PARTNER

**Partnership for AiR Transportation Noise and Emission Reduction**

*An FAA/NASA/TC-sponsored Center of Excellence*

# Environmental Design Space


**Dr. Dimitri Mavris**

**Boeing Professor of Advanced Aerospace Systems Analysis**

**Georgia Institute of Technology**



**Aircraft Noise and Emissions Reduction Symposium**

**June 25-27, 2007**

**La Baule - France**

# EDS Development Team

**Partnership for AiR Transportation Noise and Emissions Reduction**

***An FAA/NASA/TC-sponsored Center of Excellence***

This work was funded by the FAA under Grant Nos:
05-C-NE-GIT, Amendment Nos. 001 and 003
03-C-NE-MIT, Amendment Nos. 011, 015, 018, 022, and 025

The Environmental Design Space project is managed by Joseph DiPardo

# Outline

- Genesis of EDS
- EDS functionality in context
- Potential Stakeholder requirements
- Meeting Stakeholder expectations
- Initial EDS capability demonstrator
- Next steps
- Summary

# Genesis of EDS*

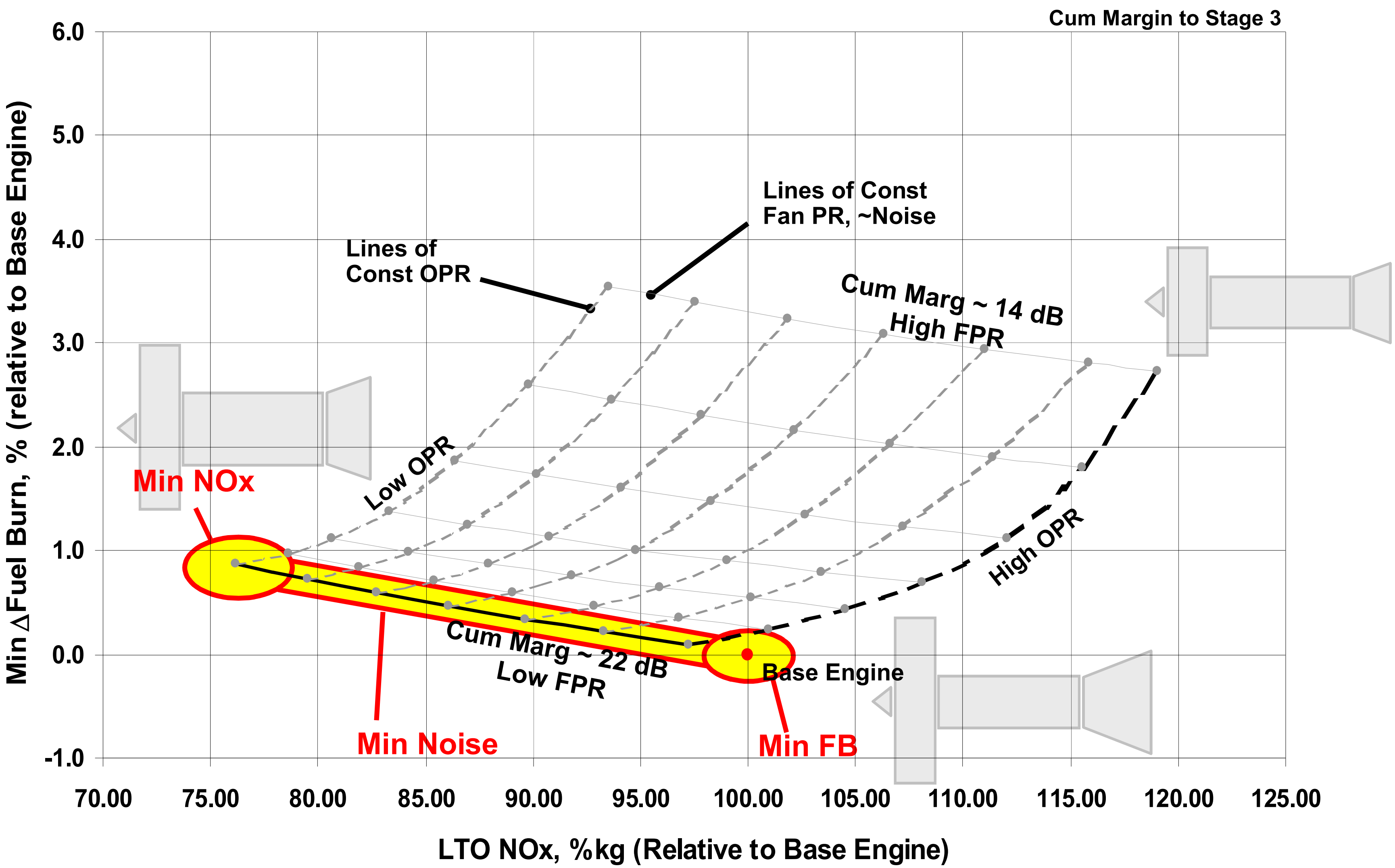
- Study initiated by Air Transport Association (Airlines) and Aerospace Industries Association (Manufacturers)
  - To support environmental regulatory discussions
  - Provide guidance for certification standards process
- Define an "Environmental Design Space" that:
  - quantifies Engine/Airplane design trade-offs in a manner that is technically feasible

    … in terms of Performance, Noise, Emissions ….
- Defines an Environmental Engine / Airplane System based on current and future technology sets
- Questions:
  - What does an "Environmental Design Space (EDS)" look like for current and future aircraft/engine systems?
  - What are the tradeoffs in terms of performance, noise, and emissions for technically feasible aircraft/engine systems?

