

# AEDT Global NOx Demonstration

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*USA/Europe ATM R&D Seminar 2007*

*Environmental Considerations in ATM System Design Session*

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**July 4, 2007**

# Introductions

**This work was funded by the U.S. Federal Aviation Administration  
Office of Environment and Energy,  
under the FAA/Volpe General Working Agreement  
and Contract Numbers: DTFAAC-05-D-00075, DTFAWA-05-C-00044,  
NNL05AA04Z, for ATAC, CSSI and Wyle, respectively.  
The AEDT effort is co-managed by Lourdes Maurice and Gregg Fleming.**

**Acknowledgements to:**

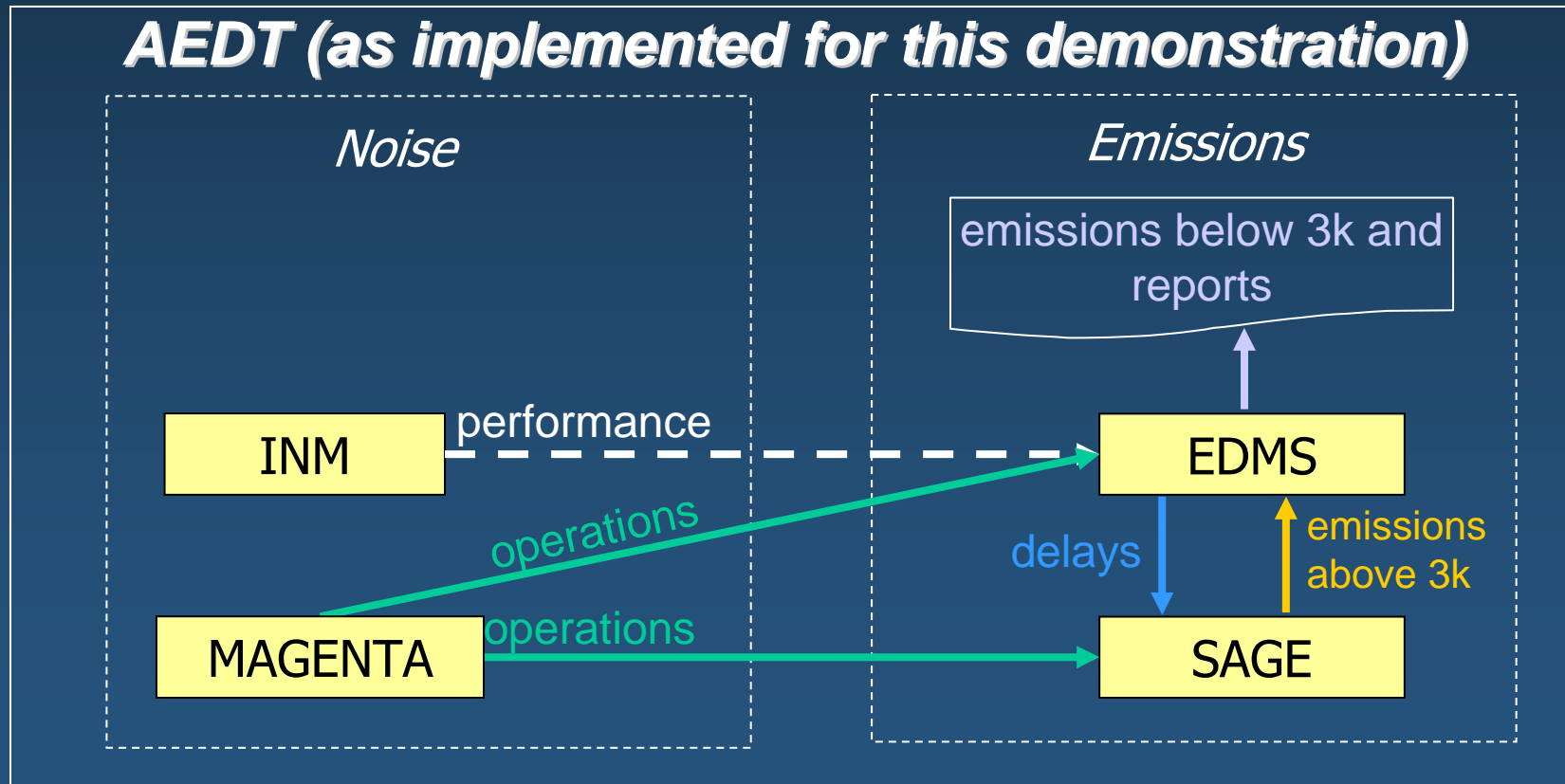


# Outline

- ◆ Introduction to AEDT
- ◆ Overview of NO<sub>x</sub> 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 NO<sub>x</sub> 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<sub>x</sub>, CO<sub>2</sub>, H<sub>2</sub>O
  - 2002, 2006, 2008, 2012, 2016, 2020
  - 5 – 30% NO<sub>x</sub> 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

