Aviation Environmental Portfolio Management Tool (APMT)

OVERVIEW

Presented to: TRB AEDT/APMT Workshop #4

By: Professor Ian A. Waitz

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APMT Development Team

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UNC CAROLINA ENVIRONMENTAL PROGRAM

the VOLPE center

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PARTNER

Partnership for AiR Transportation Noise and Emission Reduction

An FAA/NASA/TC-sponsored Center of Excellence

Outline

- **Statement of needs**
  - CAEP and JPDO
  - Best practice in environmental policy-making
  - Guidance from TRB
- **APMT Requirements Study**
- **APMT Architecture**
- **The APMT Prototype**
- **Assessment and capability demonstration**
- **Example APMT "Balance Sheets"**
- **Overview of next steps**

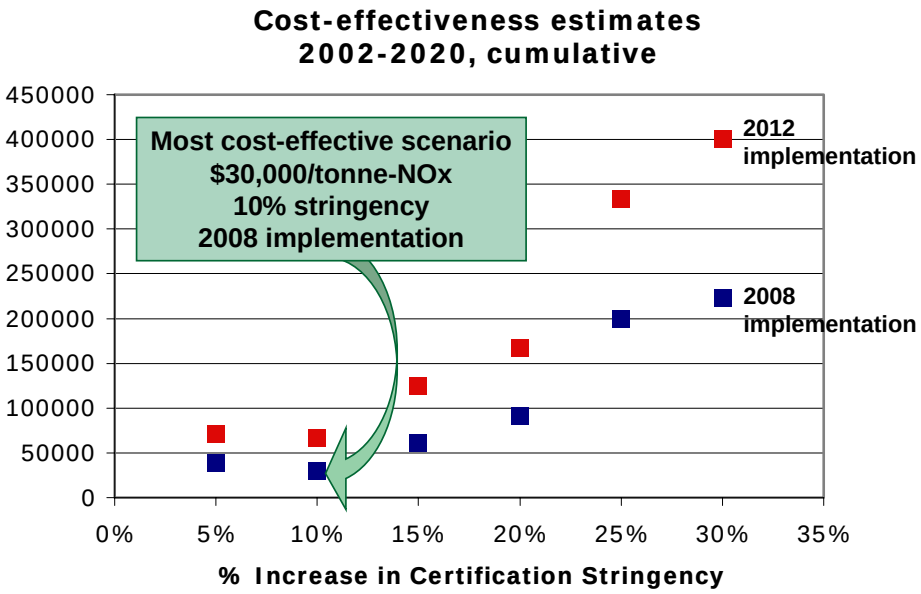
Cost-benefit terminology

- **We will use the typical terminology from environmental-economics literature**
  - "**Benefits**" = changes in health, welfare and ecosystem impacts of pollution
  - "**Costs**" = changes in monetary flows in markets
  - Benefits can be positive or negative
  - Costs can be positive or negative

Motivation for improved methods

- **Aviation benefits and environmental effects result from a complex system of interdependent technologies, operations, policies and market conditions**
- **Policy and R&D options considered in 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**
- **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

Current practice: CAEP/6 NOx stringency



Source: FESG CAEP/6-IP/13, estimates shown assume high estimate of manufacturers' NRC and lost fleet value, discount rate 3%

An incomplete balance sheet

- **CAEP/6 NOx stringency example**
  - Of several options for NOx reduction, the least expensive is $30,000/tonne-NOx; does this produce a net benefit to society?
  - How many tonnes of NOx reduction are needed?
  - **What is the impact of the additional fuel burn** estimated to be associated with the NOx reduction?
- **Must fill in the balance sheet to assess trade-offs**
  - Local air quality, noise, climate change, consumer and industry costs
- **The stakes are high (billions of $)**
  - **We, as a community, need to improve our methods and tools and do this better than we do it today**

Guidance from prior TRB workshops

- **November 2004**
- **April 2005**
- **May 2005**

Focused on APMT

TRB May 2005

✓ = good progress ✓ = limited progress

Vision and Objectives for APMT	Status	Notes
Consistency. APMT must be based on consistent, coherent, and accepted economic theory.	✓	Requirements drawn directly from international literature and policy guidance
Flexibility. APMT should be flexible and modular, more of a framework than a single model or tool, to allow its development over time and use by diverse possible stakeholders.	✓	APMT is modular
Transparency. APMT development must be transparent in general in relation to the data and methodologies employed.	✓	All methods, data, assumptions and assessments are being documented and shared publicly

