AEDT Global NOx Demonstration

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Introductions

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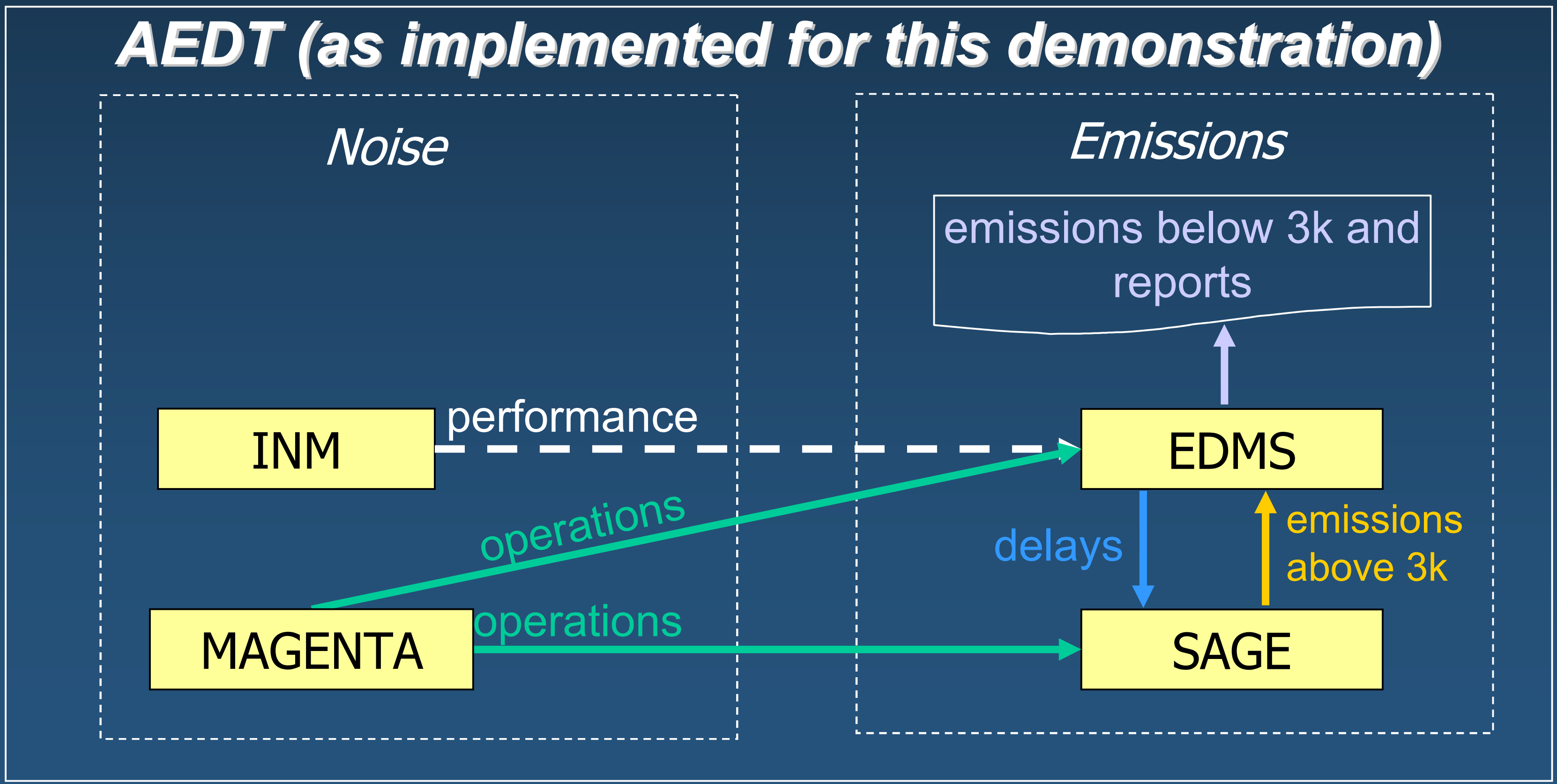
Acknowledgements to:

Outline

- Introduction to AEDT
- Overview of NOx demonstration analysis
- How it was done
  - Data and software enhancements
- Results
- Conclusions