Sources include:

- 2003: "*Environmental Tradeoffs in Commercial Aircraft Design: AIA EDS Feasibility Test and Lessons Learned*" Dave Halstead, GEAE
- "Workshop #1 FAA Aviation Environmental Design Tool," Transportation Research Board, March 31-April 2, 2004

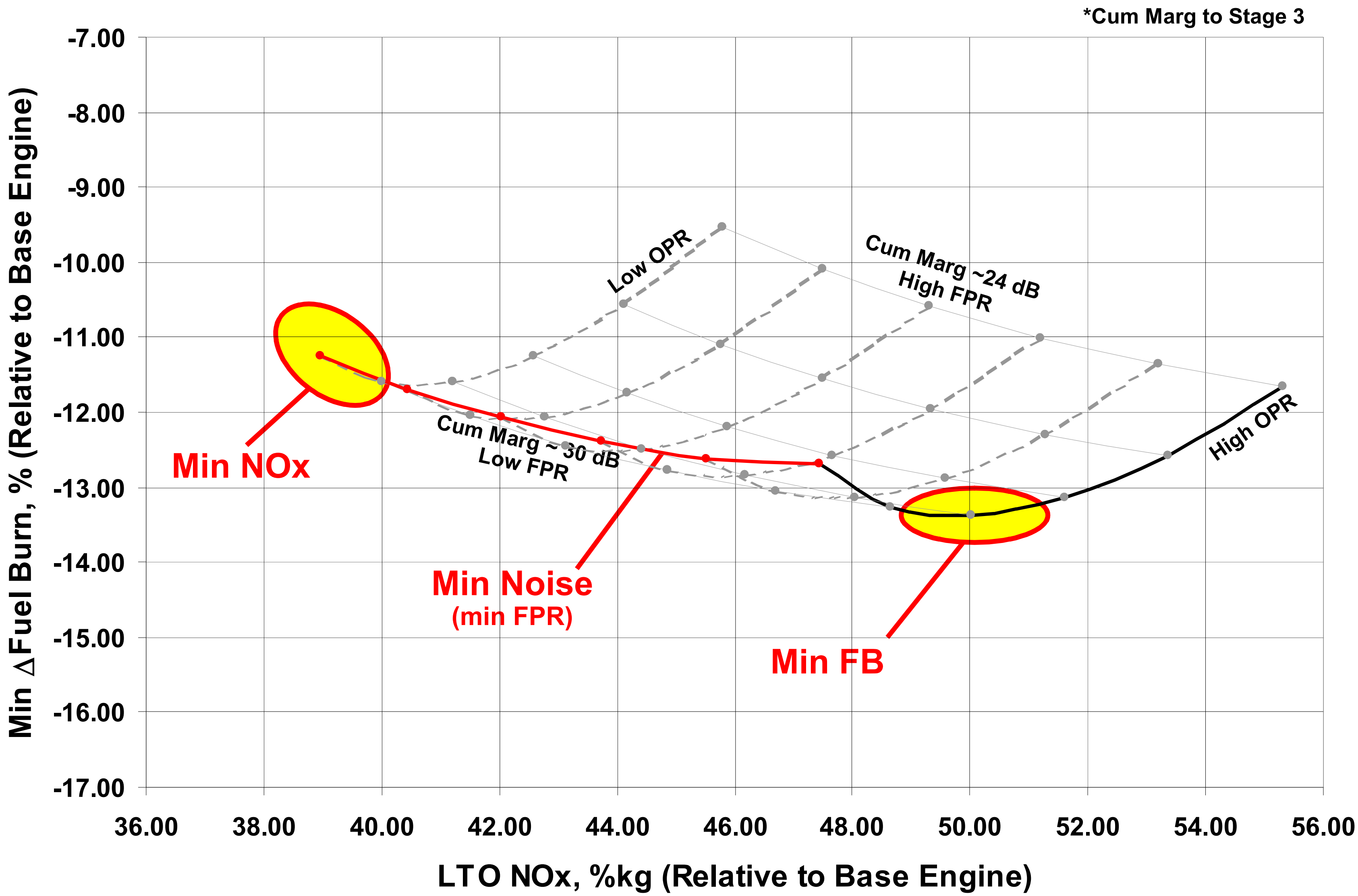
# FB/NOx/Noise Carpet Plot - Certified Product




