Project 48
Analysis to Support the Development of an Engine nvPM Emissions Standard

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Motivation

- The combustion of fuel is a source of non-volatile particulate matter (nvPM), with a size less than 2.5 µm ($PM_{2.5}$). Aircraft engines also emit "ultrafine" particles that are considered to be more harmful than larger $PM_{2.5}$ particles and may be more toxic to humans than other sources of particulate matter.
- Exposure to $PM_{2.5}$ and "ultrafine" particles has been associated with health risks such as cardiopulmonary disease leading to premature mortality.
- nvPM emissions at cruise contribute to aviation's climate impact through direct black carbon radiative forcing. They also provide a surface for ice crystals to nucleate, supporting the formation of contrails.

In order to reduce these environmental impacts, the ICAO-CAEP is developing a standard for nvPM mass and number emissions for aircraft engines to reduce aviation's environmental impact.

Objectives

This projects helps support the FAA decision-making process related to the development of the standard, while providing an independent assessment of the CAEP analyses. The main tasks include:

- Writing reviews on each of the APMT-I tools suite models and presenting these to a CAEP task force to facilitate discussions on cost-benefit analyses (CBA).
- Provide independent evaluation of candidate nvPM metrics and identify potential stringency options (SOs).
- Evaluate proposed fuel sensitivity corrections, ambient conditions corrections, and nvPM modeling approaches in collaboration with other FAA-sponsored researchers
- Verify estimates of technology responses to different nvPM metrics and stringency options.
- Generate and assess mappings from representative engines to a broader set of engine/airframe combinations accounting for variations in engine technologies.
- Develop tools and processes to be used in cost/benefit analyses of possible nvPM standards including economic, climate, air quality, and noise impacts
- Conduct CBA to identify the optimum stringency options for the nvPM metrics.

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Summary

Aviation emissions contribute to air quality and climate impacts. Policies must be developed to direct the technology towards a cleaner future. In the current policy cycle, ICAO-CAEP is developing a standard to control nvPM mass and number emissions.

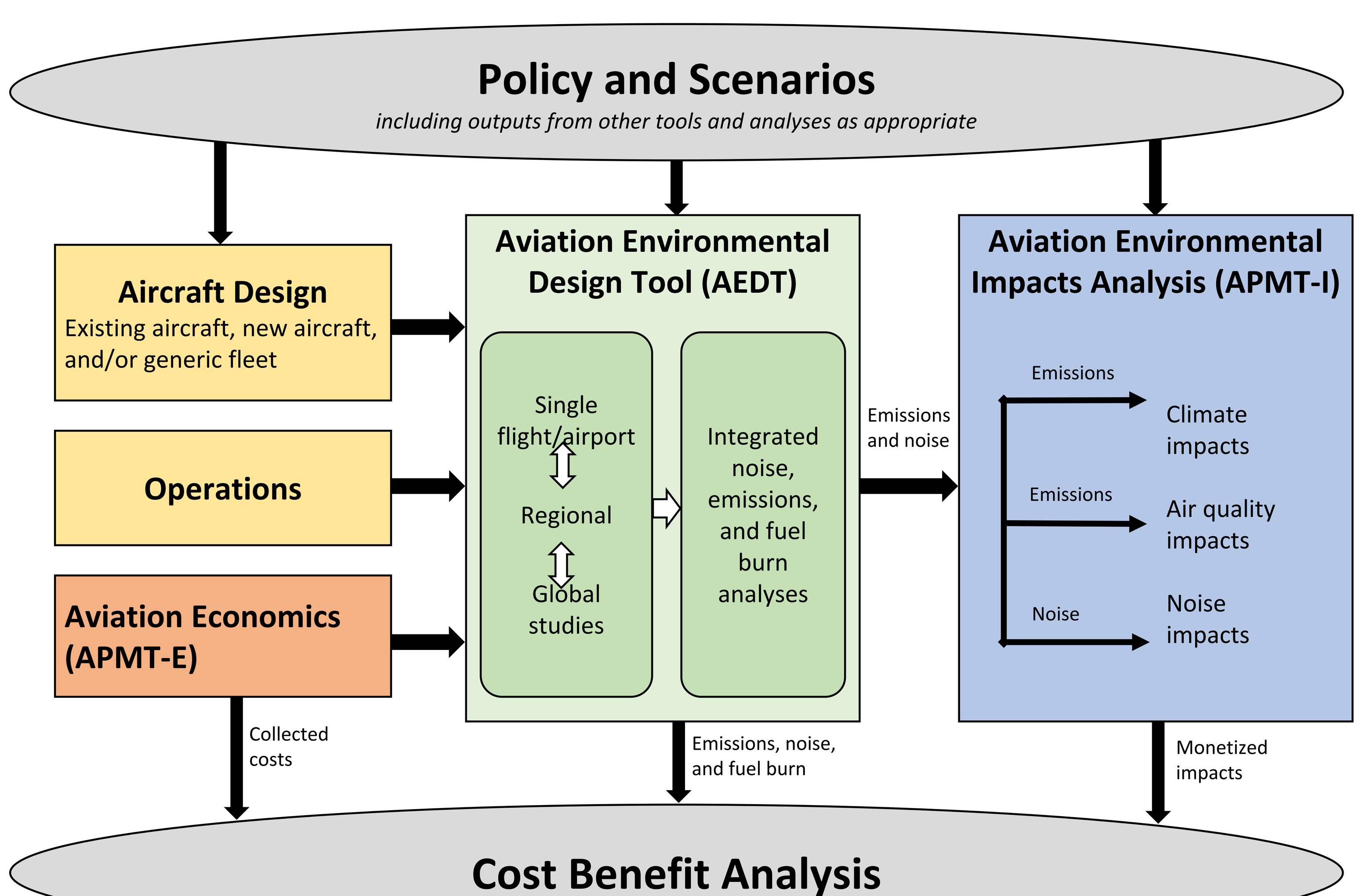
By aiding the CAEP analyses and FAA decision-making process, we aim to identify cost beneficial stringencies that can reduce aviation's environmental impact using the APMT-I tools. In addition, we aim to motivate and convince CAEP to move away from cost-effectiveness analysis (CEA) to adopt CBAs.

