Partnership for AiR Transportation Noise and Emission Reduction

An FAA/NASA/TC-sponsored Center of Excellence

Aviation Environmental Portfolio Management Tool (APMT)

Overview of requirements and architecture

Peter Belobaba
Yongki Go
Henry Jacoby
Stephen Lukachko
Ian Waitz
Karen Willcox

Kate Harback
Fred Morser
Michele Steinbach

Elena Garcia
Peter Hollingsworth
Dimitri Mavris

Maryalice Locke
Archie Muckle

Motivation

- Aviation benefits and environmental effects result from a complex system of interdependent technologies, operations, policies and market conditions
- Policy and R&D options are largely considered within a limited context
  - only noise, only local air quality, only climate change
  - only partial economic effects
- Actions in one domain may produce unintended negative consequences in another
- Current tools and processes do not support recommended practice
  - NPV of benefits-costs is recommended basis for informing policy decisions in U.S., Canada and Europe

Better informed policy: examples

- Every aircraft model has a different combination of noise, emissions, fuel burn and performance
  - What is the right balance? Will tomorrow's aircraft reflect this?
- CAEP/6 NOx stringency
  - Greater leniency for CO to enable more aggressive NOx standard was briefly considered
  - What are the relative impacts of CO and NOx?
- No PM certification standard
  - What is the health impact of PM vs. regulated emissions?
- Climate vs. local air quality vs. noise
  - What are the relative impacts?
- Thrust derate
  - Lower noise, NOx, and maintenance costs; higher fuel burn, CO and UHC
  - What is the desired balance?

High-level approach

- Developing a comprehensive suite of software tools that will allow for thorough assessment of the environmental effects of aviation
- New capability to assess the interdependencies between aviation-related noise and emissions effects and associated environmental costs
- The economic analysis function of this suite of software tools has been given the rubric Aviation Environmental Portfolio Management Tool (APMT)
  - function may ultimately be derived from existing tools, tools under development, and new tools to be developed
- Other components of comprehensive suite include Aviation Environmental Design Tool (AEDT) and Environmental Design Space (EDS)

APMT goals

- More effectively assess and communicate environmental effects, interrelationships, and economic consequences based on integrated analyses
- Facilitate international agreements on standards, recommended practices, and mitigation options
- Enable more informed international and U.S. policy and budgetary decision-making
- Start with cost-effectiveness analysis, progress to benefit-cost analysis
- Desired characteristics
  - Internationally-accepted
  - Inclusive, not competitive
  - Transparent
  - Rigorous
  - Explicitly represent uncertainty and different viewpoints

Series of three APMT studies

- Requirements document
  - Detailed functional requirements and guidance on implementation
  - Supporting discussions to place requirements within context of current practice
  - Recommended time frames for development and use
  - Geographical and economic scope for analyses
- Architecture study
  - Components of APMT architecture, interfaces among components, interfaces with tools that exist or are underdevelopment including Environmental Design Space (EDS) and Aviation Environmental Design Tool (AEDT)
  - Reviews existing tools, assesses their suitability for use in APMT, and establishes what additional development necessary to achieve APMT requirements
- Prototype work plan
  - Initial APMT prototyping effort that is intended to identify gaps or weaknesses in architecture and stimulate advancements in development
  - Delineates entities necessary for analyses, roles, data requirements, and proposed schedule

Status

- Requirements study “complete”
  - Finished internal FAA review
  - Seeking outside comments/review
- Architecture study “first draft”
  - Undergoing internal FAA review
  - Seeking outside comments/review
- Prototype work plan “in preparation”
  - Defined to large extent by Architecture study
  - Comments and suggestions welcome
  - Goal is to initiate development starting with US FY06 funds
- A challenging, complex problem
  - We don’t have all the answers
  - Guidance and advice welcome
  - Still have ample opportunity to improve, adjust and change direction

Requirements document provides detailed context and rationale (1 of 2)

Requirements document provides detailed context and rationale (2 of 2)

Requirements study

- Extensive review of literature and tools (aviation and non-aviation)
- Key literature sources:
  - EPA *Guidelines for Preparing Economic Analyses* [EPA, 2000]
  - OMB Circular A-4, *Best Practices for Regulatory Analysis* [OMB, 2003]
  - UK HM Treasury *Green Book on Appraisal and Evaluation in Central Government* [UK HM Treasury, 2003]
  - UK Cabinet Office, Better Regulation Executive *Regulatory Impact Assessment Guidance* [UK BRE, 2005]
  - OECD *The economic appraisal of environmental projects and policies – A practical guide* [OECD, 1995]
  - Transport Canada *Guide to Benefit Cost Analysis in Transport Canada* [TC, 1994]
  - WHO *Air Quality Guidelines for Europe* [WHO, 2000a]
  - Kopp, Krupnick, Toman, Resources for the Future, *Cost Benefit Analysis and Regulatory Reform: An Assessment of the Science of the Art*. [RFF, 1997]
  - Krupnick, Ostro, and Bull *Peer Review of the Methodology of Cost-Benefit Analysis of the Clean Air for Europe Programme*, [Krupnick et al., 2004]
  - Clean Air for Europe (CAFÉ) Programme *Methodology for the Cost-Benefit Analysis for CAFÉ Vol. 1* [CAFÉ 2005]

