Environmental Design Space (EDS)

OVERVIEW

Presented to: TRB AEDT/APMT Workshop #4

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EDS Development Team

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Partnership for AiR Transportation Noise and Emissions Reduction

An FAA/NASA/TC-sponsored Center of Excellence

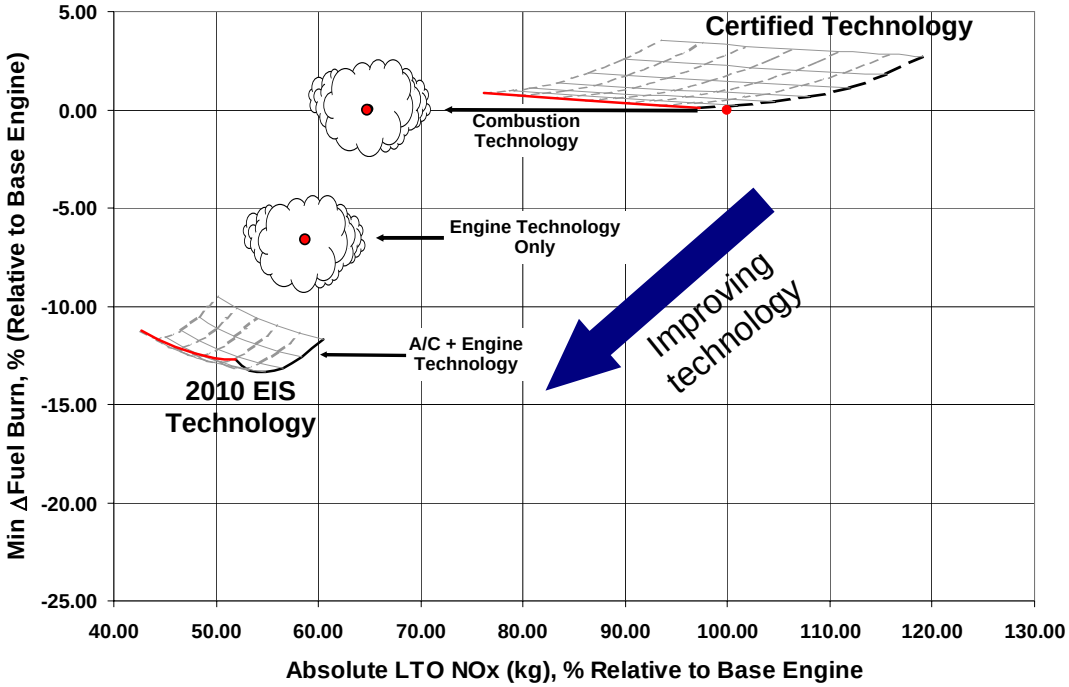
Outline

- **Statement of needs**
- **TRB guidance**
- **EDS requirements/architecture definition**
- **The EDS architecture/environment**
- **Accomplishments to date**
- **Next steps**
- **Summary**

Statement of Needs

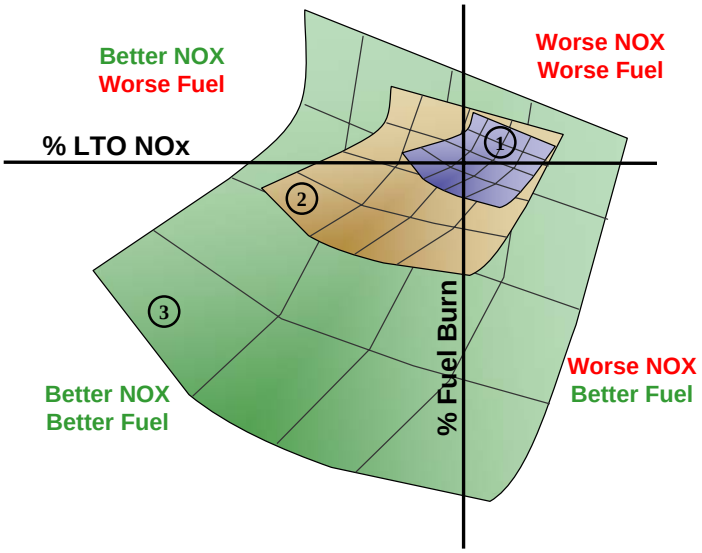
- **Physics drive the environmental trade-offs and their interdependencies**
- **Need a means to understand interdependencies for existing and future classes of vehicles**
- **Emphasis is not designing aircraft and engines, but on trends and correlations**
- **Move beyond frozen technology inventories currently being used**
- **EDS must:**
  - Provide a dynamic assessment environment based on integrated physics-based analyses
  - Consider tradeoffs in terms of performance, source noise, exhaust emissions and economic considerations for various technically feasible aircraft/engine systems
  - Provide quantitative and qualitative assessments of uncertainty