TRB May 2005

✓ = good progress ✓ = limited progress

Vision and Objectives for APMT	Status	Notes
Credibility. APMT must be credible and accepted across a wide range of stakeholder interests, including the derivation of compliance costs and monetization of externalities. APMT must meet all requirements for use within the United States regulatory context. This criterion poses a major challenge beyond the challenges of integrating many different models and data sources.	✓	APMT consistent with multiple US & EU requirements Internationally-accepted AEDT and AERO-MS models and methods are a foundation But much work remains
Uncertainty. APMT must explicitly address the many layers of uncertainty in the analysis. The ways in which the model outputs can be used to drive analyses of uncertainty should be covered in any descriptive material on the model and in its user manual.	✓	We are explicitly addressing uncertainty within the tool and through rigorous assessment processes

TRB May 2005

✓ = good progress ✓ = limited progress

Vision and Objectives for APMT	Status	Notes
Integration. A robust modeling effort must consider that increased airline and manufacturer costs of compliance with new requirements would affect the demand side for air transportation and therefore the level of emissions. Thus, APMT needs some feedback loop to reach an equilibrium state.	✓	We use partial equilibrium modeling of the aviation market
Distributive Effects. In addition to providing summary information about overall social welfare impacts, APMT should be capable of providing data about the incidence of costs and benefits associated with aviation environmental issues.	✓	We provide distributional analyses on many dimensions (geographical, by market segment, by impact type, etc.)

TRB May 2005

✓ = good progress ✓ = limited progress

Next Steps in APMT Development	Status	Notes
Work Plan. FAA should immediately develop a more detailed work plan with specific milestones and schedule for the APMT project and its interface with AEDT. The work plan should identify the human and other resources needed to develop APMT to a level at which it can be accepted as a tool to support deliberations in the U.S. as well as in the international community.	✓	The prototype work plan is available at www.partner.aero
Staffing. Concomitant with the work plan, FAA should identify adequate economic capabilities within its project staff to advise or lead the APMT development effort.	✓	Several economists are part of the development team, but we are seeking more

TRB May 2005

✓ = good progress ✓ = limited progress

Next Steps in APMT Development	Status	Notes
Requirements Development		APMT Requirements Document is available at www.partner.aero
Detail necessary and desirable outputs for APMT.	✓	Complete
Specification of the economic framework to achieve these ends.	✓	Complete
Map of critical data needs and relationships.	✓	Complete
Identification of data & model availability and gaps.	✓	Complete
Specification of architectural needs.	✓	The APMT Architecture Study is available at www.partner.aero
A more complete survey of the available literature, models, and data relating to the APMT elements.	✓	Complete

TRB May 2005

✓ = good progress ✓ = limited progress

Next Steps in APMT Development	Status	Notes
Prototype Study. The committee believes that, after development of the detailed requirements, it would be useful for FAA and its partners to undertake a 6- to 9-month prototype study to explore the feasibility of the concept. It might be useful to demonstrate some features of APMT in a limited way within a working prototype. This study should use a scenario that captures the multi-pollutant and noise trade-offs.	✓	The APMT Prototype Workplan is available at www.partner.aero APMT Prototyping effort was launched in February 2006 APMT Prototype is now operational
Interaction with AEDT Architecture Study. FAA should--to the extent possible--account for the likely requirements of APMT in the architecture study that will be needed soon for AEDT.	✓	The AEDT and APMT development teams have many common members