Nomenclature

Types of Analysis	Question Answered	Tools of Analysis
Cost-Effectiveness Analysis (**CEA**)	"Given several options for addressing an environmental problem which option provides the greatest change in a surrogate for environmental impact per unit of cost?"	**CEA.1** Benefits Assessment: Requires some measure of system performance that serves as a surrogate for the full monetized environmental benefit value (e.g. lbs of NOx per year or # of people living in DNL 55dB).
		CEA.2 Costs evaluation: Considers the changes in capital and operating costs in primary markets and potentially enforcement costs (e.g. FESG spreadsheet that calculates manufacturer and airline marginal costs in response to a po licy scenario) with appropriate discounting.
Benefit-Cost Analysis (**BCA**)	"Relative to a well-defined baseline scenario, to what degree does a policy scenario improve economic efficiency?"	**BCA.1** Social Benefits Assessment: Requires methods to convert system performance to both health and welfare impacts (e.g. # of asthma cases, premature mortality, etc.) and other benefits (e.g. operational efficiency) in comparable ways (usually monetary values since this is also comparable to the social costs metric) with appropriate discounting. **BCA.1.1** Revealed preference methods, stated preference methods and out-of-pocket expenditures—and hybrids thereof for assessing direct effects (e.g. hospitalization, lost wages, housing devaluation) **BCA.1.2** General economic models (e.g. input-output models for marginal sensitivities, and models for reaching a new optimization point) for assessing indirect (e.g. changes in household consumption patterns in response to environmental disbenefits) and induced (any multiplier effects after the consumption patterns change – e.g. people get sick more often and they buy less paper so it impacts the paper industry) benefits. These techniques are currently a research activity.
		BCA.2 Social Costs Assessment: **BCA.2.1** Partial equilibrium models to evaluate costs in the primary market (e.g. supply = airlines and demand = travelers and freight). This allows consideration of market-based options, of command and control options, etc. **BCA.2.2** General equilibrium models to assess the indirect and induced effects (e.g. how do ch anges in production and consumption in the aviation industry, change production and consumption in other parts of the economy).
Distributional Analysis (**DA**)	"Which entities pay the costs and receive the benefits?"	**DA** General equilibrium models, national or global in scope, are required to assess who pays and who receives the benefits.
		DA.1 Economic Impacts Analysis: Determines the costs-and benefits that accrue to various potentially impacted entities.

Functional requirements: analysis

- CEA.1 Benefits Assessment
- CEA.2 Cost Assessment
- BCA.1 Social Benefits Assessment
  - BCA.1.1 Monetization of Benefits
  - BCA.1.1.2 Benefit categories to be considered
  - BCA 1.1.3 Effect-by-Effect Benefits Analysis
  - BCA.1.1.4 Adoption of existing benefits studies and flexibility to incorporate new work.
  - BCA.1.2 Indirect and Induced Benefits Assessment
- BCA.2 Social Costs Assessment
  - BCA.2.0.1 Cost categories to be considered
  - BCA 2.1 Direct Primary Market Social Costs Assessment
  - BCA 2.2 Indirect and Induced Social Costs Assessment
- DA.1 Economic Impact Analysis and DA.2 Equity Assessments

Functional requirements: general

- GE.1 APMT-AEDT Interface, Input/Output and Consistency
- GE.2 Uncertainty
- GE.3 Sensitivity Analyses
- GE.4 Policy Baselines
- GE.5 Time Span for Analysis
- GE.6 Discounting
  - GE.6.1 Discounting Non-Monetized Effects
- GE.7 Alternate assessments of risk
- GE.8 Exogenous Technological Change

Guidelines for development and use

- DU.1 Full-disclosure and transparency
- DU.2 Thoroughness and Practicality
- DU.3 Engagement of Stakeholders
- DU.4 Treatment of Non-Quantified Impacts
- DU.5 Professional Judgment
- DU.6 Documentation of APMT Development
- DU.7 Assessment and Improvement

Every requirement drawn directly from U.S. and European policy guidance
Example 1

BCA.1.1 Monetization of Benefits

APMT must be capable of monetizing the benefits through best available techniques including revealed preference methods, stated preference methods, out-of-pocket expenditures, and hybrids of these methods.

- *To the extent feasible and warranted by their contribution to the results, as many of the effects of a policy as possible should be monetized. This enhances the value of the conclusions to policy makers weighing the many, often disparate consequences of different policy options and alternatives.* [EPA, 2000, p176]
- *The general rule is that benefits should be valued unless it is clearly not practicable to do so.* [UK HM Treasury, 2003, p19]
- *The quantification of potential social, health or environmental impacts normally requires an alternative approach to valuation. Techniques to establish money values for this type of non-market impact generally involve the inference of a price, through either a revealed preference or stated preference approach..* [UK HM Treasury, 2003, p57]
- Etc….

Every requirement drawn directly from U.S. and European policy guidance
Example 2

GE.2 Uncertainty

APMT should employ techniques that enable uncertainty to be explicitly represented and communicated as part of the policy analysis process. To the extent possible, quantitative estimates of uncertainty should be provided. If the uncertainty is a function of the interval of time over which the analysis is focused, this should be made explicit.