Evolution of EDS Concept and Application



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

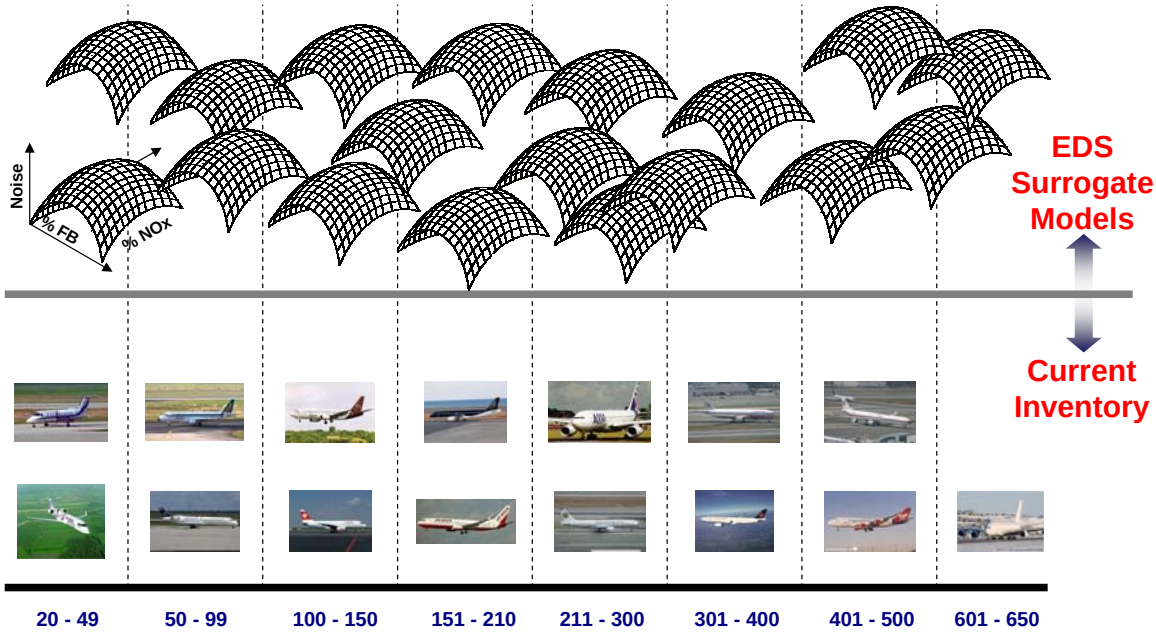
EDS Products: Trade Spaces



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 Products: FESG Vehicle Classes



EDS Objectives

The EDS Environment is designed to provide AEDT and APMT with the necessary aircraft information to:

- Enable more informed Federal research, policy and budgetary decision-making *(JPDO/NextGen, FAA, NASA, EPA)*
- More effectively assess and communicate environmental effects, interrelationships, and economic consequences based on integrated analyses *(JPDO/NextGen, FAA, CAEP)*
- Facilitate international agreements on standards, recommended practices, and mitigation options for international policy making *(CAEP)*
- Possibly serve as a mechanism for an expert-driven process that collects, incorporates and quantifies long-term technology impact assessments *(JPDO/NextGen, FAA, CAEP)*