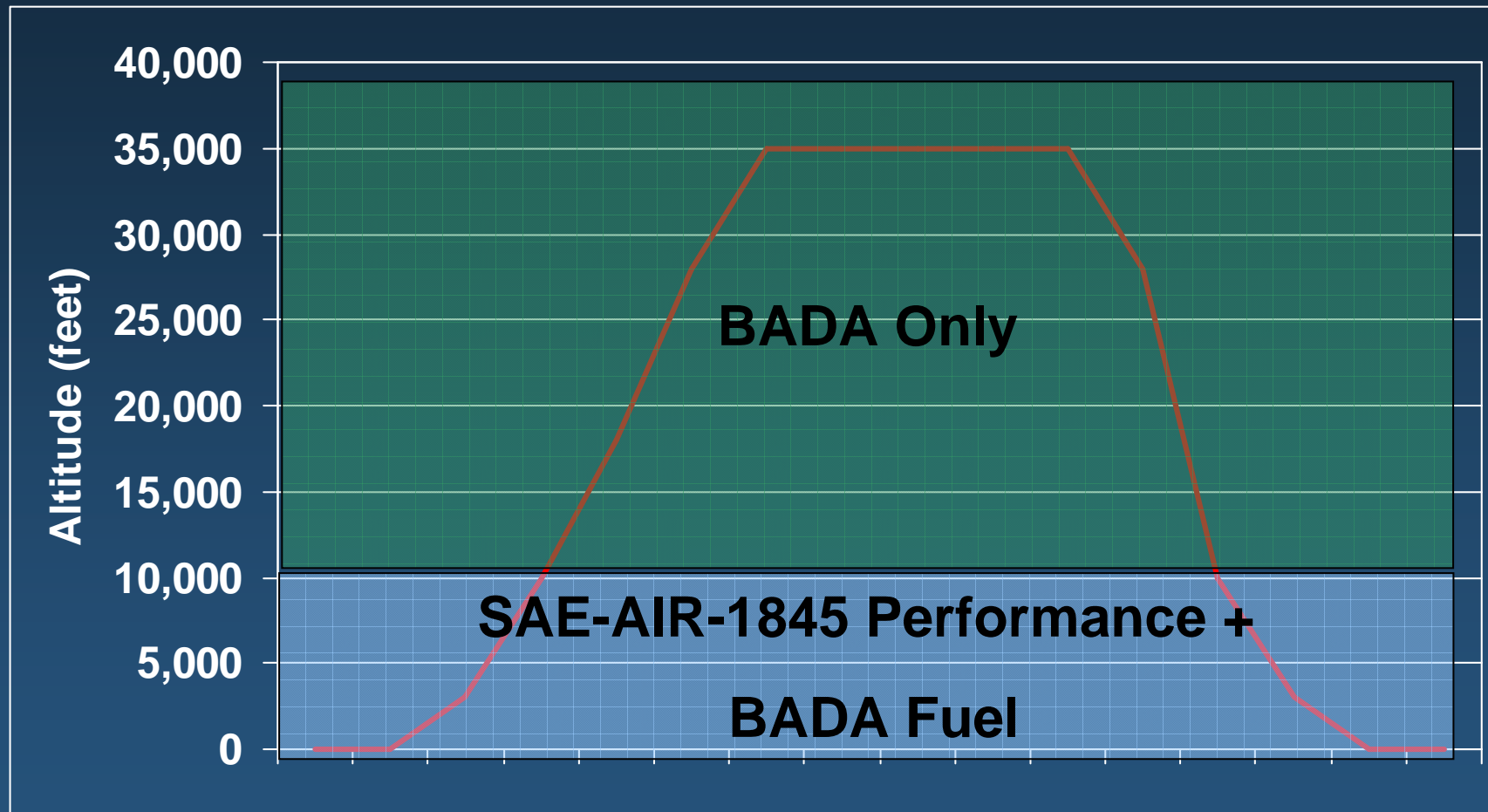
# Aircraft Operations (concl.)