Introduction to AEDT

- **Aviation Environmental Design Tool**
  - **Primary objective**: Develop a system for assessing aviation noise and emissions interdependencies
  - Accomplished by building on and integrating proven tools



Overview of the NOx Demonstration Analysis

- First demonstration of AEDT
- Supported International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP)
- The 35th Session of the ICAO Assembly (A35) established 6 Strategic Objectives to "achieve its vision of safe, secure and sustainable development of civil aviation through cooperation amongst its member States"
- Strategic Objective C, *Environmental Protection*
  - *Minimize the adverse effect of global civil aviation on the environment,* will be attained, in part, by developing, adopting, and promoting new or amended measures to:
    - limit or reduce the number of people affected by significant aircraft noise
    - **limit or reduce the impact of aviation emissions on local air quality**; and
    - limit or reduce the impact of aviation greenhouse gas emissions on the global climate

Overview of the NOx Demonstration Analysis (cont.)

- Demonstrate the ability to model the effects of imposing an emissions stringency on aircraft
  - *Stringency = required % emissions reduction vs. previous standard for new deliveries*
- Demonstrate progress toward developing a suite of tools to assess noise and emissions interdependencies

Overview of the NOx Demonstration Analysis (concl.)

- 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 implemented in 2008, 2012
  - 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

Aircraft Operations

- Modified 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
  - Provided number of operations by seat class, region, and broad market pair
- Resulted in a schedule of operations
- Origin and Destination airport information preserved
- Takeoff weight estimated based on trip length

Aircraft Operations (concl.)