- *It is essential to consider how future uncertainties can affect the choice between options.* [UK HM Treasury, 2003, p32]
- *Probabilistic methods, including Monte Carlo analysis, can be particularly useful because they explicitly characterize analytical uncertainty and variability. However, these methods can be difficult to implement, often requiring more data than are available to the analyst*. [EPA, 2000, p28]
- *The model for estimating benefits and costs (as well as any effectiveness measures used for cost-effectiveness analysis) should be capable of fully addressing statistical uncertainty, in the sense of capturing standard errors around all key parameters and promulgating these distributions through the analysis to yield probability distributions of benefits, costs, effectiveness measures and net benefits.* [Krupnick, et al., 2004, p42]

APMT Requirements Timeline

Development Time Frame	Title	Scope	Capabilities
Years 1-3	APMT v1 Enhanced Cost-Effectiveness Capability	National/Global	Cost-effectiveness analysis which replicates existing CAEP practice, but uses inputs from AEDT to provide integrated assessment of noise, local air quality and climate variables (CEA.1 and CEA.2)
Years 1-6	APMT v2 Benefit-Cost Assessment Capability	National/Global	Add monetized benefits and partial equilibrium modeling of the primary markets (BCA.1.1 and BCA.2.1) enabling limited distributional assessments (DA.1 and DA.2)
Years 3-8	APMT v3 Benefit-Cost Assessment Capability with Indirect and Induced Costs	National/Global	Indirect and induced cost assessment using a general equilibrium model (BCA.2.2) to enable more complete distributional assessments (DA.1 and DA.2)
Years 6-8+	APMT v4 Benefit-Cost Assessment Capability with Indirect and Induced Costs and Benefits	National/Global	Addition of indirect and induced benefits

APMT Architecture study

- Describes components of APMT architecture
- Outlines interfaces required among components
- Establishes how APMT will interface with other tools that exist or are underdevelopment including
  - Environmental Design Space (EDS)
  - Aviation Environmental Design Tool (AEDT)
  - And others
- Reviews existing tools available for these types of analyses, assesses their suitability for use in APMT
- Establishes what additional development will be necessary to achieve APMT requirements

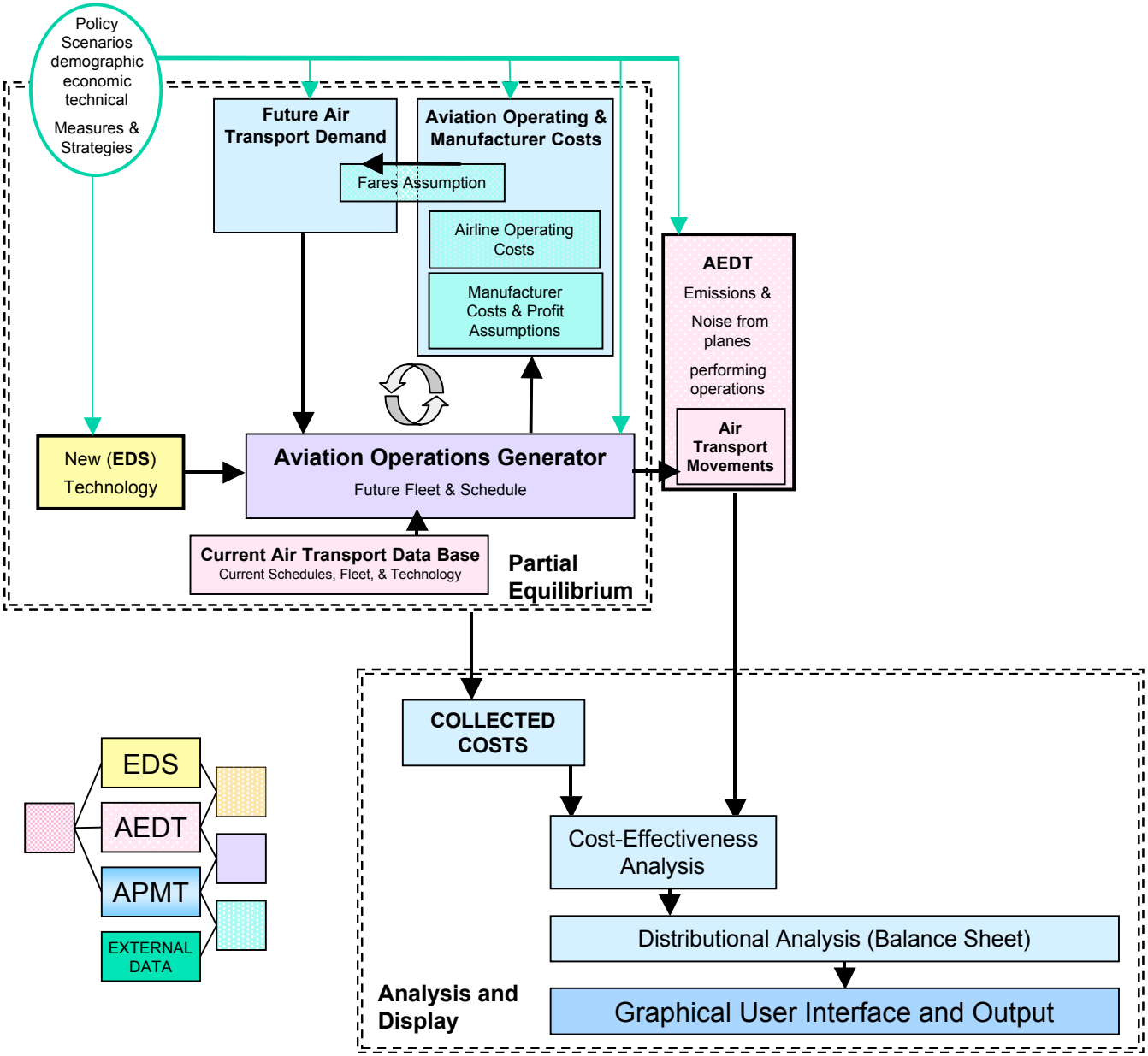
Tools and methods reviewed (selected)