TRB Workshop Guidance

- **In sum, the TRB workshop participants said:**

  FAA must make APMT an immediate priority

  It is. **(40 people, $1.7M for one year prototype effort)**

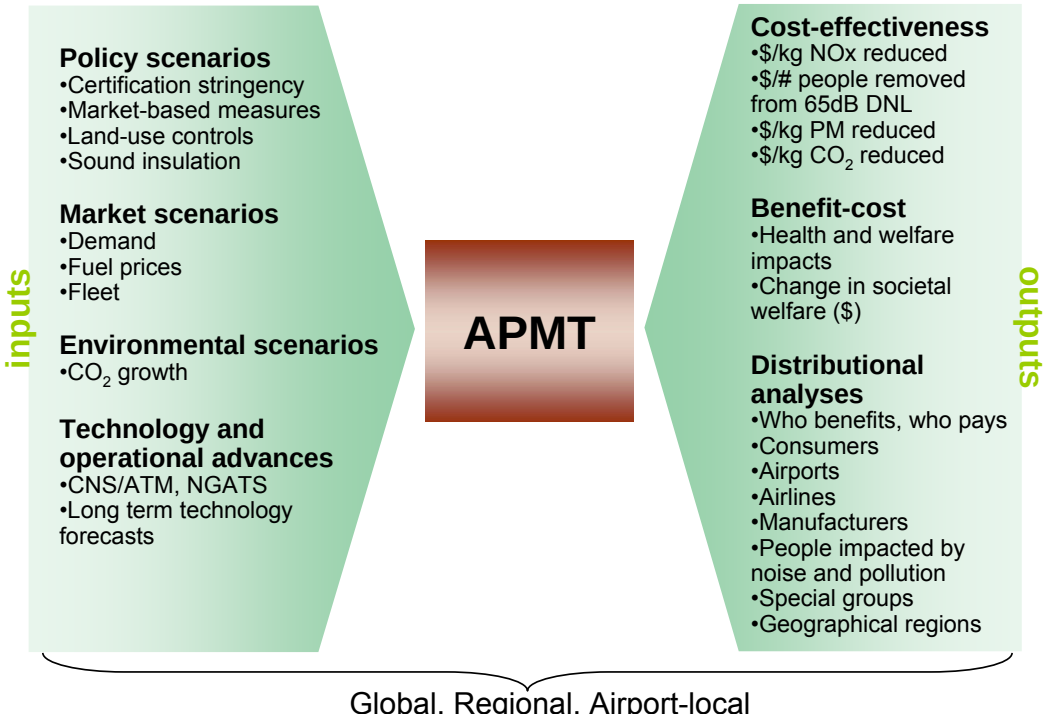
Series of three APMT studies

- **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

Literature review to establish recommended practice

- **Extensive review of literature and tools (aviation and non-aviation); key 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]

APMT requirements



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**

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]

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]

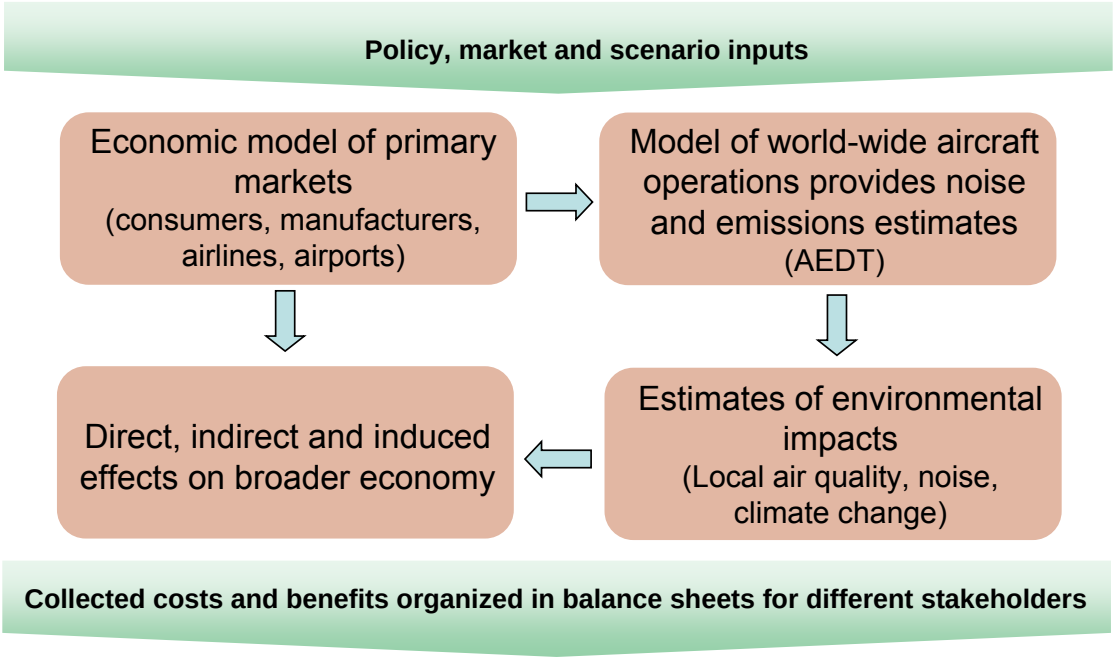
Recommended timeline for responding to requirements