TRB Guidance

✓ = good progress ✓ = partial progress

EDS Requirements	Status	Notes
Transparency: EDS should be open, available, and transparent in concept and execution	✓	**Ongoing:** Version controlled modules and databases
Flexibility: EDS should have flexibility to adapt to and accept future modifications, be able to respond to changing future needs, and be able to access future technologies and new functionalities. It should also be modular and flexible, to allow users to incorporate other tools.	✓	**Ongoing:** Developing detailed fidelity management system
Accessibility: EDS should be PC based.	✓	**Completed**
Uncertainty: EDS should be able to manage uncertainties within its modeling capacity.	✓	**Ongoing:** Developing detailed fidelity management system
Predictive: EDS should have a predictive capability as part of its functionality.	✓	**Ongoing:** Future technologies will be modeled with expert driven, industry involvement
Availability: EDS inputs must be nonproprietary.	✓	**Ongoing:** Based on publicly available information
Coordination: EDS must be able to interface with existing tools and the AEDT.	✓	**Ongoing:** Initial Capability, improved capability coming

TRB Guidance

✓ = good progress ✓ = partial progress

EDS Development Process	Status	Notes
Extensible: EDS should be able to accommodate additional and newer aircraft types, such as helicopters and general aviation and various military aircraft.	✓	Not a current priority
Improved Emissions: EDS should be able to accommodate additional emissions species and fates that have not been subject to analysis in the past.	✓	**Ongoing:** Working improved and additional emissions capabilities
Interaction: EDS should be developed with active stakeholder involvement	✓	**Ongoing:** EDS Technical Advisory board and industry collaboration
Validation: EDS development process should include a validation plan that involves input from a variety of stakeholders.	✓	**Ongoing:** Collaboration with GE, P&W, and Boeing, looking for additional partners
Coordination: The development process should assure that EDS and the AEDT are developed on parallel tracks.	✓	EDS, APMT, AEDT teams have common members, interaction

TRB Guidance

✓ = good progress ✓ = partial progress

Technical Initiatives Involving AEDT Design and the EDS Component	Status	Notes
Distributable: Although not all NASA models can be distributed, this work should result in a product that is distributable. Consolidation of the NASA models should take this distribution requirement into consideration.	✓	We use surrogate models to protect NASA models and information and enable distribution
While certain individual components have already been tested independently, the research should examine new vehicles under EDS so that the final tool will surpass and leverage existing capabilities.	✓	**Ongoing:** Developing detailed fidelity management system
The committee recommends that FAA clarify the different roles of EDS outputs versus databases of existing aircraft to help stakeholders understand the uses of the model in different contexts.	✓	**Ongoing:** Continuing interactions with stakeholders through CAEP papers, workshops, and EDS Technical Advisory Board

TRB Guidance

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Project Management	Status	Notes
Coordination: The committee also recommends that FAA indicate how it plans to coordinate with international and national nongovernmental organization (NGO) stakeholders.	✓	**Ongoing:** Presentations and participation in ICAO CAEP WG2 and FESG; EDS TAB; APMT/FESG Ad Hoc Group; SAE A-21 & E-31; InCoG, PARTNER
Stakeholder Acceptance: FAA should initiate interaction with international stakeholders, international and domestic governmental entities, NGOs and corporations, and U.S. air carriers.	✓	**Ongoing:** TAB, industry collaboration, an effort to reach out to a wider audience
Expert Interaction: Recommends that future workshops include, especially during the APMT discussions, more participants from airlines and manufacturers that have an economic stake in the outcome.	✓	**Ongoing:** Existing industry collaboration, an effort to reach out to a wider audience has been made
Appropriate Use: Recommends that FAA develop a plan for managing the appropriate use of AEDT (especially EDS) to reduce the potential for its abuse.	✓	No plans for a public release of EDS. "Currency of communication" is through surrogates.

