ACRP Problem No. 12-02-12

Improved Take-Off Thrust Setting Estimates for Airport Emissions Inventories

ACRP Staff Comments: The proposed research would build on and would need to consider ACRP Project 02-03A, Measurement of Gaseous HAP Emissions from Idling Aircraft as a Function of Engine and Ambient Conditions; ACRP Report 9, Summarizing and Interpreting Aircraft Gaseous and Particulate Emissions Data; ACRP Report 11 and Web-Only Document 2, Guidebook on Preparing Airport Greenhouse Gas (GHG) Emissions Inventories; ACRP Project 02-08, Quantifying Contributions to Local Air Quality Impacts from Airport-Related Emissions; and ACRP Project 02-12, Environmental Optimization of Aircraft Departures: Fuel Burn, Emissions, and Noise.

TRB Aviation Group Committees Comments: AIRCRAFT/AIRPORT COMPATIBILITY CMTE - The ultimate deliverable is not well defined, and that is key to the research having value. The resulting model should be able to predict thrust settings and the emission levels that result.

ENVIRONMENTAL IMPACTS OF AVIATION CMTE - Support. This problem statement is essentially identical to Problem Statement 12-02-09, Modeling Reduced Thrust Takeoffs in Standard Environmental Tools, except that it focuses on emissions rather than noise. Actually, it’s not so much a noise or emissions issues but rather one of aircraft performance and operations. Both of these proposed projects will help fill a gap in the Integrated Noise Model (INM)/Emissions Dispersion Modeling System (EDMS) and the Aviation Environmental Design Tool (AEDT) that have persisted for a long time. Although the funding level for this project is $450,000, it can be combined with 12-02-09 for a total of $400,000.

Review Panel Comments: Recommended — Consider combining this with ACRP Problem Statement 12-02-09, with 12-02-12 serving as the primary problem statement. Should have a combined emphasis on noise and air quality. Some work has been done, but questions remain on the compatibility between modeling results and actual data. Other research in this area of inquiry is not completely verified against field data. If additional data is required, budget should be increased to cover both air quality and noise.

AOC Disposition: Approved and funded at $450,000. Some questioned whether this was beyond the purview of ACRP and more appropriately handled by the FAA; however, their research funding has been reduced. This effort should be combined with Problem Statement 12-02-09, Modeling Reduced Thrust Takeoffs in Standard Environmental Tools. The AOC cautioned the research panel to make sure the information needed to undertake the study is available and readily obtained; otherwise, the project should not be undertaken.
I. PROBLEM TITLE

Improved Take-Off Thrust Setting Estimates for Airport Emissions Inventories

II. RESEARCH PROBLEM STATEMENT

The take-off roll contributes a large fraction (typically 40%) of ground-level NOx emissions from aircraft. Although the duration of the roll is relatively short, the emission rate is high because both emission index (g NOx per kg fuel) and fuel flow (kg/s) increase with thrust for most aircraft types, so that NOx emission rate is roughly proportional to the square of thrust. This also means that the emission rate is very sensitive to the thrust used. Although NOx emissions are particularly sensitive to thrust, fuel use (and therefore CO2 and other emissions) are also thrust-dependent (approximately proportional). Emissions of PM are somewhat dependent on thrust, but slightly less sensitive than fuel.

At many airports, aircraft routinely use less than full thrust when taking off, primarily to reduce wear on the engines and increase the life of the high temperature components. The extent of this thrust reduction is limited by operational regulations, but may be as much as a 25% reduction from full thrust (and may be greater if engine derate is used as well). However, the actual thrust settings used on take-off are not readily available to compilers of inventories, leading to uncertainty in the results of airport emission inventories for pollutants such as NOx, PM and CO2 inventories, and in modeled ambient concentrations around airports.

One existing method for estimating take-off thrust is based on the ratio of actual take-off weight to performance-limited take-off weight, however both of these numbers can be difficult to obtain either on a per-movement basis or on a more aggregated (e.g. per-airline, per-aircraft type) basis.

III. OBJECTIVE

To develop an improved methodology for estimating aircraft take-off thrust settings, suitable for use in compiling airport emissions inventories. The input data for the methodology would be simple, readily-available, high-level data such as aircraft type, operator, airport type, simple meteorological parameters etc. The methodology would not necessarily be able to predict the thrust setting for a given take-off with high accuracy, but would provide an accurate average when taken across all movements at an airport over the course of a year.

IV. RESEARCH PROPOSED

Steps involved in this study could potentially include:

1. A literature review to document existing work undertaken, including how Base of Aircraft DAta (BADA) is used within EDMS/AEDT and how Quick Access Recorder (QAR) data could be used to refine the takeoff methodology.
2. Data collection of QAR and related data.
3. Methodology development.
4. Memorandum on incorporating the methodology into AEDT.
5. Testing of the methodology at case study airports.
6. Quantifying the difference of emissions of key pollutants (i.e., estimated emissions with and without the applied methodology).
V. ESTIMATE OF THE PROBLEM FUNDING AND RESEARCH PERIOD

Recommended Funding: $450,000

Research Period: 18 months, including 3 months for review and revision of a draft final report.

VI. URGENCY AND PAYOFF POTENTIAL

Concentrations of air pollution around many airports is an issue of public health concern, with levels close to or above regulatory limits. Approximately 50 major US airports are located in non-attainment areas and are subject to emissions reduction programs. The ability to produce accurate inventories is a key step in managing this issue. A high-quality inventory is also a key element in a dispersion modeling study for the calculation of ambient air pollution levels at key locations that can be directly compared to regulatory air pollution limits. In addition, a high quality inventory can be used to apportion the emissions and therefore enable actions to be taken to reduce emissions of the key sources.

The aircraft take-off phase is an important contributor to such concentrations. The current difficulty in estimating thrust settings is one of the major sources of uncertainty in estimating emissions from this source. The outcome of the research would be guidance on modeling take-off thrust levels which would reduce the uncertainty of these emission sources. In addition, the data and methodology could potentially be incorporated into AEDT.

VII. RELATED RESEARCH

The method recommended by the UK’s Project for the Sustainable Development of Heathrow was developed by British Airways (BA) based on their analysis of an extensive set of take-off thrust (FDR data) and weight data for their fleet at London Heathrow. BA found that, to a reasonable approximation, when flexible thrust is being used, the ratio of actual take-off thrust to maximum take-off thrust is given by the ratio of actual take-off weight (ATOW) to Performance Limited Take-Off Weight (PLTOW), subject to a lower limit set by regulation, normally 75%. (Reference: Morris K M (2002) Take-off at less than full power. ICAO/CAEP/Working Group 3 AEM Task Group, 27-28th June 2002, London, UK.)

Other related work is ongoing in the development of AEDT.

VIII. PERSON(S) DEVELOPING THE PROBLEM

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IX. PROCESS USED TO DEVELOP PROBLEM STATEMENT

This problem statement was developed by PPC/AEA Group’s Aviation team within the Sustainable Transport practice, with input from colleagues in both US and UK.

X. DATE AND SUBMITTED BY