Development Time	Title	Scope	Capabilities
Years 1-3	APMT v1 Enhanced Cost-Effectiveness Capability	National/Global	Cost-effectiveness analysis that 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
Years 6-8+	APMT-Local v1	Local/Regional	Perform benefit-cost assessment on local/regional scale

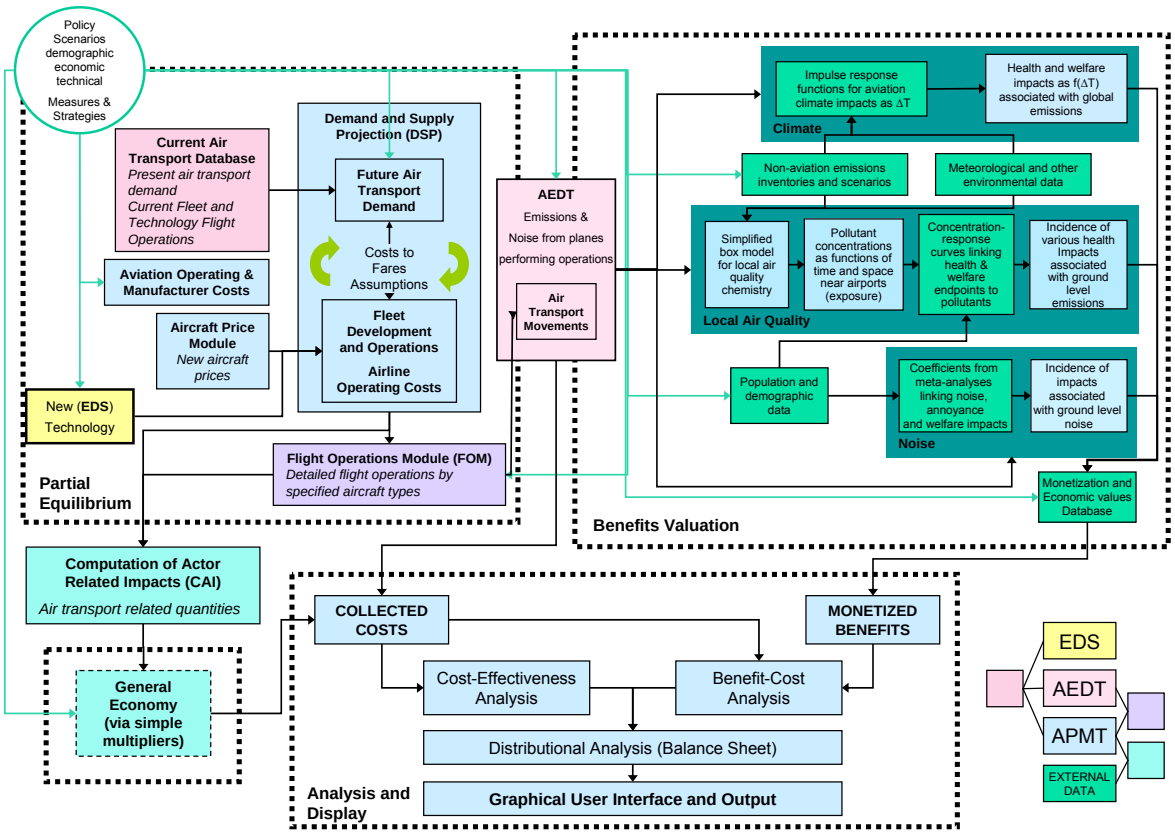
Competing objectives

- **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

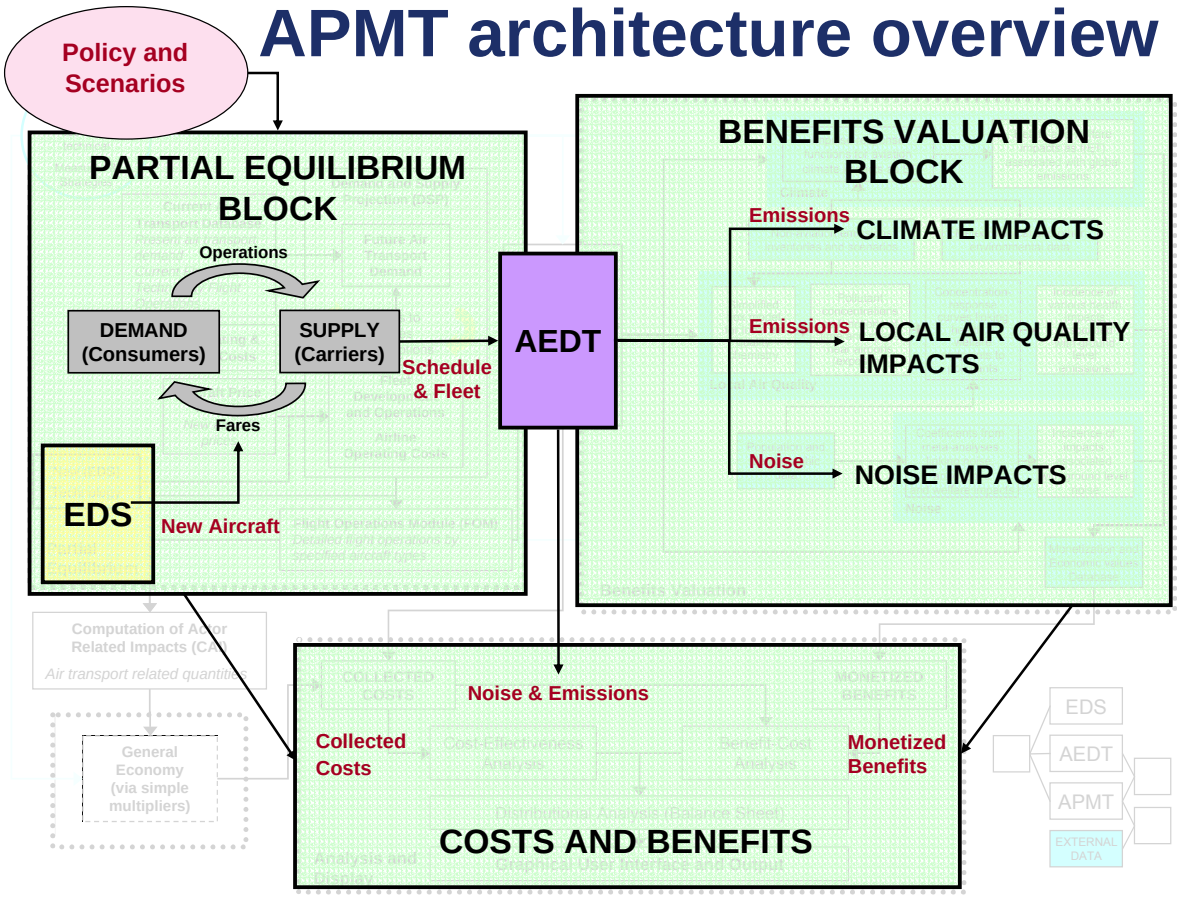
APMT architecture concept



APMT architecture detail



APMT architecture overview



Prototype work plan

- **Describes steps taken in first year to develop an *APMT Prototype***
- **APMT Prototype constructed to identify gaps or weaknesses in architecture and stimulate advancements in development of APMT**
- **Have constructed all of the functional modules of APMT, although in some cases with more limited capabilities than planned for the final versions**
- **Now testing the functionality of APMT for addressing various policy questions**
- **Assessing and propagating uncertainties from the module level to the APMT system level to guide the determination of high priority areas for future development and refinement**

