**Space Systems of Systems Generative Design Using Concurrent MBSE:**

**An Application of ECSS-E-TM-10-25 and the GCD Tool to Copernicus Next Generation**

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The Concurrent Design Platform 4 (CDP4®) [1], developed by the Systems Engineering Methods and Tools (SEMT) business unit at RHEA Group, aims to address the modern challenges of Model-Based System Engineering (MBSE). CDP4® is a collaborative software tool conceived for architecting complex systems, across integrated tools, domains and industrial applications allowing agile tailoring of systems engineering methodologies. Key features of the tool among others are enabling semantic interoperability, configuration management, requirements-to-architecture mapping, systems modelling and analysis, model re-use via catalogues.

Nevertheless, there are limitations concerning the manageable number of system options both on the tool and the user level. The Siemens prototype for generative engineering, Dx [2], is attempting to overcome this limitation by enabling automatic synthesis and evaluation of architecture variants.

The motivation for the Generative Concurrent Design (GCD) project as a collaboration between RHEA, Siemens and OHB is to develop a combined prototype of these two tools. Speaking the language of goals and constraints, engineers will therefore be able to collaboratively explore a larger design-space. Design is co-executed by the users and the computer, exploiting the computational power of the latter and the ability to pose the right questions of the formers. This workflow can be outlined in the following steps:

1. A CD Team makes use of CDP4® to define the initial elements of the system of interest and to implicitly model all its potential architectures in one single, condensed diagram view, by means of design constraints.
2. Dx is used to compute all the feasible architecture variants from that single model; if the feasible solutions are not reasonable, the user can return to Step 1 and make adjustments.
3. A domain-specific tool can be used to simulate the behavioural constructs associated to the feasible architecture solutions; for less complex parametric calculations, a simple script can also be used.
4. Dx displays the evaluated results on a pareto plot and other types of charts, so that the CD Team can make trade-offs by filtering, sorting and selecting the preferred option(s) against user-defined criteria.
5. The selected option(s) from Dx are added to CDP4, becoming the new baseline for another iteration from Step 1 or for detailed design, hence following a spiral process. These steps can be performed for the whole system or in parallel for its constituents e.g. sub-systems, managed by domain experts.

GCD represents a paradigm shift for concurrent systems architecting, speeding up the overall process and providing an improved starting point for the subsequent detailed design phases. This paper – written in the context of the GCD co-funded GSTP activity – presents a modellisation of Copernicus Next Generation, using generative capabilities in a typical Phase-0 study. It represents the third step of the bottom-up GCD validation, indended to investigate how architecting differs among “Sub-system”, “Systems” and “Systems of Systems (SoS)” in ECSS-E-TM-10-25 [3]. Therefore, this work both provides an architecting strategy which can be generalised for other SoS use-cases (in different industrial applications) and contributes to assess whether extensions to ECSS-E-TM-10-25 are necessary to successfully support GCD.

**References**

[1] CDP4-IME <https://www.rheagroup.com/cdp>

[2] Menu, J., Nicolai, M., Zeller, M., “Designing Fail-Safe Architectures for Aircraft Electrical Power Systems”, AIAA/IEEE Electric Aircraft Technologies Symposium, AIAA Propulsion and Energy Forum, (AIAA 2018-5032), 2018

[3] ECSS E-TM-10-25A, “Space engineering – Engineering design model data exchange (CDF)”, ECSS Secretariat, made available 20 October 2010.