*"Environmental Tradeoffs in Commercial Aircraft Design; AIA EDS Feasibility Test and Lessons Learned"*
*Dave Halstead, GE Aircraft Engines, January 12, 2004*

# FB/NOx/Noise Carpet Plot - 2010 Product

PARTNER




*"Environmental Tradeoffs in Commercial Aircraft Design; AIA EDS Feasibility Test and Lessons Learned"*
*Dave Halstead, GE Aircraft Engines, January 12, 2004*

# Summary and Lessons Learned*

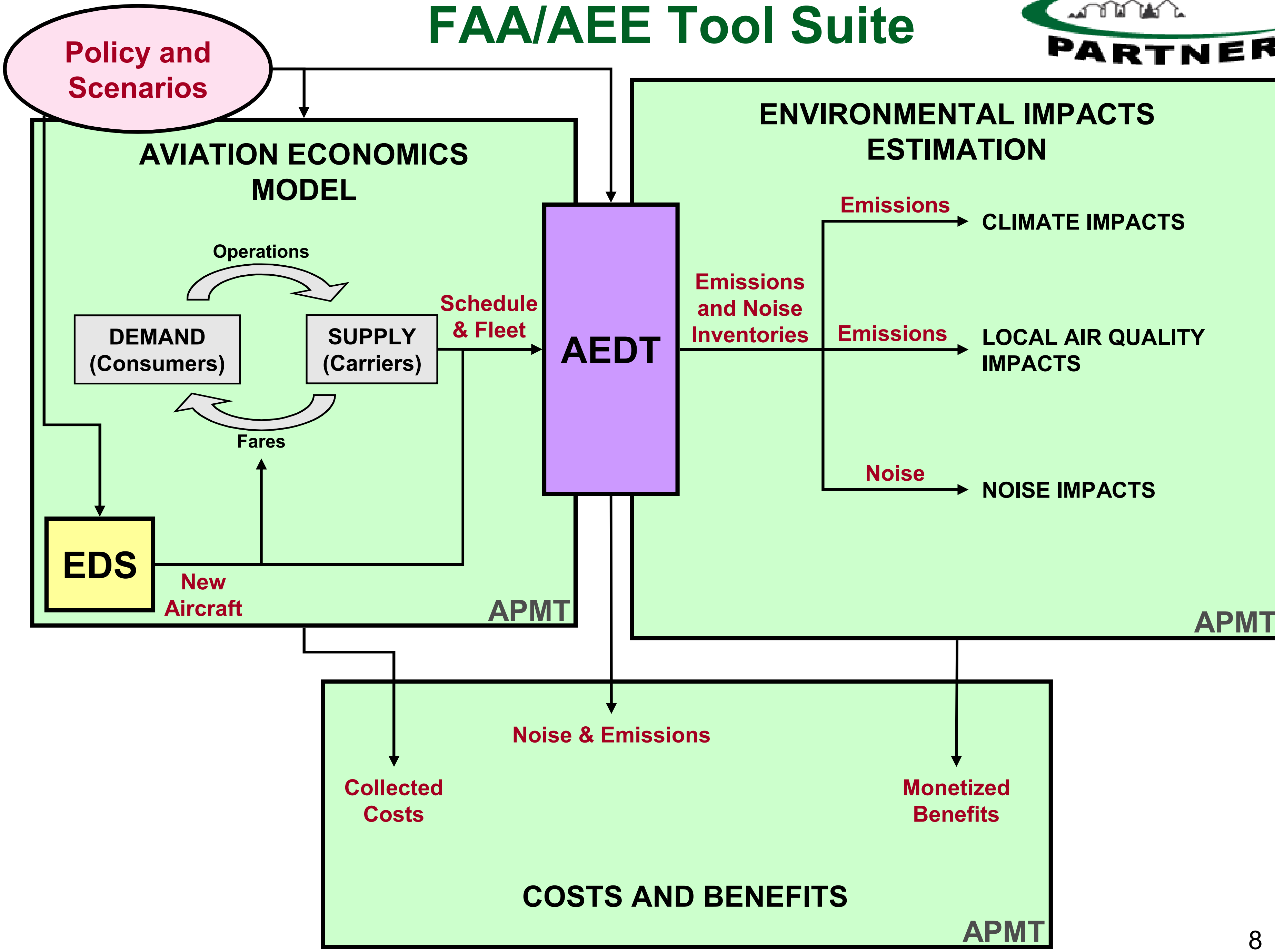
PARTNER

- Quantifying environmental impact is a complex, multi-disciplinary, systems-based problem
- **Significant environmental trades do occur…**
  - Best Noise solution is **not** best NOx solution is **not** best $CO_2$ (i.e., fuel burn) solution
- **An integrated approach is key to attaining balanced environmental regulatory strategy**
  - Noise vs. CO2 vs. NOx (and other emissions)
  - Local vs. national vs. global impact
  - Implications to costs and benefits to achieve a balanced solution

**The FAA took the initiative to pursue the development of a tool set to address these needs**

* Source: 2003: "*Environmental Tradeoffs in Commercial Aircraft Design: AIA EDS Feasibility Test and Lessons Learned*" Dave Halstead, GEAE