Prototype progressing rapidly

- ***September 2005***
  - Requirements and Architecture defined
  - Reported on APMT at ICAO/CAEP/FESG meeting in Reykjavik
- ***February 2006***
  - Prototype work plan developed
  - **International review of Requirements Study, Architecture Study and Prototype Work Plan**
  - International team formed
  - APMT Prototype contract in place (12 month period)
  - Kick-off meeting held Feb 16-17, 2006
  - Reported on APMT at ICAO/CAEP/FESG meeting in Montreal

Prototype progressing rapidly

- ***July 2006***
  - All components of APMT Prototype coded and provided to integration team
  - Component and system-level assessment and capability demonstrations initiated
- ***August 2006***
  - ICAO/CAEP/TG2-FESG Ad Hoc Group meeting
  - All components of APMT Prototype fully functional

Prototype progressing rapidly

- ***December 2006***
  - **Fully-integrated APMT Prototype complete**
  - Capability demonstrator problems 90% complete
  - Component-level assessment 30% complete
  - Preparing documentation on methods, assessment and capability demonstration problems
  - Preparing work plan for next year

APMT assessment and evaluation

- **Four components:**
  - Formal statistical analysis of uncertainties and propagation to system-level metrics (30% complete)
  - Capability demonstrator problems (90% complete)
  - Initial expert review of some components/modules (100% complete)
  - Comparison with AERO-MS (100% complete)

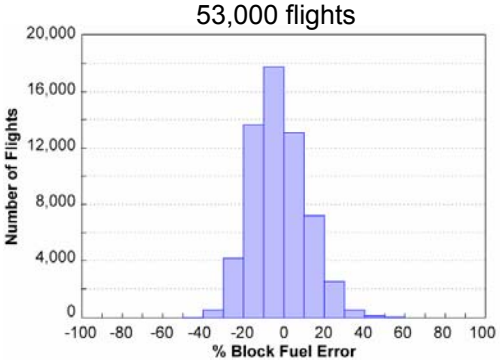
Formal analysis of uncertainty

1. **Document module assumptions**
2. **Identify and categorize module inputs**
3. **Identify module outputs**
4. **Perform a design of experiments (DoE)**
5. **Perform an analysis of variance (ANOVA) to identify the key inputs**
6. **Quantify module uncertainty**

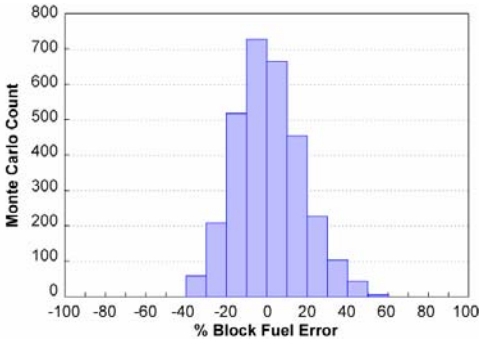
Result: **A table listing key inputs and assumptions with a quantitative estimate of their impact on system level metrics**

Formal analysis of uncertainty
example from AEDT/SAGE

Comparison to airline data
53,000 flights



SAGE Monte Carlo simulation



Parameters	Beta	Std. Err.	Contribution to Var.
Engine fuel consumption	0.480	0.00271	24.0%
Aerodynamic drag	0.592	0.00313	36.5%
Takeoff weight	0.374	0.00132	14.6%
Winds aloft	0.249	0.00271	6.46%
Ambient temperature at cruise	0.024	0.00271	0.060%
Cruise altitude	-0.111	0.00374	1.28%
Dispersion track	0.406	0.00374	17.2%

"Assessment of Uncertainty in the SAGE Fuel Burn and Emissions Model and Applications to Policy Analysis", Joosung J. Lee, Ian A. Waitz, Brian Y. Kim, Gregg G. Fleming, Lourdes Maurice, and Curtis A. Holsclaw, in review, 2006.

