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# ENHANCING SPACE MISSION PRE-DESIGN: INTEGRATING GROUND SEGMENT AND OPERATIONS INTO CONCURRENT ENGINEERING METHODOLOGIES

**Abstract**

Concurrent Engineering (CE) represents a collaborative approach optimizing system design through multidisciplinary team involvement. While commonly utilized in space systems conceptual design, CE methodologies have predominantly focused on space segments and payloads. Ground segments and utilization aspects were traditionally addressed at a higher level, favouring conventional approaches. However, the changing landscape of the space ventures, marked by increasing complexity and interdependencies within ground segment components and user aspects, requires a more adaptable framework. This complexity, driven by the rapid expansion of satellite constellations and complicated formations, underscores the need for a differentiated CE approach in Ground Segments and Operations (GS&OPS). As space missions evolve, there is a shift from the traditional top-down approach to mission planning towards a GS&OPS perspective, with users actively participating in defining mission conditions and requirements. This user-centred approach highlights the limitations of relying solely on established solutions without thorough technical considerations. It emphasizes the importance of moving beyond familiar solutions without proactive engineering, particularly given the challenges of sustainability and strategic feasibility in the evolving space environment. This transformation demands an innovative and user-centric approach to managing the operational complexity of larger constellations and integrated applications. In response to the challenges encountered in modern space missions, the Technical University of Darmstadt (TU Darmstadt) and the European Space Agency (ESA) collaborated to establish the Concurrent Engineering Lab (CEL).

This paper outlines the development and definition of a comprehensive CE process for the GS&OPS domain, elevating GS&OPS to a fully integrated element within the CE process. CE participants are divided between the Space Segment system (e.g. ESA's CDF) and GS&OPS system (e.g. CEL), highlighting novel challenges such as domain allocation, novel system architecture modelling within the CDP4-COMET framework, and the crucial need for effective communication between multidisciplinary teams. The paper also describes the novel methodological approach and shares experiences from the preparation and execution of the first study case where the unique CE methodology was applied. Additionally, the paper navigates through the development and implementation of a model architecture tailored specifically for the preliminary design of GS&OPS within CDP4-COMET.