Estimating Performance of Modified Aircraft Configurations Using an Uncertainty Framework to Aid Airworthiness Certification

To certify modified aircraft, regulatory agencies such as the FAA, EASA, and NAVAIR require that modified aircraft configurations repeat most, if not all, of the testing required for the original certified aircraft. The certification process is independent of the size and impact of the proposed modification; the addition of an antenna is treated the same as the addition of wing-mounted payload pods. Due to the high costs of flight testing and the rise in availability of accurate modeling and simulation techniques including computational fluid dynamics (CFD), there is a growing demand for certification by analysis to replace or reduce flight testing.

Non-deterministic simulations of aircraft configurations are proposed to estimate the performance of modified aircraft, potentially providing a more efficient and cost effective avenue for the certification process. Adequate flight test data or other high fidelity data is not always available for traditional model tuning, uncertainty quantification, and non-deterministic simulations. Therefore, the proposed process uses knowledge of the unmodified, or nominal, configuration to assist in the updated simulation. Two methods using aspects of the nominal system are proposed here to estimate the modified aircraft dynamics and the related uncertainties. These methods can then be used to perform non-deterministic simulations. This process is designed to be independent from the data quality, the data source, the model form, or the model accuracy and can be used prior to flight testing to estimate the expected performance.

Baseline models of both the nominal and modified configurations are first created using lower fidelity data derived from sources such as CFD simulations or wind tunnel experiments. For the nominal configuration, a tuned model is then created from the higher fidelity flight test data. Uncertainty due to the simplification of the model is approximated using the error between the evaluated model and the flight test data. For linear models, this uncertainty is a constant value applied to the state equation, while non-linear models allow for uncertainty that fluctuates as a function of state and data sampling density. The baseline model, the tuned model, and the uncertainty are then used to estimate the updated model and uncertainty bounds for the modified aircraft, using one of two methods. Method 1 assumes that the tuning corrections between the lower fidelity and higher fidelity data for the nominal configuration are still valid and that the modification does not increase the uncertainty calculated from the tuned model and the higher fidelity data. Method 2, which is intended for more significant modifications, assumes the tuning correction is no longer valid and the uncertainty is calculated by comparing the baseline model to the higher fidelity data. The two methods of estimating the uncertainty are dependent upon the characteristics of the model, but the second method provides a more conservative estimate.

Non-deterministic simulations are conducted using the updated model and uncertainty bounds to predict the performance of the modified aircraft. Additional stochastic parameters such as wind turbulence can be included to estimate performance at a variety of conditions. Performance metrics relevant to the airworthiness certification process including maximum cross track error, climb rate, and stability can be derived from the results.

Future work will involve estimating the performance and associated uncertainties of various categories of aircraft from unmanned aerial vehicles including the AeroStar UAS, to multi-engine passenger aircraft such as NASA’s X-57. The results will then be compared to certification criteria to evaluate the potential of the framework to provide sufficient information for the airworthiness certification process.