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FLIGHT DYNAMICS SIMULATION AND AERODYNAMIC DATABASE OF A RETRO-PROPULSION ASSISTED REUSABLE LAUNCHER WITHIN THE RETPRO PROJECT

Abstract

Reusability applied to launchers is expected to reduce costs for access to space and increase operational flexibility. The RETPRO project (Validation of Wind Tunnel Test and CFD Techniques for Retro-propulsion), as part of ESA's Future Launchers Preparatory Program (FLPP), aims to prepare and validate the use of the tools necessary for reliable design and simulation of future launch vehicles or spacecrafts, in particular vertical takeoff and landing (VTVL) configurations using retro-propulsion. The topic of this paper is the 6-DoF flight dynamics simulation of typical reference missions including acquisition of necessary data for aerodynamic database (AEDB) preparation, creation of a simulation model and the simulation itself. Its aim is verification of the RLV concept feasibility concerning stability and controllability. Outputs include trajectory data and control system actions for control surfaces, RCS and TVC. During mission analysis, emphasis is laid on the impact of retro-propulsion on aerodynamics to provide insight in the feasibility of the reference configuration regarding flight dynamics limitations. The RETPRO reference configuration is a generic launcher similar in size and configuration to the SpaceX Falcon 9 launcher. Necessary for simulation input data is thus obtained from publicly available information, webcast telemetry data and from preliminary 3-DoF simulations. The 6-DoF simulation model enables performance analysis and a first evaluation of stability and controllability for all flight phases including ascent and descent. Since typical return flights include flight direction changes and hovering, the aerodynamic flow direction can be arbitrary. Stream conditions thus need to be defined uniquely avoiding any singularities, which is one of the main challenges for creation of 6-DoF compliant AEDB for simulation of VTVL launch vehicles. The 6-DoF flight dynamics simulation model was developed in a MATLAB/Simulink environment. It allows performance analysis on a close to reference full-scale VTVL launcher representation for all flight phases of RTLS and DRL missions. The specifically created AEDB based on low-fidelity CFD simulations, providing estimates of aerodynamic forces and moments for all flight configurations along the reference mission trajectories including impact from retro-propulsion. The guidance strategy is based on attitude control in a semi-closed loop with additional closed-loop thrust control for the soft landing. The model provides a first evaluation of structural loads based on a g-load analysis along the reference trajectories. The analysis confirms feasibility of the selected reference case and comparison of the 6-DoF flight simulation with public telemetry data from missions of similar configurations validates the flight simulation toolkit.