RANK	CAEP/6-IP/13	AEDT NOx Modeling Demonstration	AEDT NOx Modeling Demonstration	AEDT NOx Modeling Demonstration
	Stringency	Stringency	Stringency	Stringency
Highest	-30% in 2008	-30% in 2008	-30% in 2008	-30% in 2008
2nd	-25% in 2008	-25% in 2008	-25% in 2008	-25% in 2008
3rd	-20% in 2008	-20% in 2008	-20% in 2008	-20% in 2008
4th	-15% in 2008	**-30% in 2012**	-15% in 2008	-15% in 2008
5th	-30% in 2012	**-15% in 2008**	-30% in 2012	-30% in 2012
6th	-25% in 2012	-25% in 2012	-25% in 2012	-25% in 2012
7th	-10% in 2008	**-20% in 2012**	-10% in 2008	-10% in 2008
8th	-20% in 2012	**-10% in 2008**	-20% in 2012	-20% in 2012
9th	-15% in 2012	-15% in 2012	-15% in 2012	-15% in 2012
10th	-10% in 2012	-10% in 2012	-10% in 2012	-10% in 2012
11th	-5% in 2008	-5% in 2008	-5% in 2008	-5% in 2008
Lowest	-5% in 2012	-5% in 2012	-5% in 2012	-5% in 2012

Sample Results: NOx emissions values

Percent of Total NOx

	NOx Modeling Demonstration						CAEP/6-IP/13					
Seat Class / Year	**2002**	**2006**	**2008**	**2012**	**2016**	**2020**	**2002**	**2006**	**2008**	**2012**	**2016**	**2020**
20 - 99	11%	12%	12%	13%	14%	15%	5%	5%	5%	6%	6%	6%
100 - 210	55%	54%	53%	51%	48%	45%	55%	53%	51%	46%	43%	39%
211 - 650	34%	34%	35%	36%	38%	41%	40%	42%	44%	48%	51%	55%

LTO Counts

	NOx Modeling Demonstration						CAEP/6-IP/13					
20 - 99	11,389,659	12,072,458	12,784,766	14,242,075	15,784,100	17,483,371	3,615,302	4,500,883	5,448,739	7,608,327	9,735,241	11,911,474
100 - 210	12,753,038	13,734,367	14,741,056	16,636,700	18,241,168	19,325,300	13,596,379	14,764,100	15,700,006	17,746,231	19,926,451	22,284,635
211 - 650	2,173,776	2,540,231	2,871,883	3,613,505	4,605,716	6,082,047	2,986,015	3,534,049	4,045,619	5,299,321	6,812,078	8,693,656
Total	**26,316,473**	**28,347,056**	**30,397,705**	**34,492,280**	**38,630,984**	**42,890,718**	**20,197,696**	**22,799,032**	**25,194,364**	**30,653,879**	**36,473,770**	**42,889,765**
% Δ From IP-13	**30%**	**24%**	**21%**	**13%**	**5.90%**	**0.00%**						

Percent of Total LTOs

	NOx Modeling Demonstration						CAEP/6-IP/13					
20 - 99	43%	43%	42%	41%	41%	41%	18%	20%	22%	25%	27%	28%
100 - 210	48%	48%	48%	48%	47%	45%	67%	65%	62%	58%	55%	52%
211 - 650	8%	9%	9%	10%	12%	14%	15%	16%	16%	17%	19%	20%
Pounds of NOx per LTO	15	15.5	16	16.9	18	19.1	26.7	27.5	28.2	29.6	31	32.6
% Δ From IP-13	**-44%**	**-44%**	**-43%**	**-43%**	**-42%**	**-41%**						

Sample Results: Comparison with IP-13 Conclusions

- Up to 30% more LTOs for 2002 by including small aircraft
- Over 40% less NOx in LTO cycle from modeling aircraft performance instead of using the default times in mode
- Minor changes to ranking for cumulative NOx stringencies
- Reported emissions for entire flight, not just LTO cycle

Context for AEDT

- NOx Demonstration is a **significant *step* toward a noise/emissions tradeoff capability**
- **Key accomplishments**
  - Harmonized data between EDMS, INM, MAGENTA, SAGE
    - Airports
    - Fleet
  - Harmonized performance module
  - Harmonized emissions module

Conclusion

- **The NOx Modeling Demonstration successfully demonstrated the following elements of AEDT**
  - Dynamic gate-to-gate aircraft performance data, methodologies, and a global airport, operations and fleet database that are necessary to assess interdependencies;
  - Implementation of a CAEP-approved flexible forecasting system rather than a set of static lookup tables;
  - Use of meteorological data;
  - Use of BFFM2;
  - A broad range of aircraft type and traffic types – no longer restricting global analyses to commercial jets; and
  - Use of schedule data and delay modelling;
- **Using noise and emissions modules that are now harmonized within AEDT**
- **Moves AEDT closer to being able to model noise and emissions trades and interdependencies**
  - Critical for providing comprehensive evaluation of future policies

??? Questions ???

FAA Environmental Tools web site:

http://www.faa.gov/about/office_org/headquarters_offices/aep/models/