- **AERO-MS:** Aviation Emission and Evaluation of Reduction Options Modeling System - Provides a comprehensive approach to quantifying the economic and environmental impacts of emissions policy in aviation, under different future scenarios. It uses a projection framework that leaves demand and traffic proportional to a base year (1992).
- **SCSM:** Stratus Consulting Spreadsheet Model - Designed to build upon, enhance and validate the AERO-MS model in the evaluation of potential CO_2 reduction measures.
- **BenMap:** (Environmental) Benefits Mapping and Analysis Program - Estimates economic values for air quality endpoints given an estimate of the change in air quality for communities in proximity to airports.
- **MAIPA**: Multi-Attribute Impact Pathway Analysis – Calculates environmental costs resulting from aviation noise and emissions.
- **TAF**: Terminal Area Forecast – Estimates airport operation growth given a database for Passenger, GA, Military and Air Taxi categories by individual airports.
- **FESG:** Forecasting and Economics Support Group - Produces traffic and fleet forecasts for use in CAEP policy and economic analyses
- **SEER-H**: Hardware element of SEER tools, it is a decision support tool providing Lifecycle Cost (LCC) for any scale hardware project
- **PRICE-H**: Price Systems Hardware cost estimator - Software used to estimate the cost of hardware related items for projects of any scale
- **ACEIT-ACE:** Automated Cost Estimating Integrated Tools – Automated Cost Estimator –Cost estimating tool for project-specific scenarios.
- **ALCCA:** Aircraft Life Cycle Cost Analysis – Estimates manufacturing costs and operating cost for a single aircraft
- **TCM**: Tailored Cost Model – Estimates manufacturing and operating costs for a single aircraft
- **AOGCM:** Atmosphere-Ocean General Circulation Model
- **BeTa**: Benefit Table (database) - Contains values per tonne of several emissions differentiated by country and by urban versus rural providing a source of comparative damage costs.
- **ACIM**: Air Carrier Investment Model - Models the relative advantages of investment decisions into new aircraft technologies by airlines and manufacturers in terms of impact on fleets, fares, airline traffic.
- **FATE**: Future Aviation Timetable Estimator - Translates passenger demand for air travel into a forecast of aircraft operations based on existing route networks.
- **NEMS**: National Energy Modeling System - Models the entire supply-side and demand-side of the energy sector, the resulting impacts on the economy, as well as policy changes and their impacts on energy demand and supply.
- **EDMS**: Emissions and Dispersion Modeling System - Computational, local aviation emissions modeling code
- **INM**: Integrated Noise Model – C omputational, local aviation noise modeling code
- **MAGENTA**: Model for Assessing Global Exposure form Noise of Transport Airplanes - Global, computational noise code
- **SAGE**: System for Assessing Global Aviation Emissions - Computational, global aviation emissions modeling code

