Fuel consumption modeling in support of ATM environmental decision-making

paper #48

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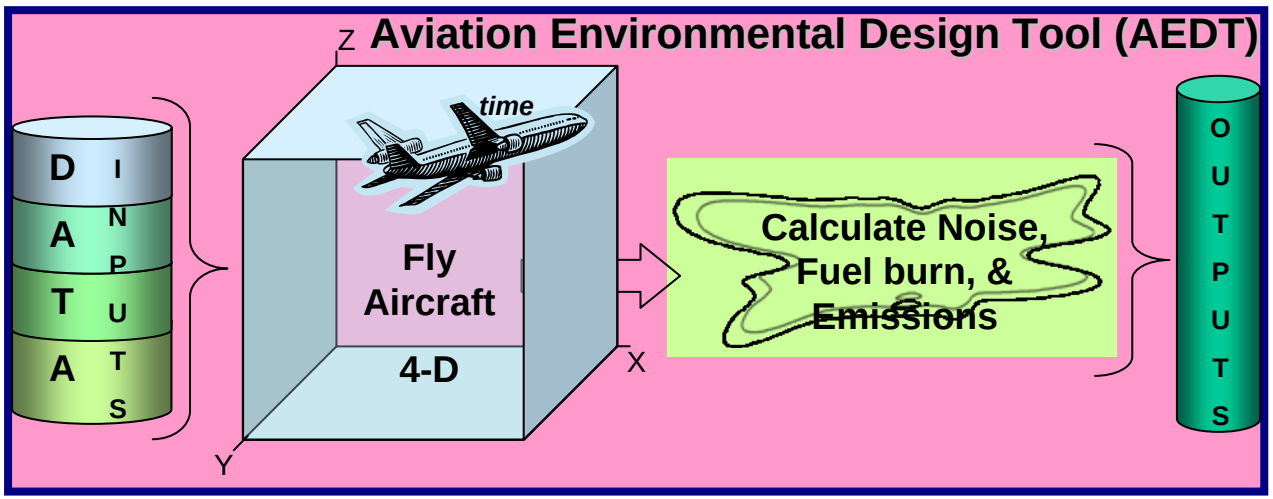
Federal Aviation Administration

Motivation: FAA fuel consumption modeling

- FAA's Office of Environment & Energy is developing AEDT
  - **Dynamically models aircraft in 4 dimensional space & time**
  - **Scalable from single flight → global analyses**
  - **Singular environmental policy and regulatory tool**
  - **Will handle inputs from radar and/or simulation tools**
  - **Capable of analyzing interdependencies of noise and emissions**
  - ***Aircraft performance and fuel burn calculations are critical to quantify environmental consequence***