Capability demonstrator problems

- **The objective IS**
  - to demonstrate capability by assessing system level responsiveness and sensitivity to relevant policy scenarios
- **The objective IS NOT**
  - to accurately quantify costs and benefits for specific policies
- **Therefore, we make many assumptions for convenience and expedience**
  - For example, using a representative day x 365, 2002 datum year, only one seat class for EDS aircraft, etc.
  - **These assumptions should not be interpreted as model limitations**

Capability demonstrator problems

- **Reduced thrust take-offs (consistent with CAEP sample problem)**
- **Fuel price (with and without EDS aircraft)**
- **NOx technology stringency (with and without EDS aircraft)**
- **Noise-phase out**

Expert review and collaboration

- **ICAO/CAEP TG2-FESG Ad Hoc Group**
  - Aviation environmental policy analysis
- **University of North Carolina (Arunachalam, Hanna)**
  - Local air quality modeling
- **Climate experts (Shine, Sausen, Wuebbles)**
  - Climate impact modeling
- **Harvard School of Public Health (Levy, Spengler)**
  - Health impact assessment and valuation

Comments from expert reviews

- **Professor Levy (Harvard School of Public Health) on health impacts assessment**
  - *APMT approach is widely accepted and will yield interpretable results*
  - *Method for economic valuation of health endpoints in APMT is sound*
  - *I applaud the APMT model team for incorporating a health benefits assessment methodology which is in agreement with the general framework used in environmental risk assessment."*
- **Professors Shine, Sausen and Wuebbles on climate impact modeling**
  - *Our overall assessment is that [the APMT team has] developed an appropriate modelling tool, consistent with current understanding in climate science and of a complexity which is consistent with other assessment tools used more generically within climate research.*
  - *The method will facilitate the possibility of quantitative comparisons of different environmental impacts of aviation such as climate, air quality and noise effects which we understand to be the aim of APMT.*

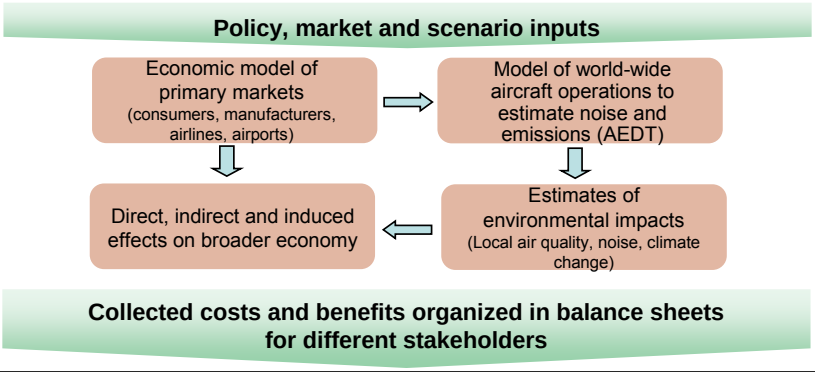
AERO-MS and APMT comparison

- **AERO-MS and APMT PEB: common team members**
- **AERO-MS and APMT compared in terms of**
  - Scope:
    - Environmental policies considered
    - Scope of aviation noise and emissions computed
    - Scope of forecasting capabilities
    - Environmental impacts
    - Economic impacts
  - Main modeling principles and assumptions:
    - Cost-to-fare translation mechanism
    - Fleet choice model
    - Fleet retirement
    - Snapshot versus year-to-year forecasting
    - Spatial schematization
    - Price elasticities
    - Integration and Model running and analysis facilities