TRB Workshop Guidance

- **In summary:**

EDS development is following the guidance of the TRB study committee and workshop participants

EDS Requirements/Architecture Definition

- **Requirements and Architecture studies in response to the guidance from the NRC-TRB**
- **Requirements study**
  - Detailed functional requirements and guidance on implementation
  - Protection of proprietary codes, data, design philosophies
  - Recommended time frames for development and use
- **Architecture study**
  - Consideration of components of EDS architecture
  - Interfaces among components
  - Interfaces with tools that exist or are under development including Aviation Portfolio Management Tool (APMT) and Aviation Environmental Design Tool (AEDT)
- **Detailed multi-year work plan**

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

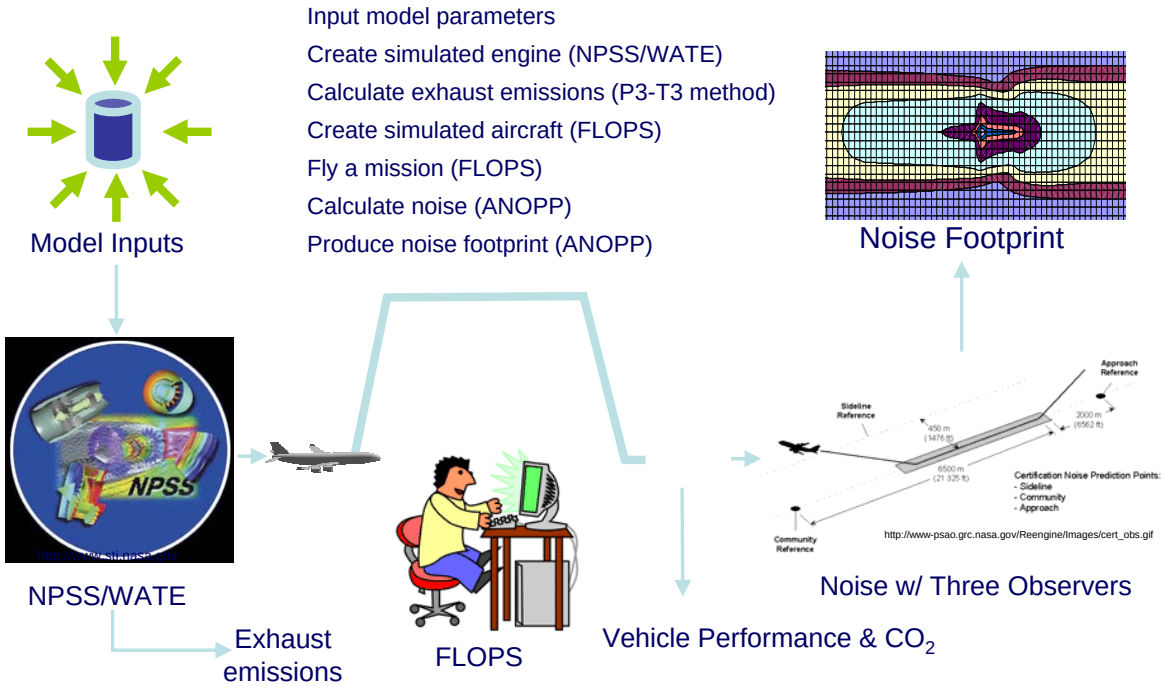
Risk Mitigation Strategy

Risk	Level	Remedy
Modeling assumptions	High	• Industry collaboration • Benchmarking • Assessment studies
Design philosophies	High	• Understand differences through industry collaboration • Adopt consensus path forward
Lack of empirical corrections	High	• Comparison of end results against similar capabilities within industry
Tool acceptability by community	High	• Interact with CAEP working groups and industry • Formation of EDS Technical Advisory Board
Tool selection	High	• Need to use non-proprietary tools • Improvement of tools through industry guidance
APMT/AEDT connectivity	Medium	• Weekly telecons and working meetings with leads teams
Need to use Non-proprietary data	Medium	• Extensive literature search of public domain data