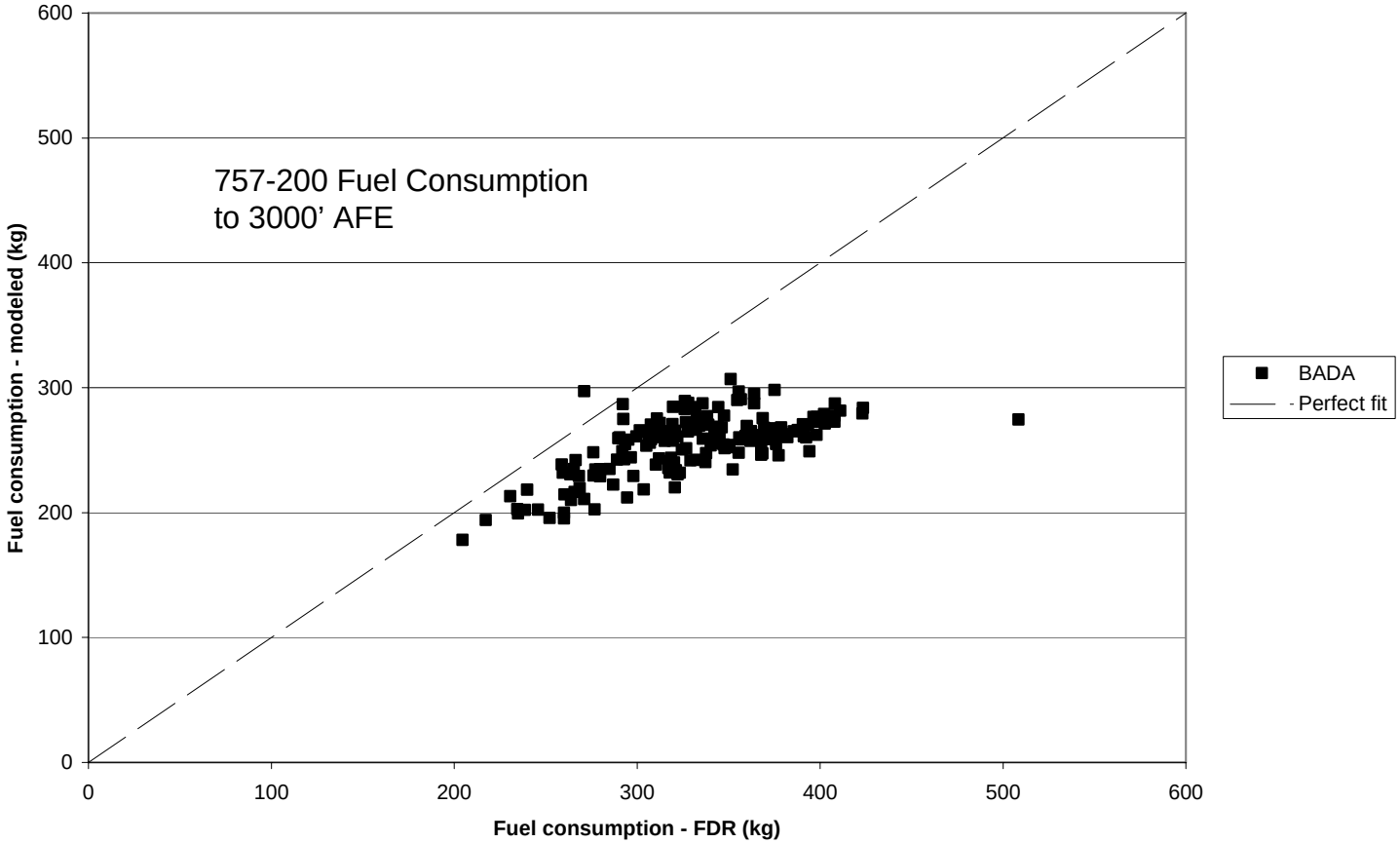


Background: FAA fuel consumption modeling

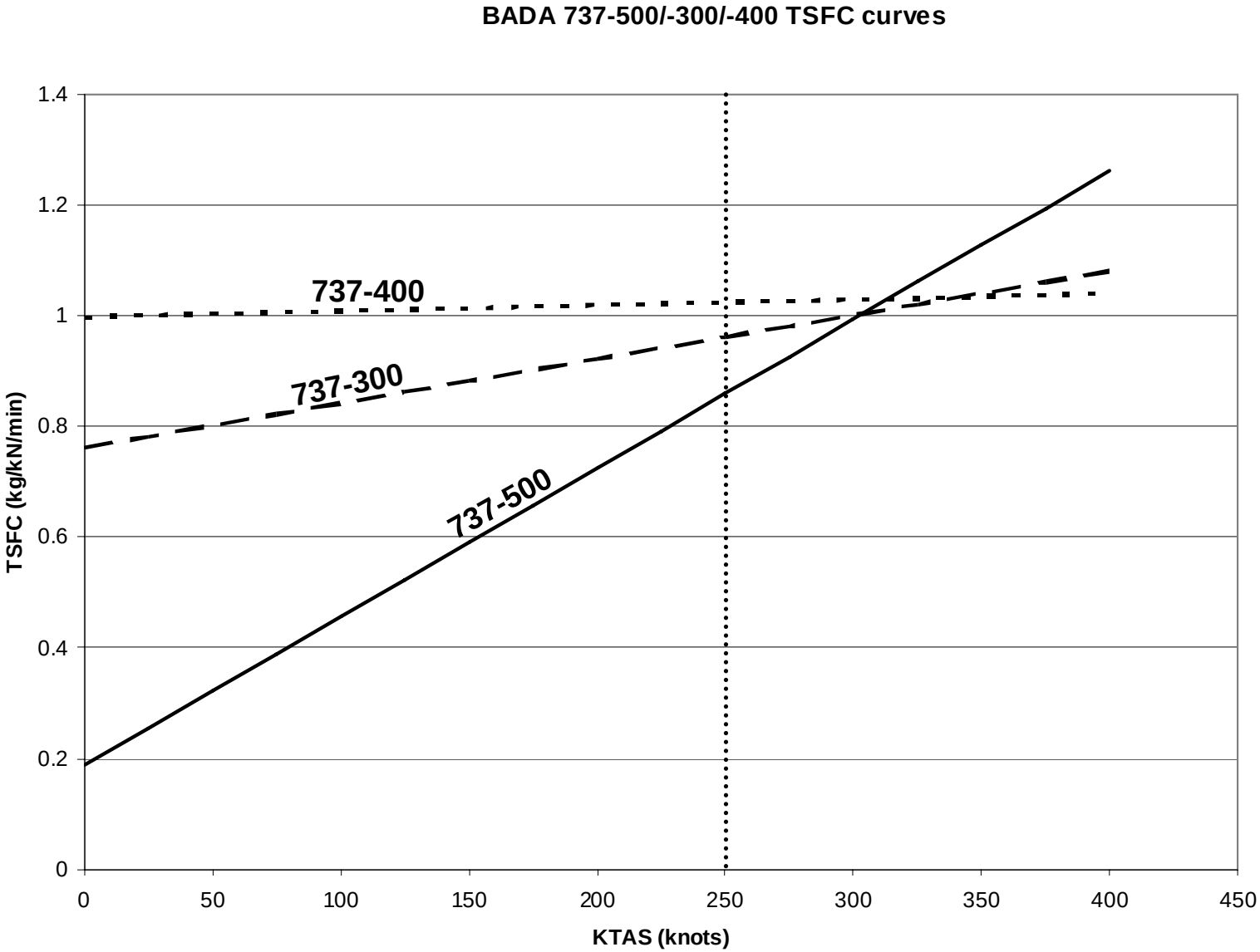
- Historically, we have used a combination of SAE-AIR-1845 thrust and EUROCONTROL's Base of Aircraft Data (BADA) Thrust Specific Fuel Consumption (TSFC) to predict fuel burn in the terminal area
- BADA is intended as an enroute Air Traffic Management tool