- ◆ 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<sub>2</sub> and H<sub>2</sub>O 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
<b>Total</b>	<b>26,316,473</b>	<b>28,347,056</b>	<b>30,397,705</b>	<b>34,492,280</b>	<b>38,630,984</b>	<b>42,890,718</b>

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
<b><i>LTO Cycle: Below 3,000 feet (914.4m) AFE</i></b>						
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
<b>Total</b>	<b>157,750</b>	<b>176,201</b>	<b>194,839</b>	<b>234,695</b>	<b>279,364</b>	<b>328,933</b>
<b><i>Terminal Area: Below 10,000 feet (3048m) AFE</i></b>						
20 – 99	27,009	32,971	39,519	53,044	67,683	84,659
100 – 210	151,244	164,814	178,677	207,721	235,619	256,061
211 – 650	95,275	108,094	120,573	148,478	184,845	234,966
<b>Total</b>	<b>273,528</b>	<b>305,879</b>	<b>338,783</b>	<b>409,243</b>	<b>488,148</b>	<b>575,687</b>
<b><i>Entire Flight</i></b>						
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
<b>Total</b>	<b>1,885,221</b>	<b>2,082,258</b>	<b>2,294,201</b>	<b>2,741,357</b>	<b>3,208,978</b>	<b>3,649,713</b>

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	
	Policy decisions warrant investigation of NOx per passenger-mile or other normalization techniques						
20 – 99						1%	
100 – 210						4%	
211 – 650						4%	
<b>Total</b>						<b>9%</b>	
	However, this is only a demonstration of modeling capabilities, not a complete policy analysis						
20 – 99						2%	
100 – 210						7%	
211 – 650	5%	5%	5%	5%	6%	6%	
<b>Total</b>	<b>211 – 650 seat class dominant over entire flight</b>						<b>16%</b>
	<i>Entire Flight</i>						
20 – 99	4%	4%	5%	5%	5%	6%	
100 – 210	41%	40%	39%	38%	36%	35%	
211 – 650	55%	56%	56%	57%	58%	60%	
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	

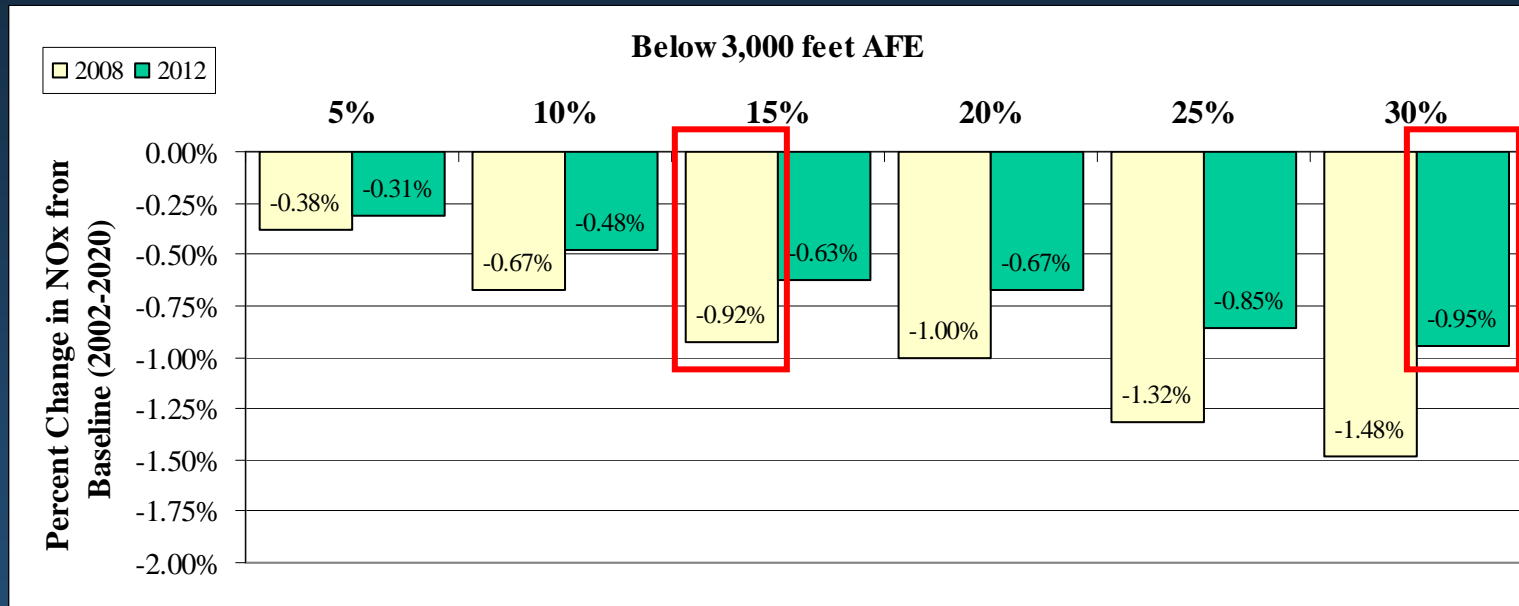
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# Sample Results:

