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A STREAMLINED DESIGN, DEVELOPMENT AND VALIDATION PROCESS FOR MICRO-LAUNCHERS

Abstract

The past years have seen an increasing demand for dedicated and responsive satellite launches, which gave rise to a rapidly growing micro-launcher industry. The motivations range from national and regional security, to fast replacement of constellation layers for very low-Earth satellite networks, and to rapid low-cost execution of scientific experiments. Agile design, development and validation(DDV) is critical within the competitive micro-launch environment, and versatile simulation tools are a key enabler for rapid iterations. Deimos has a heritage of flight-proven design methodologies from missions such as the ESA IXV re-entry vehicle, the Deimos-1 and Deimos-2 observation satellites, among others, that aim to address these challenging DDV constraints, while allowing for missionization needs.

Currently, several ongoing projects focus on extending these capabilities to micro-launchers and providing support to the emerging European small-launch enterprise. In this regard, Deimos currently is responsible for the mission analysis and for the Guidance, Navigation, and Control (GNC) design, entailing, in particular, the development of the Functional Engineering Simulator (FES), for the Orbex Prime vehicle. The present paper outlines the end-to-end Deimos GNC DDV applied to the development of cost-effective micro-launchers. Special emphasis is placed on the pervasive role of the FES throughout the product lifecycle, that support a wide palette of activities: from actuator sizing, controllability analysis, controller synthesis, range safety assessment, to requirements validation, etc. The subsequent verification and testing methodologies are also illustrated by presenting the SimPlat-based FES, which facilitates the transition from model-in-the-loop (MIL) to software-in-the-loop (SIL), but also to later testbenches, such as processor-in-the-loop (PIL) and hardware-in-the-loop (HIL). The proposed approach ensures continuous development and testing through an auto-coding methodology, while guaranteeing the satisfaction of the standards required for software quality assurance.

A section is dedicated to outlining a typical micro-launcher simulator, with implementation concerns such as environment modelling, rigid and multibody dynamics, and their implications on the control strategy. Finally, a detailed discussion on the modern GNC and fault detection, isolation and recovery (FDIR) techniques is provided. Theoretical frameworks, such as the robust control theory, developed over the past two decades are currently applied to improve the performance of micro-launchers. The discussion concludes with lessons learned, best practices for the GNC DDV of small launch vehicles, and a roadmap for the advancement of current capabilities through machine learning techniques (explored in projects such as the AI4GNC ESA study, led by Deimos), propulsive landing (the H2020 RETALT and RRTB projects), etc.