# FAA/AEE Tool Suite



# What must EDS be able to do?

- Be capable of analyzing environmental and performance effects of:
  - New Technologies
  - New Aircraft both replacement and new system types
- Methods and assumptions must be **non-proprietary** and data generated must be accessible to the international community to **increase transparency**
- Enable the exploration of **trade-offs and interdependencies** amongst and between technology, economics and environmental impacts at the aircraft level
- Sufficient flexibility to be employed in a **parametric mode** to explore potential variations within an aircraft class
- Serve as a mechanism for collecting, incorporating and quantifying **long-term technology impact assessments**. This will be an inherently **expert-driven** process drawing on industry advice
- Inputs, outputs and execution times must be compatible with **AEDT and APMT needs**

# Meeting Stakeholders Needs

- Functionality of EDS must be accessible to both U.S. and international partners
- EDS results must be open to the community and based on **public domain information**
  - No proprietary data or assumptions
  - No empirical corrections of trends
- To ensure the results from EDS are satisfying the customer base at an acceptable level of accuracy a two prong approach was pursed:
  - Assessment of EDS capabilities
  - Industry collaboration

# Assessment Plan Focus

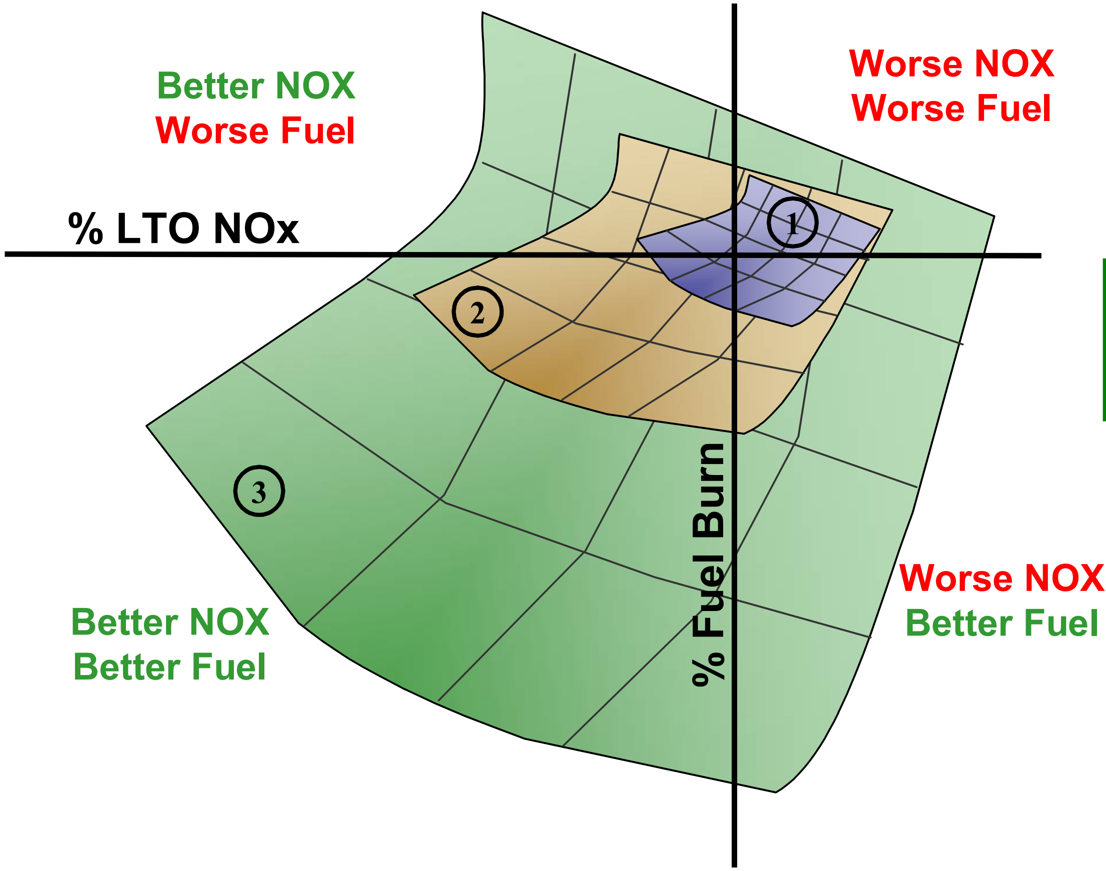
- Assessment is critical for ensuring that the final EDS results are reasonable
- Achieving international confidence of EDS relies on a thorough documented assessment of the tools, architecture, assumptions
- To address *“How accurate is accurate?”*, we must:
  - Define what assessment metrics are appropriate for EDS
  - Determine uncertainties associated with EDS tools
  - Determine the appropriate level of fidelity
  - Identify process to engage broader community in assessment efforts
  - Identify appropriate process to communicate assessment outcomes to the broader community