Effects of stringency implementation ranked by amount of total NOx reduction

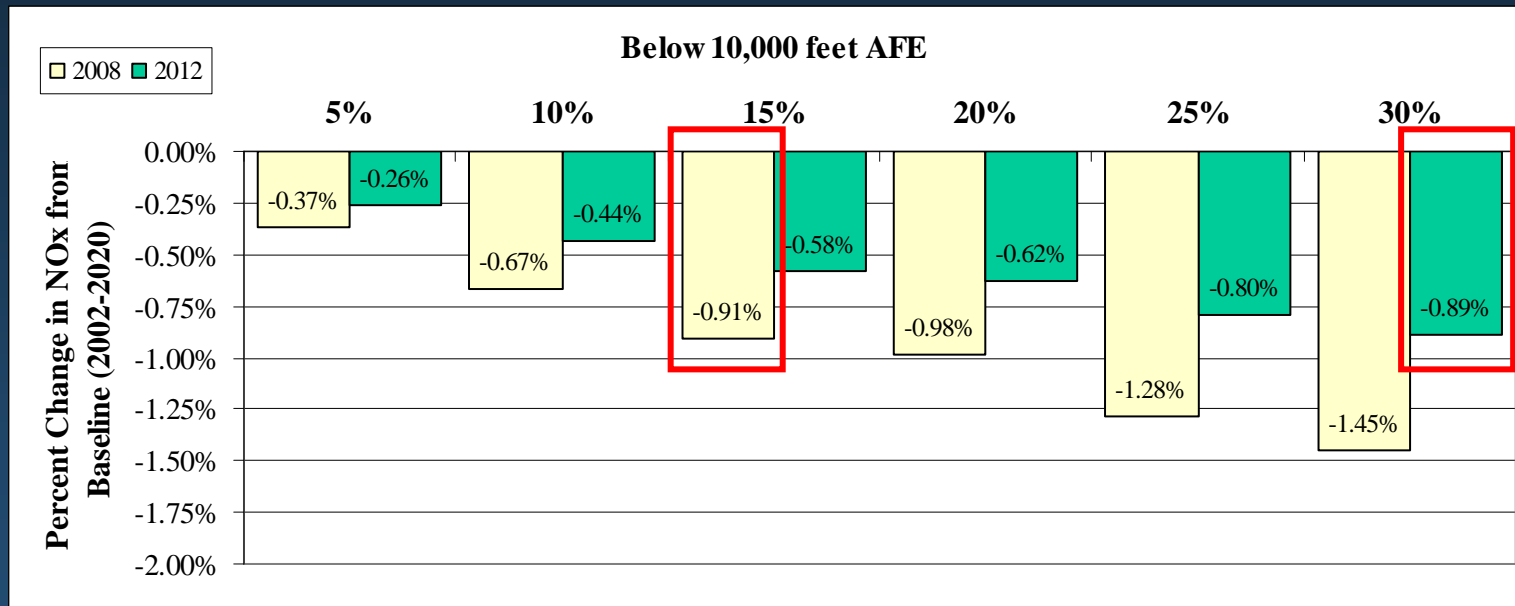
	<b>Below 3,000 Feet AFE</b>	<b>Below 10,000 Feet AFE</b>	<b>Entire Flight</b>
<b>Rank</b>	<b>Stringency</b>	<b>Stringency</b>	<b>Stringency</b>
Highest	-30% in 2008	-30% in 2008	-30% in 2008
2 <sup>nd</sup>	-25% in 2008	-25% in 2008	-25% in 2008
3 <sup>rd</sup>	-20% in 2008	-20% in 2008	-20% in 2008
4 <sup>th</sup>	-30% in 2012	<b>-15% in 2008</b>	<b>-15% in 2008</b>
5 <sup>th</sup>	-15% in 2008	<b>-30% in 2012</b>	<b>-30% in 2012</b>
6 <sup>th</sup>	-25% in 2012	-25% in 2012	-25% in 2012
7 <sup>th</sup>	-20% in 2012	<b>-10% in 2008</b>	<b>-10% in 2008</b>
8 <sup>th</sup>	-10% in 2008	<b>-20% in 2012</b>	<b>-20% in 2012</b>
9 <sup>th</sup>	-15% in 2012	-15% in 2012	-15% in 2012
10 <sup>th</sup>	-10% in 2012	-10% in 2012	-10% in 2012
11 <sup>th</sup>	-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