Results & Discussion

The first two tasks have now been completed.

APMT-I presentations to CAEP

Four reviews have been developed outlining the physical basis of each of the APMT-I models (air quality, climate and noise) and the concept of CBA. The reviews includes a detailed overview of the scientific models, the uncertainties and the methods used to monetize the environmental impacts. Each review has been presented to a CAEP task force that will assess the validity of each model and the potential of using CBA in addition to cost-effectiveness analysis (CEA).



Development of candidate nvPM metrics and stringency options

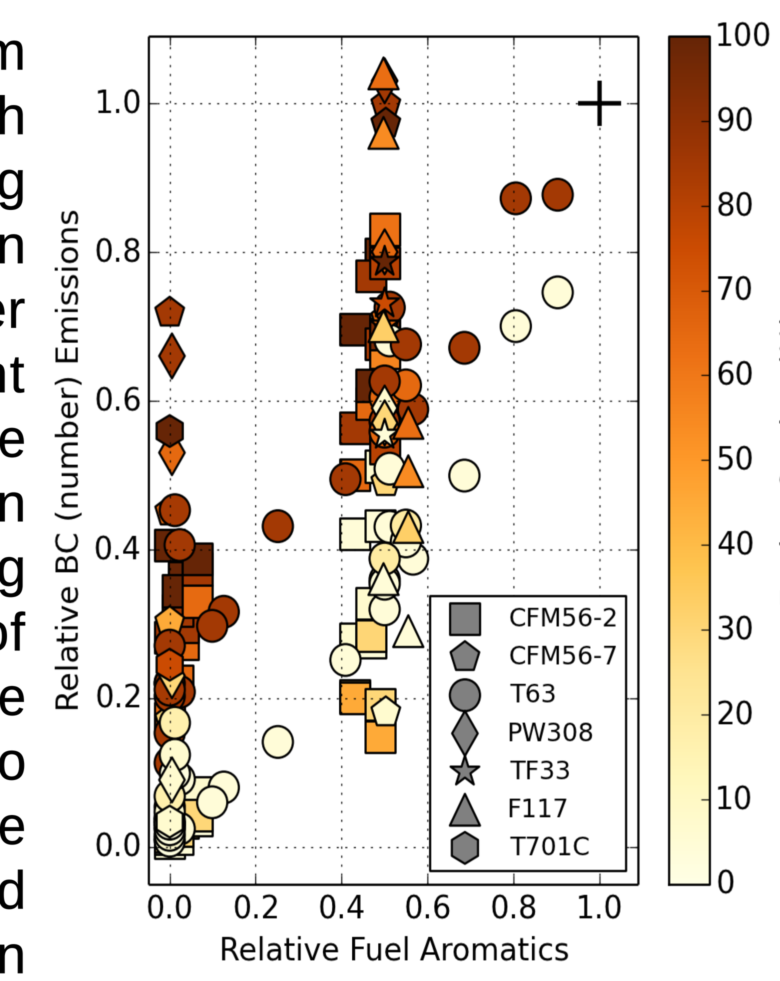
Detailed measurements of nvPM emissions from a range of engines have been collected from engines chosen such that they span the expected design space, allowing their measurements to be used to select an appropriate metric. We have aided the CAEP process in selecting a final metric and this has been used to develop In-Production and New-Type stringency options (SOs).

This process has involved:

- Finding trends in the measurements that may identify parameters that are well correlated with nvPM emissions.
- Identifying metrics such that they can characterize the benefits (i.e. thrust) and costs (i.e. nvPM emissions).
- Considering the fundamental size limitations that should be incorporated in SOs.

Fuel sensitivity corrections

Emissions data collected from engines operating on fuels with varying composition is being used to determine correction factors for mass and number emissions for different certification fuels. Candidate correction methods have been developed and are being evaluated. Preferred features of the correction method are simplicity and the ability to quantify uncertainties. The corrections will be incorporated into Annex 16, Vol II for use in future regulations.



Speth et al. (2015)[1]

Future Work

Using the developed SOs, manufacturers are preparing to submit technology responses. Our next steps involve verifying these responses and the costs involved and using them to assess the effect of imposing the different stringency options on the environment. In addition, we are conducting the mapping from representative engines where nvPM emissions are known to a broader set of engines that are required for forecasting emissions.

Contributors & Collaborators:

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[1] Speth, R.L., Rojo, C., Malina, R., Barrett, S.R.H., 2015. Black carbon emissions reductions from combustion of alternative jet fuels. Atmospheric Environment 105, 37–42.