- 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

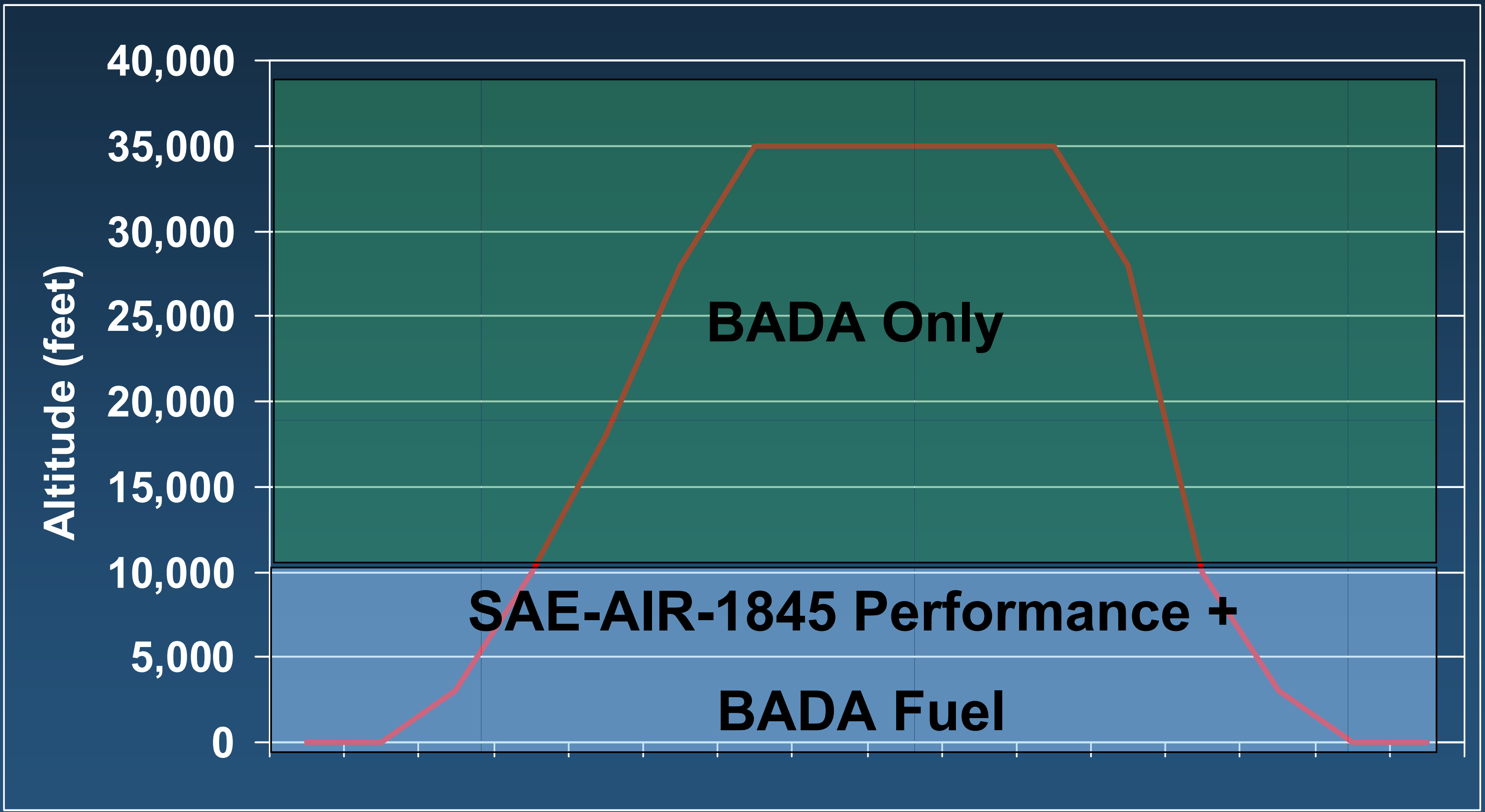
    2% B757-200 with PW2040 engines

    87% B757-200 with RB211-535E4-B engines
- 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 comprehensive global operations database

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
    - 3 – Substitution with other available certified current technology engine
    - 4 – Development of a new current technology engine
    - 5A – New technology using current industry best practice
    - 5B – New technology (beyond current best)
  - TL3 and TL4 not included in study due to a lack of economic incentive for the engine manufacturer

Aircraft Performance



Emissions Calculations

- Aircraft performance module output thrust level and fuel consumption for each flight segment
  - This enabled modeling CO_2 and H_2O which are directly proportional to fuel consumption
- Boeing Fuel Flow Method 2 was used to obtain thrust-specific emission indices
- 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
- All emissions were applied to origin airport (and its ICAO Region) per United Nations Framework Convention on Climate Change (UNFCCC)

Other Enhancements

- WWLMINET was expanded upon to estimate airport level queuing
  - Used when airport capacity information was available
  - 26-minute ICAO default idle time used elsewhere
- A comprehensive airport database was developed with 32,000+ airports worldwide
  - Supports performance and queuing modules
  - Emissions at 6,400 airports calculated
- A reporting module was developed to automate the report generation process
  - Accepts emissions results from SAGE and aggregates them with results from EDMS
  - Output is HTML that can be copied into Excel for plotting results

Important Notes

- The next slides show sample results from AEDT
- This activity was a demonstration of the capabilities of AEDT and not a comprehensive policy analysis

Sample Results:

Number of LTOs by Seat Class

Seat Class	2002	2006	2008	2012	2016	2020
20 – 99	11,389,659	12,072,458	12,784,766	14,242,075	15,784,100	17,483,371
100 – 210	12,753,038	13,734,367	14,741,056	16,636,700	18,241,168	19,325,300
211 – 650	2,173,776	2,540,231	2,871,883	3,613,505	4,605,716	6,082,047
Total	**26,316,473**	**28,347,056**	**30,397,705**	**34,492,280**	**38,630,984**	**42,890,718**

Seat Class	2002	2006	2008	2012	2016	2020
20 – 99	43%	43%	42%	41%	41%	41%
100 – 210	48%	48%	48%	48%	47%	45%
211 – 650	8%	9%	9%	10%	12%	14%

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

Note small percentage of large aircraft

Sample Results:

Baseline NOx emissions by altitude and entire flight

Seat Class	2002	2006	2008	2012	2016	2020
	Metric Tons	Metric Tons	Metric Tons	Metric Tons	Metric Tons	Metric Tons
	LTO Cycle: Below 3,000 feet (914.4m) AFE					
20 – 99	14,526	17,779	21,359	28,750	36,760	46,075
100 – 210	87,415	95,254	103,169	119,683	135,531	147,128
211 – 650	55,810	63,168	70,311	86,262	107,074	135,730
Total	**157,750**	**176,201**	**194,839**	**234,695**	**279,364**	**328,933**
	Terminal Area: Below 10,000 feet (3048m) AFE					
20 – 99	27,009	32,971	39,519	53,044	67,683	84,659
100 – 210	151,244	164,814	178,691	207,721	235,619	256,061
211 – 650	95,275	108,094	120,573	148,478	184,845	234,966
Total	**273,528**	**305,879**	**338,783**	**409,243**	**488,148**	**575,687**
	Entire Flight					
20 – 99	80,252	92,459	106,248	134,715	165,407	200,957
100 – 210	775,516	833,527	899,067	1,035,410	1,167,627	1,272,087
211 – 650	1,029,453	1,156,272	1,288,886	1,571,232	1,875,945	2,176,668
Total	**1,885,221**	**2,082,258**	**2,294,201**	**2,741,357**	**3,208,978**	**3,649,713**

