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AN OPEN-SOURCE METHOD FOR MODEL-BASED DEVELOPMENT OF EMBEDDED SYSTEMS: EXPERIENCE REPORT FROM A CUBESAT STUDENT PROJECT

Abstract

As space engineering projects become more complex, MBSE (Model-Based Systems Engineering) practices have been gaining popularity to enforce consistency throughout the multiple facets of an integrated system. However, most such approaches are often confined to the top levels of systems engineering, leaving tooling gaps between the design and the implementation, integration, and testing phases, which can be the source of inconsistencies. Exceptions are few and typically proprietary, leaving limited freedom for customisation.

Building on previous work from N7 Space, this paper presents a comprehensive, V-shaped methodology integrating Capella and TASTE workflows into an end-to-end model-centric process for developing embedded software within complex systems. Capella is an opinionated MBSE tool, created by Thales to enforce the Arcadia framework, which structures the design process on multiple levels: Operational, System, Logical, and Physical; TASTE is a model-driven software development toolchain targeting heterogenous embedded systems, which centres its workflow around Data, Interface, and Deployment views. Both tools are Free and Open-Source Software.

This methodology exploits the parallels between entities in the two tools to rigorously link the design and implementation phases, enabling verification and validation activities based on simple diagram comparisons. Capella is first used to reason about the operational scenarios required to accomplish the chosen mission, then to consistently define the architectures of the system, its logical subsystems, and the physical components. The final products of the design stage are rigorously transitioned to TASTE, exploiting its SDL (Specification and Description Language) support to develop embedded software faithfully to the model. Finally, TASTE's integration with model-checking frameworks enables formal verification to be carried out on selected software requirements, whereas MSC (Message Sequence Chart) generation enables validation of its structure against the designs at multiple levels.

To illustrate the process, we report the resulting software architectures and their integration into the broader system of a student CubeSat project, where this method is currently being adopted to develop and test both flight and ground software, including TTMC, housekeeping, and mission functionalities. While we highlight its particular benefits to student projects, the method's exclusive reliance on open-source tools makes it easily adaptable to more complex use cases, and widely accessible regardless of financial and computational means.