Modelling Avionics Interfaces and Generating Interface Control Documents for the Propulsion Subsystem of the MPCV European Service Module

Delia Cellarier, Antonio Preden
MPCV-ESM Engineering Team, European Space Agency, Noordwijk, the Netherlands
delia.cellarier@esa.int

***Abstract* — In complex systems such as the MPCV European Service Module (ESM), Interface Control Documents (ICDs) are key system engineering artefacts that are used to specify and control interfaces. In current practice, ICDs are largely created, maintained and verified manually, leading to tedious and error-prone activities. A model-based approach can be implemented to use a model as "single source of truth". It thus enforces consistency and can be a basis for generating ICDs. This paper explains why and how this approach was applied with Capella to the avionics interfaces of the ESM Propulsion Subsystem.**

Keywords — Model-Based System Engineering, Interface Control Documents, Capella

1. Context and Motivations

Interface management is a crucial system engineering activity for space projects. As described in the dedicated ECSS standard, its objective is "to achieve functional and physical compatibility amongst all interrelated items in the product tree" [1], ensuring that the different components will be integrated into a working system. It is particularly challenging for complex systems such as spacecrafts, involving many parties (space agencies, main contractors and suppliers) and disciplines.

This is the case for the European Service Module (ESM), ESA's contribution to NASA's Orion spacecraft (MPCV). Built by main contractor Airbus Defence and Space, with many other companies supplying components, it provides propulsion, power, thermal control, and water and air for astronauts. Several spacecrafts will be provided to support the Artemis missions , and the third one is currently in design phase.

In this context, Interface Control Documents (ICDs) are used throughout the lifecycle to specify and control interfaces of subsystems. Their role in the ESM development makes them difficult to manage, though. Indeed, because of both their technical and contractual aspect, ICDs are subject to a standardized change process that can create inconsistencies between documents. Moreover, information is sometimes redundant between ICDs of different levels (e.g. Propulsion subsystem and equipment ICDs) or separated in data ICDs specific to some equipment. Maintenance and verification of those ICDs are for now largely done manually, making it difficult to keep consistency.

The purpose of this work is to implement a model-based approach, using MBSE technologies to effectively manage information and generate ICDs from a model [2]. This approach is evaluated through a case study, the avionics interfaces of the ESM Propulsion Subsystem, with the objective of being applicable in the project's future.

This paper will first give an overview of the process which led to the selection of Capella as MBSE solution. It will then describe the first results and the methodology applied to the whole project.

2. Trade-off Between MBSE Solutions

The project started with a study and a trade-off to choose the most appropriate MBSE tool. First of all, requirements have been defined according to project's needs (e.g. document generation features) and ECSS standards, and then refined through interviews of projects experts in various disciplines.

A state of the art revealed similar approaches in space projects, all based on SysML. However, the authors either extended SysML with a profile [3], the language being too generic for their needs, or focused on software interfaces [4]. Some initiatives at ESA were also explored:

- *Electronic Data Sheets*, for Data Handling and Electrical interfaces of spacecraft avionics;
- *ESA SysML Profile*, developed by ESA MBSE Core team for System Engineering of space projects.

Technology readiness, coverage of multi-disciplinary interfaces and understanding for newcomers to MBSE narrowed the choice of an MBSE tool to Capella and Enterprise Architect extended with ESA SysML Profile. A trade-off based on a mock-up has been made between those two solutions to evaluate them against our requirements. Both tools offer most of the desired features, but Capella was preferred, among other things, for its accessibility and its customization.

3. Methodology to Manage Interfaces with Capella

The mock-up under Capella included two avionics boxes and a few electrical interfaces. Thanks to M2Doc, an open-source add-on by Obeo to generate MS-Word documents from Capella models, parts of an equipment ICD could successfully be generated. M2Doc uses Word templates written in a language built on top of Acceleo Query Language (AQL) for querying the model. This enables flexible and custom document generation.

As a consistent implementation is necessary to efficiently generate ICDs, scaling-up to the whole Propulsion Subsystem implies a more systematic approach. A mapping has thus been made between types of avionics interfaces (part of Mechanical, Thermal, Electrical or Numerical ICDs) and model elements (e.g. Physical Link, Component Exchange, etc.). On another hand, M2Doc templates can become complicated for non-practitioners when the model grows in complexity. To make them easily modifiable by end-users, M2Doc template patterns and services (i.e. Java functions) will be developed.

Our case study involves some specificities compared to a generic approach in Capella. Indeed, the model and generated ICDs are realized by shadow engineering, showing how Capella can be introduced in a project where the design is already well advanced and documents remain key deliverables. In this case, the model focuses on an effective management of information and interfaces with existing artefacts, such as the Harness Database, rather than trying to replace everything. Concerning the ARCADIA method, considering that a design was already existing, the usual steps were not followed and we started directly with the modelling of the Physical Architecture.

An interesting feature of Capella is the possibility to extend it thanks to the viewpoint technology provided by Capella Studio. It allows to adapt or add definition of new data, diagrams, user interfaces or validation rules. In our project, it can be used to help experts from each discipline focusing on their interfaces and controlling them.

Eventually, as traceability throughout the life cycle is a major concern, existing Viewpoints will be used to demonstrate its feasibility in Capella: the *Requirement Viewpoint* can specify links with data extracted from Interface Requirement Documents, while the *V&V/TestMeans Viewpoint* (a commercial add-on by Artal) can refer to test campaigns.

4. Conclusion and Future Work

Through a study of related work and a detailed trade-off, MBSE and Capella in particular have proven to be a promising solution for specifying and controlling interfaces as well as automatically generating ICDs.

At the time of writing this abstract, ongoing work is carried out to extend the model to all avionics interfaces of the ESM Propulsion Subsystem, by applying a tailored methodology and by implementing artefacts for ICDs generation in Capella. A Viewpoint dedicated to interfaces will potentially be developed. Results will be compared with the ones obtained by industry with the standard approach. The expected outcome is that, providing initial efforts to endorse MBSE, management of interfaces will be facilitated, even for an advanced document-based project.

Future work would involve applying this concept to a real project, so lessons learned from this experience will be exploited to provide recommendations for the integration of modelling activities in current processes.

References

[1] ECSS, ECSS-E-ST-10-24C – Interface Management, June 2015.

[2] D. Cellarier, ESA-MPCV-RP-0060 YGT Report: Modelization of Avionics Interfaces.

[3] E. Fosse and C. L. Delp, "Systems Engineering Interfaces: A Model Based Approach," in *IEEE Aerospace Conference Proceedings*, 2013.

[4] S. J. I. Herzig, R. Karban, G. Brack, S. B. Michaels, F. Dekens and M. Troy, "Verifying Interfaces and Generating Interface Control Documents for the Alignment and Phasing Subsystem of the Thirty Meter Telescope from a System Model in SysML," *Proc. 8th Modeling Syst. Eng., Project Manage. Astron.,* vol. 10705, no. Art. no. 107050V, 2018.