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APPLYING THE MODEL-BASED CONCEPTUAL DESIGN APPROACH TO ADCS DEVELOPMENT: A CASE STUDY OF A CUBESAT SWARM MISSION

Abstract

Conceptual design plays an important role in the space product development process. The model-based concept framework (Menshenin and Crawley 2018) rooted in design theory contains information about key entries that should be taken into account during the early design phase. This framework emphasizes not only the question “what” should be specified during the conceptual design phase, but also proposes “how” it should be done using a strict ontology and semantics supported by a conceptual modeling language, such as the Object-Process Methodology (OPM) (Dori 2002). In many cases, space systems engineering approaches are applied to the whole space system. In this paper we demonstrate the applicability of the framework to the development of a space subsystem, namely, the attitude determination and control system (ADCS) for a CubeSat. We describe the concept framework development starting from the upstream information – stakeholders and their needs, going down to the problem formulation and alternative solutions elicitation. We show that in such highly conservative systems as space ones, the alternatives might appear at the level of integrated concept, although the design principles remain the same regardless the level of granularity (Maier et al. 2016). We conclude the framework with the information about the concept of operations. Based on the system architecture principles, we identify alternatives of the ADCS components architectures. Presented with this set of alternatives, the ADCS designer is able to choose a specific architecture based on the mission requirements and engage the corresponding domain-specific tools for further simulations. We showcase this process by applying the proposed framework to a CubeSat swarm mission to detect gamma-ray bursts. The software developed as part of this case not only allows to determine the mass, power, and cost budgets but also provides estimates for such ADCS performance indicators as detumbling time, pointing and attitude determination accuracy. Informed by this data, the ADCS designer is then able to determine if the chosen architectural solution meets the requirements. Another utility of the proposed framework is that it facilitates the ADCS development in the Concurrent Engineering Design environment (Prasad 1996) by identifying functional interactions between the ADCS and its surrounding systems – other Cubesat subsystems – and thus informing the dataflow between the corresponding design teams. To support this flow, the software developed has the capability to produce various attitude-specific data relevant to other subsystems.