Example of fuel consumption under-prediction

- Flight Data Recorder (FDR) analyses showed that the **SAE/BADA method** did not accurately model terminal area fuel burn for some aircraft
- Incorrect fuel consumption leads to incorrect emission calculations and potentially ill-informed policy decisions



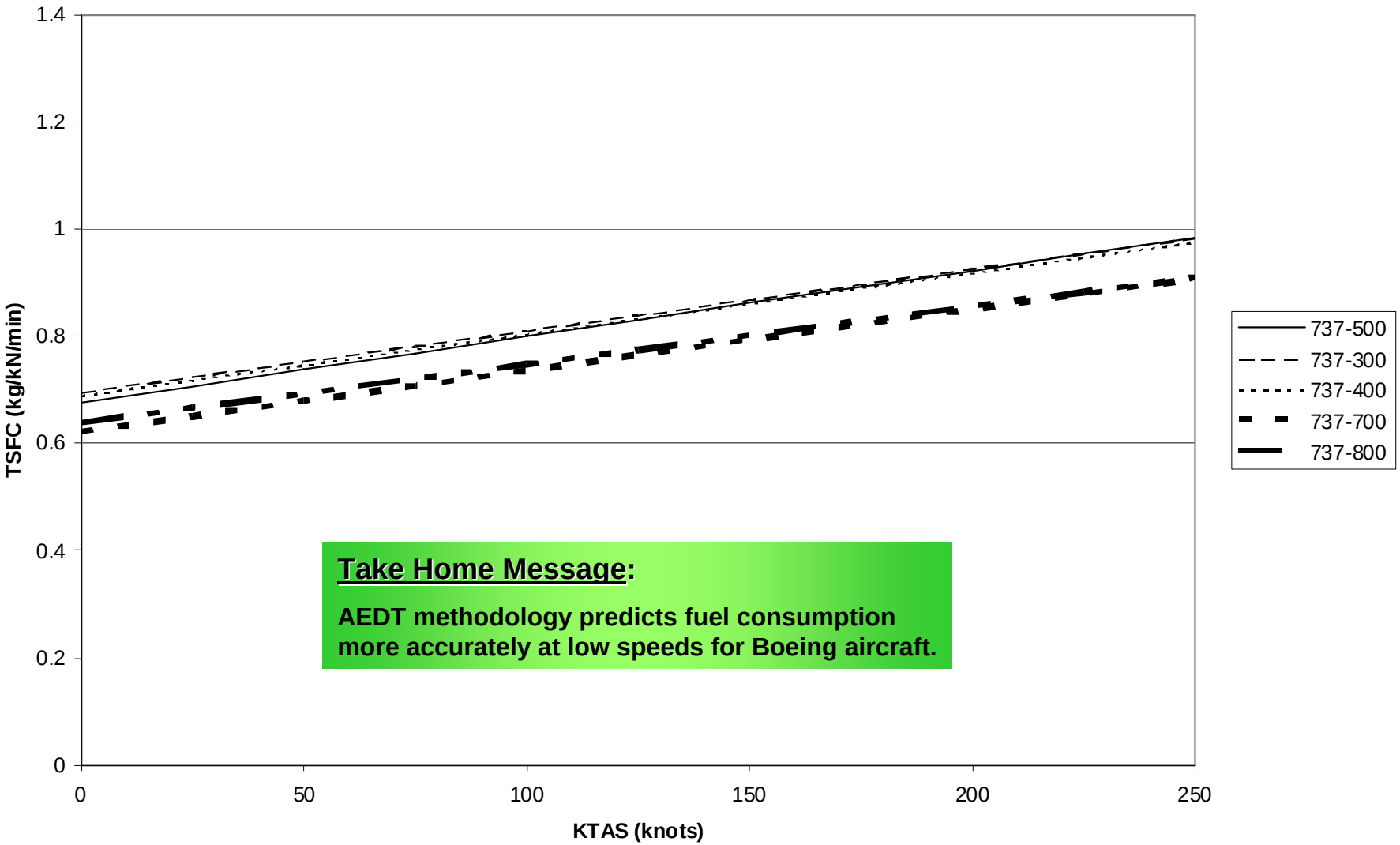
Example of why BADA has trouble at low speeds