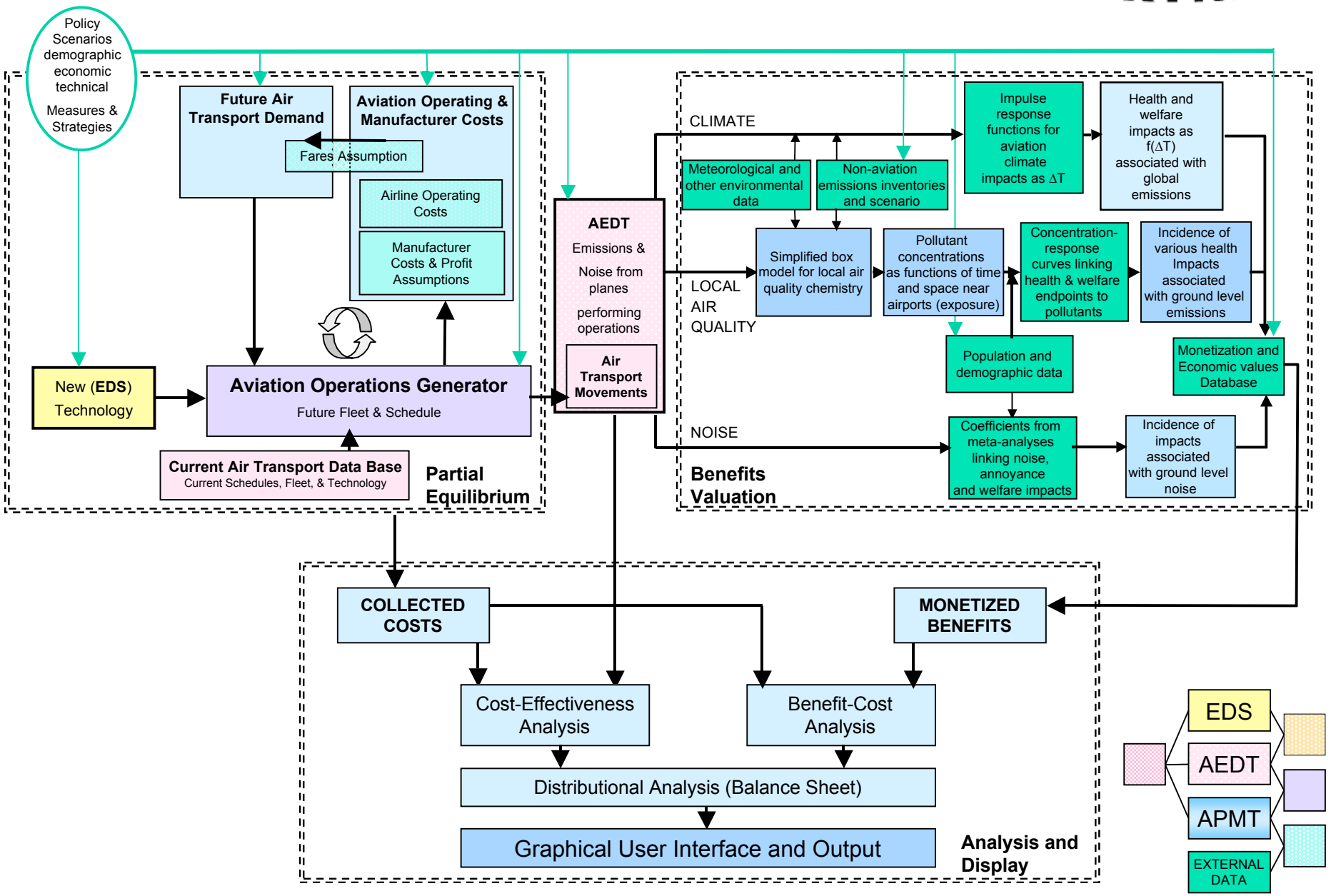
Five blocks recommended

- Partial equilibrium model of primary markets
  - Based on existing CAEP practice (e.g. AERO-MS)
- Aviation Environmental Design Tool (AEDT)
  - Based on existing tools (SAGE, MAGENTA, EDMS, INM)
- Benefits valuation
  - New, but drawn from existing practice outside CAEP
- General economy
  - New, but very simplified approach
- Analysis and display
  - New

