Project 011(B) Development of Rapid Fleet-Wide Environmental Assessment Capability using a Response Surface Modeling Approach

Massachusetts Institute of Technology

Project Lead Investigator

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- Period of Performance: Aug. 18, 2014 to Aug. 31, 2016
- Task(s):
    1. Develop Model Architecture
    2. Extend Existing Capabilities of TASOPT
    3. Develop Simplified Version of Surrogate Model (Fuel-Only)
    4. Develop Noise Modeling Approach
    5. Develop Multi-Output Surrogate Model
    6. Test the Multi-Output Rapid Assessment System on a Representative Sample Problem
    7. Develop Revolutionary Technology Evaluation Capability
    8. Coordination within FAA and Volpe

Project Funding Level

$420,000 FAA funding and $420,000 matching funds. Sources of match are approximately $189,000 from MIT and $231,000 from Byogy Renewables, Inc.

Investigation Team

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Project Overview

The objective of the research is to continue development of an analytical framework for evaluating the environmental impact of aviation. This framework will use surrogate models for aircraft-level performance and noise, enabling broad scenario explorations and fast parametric analyses in environmental studies. Phase I of this research consisted of general analysis framework development, sample problem selection, and surrogate model development. Phase II of this research aims to demonstrate the capability of the surrogate modeling approach on a multi-dimensional output space, with emphasis on system-level aviation noise sample problems. The research will extend the surrogate modeling method developed by Yutko, with aircraft performance derived from the Transportation Aircraft System OPTimization (TASOPT) tool. The resulting surrogate model(s) will be used to solve a relevant sample problem that will demonstrate the capability of the method for analyzing environmental impacts. As part of this project, TASOPT will also be extended to better predict aircraft-level noise and to allow for a more flexible flight trajectory for operational noise mitigation studies.

Task Progress and Plans

Task 1: Develop Model Architecture
In the first task, completed under Phase I of this research, the system architecture and general modeling framework have been developed. The set of potential scenario input variables and their forms are defined based on anticipated policy or technology impact questions. Some of these are discrete inputs, some are parametrically defined, and some are defined in standard forms such as the TAF or CAEP forecasts, retirement curves or reference initial conditions such as the 2010 COD flight database. In addition, the desired output space must be defined. This may include standard AEDT outputs such as fuel burn, CO2, NOX, Noise as well as the capability to define other impact parameters of interest. Based on the inputs and outputs, the general model framework has been defined. The working model includes the capability for multiple surrogate model response surfaces to interact in a hierarchical framework, depending on the complexity and scope of the problem at hand. In Phase II of the project, the model framework will continue to be assessed to ensure that tradeoffs between computational speed and fidelity are appropriate for the chosen sample problem.

Task 2: Extend Existing Capabilities of TASOPT
In order to meet the project objectives, the capabilities of TASOPT has been extended under Phase I of this project. Aircraft-level noise modeling has been added to TASOPT as a post-processing module. This involves an interface with NASA's ANOPP noise modeling code. In Phase II of the project, flexibility will be added to the aircraft trajectory and performance assumptions to enable studies of the environmental impacts of operational changes.

Task 3: Develop Simplified Version of Surrogate Model (Fuel-Only)
Under Phase I of the project, the model framework has been evaluated using a simplified version of the architecture. This results in a surrogate model with a single output variable (fuel burn) using TASOPT as the high-fidelity basis. This version can be rapidly implemented as it can build on the existing artificial neural network models developed by Yutko. The preliminary version will be validated against AEDT or other available data sets.

Task 4: Develop Noise Modeling Approach
Under Phase I of this project, options for surrogate noise models that can be used as the basis for rapid fleet-wide analysis were explored. An approach using an aircraft-level surrogate model for performance and noise has been identified as the most promising solution, with direct system-level calculation generated with a gridded superposition approach. The output of this task is a detailed noise modeling approach that falls under the general modeling framework conceptualized in Task 1. Under Phase II of this project, refinements to the surrogate noise modeling approach may be necessary based in practical implementation challenges.

Task 5: Develop Multi-Output Surrogate Model
This task will develop a multi-output version of the surrogate model that will include all of the key environmental outputs identified in Task 1, likely including Fuel Burn, NOx, and Noise. Noise related surfaces would be created using the method developed in Task 4.

Task 6: Test the Multi-Output Rapid Assessment System on a Representative Scenario Evaluation Problem (Sample Problem)

One or more representative evaluation problems will be defined and the multi-output version will be used to evaluate relevant scenarios for that problem. The rapid assessment results can be used to identify specific AEDT cases that will be run both to explore the problem of interest and also to validate the rapid assessment model.

Task 7: Develop Revolutionary Technology Evaluation Capability

Methods will be evaluated for modeling revolutionary technological advances that a simple extrapolated prediction framework would not capture. Both physics based models and historical case studies will be used to identify how historical or potential technologies could change the response surfaces. It is expected that it should be possible to identify standard ways in which the response surface changes. If this were correct, these insights would be used to define indicators of potential future capability that could be evaluated parametrically to explore potential future performance spaces.

Task 8: Coordination within FAA and Volpe

The research team will be utilizing a number of tools within the FAA Tool Suite for which experts reside at FAA and Volpe, specifically AEDT. TASOPT has previously been connected with AEDT, and it may be useful to call on experts that have worked in this specific area.

Major Accomplishments

Have developed and demonstrated TASOPT and ANOPP connection and modeled several aircraft types with good agreement with certification data. Have demonstrated surrogate modeling approach on fuel only example problem.

Publications

None

Outreach Efforts

Several briefings on FAA Tools Team meeting

Awards

None

Student Involvement

Graduate students have been involved in all aspects of this research and have been the key implementers.