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 form, 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.
- 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.

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.

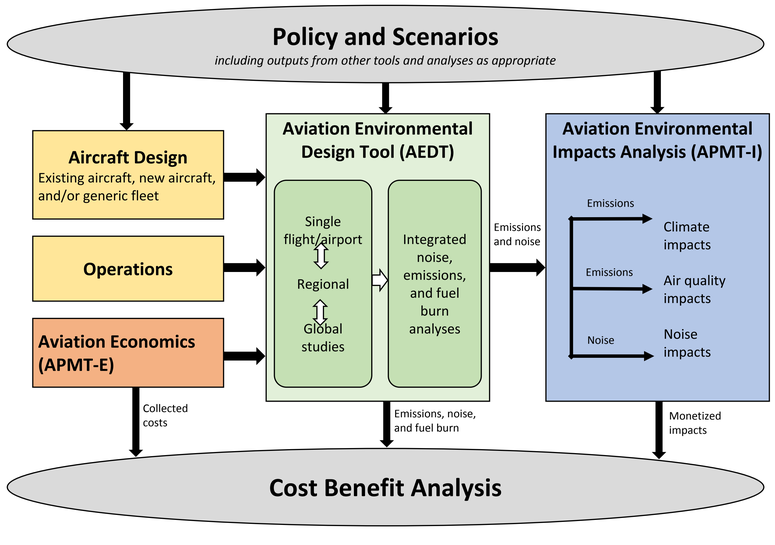
By aiding the CAEP analyses and FAA decision-making process, we aim to identify cost beneficial stringencies that can reduce aviation's environmental impact using the APMT-I tools. In addition, we aim to motivate and convince CAEP to move away from cost-effectiveness analysis (CEA) to adopt CBAs.

Results & Discussion

The current focus of work has been on supporting the CAEP processes defined in the first three tasks.

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 is being 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).



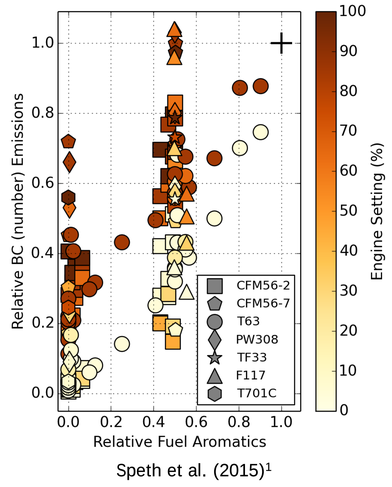
Evaluating candidate nvPM metrics

Detailed measurements of nvPM emissions from a range of engines has been collected from engines chosen such that they span the expected design space, allowing their measurements to be used to select an appropriate metric. This process has involved:

- Finding trends in the measurements that may identify parameters that are well correlated with nvPM emissions.
- Studying potential metrics that can characterize the benefits (i.e. thrust) and costs (i.e. nvPM emissions).

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. Fuel characteristics being examined include hydrogen content, aromatics content, and naphthalene content. Dependencies of the correction factor on engine parameters are being evaluated.



Speth et al. (2015)[1]

Future Work

As the nvPM metric and correlating parameter is finalized, appropriate stringency options will be developed. These selections will feed into emissions and economics models that can be used to conduct a CBA using the APMT-I tools. Our immediate goal is to work with the FAA to independently evaluate stringency options chosen by the CAEP task groups.

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.