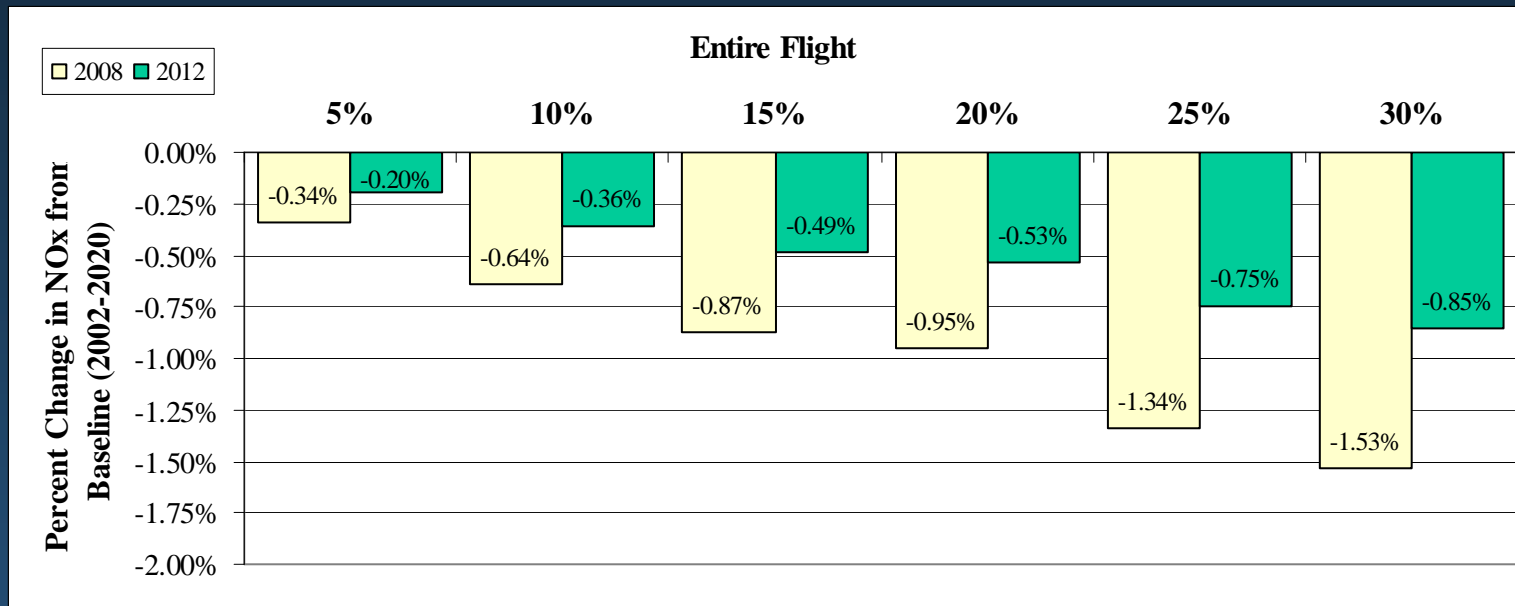
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# Sample Results: Cumulative change in NOx 2002-2020



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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.

# Context for AEDT

- ◆ NO<sub>x</sub> 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 NO<sub>x</sub> Prototype
  - ❖ EDMS 5.0 used for the demonstration
  - ❖ INM 7 includes harmonized system tables

# Conclusions

- ◆ The NO<sub>x</sub> 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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