AEDT Fuel Burn Modeling Improvement

- In agreement with Boeing – FAA obtained the Boeing Climb-Out Program (BCOP) software
  - BCOP yields improved low speed performance and fuel burn predictions
- Results: More accurate empirical models for arrivals and departures.

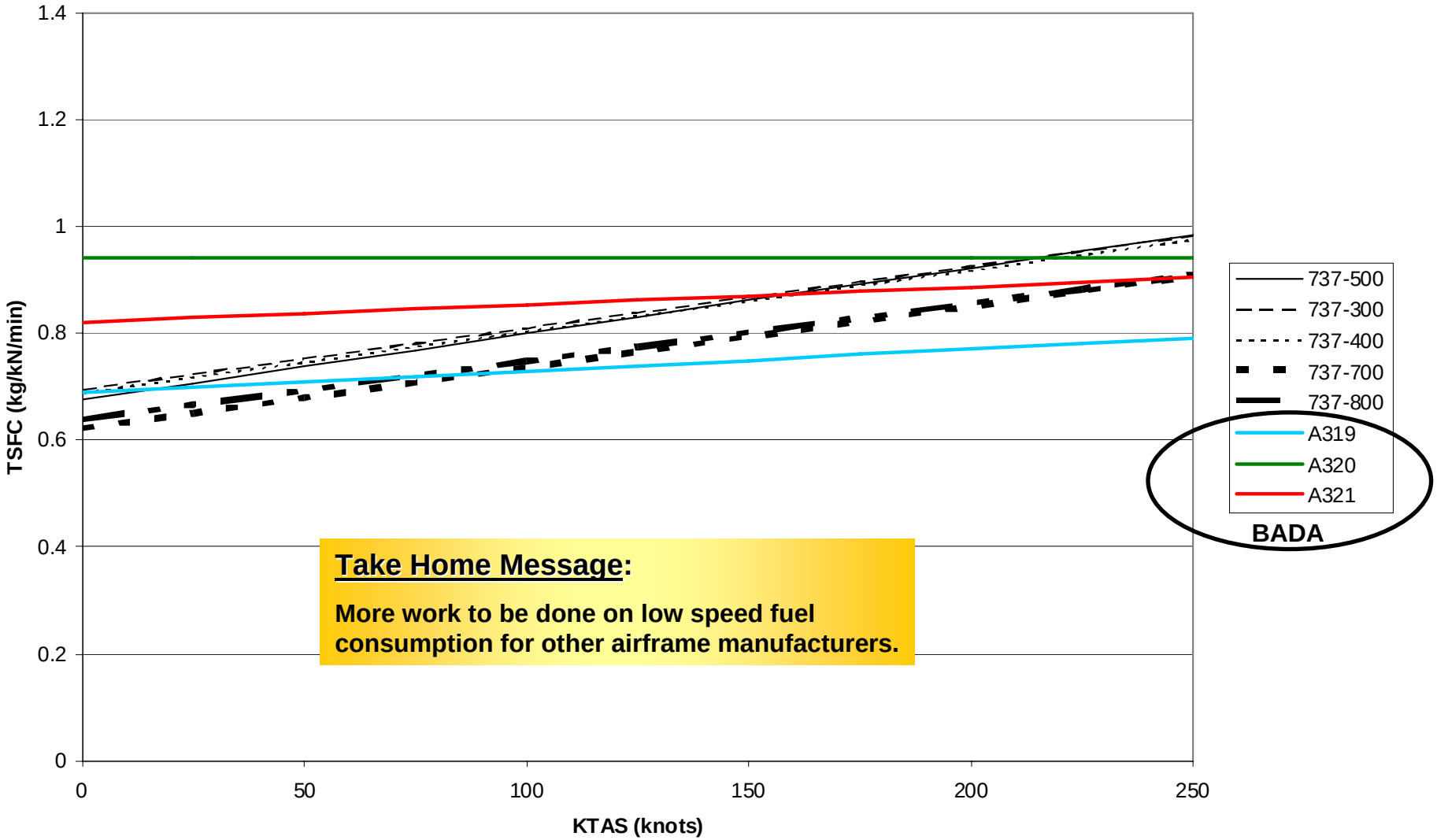
New AEDT Fuel Burn Methodology – 737 family



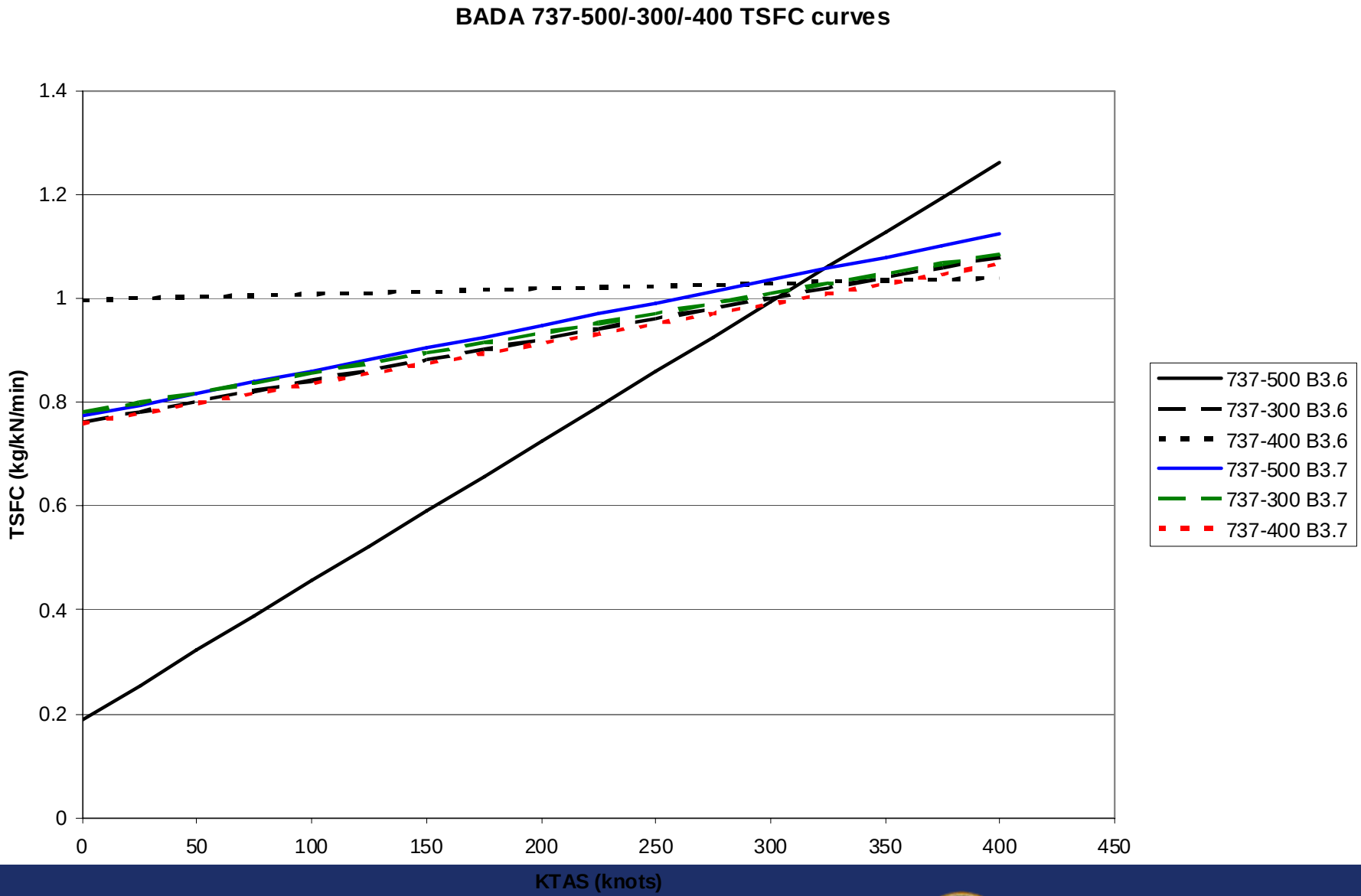
Take Home Message:

AEDT methodology predicts fuel consumption more accurately at low speeds for Boeing aircraft.

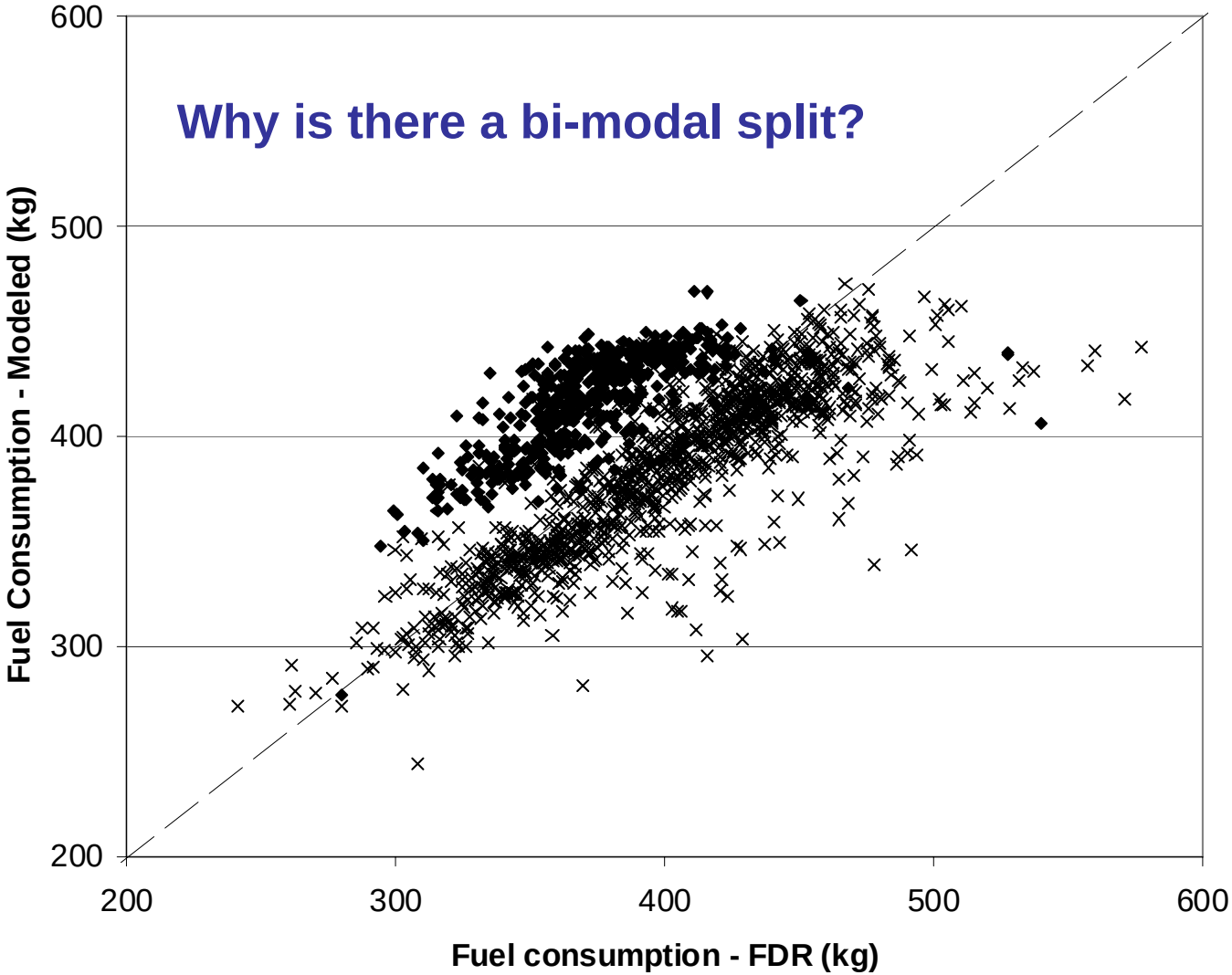
BADA A320 family vs. AEDT 737 family



BADA 3.7 may be a significant improvement at low speeds



How well does our tool work? Another B757 example…



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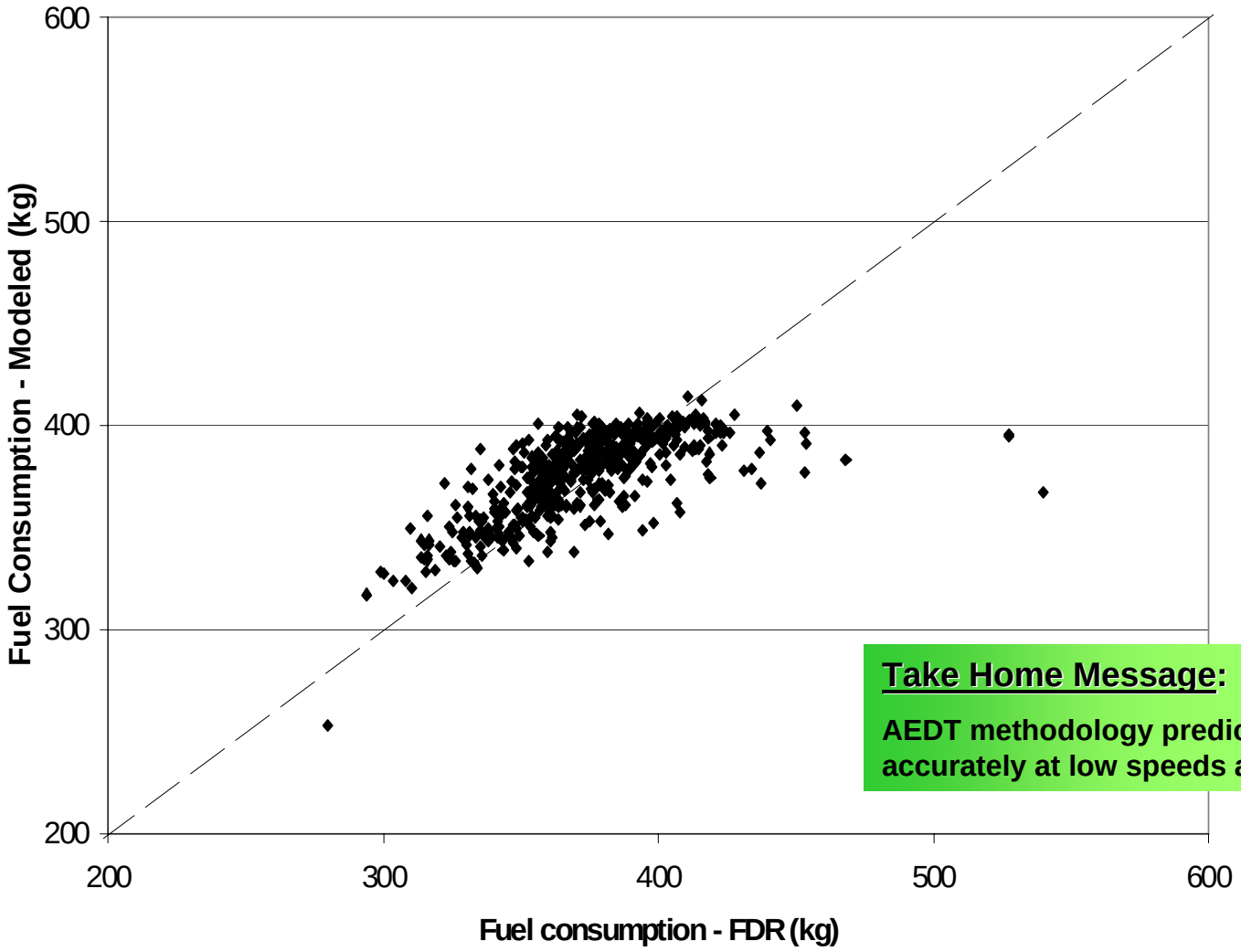


Take Home Message:

AEDT methodology predicts fuel consumption accurately at low speeds and proper flap settings.

Tailored Arrival Demo – Sept 2008, Miami Int'l Airport

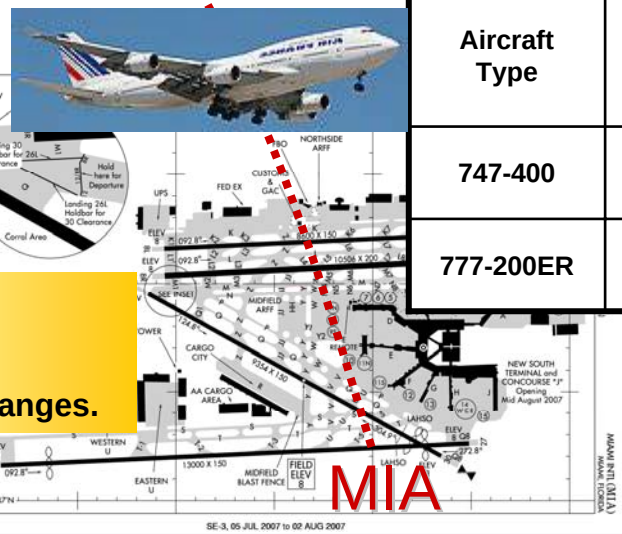
"Modeled versus Measured"

Tailored Arrival Flight	Fuel Burn FDR (kg)	Fuel Burn AEDT (kg)	Difference (kg)	Difference (%)
1	3112	2942	-170	-5.5%
2	3278	3367	+89	+2.7%
3	3029	3063	+34	+1.1%

AIRE
Atlantic Interoperability Initiative to Reduce Emissions

"Modeled Operational Differences"

Aircraft Type	Standard Arrival (kg)	Tailored Arrival (kg)	Difference (kg)	Difference (%)
747-400	4080	3930	-150	-3.7%
777-200ER	3141	3003	-138	-4.4%



Take Home Message:

The model can capture small differences due to operations changes.

Summary

- The FAA's Office of Environment and Energy has a process in place to generate airplane fuel burn data from manufacturers' performance tools
- Fuel consumption data from these airplane performance tools-derived methods match the FDR fuel consumption data in the terminal area within 5%
- We have added the new fuel burn data for the current generation of Boeing airplanes into new environmental models – AEDT
- These improved tools enable improved studies which involve trades between noise, emissions, and fuel burn

Next Steps

- Expand the new terminal fuel burn methods to other manufacturers – Airbus, Bombardier, etc.
- Examine how to model fuel consumption of turboprop aircraft
- Test limits of new method