Presented to show the order of magnitude of the global emissions

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

Sample Results:

Baseline NOx emissions by altitude and entire flight

Seat Class	2002	2006	2008	2012	2016	2020
	Metric Tons	Metric Tons	Metric Tons	Metric Tons	Metric Tons	Metric Tons
	[illegible]					
20 – 99	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1%
100 – 210	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4%
211 – 650	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4%
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	**9%**
	[illegible] feet					
20 – 99	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2%
100 – 210	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7%
211 – 650	5%	5%	5%	5%	6%	6%
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	**16%**
	Entire Flight					
20 – 99	4%	4%	5%	5%	5%	6%
100 – 210	41%	40%	39%	38%	36%	35%
211 – 650	55%	56%	56%	57%	58%	60%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Policy decisions warrant investigation of NOx per passenger-mile or other normalization techniques

However, this is only a demonstration of modeling capabilities, not a complete policy analysis

211 – 650 seat class dominant over entire flight

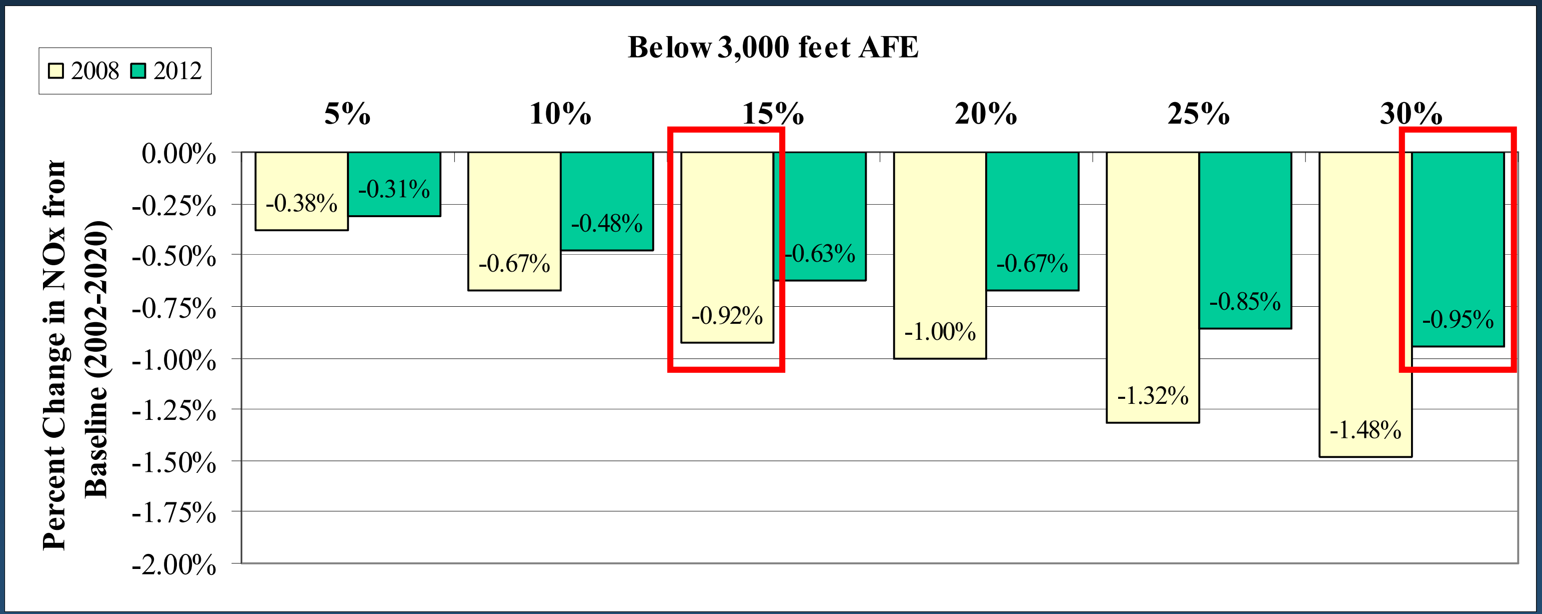
Note: These results reflect assumptions that are specific to this analysis. Changes to these assumptions will affect the results.

