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Outline

• Motivation and Related Research

• Framework for Estimating Performance of Modified Configurations

• X-57 Maxwell
  – Generation of Baseline Models
  – Generation of Tuned Model
  – Uncertainty Estimation
  – Validation of Mod-I Performance
  – Prediction of Mod-II and Mod-III Performance

• Summary and Future Work
Motivation and Related Research

• This project arose out of collaboration with the Virginia Tech Airworthiness Center and NAVAIR

• NAVAIR must perform an airworthiness certification on a growing number of aircraft and configurations
  – This includes flight testing, which has significant time and monetary costs

• Virginia Tech’s Nonlinear Systems Lab has previously used non-deterministic simulations to predict aircraft performance and loss of control

• How can we estimate the performance and uncertainty of modified aircraft without flight testing?

Framework for Estimating Performance and Uncertainty

• Framework developed to meet the goal of estimating the performance of modified aircraft configurations, including uncertainty
  – Framework includes two methods to account for small and moderate modifications
• Framework designed to be independent of the data sources, model form, or system identification method used
• Framework tested using simulated flight test data of NASA’s GTM aircraft

Generalized Framework

**Generation of Baseline Models**
Baseline models of nominal and modified aircraft configurations generated using lower-fidelity data

**Generation of Tuned Model for Nominal Configuration**
Tuned model of nominal configuration generated using system identification of higher fidelity flight test data

**Estimation of Model Form Uncertainty for Nominal Configuration**
Model form uncertainty estimated using error between the observed flight test data and calculated models for the nominal configuration

**Extension to Modified Aircraft Configurations**
- Tuned Model Method assumes model tuning remains valid for modified configuration and generates smaller uncertainty bounds
- Baseline Model Method does not assume that tuning remains valid for the modified configuration and generates larger uncertainty bounds

**Non-Deterministic Simulations**
Simulations which account for uncertainty and wind turbulence are conducted and quantities of interest are calculated

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NASA’s X-57 Maxwell

- The X-57 Maxwell is an experimental aircraft that aims to demonstrate the benefits of distributed electric propulsion through a series of incremental modifications to a commercially available aircraft.
- Tecnam P2006T serves as a basis for both performance and certification criteria.

X-57 Maxwell Configurations

Incremental modifications of the X-57 Maxwell, from the Tecnam P2006T to the complete distributed electric propulsion aircraft. [4]

Analysis of X-57 Configuration Performance

• Framework applied to the X-57 using available flight test data for the Tecnam P2006T and simulation models for the modifications based on wind tunnel and CFD analysis
  – Generation of models
  – Uncertainty estimation
  – Validation of results for nominal configuration

• Performance for these modifications is not known – Mod II and Mod III flight tests have not occurred
Generation of Baseline Model

Baseline models for the nominal and modified configurations generated from linear models based on CFD and wind tunnel data

Comparison of flight test data and the baseline model generated from CFD and wind tunnel data
Generation of Baseline Model

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Comparison of flight test data and the baseline model generated from CFD and wind tunnel data.
Generation of Tuned Model

Tuned model of the nominal, Mod-I, configuration created using system identification of flight test data of a Tecnam P2006T

Comparison of flight test data and the tuned model generated from system identification of flight test data
Generation of Tuned Model

Tuned model of the nominal, Mod-I, configuration created using system identification of flight test data of a Tecnam P2006T

Comparison of flight test data and the tuned model generated from system identification of flight test data
Uncertainty Estimation

- Uncertainty is estimated by comparing the flight test data to the aerodynamic models.
- Because of the large amount of flight test data and variation of included maneuvers, the uncertainty remains steady for a wide range of aircraft states.

Model error and estimated uncertainty bounds generated using the tuned model.
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Validation of Nominal Model (Mod-I)

- Before performance of the modified configurations can be predicted, models must be validated for the Mod-I configuration.
- Both model and uncertainty are compared to actual flight test data.
Performance Prediction for Mod-II and Mod-III Configurations

- Because there is no Mod-II or Mod-III flight test data, results cannot be compared to flight test data and cannot be validated.
- Predicted performance between the two is quite similar, due to large impact of noise in flight test data and design of modification.
Summary

- Framework was applied to NASA’s X-57 Maxwell, an experimental aircraft with a series of modifications applied to a general aviation aircraft
- Because flight test data is not available for Mod-II and Mod-III, performance estimates cannot be validated

Future Work

- Compare analysis and non-deterministic simulation results for future X-57 flight test data to validate framework for estimating performance of modified aircraft in real-world scenarios
- Continue investigating how this framework could be applied to real-world certification by analysis scenarios