**Engage industry through collaborative assessments to address these objectives**

# Industry Collaboration Focus

- Participate in collaborative assessment projects in which EDS-derived results will be compared to those obtained by industry collaborators who will use proprietary analysis tools
- Current interactions with industry:
  - General Electric
  - Pratt & Whitney
  - Boeing
- Key objectives:
  - Define appropriate design rules for different engine/airframe combinations
  - Validating trade-spaces and trends of NOx vs. Noise vs. $CO_2$
- An **Industry Review Group** was been formed that interacts with EDS to vet trade spaces for applicability to CAEP

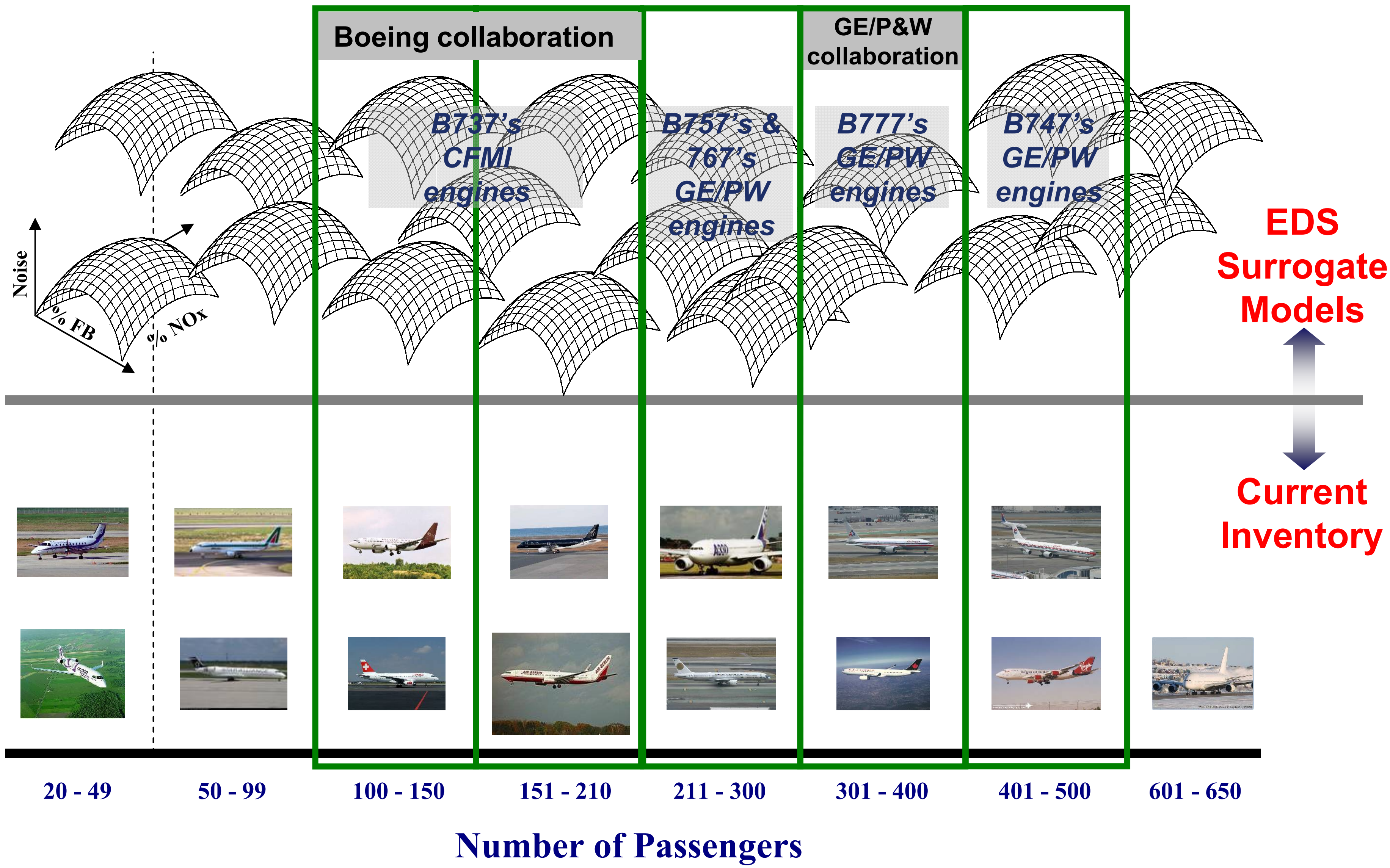
# EDS Trade Spaces




Three different trade spaces for a given airframe/engine architecture type within a vehicle class may be investigated:

1. Trade space about current technology
2. Trade space about incremental changes from current technology (e.g., winglets or new combustor)
3. Trade space for future technologies

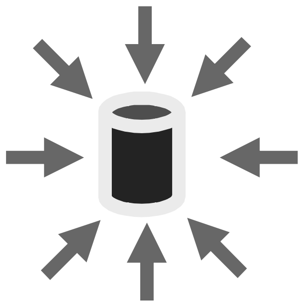
# EDS Current Vehicle Trade Spaces Status



