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SPACECRAFT DIGITAL ENGINEERING: THE TALE OF "DIGITAL TWINS" AND LESSONS LEARNED

Abstract

Model Based Systems Engineering (MBSE) approach has proved its efficiency in the design of many complex systems. It provides a mechanism for sequential linking of requirements, logical elements, and simulation models, while all information is stored in the central "the only source of truth" database. In this study, we looked at the status of existing simulation models in spacecraft engineering domain and means of connecting them into a "digital twin". We evaluated the complexity of modelling required to analyze an astrophysical mission based on a constellation of CubeSats. The main mission goal is to demonstrate coordinated observation of gamma ray events.

Conceptual design of satellites can be successfully performed based on 1D modelling, with some interfaces to detailed 3D analysis. For example, ValiSpace offers an excellent product for 1D modelling and offers a wide range of interfaces. We set out to put together the best tools available (including PLMs) on the market for detailed 3D design. The approach has been validated while building two 3U CubeSats launched in August 2022. We investigated the classical domains of a space project: mission design, systems engineering, environment modelling, mechanical and thermal design, electrical systems, communication systems, payload simulation, electronics development, flight software, attitude determination and control system and electric propulsion.

A "Digital Twin" can be defined as a physics-based description of the system resulting from the generation, management, and application of data, models, and information from authoritative sources across the system's lifecycle. The Digital Engineering approach should have a virtual product description and a virtual process definition, as well as continuous connections and physics-based simulation. Despite a clear and concise definition, this concept is hard to implement. Here we tried to analyze why.

We have analyzed in detail all domains that were mentioned above to understand what tools are used there and how we can connect them to each other. We will discuss the main difficulties encountered (model complexity, interfaces, amount of work required and last-minute changes) to establish a "digital twin". Our conclusion is that the key activity all teams must go through is to optimize how much resource will be devoted to documentation and modelling vs. how many people will be involved in assembly, integration, and testing activities.