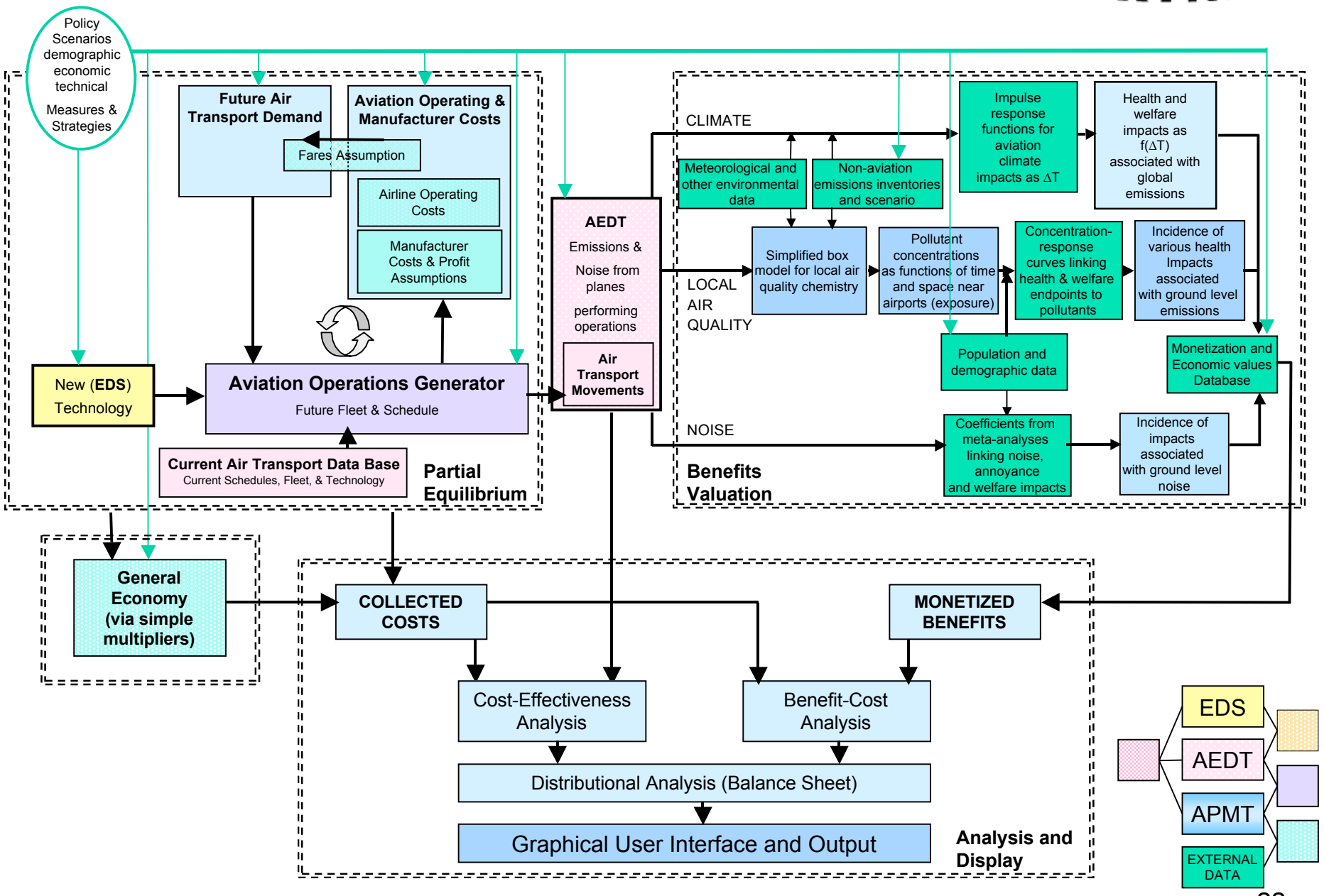
APMT Version 1



APMT Version 2



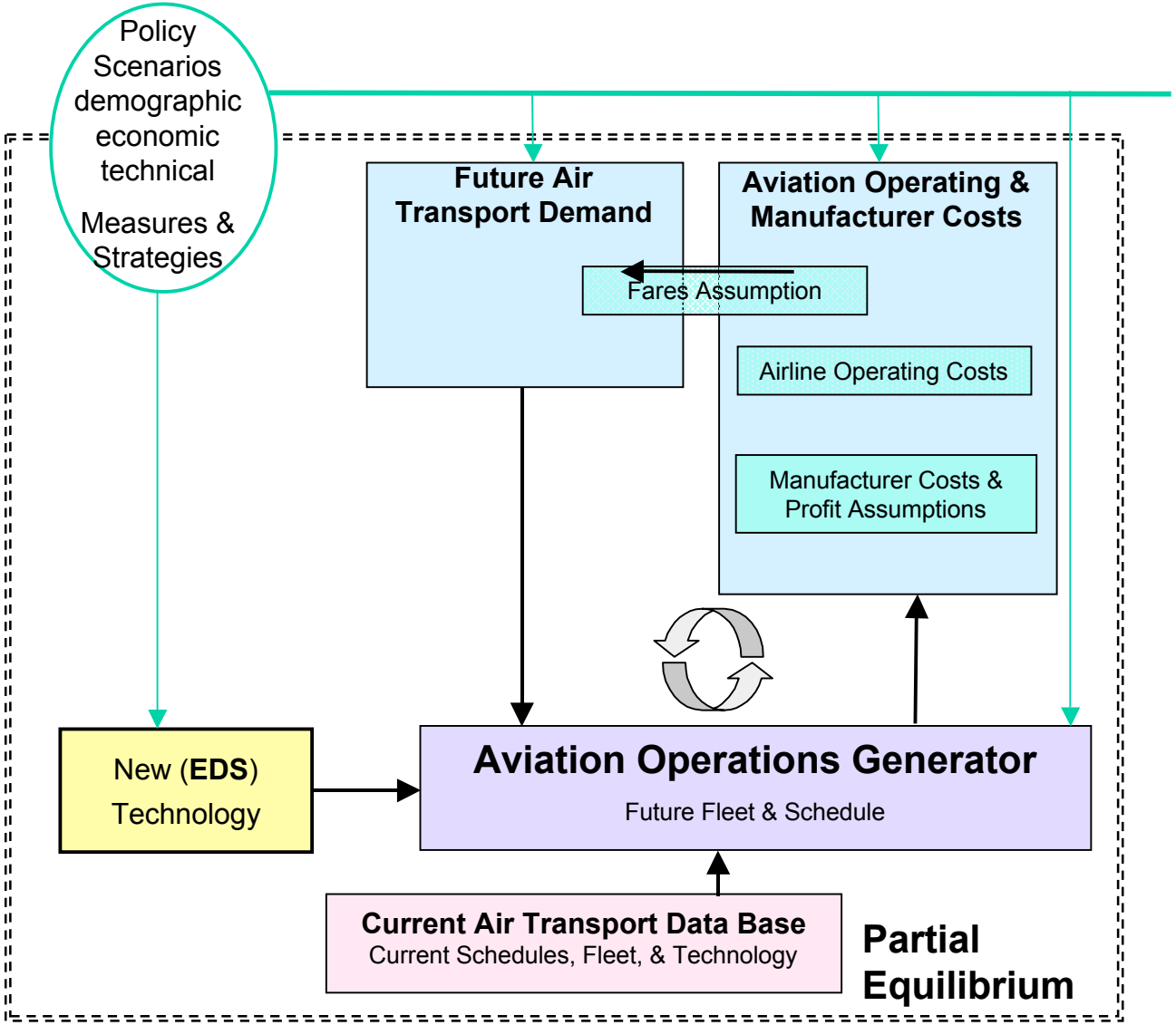
APMT Version 3

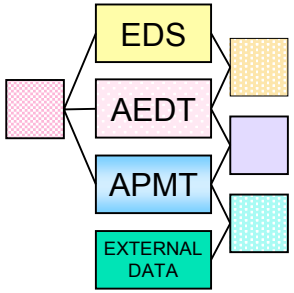


Competing objectives

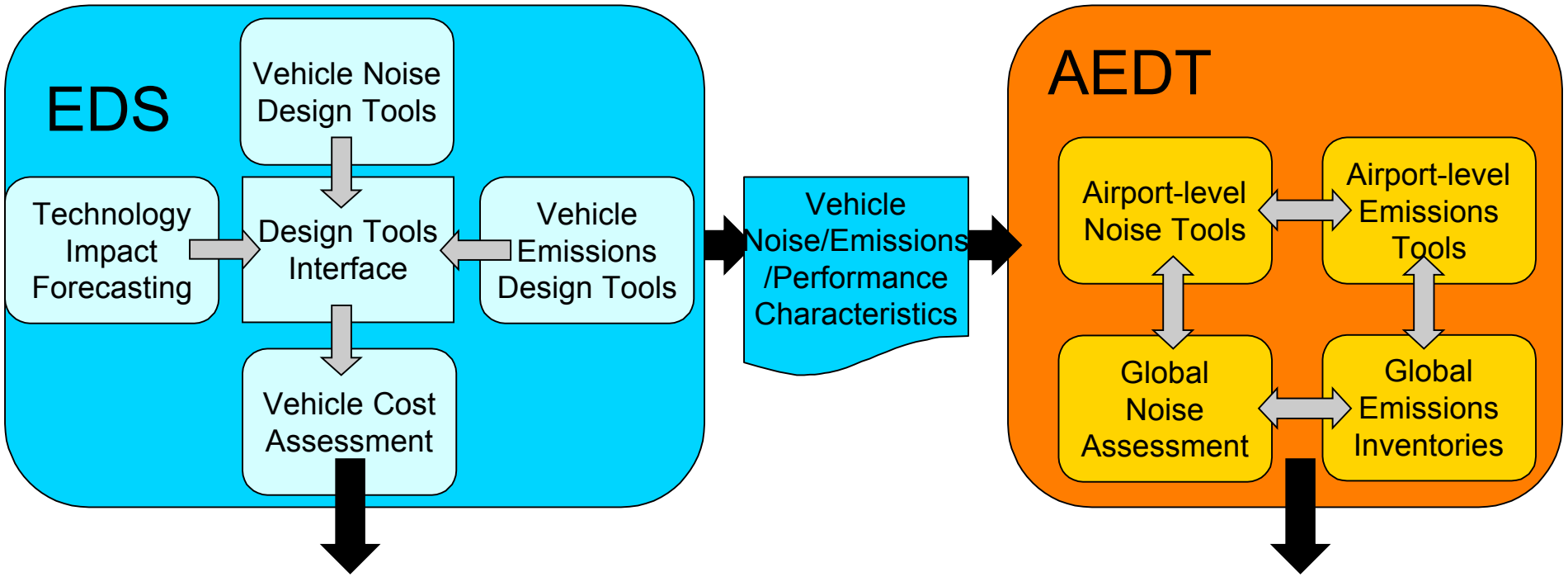
- Transparency vs. complexity
- Practicality vs. thoroughness
- New methods vs. existing practices
- The framework is general, but our development recommendations lean towards
  - Transparency
  - Practicality
  - New methods AND incorporation of existing practices
- Examples:
  - To capture ripple effects in broader economy we recommend using a carefully chosen, referenced, range of multipliers NOT a general equilibrium model
  - To estimate fares pass-through of costs we recommend choosing a range of scenarios and/or adopting simple constraints like AERO-MS
  - For converting FESG forecasts to operations we recommend starting with the MAGENTA approach but modifying it to include new technology aircraft from EDS