# Selecting EDS Components

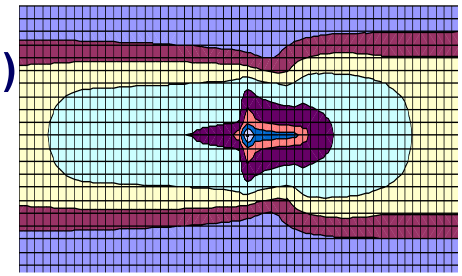
- Trade-offs
  - Transparency vs. complexity
  - Practicality vs. thoroughness (spiral development)
  - New methods vs. existing practices
  - Restrictions vs. accessibility of codes
- Considerations
  - Leverage work performed by FAA, NASA, and universities
  - History of tool validation and assessment
  - Use tools that are state of the art within the government
  - Promote industry collaboration and incorporate industry feedback

# EDS Architecture/Environment



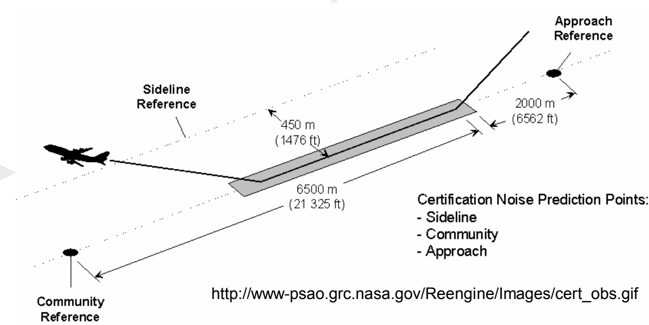
**Model Inputs**

**Input model parameters**
**Create simulated engine (NPSS/WATE)**
**Calculate exhaust emissions (P3-T3 method)**
**Create simulated aircraft (FLOPS)**
**Fly a mission (FLOPS)**
**Calculate noise (ANOPP)**
**Produce noise footprint (ANOPP)**