EDS Technical Advisory Board (TAB)

- **Current TAB consists of industry partners including:**
  - Richard Altman (P&W)
  - Howard Aylesworth (AIA)
  - Colin Beesley (RR)
  - Dominique Collin (Snecma)
  - Mark Huising (Bombardier)
  - Alain Jozelson (Airbus)
  - Muni Majjigi (GEAE)
  - Eric Nesbitt (Boeing)
  - Joseph (Brent) Staubach (P&W)
- **TAB engagement**
  - Periodic reviews of EDS analysis
  - Recommendations for improvements in EDS tools
  - Two formal meetings so far, Boston, Atlanta
  - Next review scheduled for January 2007

EDS Architecture/Environment



Long-term Schedule

End of CY	CAEP Cycle	Deliverable
2004	**End CAEP/6** **Begin CAEP/7 Work Program**	AEDT Work Plan Completed and Development Effort Initiated
✓ 2005		**EDS Requirements and Architecture Defined** APMT Requirements and Architecture Defined AEDT Prototype Demonstration (v 0.0)
✓ 2006		AEDT Version 1.0 for CAEP/7 Introduction **EDS (v1)** and APMT (v1) Capability Demonstration
2007	**CAEP/7** **Begin CAEP/8 Work Program**	**EDS (v2)**, AEDT Version 1.1 and APMT (v2) for CAEP vetting
2008		**EDS (v3)**, AEDT Version 1.2, and APMT (v2) applied for CAEP/8
2010	**CAEP/8**	**EDS (v4)**, AEDT Version 2.0 for Airport Planning Application *Meets criteria for seamless and publicly available* APMT (v3) Capability Demonstration

EDS CY05 Accomplishments

EDS Requirements Document - June 1, 2005	✓
VSP toolkit assessment – July 1, 2005 Assessment of individual public domain tools Identification of differences with respect to EDS v1.0	✓
Modification of VSP to EDS – September 1, 2005	✓
Identification of EDS v2.0 development needs	✓
Development of 300 passenger class parametric vehicle – December 1, 2005	✓
Deliverables reviewed by EDS Leads IPT (GT, MIT, FAA, NASA, Volpe) and NASA Review Team	✓

EDS CY06 Work Plan

- **Theme 1: Development**
  - Expected outcome: EDS v2 with expanded vehicle library and capabilities
- **Theme 2: Assessment**
  - Expected outcome: Initial analysis and framework definition for a Fidelity Management System (FMS), incorporation of industry feedback
- **Theme 3: Applications/Sample problems**
  - Expected outcome: Generate results from EDS for international assessment of the environment
- **Theme 4: Technology Impact Assessments**
  - Expected outcome: Initiate a proof of concept of the technology impact assessment process

Theme 1: EDS Development

- **Improve emissions and operations capabilities**
  - More physics based analyses capability including NOx, HC and CO *(Long term)*
  - Different procedures, ICAO A, ICAO B, standard for different flap schedules *(Short term)*
- **Exercise link between EDS and AEDT (*Short term*)**
  - EDS must output the required inputs to populate the AEDT fleet database
  - Focus on 300 passenger class
  - Identify linkage improvements for Year 3
- **Develop vehicle library to include five vehicles via a surrogate model approach (*Short term*)**

EDS Vehicle Library Approach

- **Three approaches for generating a vehicle library entry:**
  - Frozen technology assumptions (typical CAEP practice)
  - Potential future vehicles defined within trade spaces estimated assuming current technology *(Near term)*
  - Potential future vehicles defined within trade spaces estimated assuming potential future technology *(Mid to long term)*
- **Current approach: build a potential vehicle assuming current technology**
- **Applications of EDS for CAEP/8 or JPDO/NextGen support will include all approaches**