Summary: Assessment and Capability Demonstration

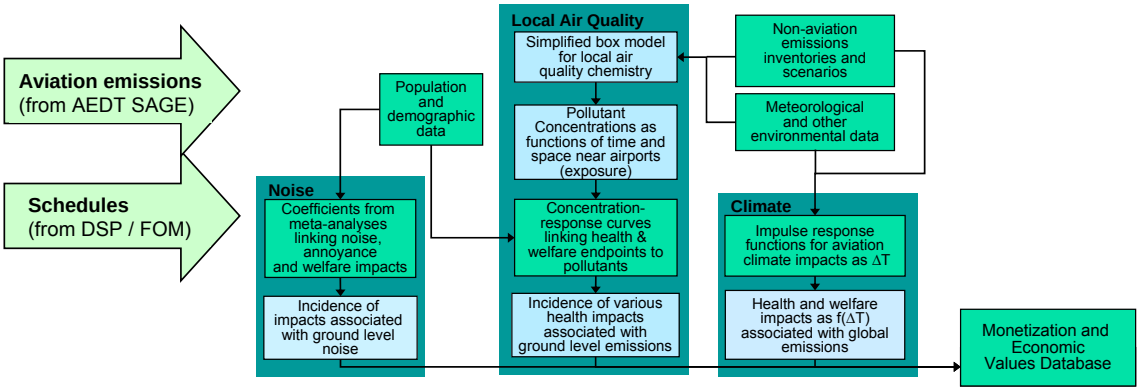
- **Robust assessment and evaluation underway for APMT**
  - Formal statistical analysis of uncertainty
  - Capability demonstrator problems
  - Expert reviews
  - Comparison with AERO-MS
- **Objectives by December 31, 2006**
  - Fully-functional prototype
  - Detailed document describing methods, data, assumptions
  - Assessment and evaluation report
  - Plan for further development of APMT

Example Balance Sheet: Monetary



$ Results for different assumptions, scenarios, user-selected preferences.					
•By airport •By aircraft type •By altitude-band •Regional emissions •Global emissions •User-specified aggregation	Costs to airlines, manufacturers, aviation consumers	Noise Benefits	LAQ Benefits	Climate Benefits	Total Benefits - Costs
Policy Case					

Balance Sheet: Environmental



Results for different assumptions, scenarios, user-selected preferences.				
•By airport •By aircraft type •By altitude-band •Regional emissions •Global emissions •User-specified aggregation	Noise Benefits **55 DNL Area Population affected Housing depreciation**	Local Air Quality Benefits **Population affected Premature mortality Morbidity for multiple health endpoints**	Climate Benefits **Change in average global surface temperature**	Total Environmental Benefits
Policy case				

APMT development and use

- **APMT will provide a flexible framework for informing policy decisions**
- **APMT will not predict the future (we know we can't do that)**
- **APMT will be used to estimate policy impacts under**
  - different scenarios
  - different perspectives on how to "value" impacts
  - different assumptions

In other words

"The root of many problems lies not in the models themselves but in the way in which they are used. Too often we ask "What will happen?", trapping us into the mug's game of prediction, when the real question should be: "Given that we cannot predict, what is our best move today?" This subtle shift in emphasis from forecasting to informing resolves many of the conundrums...

Instead of determining the "best" model that solves optimal strategies we should instead seek the most "robust" model that achieves a given level of "goodness" across myriad models and uses assumptions consistent with known facts."

Steven Popper
Senior economist, RAND Corporation, Santa Monica, California
(In a letter to the *Economist*, July 2006)

Next steps

- **Two-part ICAO/CAEP review cycle (Cost-effectiveness, Benefit-Cost)**
  - Assessment and further development of capability demonstration problems
- **System-level assessment**
- **Further development of modeling methods**
  - Air quality analysis
  - Consultation on benefits valuation
- **Streamline integration and interfaces**
- **Establishing linkage to NGATS**
- **Longer-term research and development (to 2013)**

Risk areas

Risk	Level	Strategies*
Interdependencies paradigm a challenge for policy-making bodies; information overload; APMT results not used effectively	High	• Establish research effort to engage experts in decision-making •Continuous engagement with ICAO/CAEP
Problem does not contract with further work, but expands; team is under-resourced for the scale and complexity of the problem	High	•Add team members •Develop more effective risk mitigation strategy and prioritize work effort
International data availability	High	•Establish partnerships •Add team members •Reduce scope
Research required to develop improved air quality modeling	Medium	• Increase work-effort with HSPH, UNC and EPA

**Not necessarily consistent with resource constraints*

Summary

- **TRB participants said "Make APMT a priority" -- *It is.***
- **From May 2005 to December 2005 we progressed from ideas and recommendations, to a formal requirements document, architecture study and prototype work plan**
  - Fully-consistent with prior TRB workshop recommendations
- **From January 2006 to today, we progressed from plans and legacy codes to a fully-functional operational prototype**
- **We will be pleased to share much more with you**
- **We welcome you input and engagement**

??? Questions ???

FAA Environmental Tools web site:

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