**Noise Footprint**


**NPSS/WATE**




**Noise w/ Three Observers**

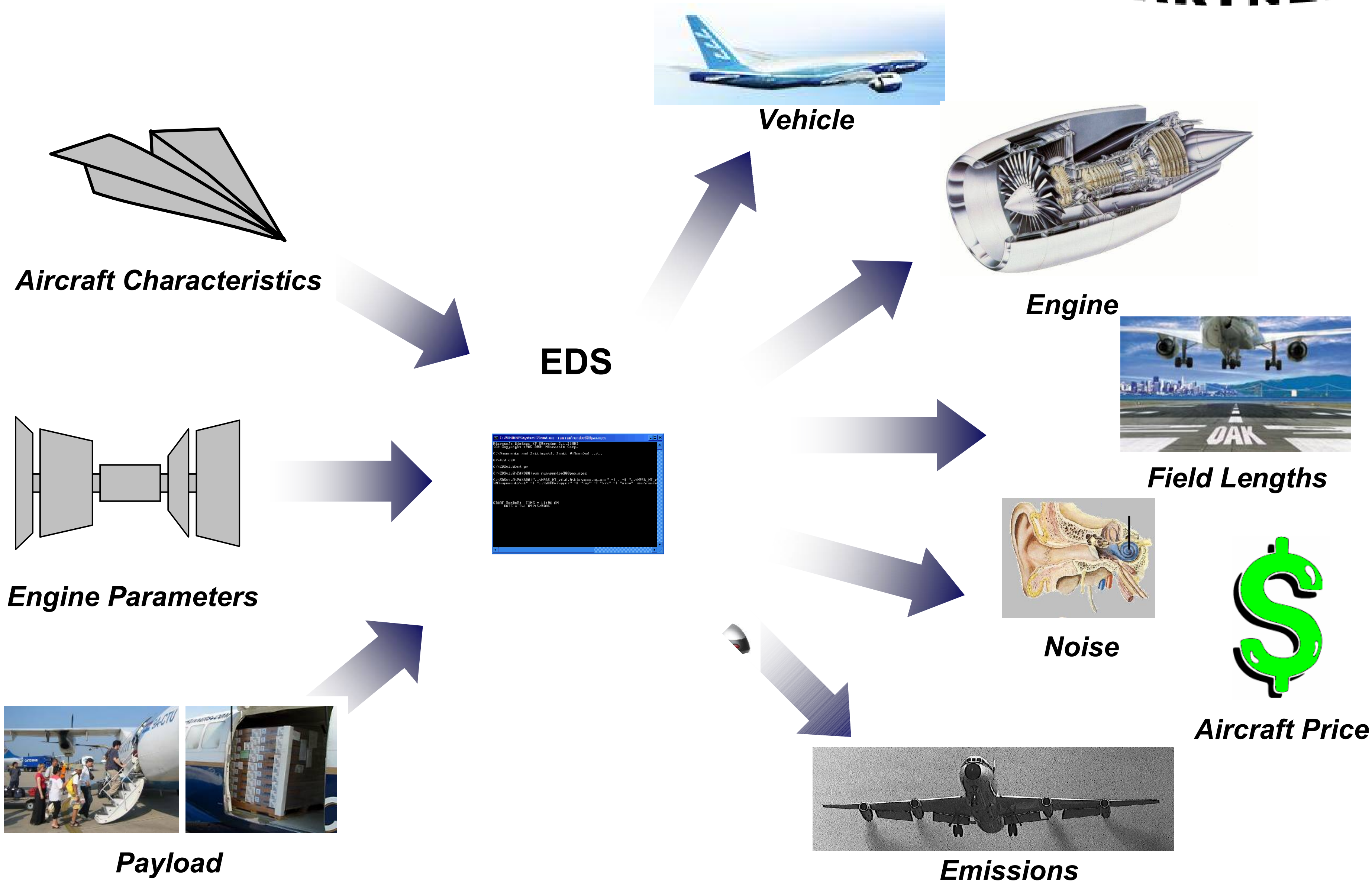
**Exhaust emissions**

**FLOPS**

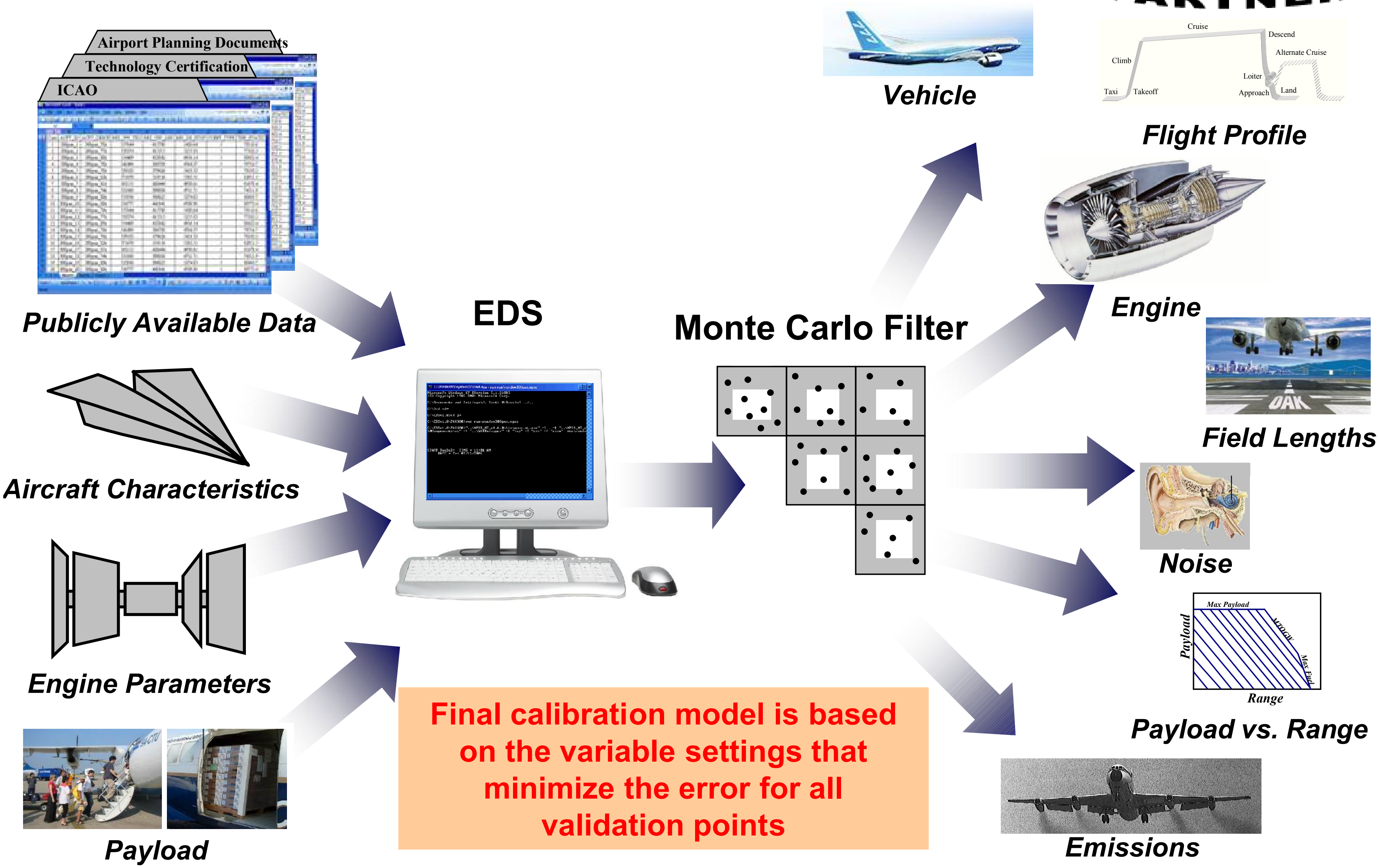
**Vehicle Performance & $CO_2$**

**http://www.niaid.nih.gov/ncn/graphics/clipart/char_sra_computer.gif**

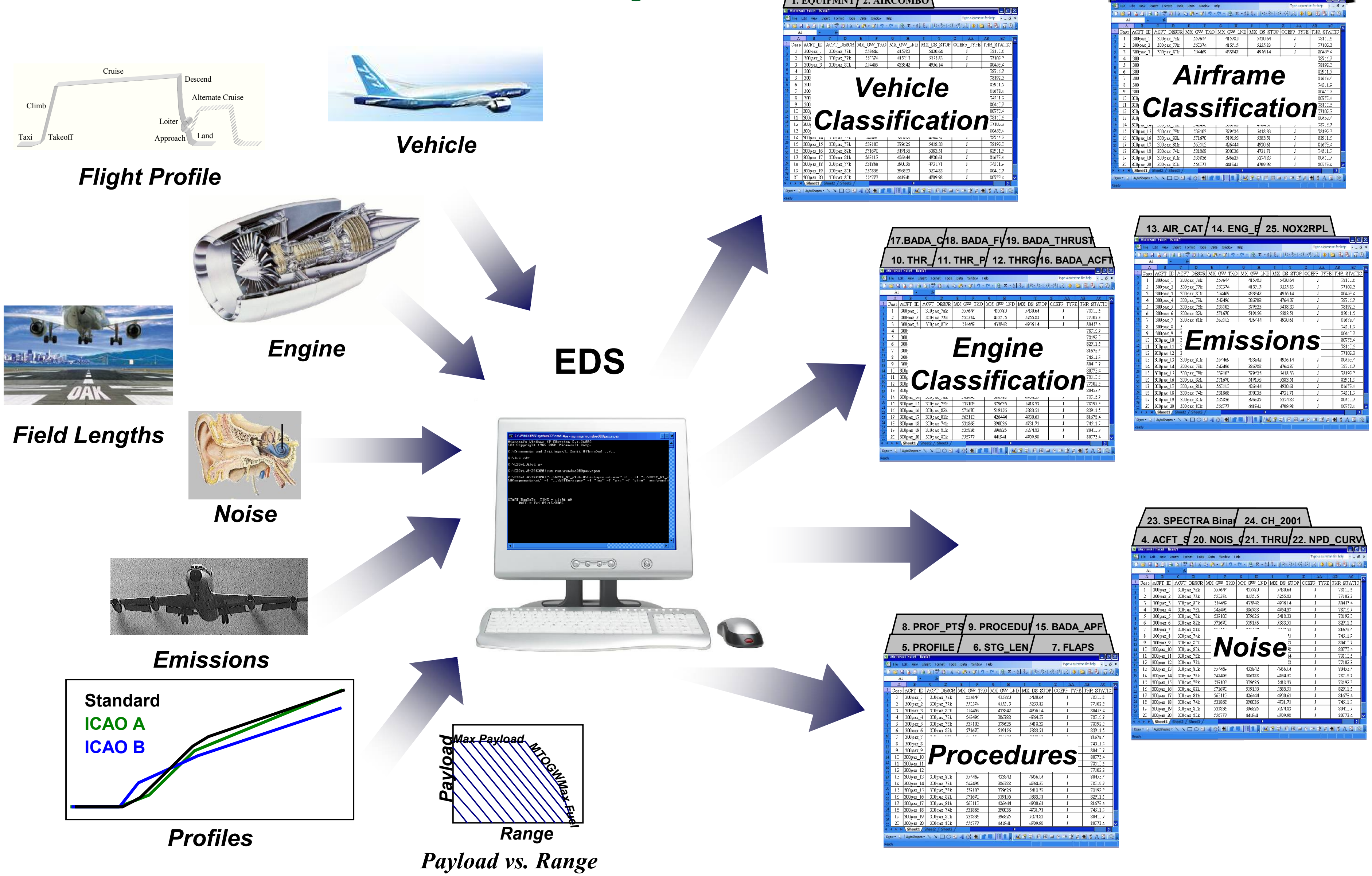
# EDS APMT Connectivity



# EDS Calibration



# EDS AEDT Connectivity



## Initial EDS Capability Demonstrators

- EDS supported two capability demonstrators in conjunction with the other FAA tools (AEDT, APMT), which included:
  - Fuel Price Increase
    - With and without EDS aircraft technology
  - NOx Emissions Certification Stringency
    - With and without EDS aircraft technology
- Prototype connectivity based on:
  - Aircraft and engine trade spaces with current technology levels
  - Same vehicles used for both scenarios as potential replacement vehicles

# Summary

- FAA has made a commitment to use EDS
  - to inform national and international decision-making
- Continue EDS development based on:
  - Assessment results
  - Industry collaboration
- We are:
  - Not building aircraft
  - Not giving “the” answer
  - Are providing insight to the trade-offs that exist between NOx vs. Noise vs. CO2
  - Actively engaging industry and international partners through this development

**EDS will allow for more effective assessment and communication of environmental effects, interrelationships, and economic consequences**