Paper ID: 66456
oral
student

IAF SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
Launch Services, Missions, Operations, and Facilities (2)

Author: Mr. Vincenzo D'Antuono
Sapienza University of Rome, Italy

Dr. Alessandro Zavoli
Sapienza Università di Roma, Italy
Prof. Guido De Matteis
Sapienza University of Rome, Italy
Mr. Simone Pizzurro
Italian Space Agency (ASI), Italy
Dr. Enrico Cavallini
Italian Space Agency (ASI), Italy

UNCERTAINTY QUANTIFICATION FOR LAUNCH VEHICLE IN ATMOSPHERIC FLIGHT

Abstract

Launch vehicles (LV) are presently the only way to guarantee a safe and economically affordable access to space. In an era where the number of satellites launched per year is continuously increasing, improvements in LV technologies is thus fundamental for reducing the cost and increase flexibility and robustness of the future space missions. Numerical modeling plays a central role in the development of the LV flight control system. Regardless of the adopted design technique, the controller must be able to account for large uncertainties on model parameters. Unlike other engineering fields, test campaigns for launch systems are extremely expensive, and impossible to be carried out in near-real operating conditions, and large scattering ranges are commonly taken into consideration in the verification and validation phases of flight control system. In this respect, post-flight analysis provides one of the best way to improve model accuracy. However, no specific manoeuvre can be executed during flight for the purpose of model identification, being the LV constrained to fly well-within a strictly-prescribed trajectory tube for flight safety and mission performance. The proposed study deals with a methodology for the post-flight analysis of a LV in atmospheric flight, with the objectives of recovering the "best-estimated" trajectory (BET) flown by and vehicle, as well as maximizing the level of information that can be extracted from flight data to improve the model fidelity. To this end, a two-step approach, based on NASA *NewSTEP* algorithm, is used to manage the measurements coming from multiple onboard, ground-based, and atmospheric data-sources (such as inertial measurement units, radar stations, and meteorological sensor), which are provided at different sample rates. An Iterative Extended Kalman Filter (IEKF) is used to deal with nonlinear filtering, while taking full advantages of all available post-flight data. Uncertainty in state estimates is evaluated basing on Cramer-Rao bounds, and validation data are then used to compare the values of inertial properties and aero-propulsive coefficients as predicted by the model to experimental data. These results allows for the estimation of model-form uncertainty, which is represented as prediction intervals. Numerical simulations are carried out to generate synthetic flight-test data, using a 6-DoF nonlinear high-fidelity model of a multistage launch vehicle, and an example analysis is conducted in order to assess, demonstrate and discuss the uncertainty quantification process.