Comments and Questions…

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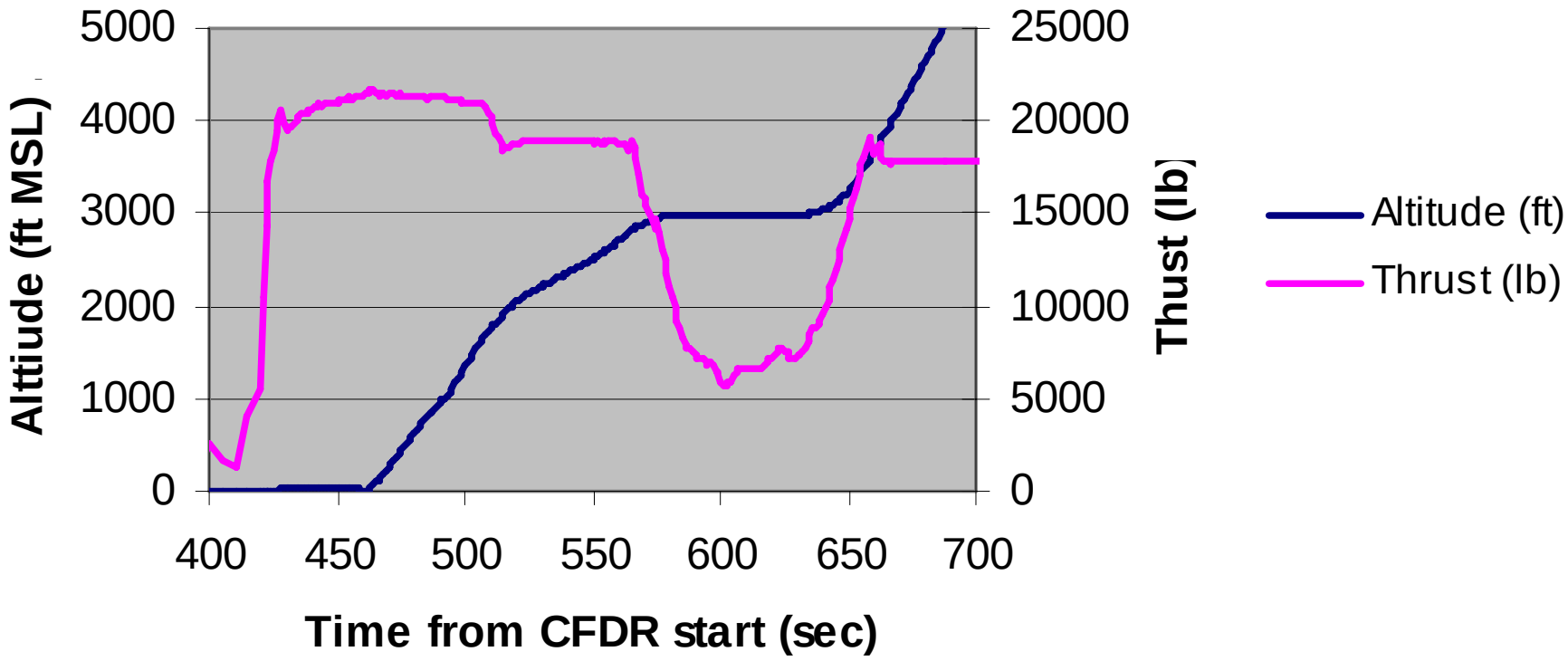
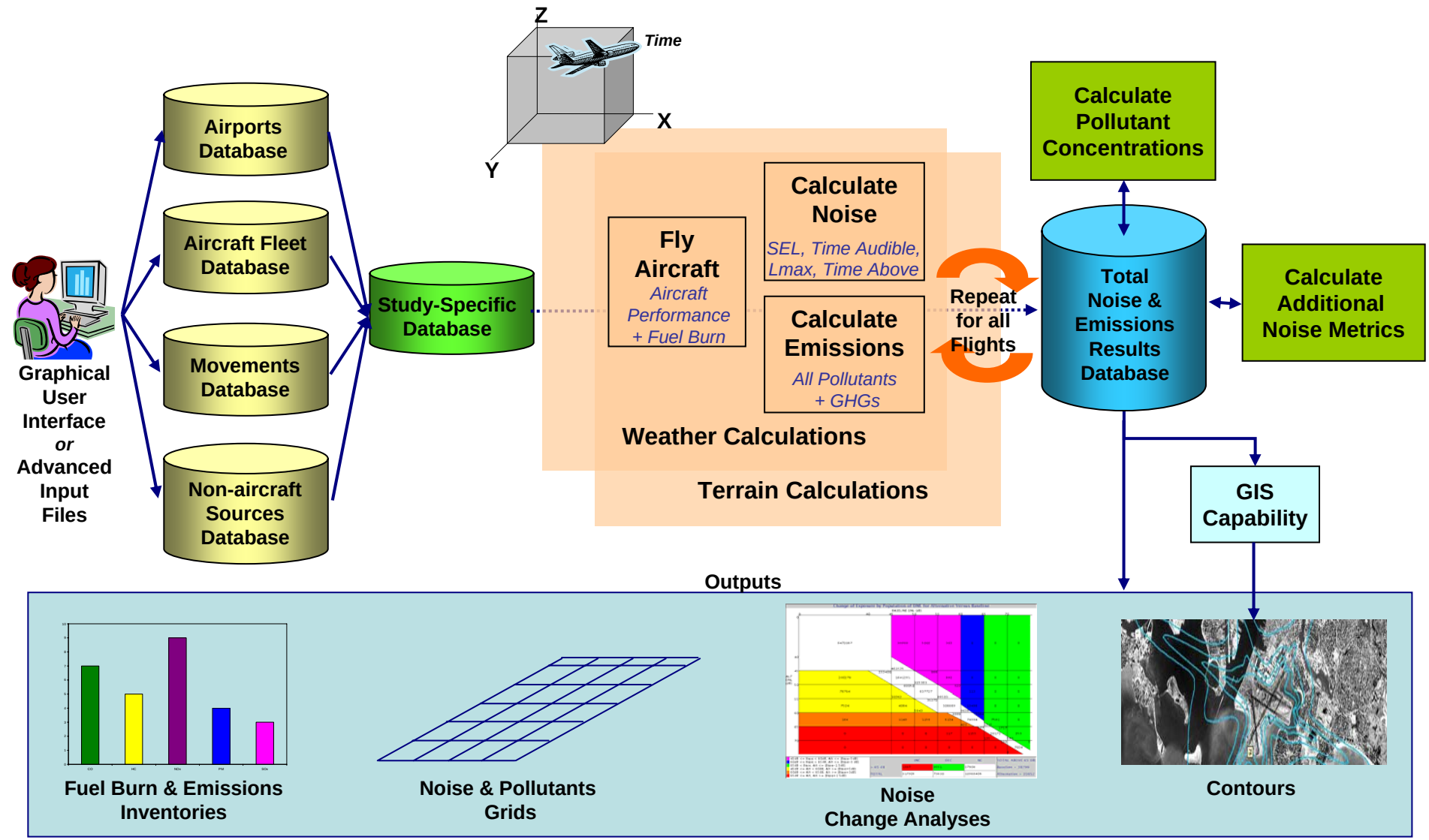
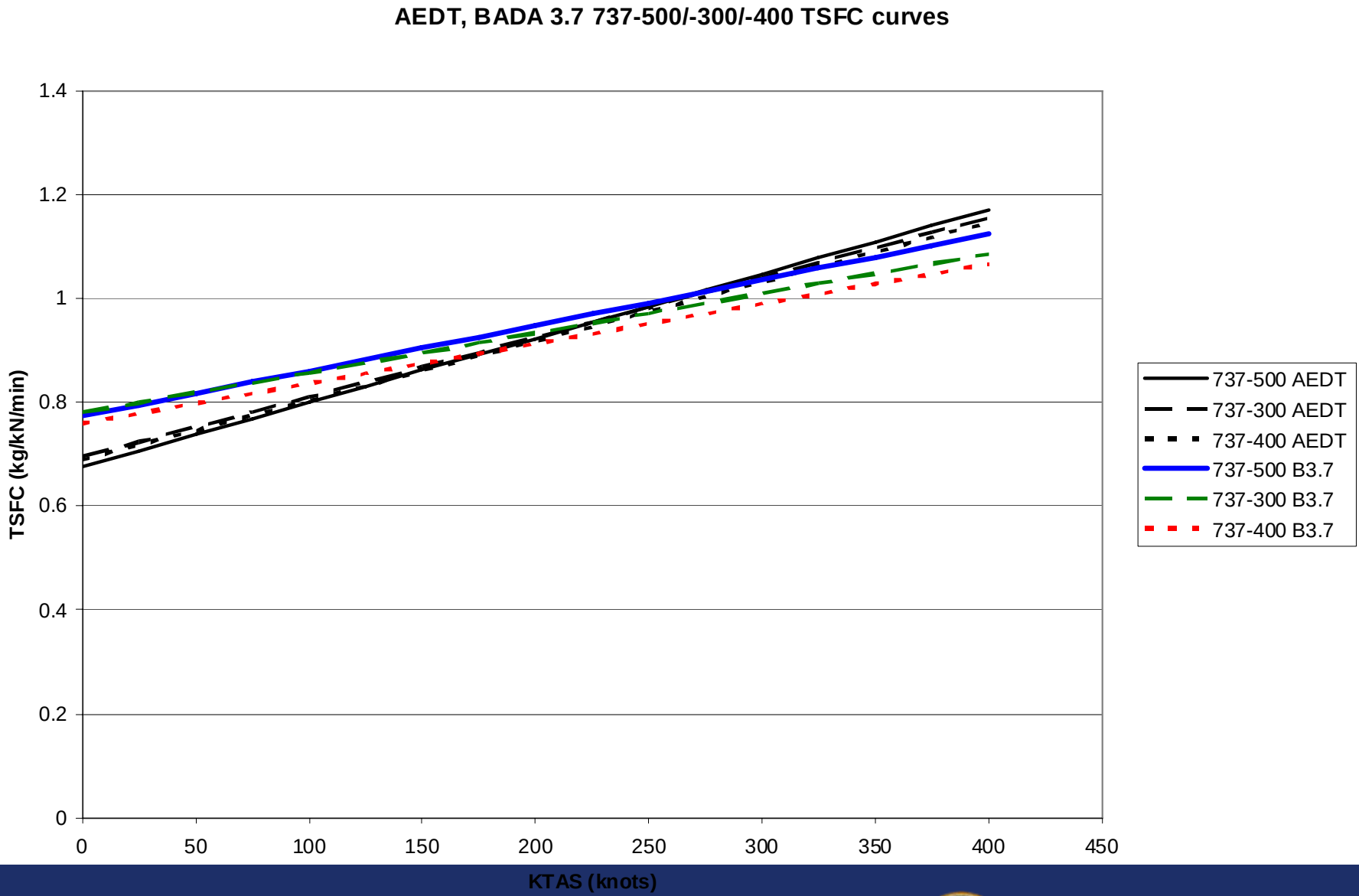
Back-up slides


