Lift+Cruise Polynomial Model Limitations

1. The Lift+Cruise polynomial model was primarily derived from computational fluid dynamics (CFD) experiments conducted using OVERFLOW. To facilitate developing an aero-propulsive model of the vehicle sufficient for flight dynamics simulations in a rapid manner, the CFD simulations were run using a coarse computational grid. The aircraft components included in the gridding were the wing, fuselage, horizontal tail, vertical tail, eight lifting rotors, and pusher propeller. The rotors and pusher propeller were modeled using a rotor disk methodology, as opposed to modeling fully rotating blades, to reduce the grid size and encourage steady-state flow solutions. The aircraft geometry was also simplified by removing the support struts for the lifting rotors and the landing gear. Additional simplification of gridding requirements was achieved by deforming the surface grids to model control surfaces and ignoring the gaps at the ends of each control surface. Furthermore, grid refinement studies and unsteady flow simulations were not performed. Although these simplifications were justified and applied using subject matter expert knowledge for this preliminary study of the conceptual Lift+Cruise vehicle, certain complexity reduction measures may need to be reassessed for future modeling efforts.
2. Based on transition simulations of the Lift+Cruise aircraft, the developers of the Lift+Cruise polynomial model and the GUAM simulation proposed extending the range of validity of the Lift+Cruise polynomial model; however, CFD resources for the project were discontinued and, consequently, these requested polynomial model updates were not made. GUAM simulation users may encounter aero-propulsive model limitations in parts of the Lift+Cruise flight envelope, which can result in triggering error statements implemented to avoid extrapolation beyond the region of validity of the polynomial model.
3. The model terms included in the polynomial response surface equations (RSEs) that form the Lift+Cruise aero-propulsive model were selected using an automated model structure determination procedure as a part of the Rapid Aero Modeling (RAM) algorithm. The automated algorithm is effective in predicting dominant terms that should be included in the model but can be more challenged to determine which borderline terms with similar modeling metrics are worthy of inclusion in the model structure. This can result in both model terms excluded from the model that should be included and other model terms included in the model that should be excluded. Therefore, after automatic model structure selection is completed, it is usually beneficial to have a subject matter expert adjust the final model structure based on physical insight combined with statistical metrics. Because of the abundance of candidate regressors and large number of model terms needed to describe complex eVTOL aerodynamic phenomena, manual model structure adjustment for many large RSEs across an eVTOL aircraft's full flight envelope is an arduous task. In the interest of demonstrating rapid model production using the RAM algorithm and from the direction of the project, manual subject matter expert adjustment of the polynomial models produced by RAM was not done for this Lift+Cruise modeling effort. As a result, the user may note some asymmetries in the RSE predictions and some model terms in the RSEs that lack physical explanation; however, because of the nature of the statistically designed experiments used to collect the data for model identification and the meticulously selected model term selection thresholds used to run the RAM algorithm, the adverse impact on the mean response predictions from the polynomial models is minimal.

Reference:

1. Simmons, B. M., Buning, P. G., and Murphy, P. C., "Full-Envelope Aero-Propulsive Model Identification for Lift+Cruise Aircraft Using Computational Experiments," *AIAA AVIATION 2021 Forum*, AIAA Paper 2021-3170, Aug. 2021. https://doi.org/10.2514/6.2021-3170.