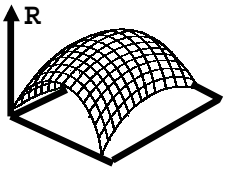
Design Space vs. Technology

- **Design Space Exploration (Current focus)**
  - Function of the metrics in terms of the design variables
  - Specific design variables varied, within the limits imposed by baseline model current technology levels
- **Technology Exploration (Future focus)**
  - Function of "technology variables" and design variables, ranges based on projected impacts of each technology
  - "Technology space" allows exploration of new designs or tradeoffs between metrics, made feasible by technology infusion

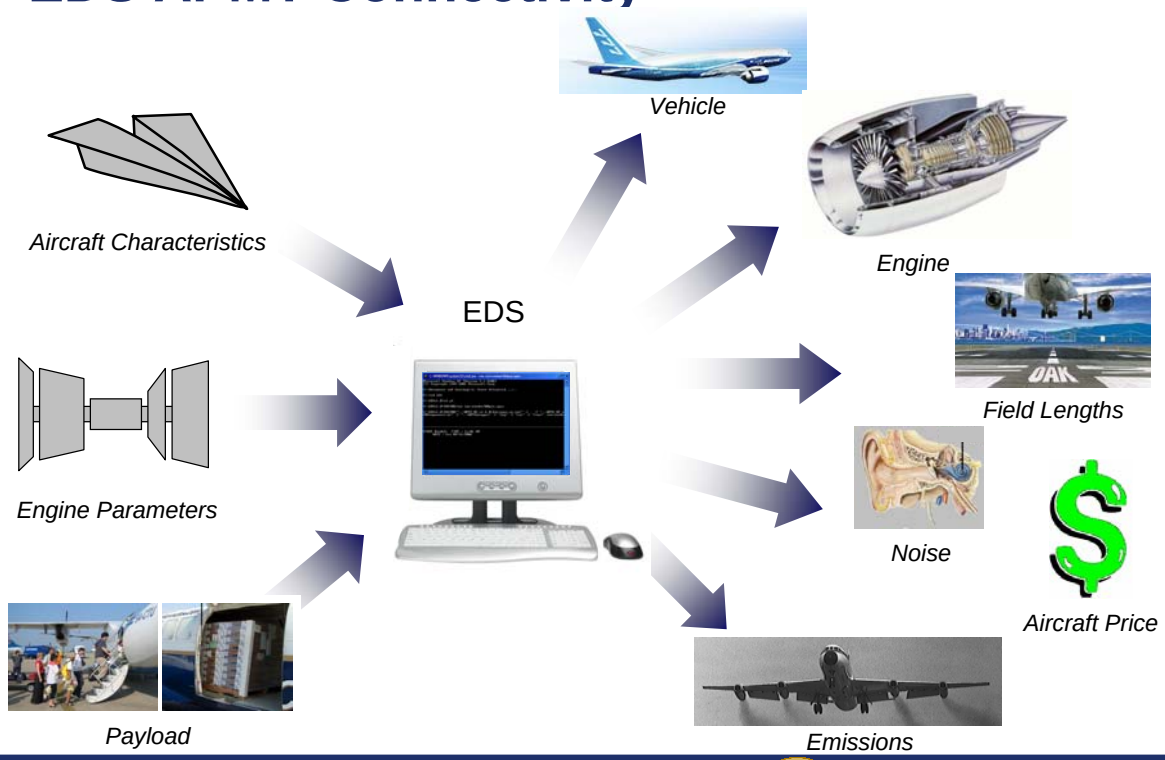
Surrogate modeling is the key enabler

Surrogate Modeling

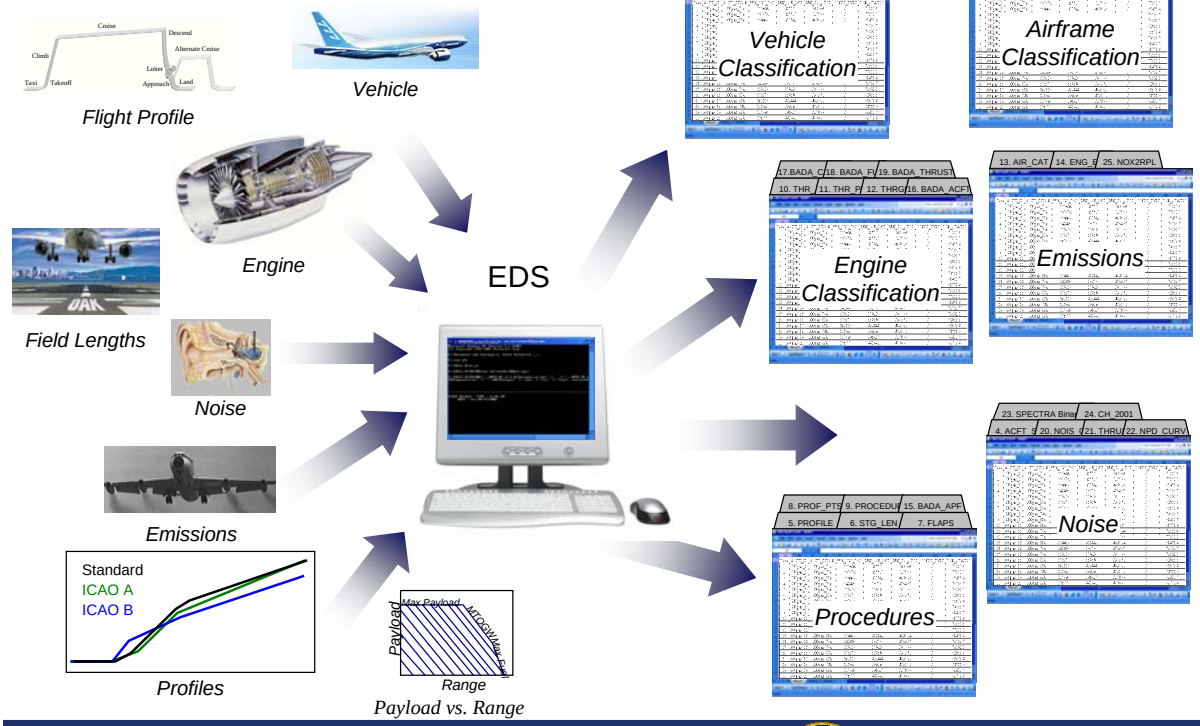
- **Enables efficient exploration of design or technology space or a combination of both**
- **Enables probabilistic methods to quantify and assess risk**
- **Currency of communication for interdependency trade-offs within existing or future systems**
- **Transitions from single-objective to multi-objective**
- **Minimal loss of accuracy from a stand-alone EDS**
- **Provides transparency in a distributable, visual, and interactive form**



EDS APMT Connectivity



EDS AEDT Connectivity



Theme 2: EDS Assessment

- **Purpose**
  - Assessment is critical to ensure the appropriate level of fidelity
  - Ensuring confidence relies on documented assessment of the tools, architecture, and technology impact assessment process
- **Objectives**
  - Determine uncertainties associated with EDS tools *(Near term)*
  - Define appropriate analysis tool capability level *(Near to mid term)*
  - Collaborate with industry *(Ongoing)*
  - Identify improvements necessary to meet CAEP and JPDO/NextGen objectives *(Near term)*
  - Understand trades and implications of decisions *(Ongoing)*
  - Understand and define what is “good enough” *(Near to mid term)*

Assessment Plan Focus

- **How accurate is accurate?**
- **Which output trends need to be "nailed"?**
- **What inputs and assumptions drive the outputs?**
- **What modules need a higher fidelity capability based on the above?**
- **Perform an error propagation analysis**
- **Initialize a Fidelity Management System**