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	**Stringency**	**Stringency**	**Stringency**
Highest	-30% in 2008	-30% in 2008	-30% in 2008
2nd	-25% in 2008	-25% in 2008	-25% in 2008
3rd	-20% in 2008	-20% in 2008	-20% in 2008
4th	-30% in 2012	**-15% in 2008**	**-15% in 2008**
5th	-15% in 2008	**-30% in 2012**	**-30% in 2012**
6th	-25% in 2012	-25% in 2012	-25% in 2012
7th	-20% in 2012	**-10% in 2008**	**-10% in 2008**
8th	-10% in 2008	**-20% in 2012**	**-20% in 2012**
9th	-15% in 2012	-15% in 2012	-15% in 2012
10th	-10% in 2012	-10% in 2012	-10% in 2012
11th	-5% in 2008	-5% in 2008	-5% in 2008
Lowest	-5% in 2012	-5% in 2012	-5% in 2012

Sample Results:
Cumulative change in NOx 2002-2020



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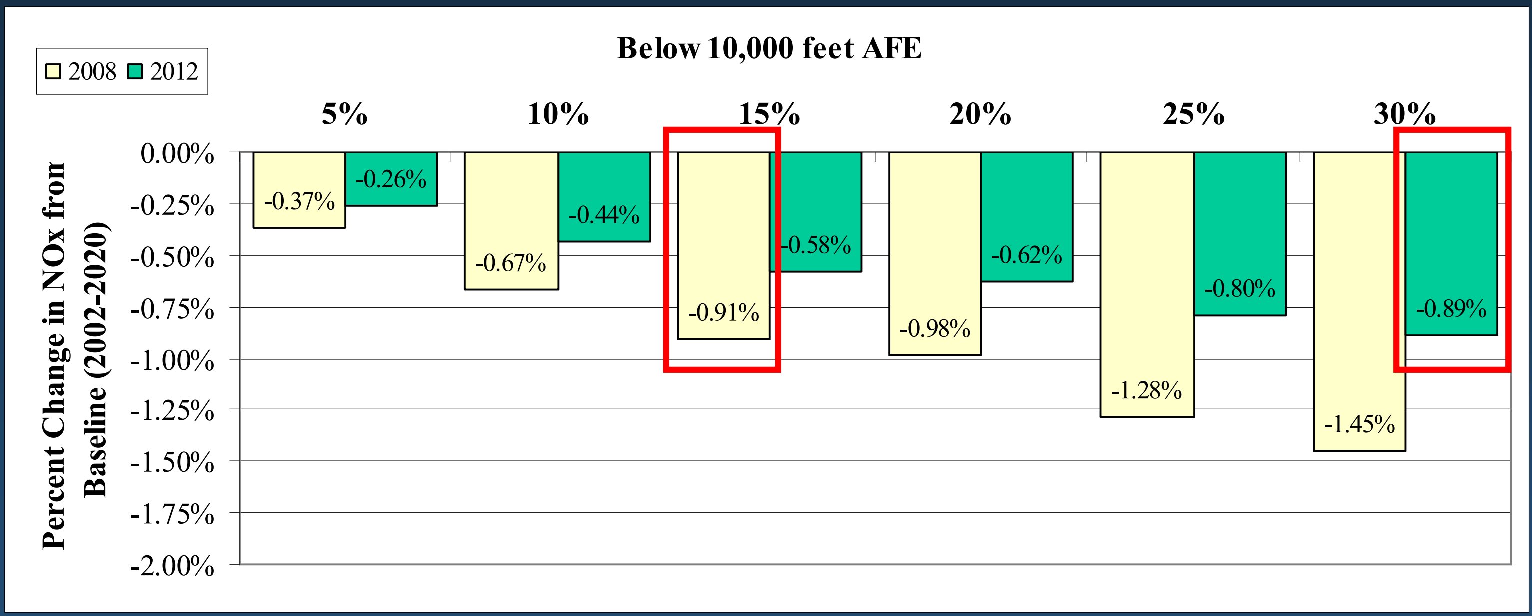