Flight 119033, example of ATC hold
Altitude (ft MSL)
5000
4000
3000
2000
1000
0
25000
20000
15000
10000
5000
0
Thust (lb)
400
450
500
550
600
650
700
Time from CFDR start (sec)
Altitude (ft)
Thrust (lb)

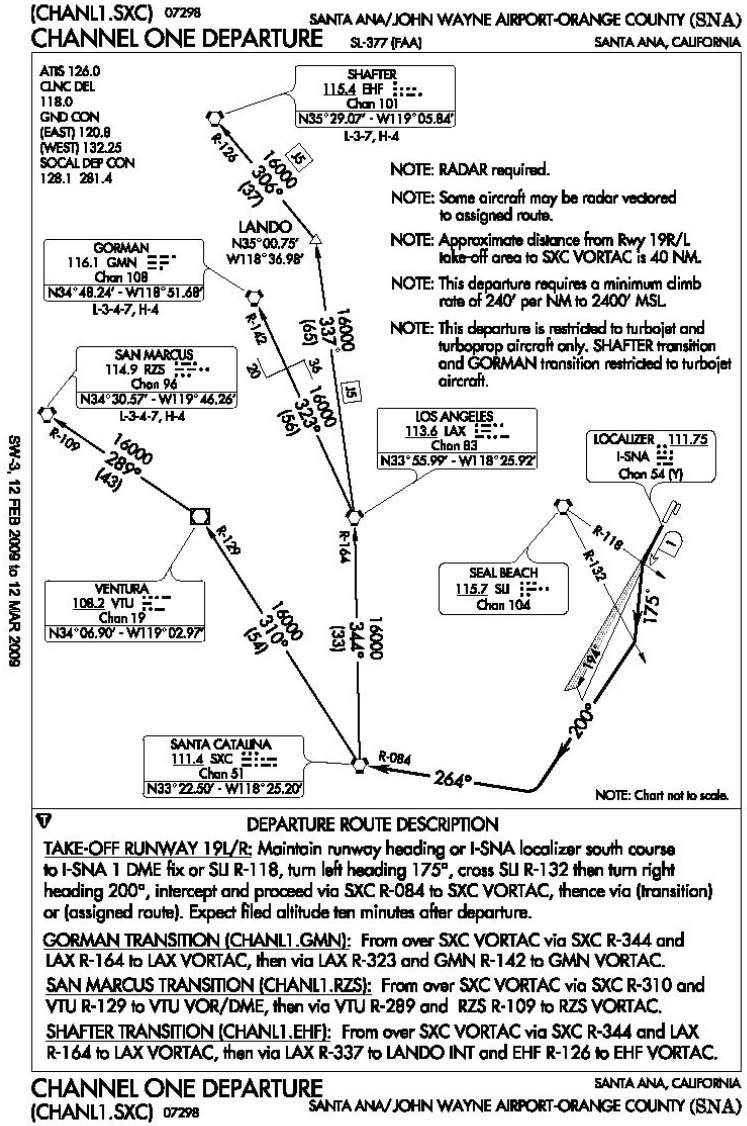
AEDT Overview



BADA 3.7 and AEDT differences are much less



Modeling single operations – SNA Example



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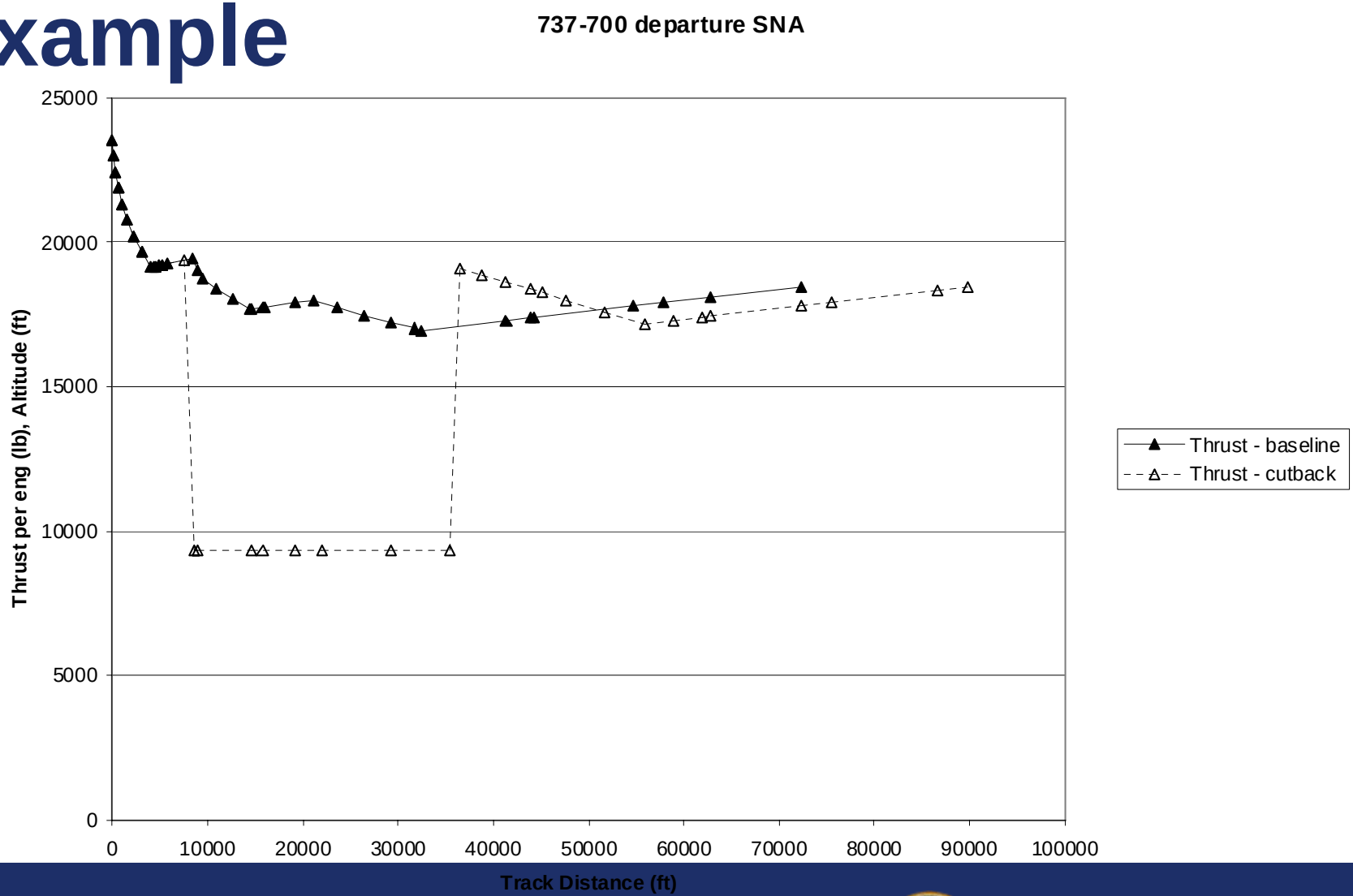