Partial equilibrium block





AEDT and EDS

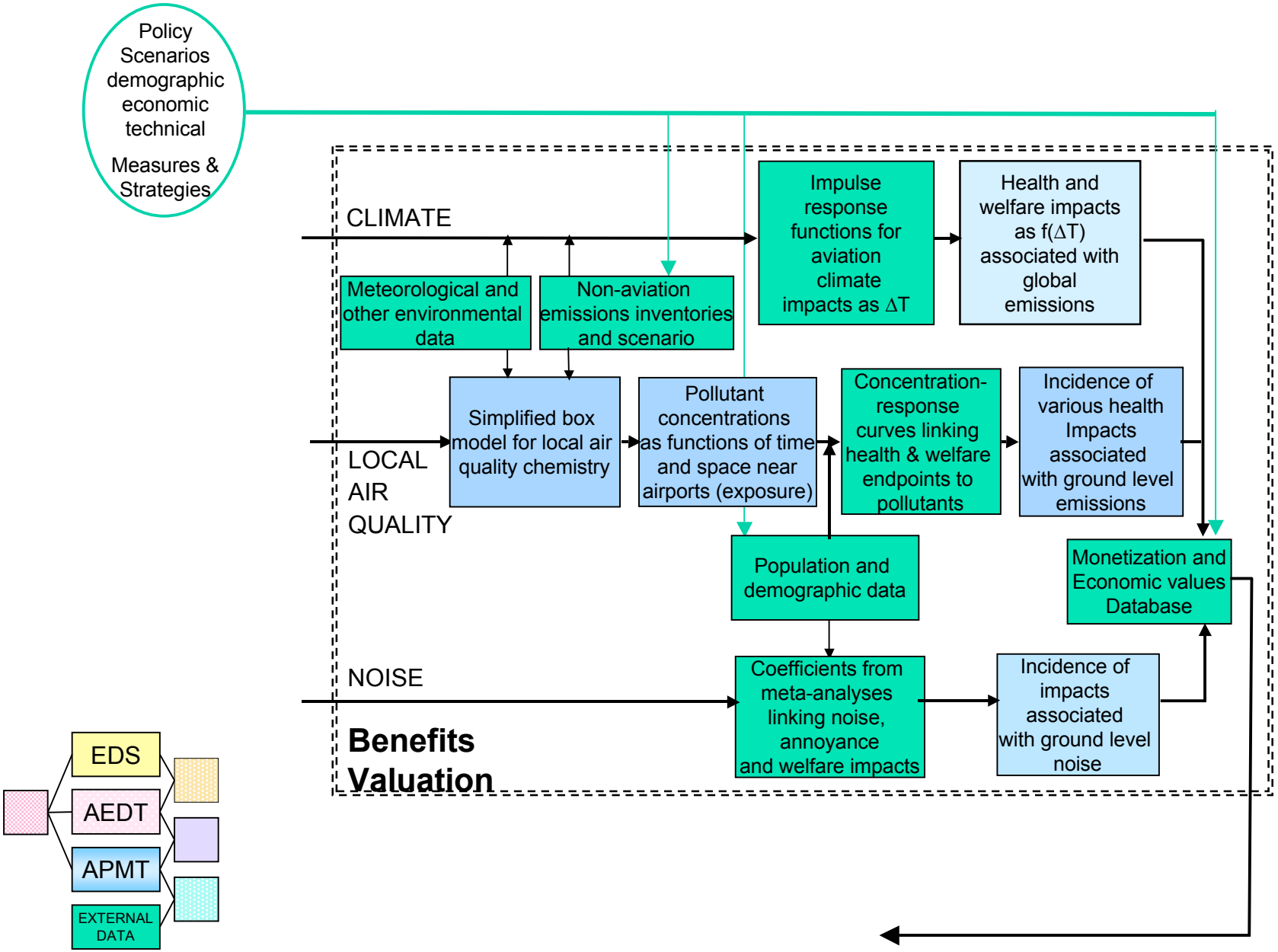


What are the costs associated with this design?

and

What are the benefits in implementing this design?

Benefits valuation block



Development recommendations

Component		Short term (Version 1)	Intermediate to Long term (Versions 2 & 3)
Partial Equilibrium	Future Air Transport Demand	Scenario Input e.g. FESG Forecast	
	Aviation Operations Generator	MAGENTA based approach	Modeling of air carrier fleet and schedule decisions
	Manufacturer Costs	Parametric representation of aircraft price databases ALCCA when desired fidelity requires	
	Airline Operating Costs	Based on AERO-MS ACOS module or similar modeling techniques	Additional modeling of fare structures
AEDT		Modified to accept input fleet and schedule	
Benefits Valuation		Development phase (not to be included in Version 1)	Use of MAIPA augmented to include components of BenMAP
General Economy		Development phase (not to be included in Version 1)	Use statistically based multipliers; Long term research on incorporation to CGE building on existing framework (EPA, MIT, or other)
Analysis and Display		Cost Effectiveness Analysis displayed in the form of balance sheets	Benefits Cost Analysis using monetized benefit outputs from benefits valuation module

Relationship to FESG

- Desire is to work collaboratively to develop models
  - That will encompass existing FESG practices
  - That will provide additional capability beyond existing practices
  - That FESG will find to be valuable and useful
- The models cannot replace the function of FESG
  - Inputs, model design, baseline choice, scenario choices, assumptions, interpretation of output, must be done by experienced experts (not computers)
- We hope the models will enhance the existing functions of the FESG

Summary

- Desire tools to enhance understanding of benefits-costs of policy options
- Initial planning steps underway
  - Requirements
  - Architecture
  - Plan for developing a prototype
- Complex, challenging task
- Seeking input and guidance
- Seeking collaboration
- For a copy of reports or to provide input: iaw@mit.edu