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Sample Results:
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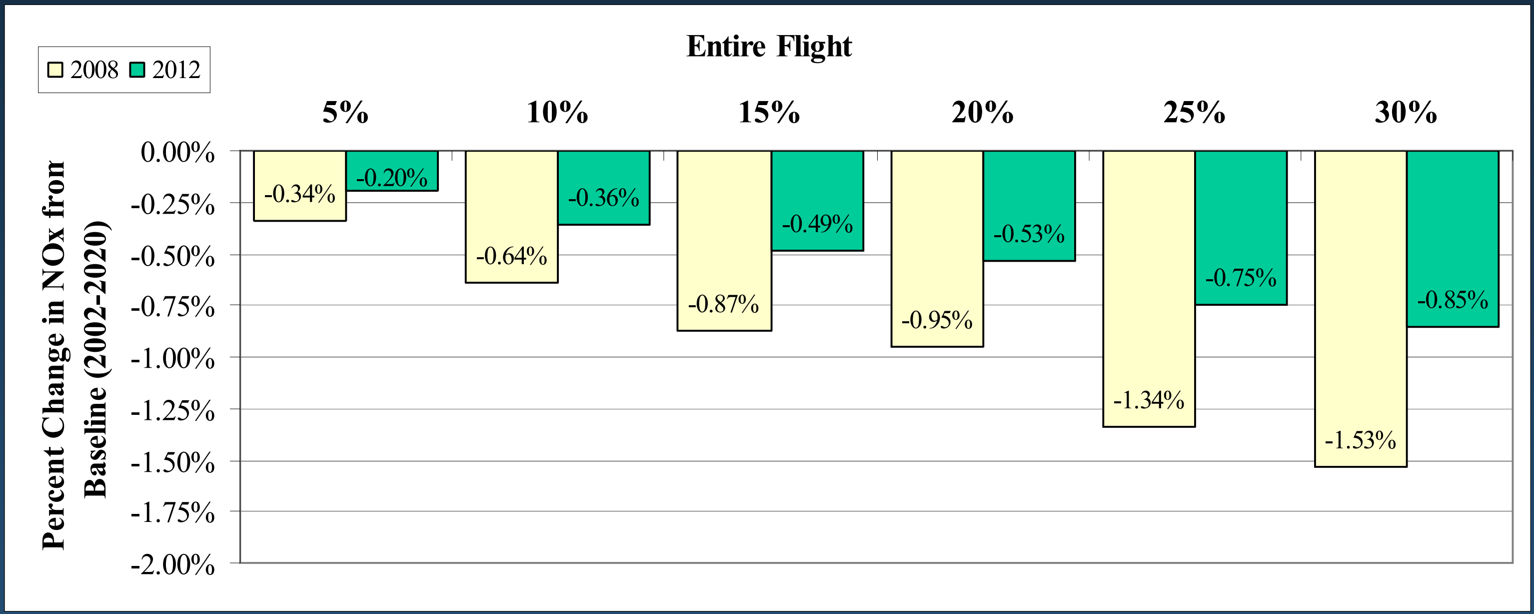

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Context for AEDT

- 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
- Distributed modules of AEDT benefit from NOx Prototype
  - EDMS 5.0 used for the demonstration
  - INM 7 includes harmonized system tables

Conclusions

- The NOx Modeling Demonstration successfully demonstrated the following elements of AEDT
  - Dynamic gate-to-gate aircraft performance data
  - Global airport database
  - Global operations database
  - Global fleet database
  - Methodologies that are necessary to assess interdependencies
  - Implementation of a CAEP-approved flexible forecasting system rather than a set of static lookup tables
  - Addition of unscheduled flights, through radar data, resulting in a more precise representation of actual global flights
  - Use of meteorological data for aircraft performance and emissions calculations
  - Use of Boeing Fuel Flow Method 2
  - Consideration of a broad range of aircraft and traffic types – no longer restricting global analyses to commercial jets
  - Use of schedule data and delay modelling

Conclusions

- The demonstration used modules that are now common to noise and emissions tools 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?

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