Engage industry through collaborative assessments to address these issues

Industry Collaborative Assessments

- **To gain international confidence, industry engagement is critical**
- **Current interactions with industry:**
  - General Electric and Pratt & Whitney:
    - Focused on Boeing 777-200ER, specifically GE90-94B and PW4090 architectures
    - NOx and fuel burn trades
  - Boeing:
    - B737-800 with a CFM56-7B24
    - Noise assessments and trends

Industry Collaboration Focus

- **Participation includes the following activities:**
  - Collaborative definition of the problems
  - Back-to-back comparisons between proprietary tools and EDS
  - Determination of sources differences between the EDS capabilities and industry-proprietary methods
- **Collaborative efforts result in new development requirements placed on EDS to address**
  - Validating trade-spaces and trends
  - Applicability to JPDO/NextGen
  - Applicability to CAEP/8
- **International industry invited to participate in similar assessments**

Theme 3: EDS Applications

- **Perform sample CAEP exercise problems progressing from simple to more complete policy analyses *(Ongoing)***
- **Capable of supporting and addressing CAEP analysis goals within the five-year program *(Mid to long term)***
- **Employing a phased approach as a development strategy**
  - Demonstrate EDS capability via a process of successively higher-fidelity integration with other aspects of the AEDT framework

Theme 3: EDS Sample Problems

- **The current EDS sample problems:**
  - Fuel Price Increase (FP)
  - NOx Emissions Certification Stringency (NX)
- **The objectives of the EDS sample problems are**
  - To provide a demonstration of the EDS capabilities to FAA, ICAO/CAEP, JPDO/NextGen, and industry
  - To provide an assessment of the effectiveness of the EDS-AEDT-APMT system at addressing policy questions and scenarios
  - To establish EDS-AEDT-APMT connectivity

Theme 4: EDS Technology Impact Assessments

- **Complete preliminary definition of an expert-driven process for technology impact assessments**
- **Establish a sample technology impact assessment activity**
  - Expected outcome: Report on technology impact assessments activity and requirements for future improvements
- **The JPDO/NextGen was identified as a potential pilot project to demonstrate capability**
  - Utilize previous studies from NASA in which experts were engaged
  - Document a process forward for engaging industry for CAEP application and support

CY06 Accomplishments

EDS v2.0 Integrated Environment Enhanced procedures analysis AEDT and APMT connectivity	✓✓
Vehicle Library (all aligned with FESG vehicle classes) Upgraded 300 passenger, twin-aisle transport 100-150 passenger class vehicle 151-210 passenger class vehicle Enhanced calibration procedure 210-300 passenger class vehicle 401-500 passenger class vehicle*	✓✓✓✓✓✓ Nearing completion
EDS Assessment Module assessments Fidelity Management System Industry collaborative assessments	 Ongoing Ongoing Ongoing
EDS Application – Sample Problems Sample problem data supplied to APMT Sample problem analysis within APMT	✓✓
EDS Technology Impact Assessment JPDO/NextGen problem defined	Nearing completion

** All tasks will be completed by the end of Year 2*

Next Steps

- **Continue industry collaboration**
- **Continue EDS development based on:**
  - Industry studies
  - Fidelity Management System results
- **Complete parametric vehicle entries for all FESG classes**
  - Current technology
  - Future vehicles and technologies
- **Increase engagement of industry experts to support definition of future vehicles and technologies**
- **Support CAEP and JPDO/NextGen needs**

Summary

- **Completing Year 2 development of EDS providing aircraft that respond to future policy scenarios**
- **EDS development is addressing TRB guidance**
- **Risk mitigation strategy in place and ongoing**
- **Rigorous process employed for FESG vehicle class entries**
- **Strong industry engagement for credibility and confidence**
- **On track for supporting CAEP/8**

EDS will allow for more effective assessment and communication of environmental effects, interrelationships, and economic consequences in support of CAEP and JPDO/NextGen

??? Questions ???

FAA Environmental Tools web site:

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