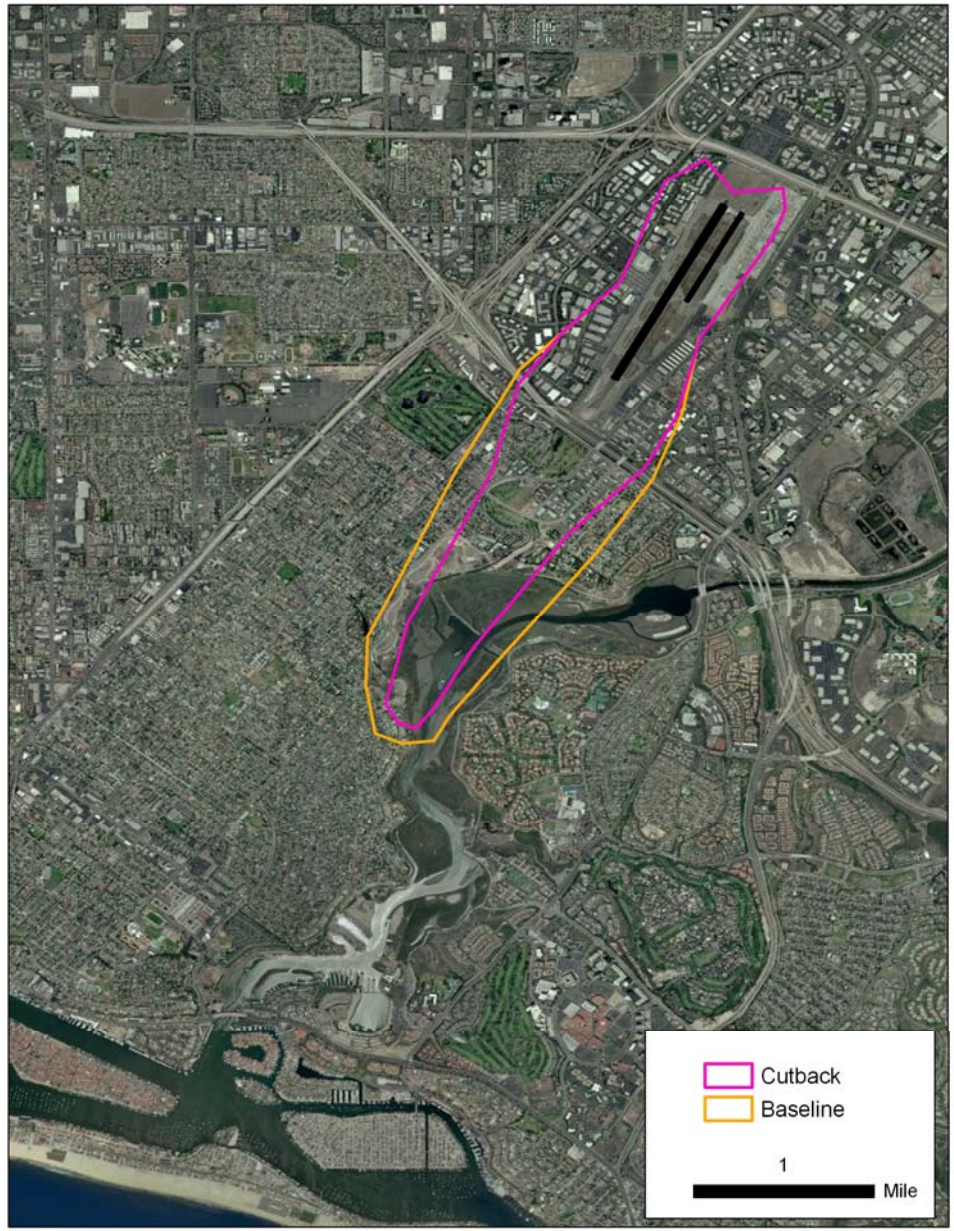


Modeling single operations – SNA Example, 85 dB SEL noise contour



Modeling single operations – SNA Example

- **Tabular comparison of noise, fuel and emissions for**

altitude	op type	Distance (ft)	Fuel (kg)	CO2 (kg)	CO (kg)	NOx (kg)
3000'	Baseline	21050	244.4	771.2	0.129	5.8
	Cutback	35500	283.3	893.9	0.192	5.6
10000'	Baseline	72272	475.6	1501	0.261	11.4
	Cutback	89870	544.6	1718	0.341	11.9