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INTEGRATING CONCURRENT ENGINEERING WITH DATA-DRIVEN AND MODEL-BASED SYSTEMS ENGINEERING FOR END-TO-END SMALL-SATELLITE DESIGN

Abstract

Concurrent Engineering (CE) is a collaborative product development approach that emphasizes the parallelization of tasks, and integrates design with other crucial tasks, such as manufacturing planning, quality assurance, and serviceability, to accelerate development, reduce costs, and improve quality. The current application of CE facilitates the reduction of timelines and enhances communication among the various disciplines involved, addressing the complexities of mission analysis and feasibility phases (Phase 0 and Phase A) in space projects, with some application up to Phase B.

However, its full potential is still to be disclosed, to cover the full product lifecycle until the disposal phase. To support this extension of applicability, a critical challenge of the concurrent design approach needs first to be overcome: the seamless integration across organizational borders due to both technical limitations in data exchange systems and the inherent complexity of space systems. Achieving full compatibility between diverse systems and real-time data synchronization remains difficult, primarily due to tool, standard, and process variations across different partners. To address these challenges, an integration of Model-Based Systems Engineering (MBSE) and Data-Driven Systems Engineering (DDSE) has been proposed to further enhance the concurrent design process. While MBSE provides structured modeling for system behavior and requirements management, the introduction of DDSE enables data-driven decision-making and ensures continuous information flow across all phases of the mission. By combining these methodologies, we propose an integrated and agile approach that maintains a single source of truth, ensures continuity of information across the mission lifecycle, and facilitates collaboration among engineering teams and stakeholders.

The integrated approach is currently being successfully applied to small satellite missions and systems design, covering a wide variety of mission concepts from LEO Earth Observation missions to close-proximity operations missions, up to deep-space missions, with a focus to the CubeSat platform. The paper aims to first present the methodology and the integration of tools and subsequently present the result from a case study, showcasing how the efficiency and effectiveness of design and decision-making processes have been improved. This methodology demonstrates how CE, when combined with MBSE and DDSE, can optimize space mission design from concept to manufacturing and testing up to in-orbit operations and disposal, providing a robust solution for small satellite and space systems development.