Successful MBSE landing on a CNES operational use case

Jonathan LASALLE and Benoit VIAUD
ARTAL Technologies, 1 rue Ariane, 31520 Ramonville-Saint-Agne, {jonathan.lasalle, benoit.viaud}@artal.fr

Martine JOURET, Anthony JUIN, Fabienne SCHAFFHAUSER and Raymond SOUMAGNE
CNES, 18 avenue Edouard Belin, 31400 Toulouse {martine.jouret, anthony.juin, fabienne.schaffhauser, raymond.soumagne}@cnes.fr

1 Introduction

The Space Variable Objects Monitor (SVOM) is a space system dedicated to gamma ray detection and study, under development by China National Space Administration (CNSA) and the French Space Agency (CNES), to be launched in 2021. The system shall be able to trigger alerts of Gamma Ray Burst (GRB) in real-time with a maximum of associated data. The space segment consists in a set of sensors going from large angle of view for detection to narrow angle of view for data measurements. Since GRB are very transient events, it requires the satellite to autonomously (i.e. without communication with ground) point on target the different sensors that, each in turn, provide more accurate position and data. As an addition to the system scientific and technical challenges, the organisation of the system operation by the two agencies introduces some more complexity.

The design of this system was conducted within the framework of the CNES engineering process, based on a set of documents cascading the textual requirements from the high-level concept of operations to the technical specification of equipment. The validation of the obtained specification mainly relies on human expertise and on the validation campaign.

The complexity of the system makes it a perfect candidate for an experimentation of MBSE. This paper presents the results of a study that has been led after the design has been already defined but while the system was still in development and the topic still fresh in the heads of the architects. The study tried to assess the benefits that MBSE could bring in this specific context.

2 MBSE-oriented objectives

Why injecting the MBSE methodology inside an existing process that proved its efficiency several times? Three main objectives are often associated to MBSE:

1) Communicate: to improve the communication between stakeholders by using a rigorous and yet reader-friendly language, and thereby reducing ambiguities.
2) Secure: to assist the system definition validation by using traceability and coverage mechanism to ensure consistency, completeness…
3) Generate: to take advantage of the formal description of the system to generate engineering assets (documents, code, database schema, etc.) or to assist the specification refinement by automatically initializing sub-level representations.

The current fully-operational CNES engineering process can thus be potentially improved, along these axes, by injecting a pinch of MBSE on it. Based on this conjecture, two projects took place successively. The first one was an R&T study, dedicated to the analysis of the current process and the evaluation of the potential benefits that MBSE could bring. Due to promising results, a second project, based on the models realized during the first study, was dedicated to the operational capture of the system validation.

Artal worked in close collaboration with the CNES in order to provide its MBSE expertise to the SVOM project and to CNES specialists. The MBSE activities of these projects were realized using the Capella tool [2], an open-source graphical modeller based on the Arcadia Method [1] (Arcadia is a model-based engineering method that defines high-level concepts). Capella is mainly based on four representation layers, dedicated to the system needs capture (Operational Analysis (OA) and System Analysis (SA) layers) and to its associated solution specification (Logical Architecture (LA) and Physical Architecture (PA) layers). The different representation layers are linked together in order to being able to apply traceability and coverage mechanisms.

3 MBSE-driven interface engineering

The first step consisted in analysing the CNES engineering process through the in-progress SVOM case. The main goal was to identify the capability and the relevance of capturing the system specification using Capella. In order to guide the modelling activity, we decided to focus on the interfaces specification. Indeed, it is a crucial step in the design of a complex system and the international collaboration context called for even more rigor in the definition process.

By analysing the existing specification of the system, associated to several co-modelling sessions, we were able to capture in the Capella model almost all the system description. We captured the main objectives of the system (using System Analysis (SA) layer) by specifying its interactions with external actors. We then obtained a quite bright view of the public interfaces needs.

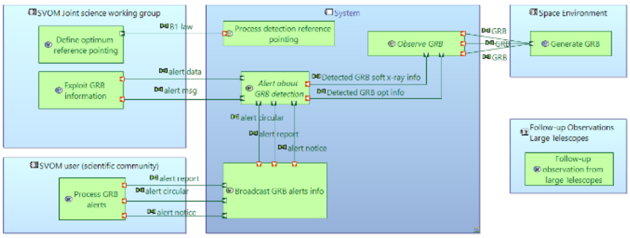

Figure 1. Partial System Analysis of the SVOM system

Then, using the Logical Architecture (LA) layer, we captured the internal system definition by representing all sub components, their functions, and their associated exchanges.

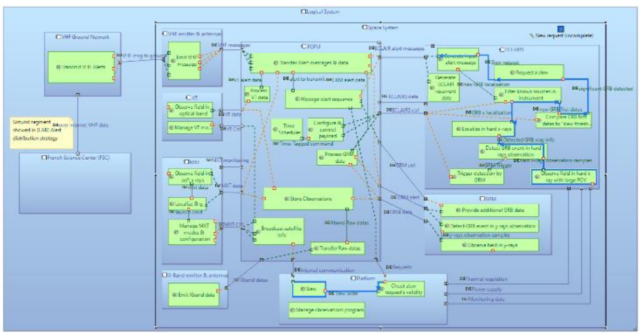

Figure 2. Partial Logical Architecture of the SVOM system

In order to address the interface engineering goal, different strategies were identified. It is possible to simply add textual description on the exchanges or on the associated communication ports. It is particularly relevant in case of subjective interfaces or if the interface detail is not required Otherwise, it is possible to refine functional exchanges by capturing the data structure associated to them. Then, it offers a clearer and more complete representation, whose only limits are those of the modeling language.

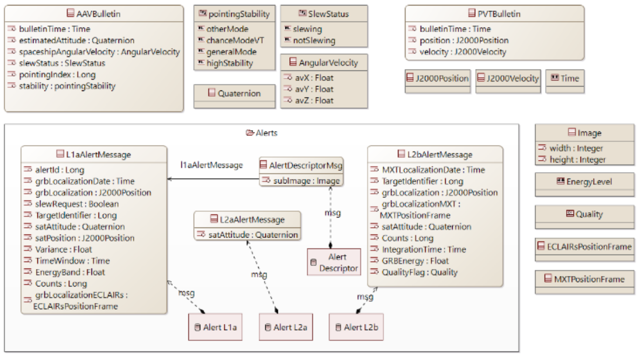

Figure 3. Data structure definition

Following the capture of the system itself, we studied the means to capture the specification of the simulator of a sub-part of the system. Using Capella internal tools, a new model, inherited form the original one, was initialized in order to derive the architecture specification into its associated simulator specification while maintaining traceability links.

Using the analysis of the obtained model and considering the three MBSE objectives defined in the section 2, the following conclusions have been drawn:

1) Considering the communication goal, the MBSE process gave us, in this context, a promising communication structure and a formal specification of the interfaces. Nevertheless, the SVOM project being in progress (and the interfaces specifications being already captured using the historic CNES process), it was not possible to clearly evaluate the capital gain.

2) As regards to the secure objective, the traceability links between the LA and the SA Capella layers gave us direct evaluation of the coverage of the capabilities by modelling items. The capture of interface detail also provide controls about the completeness of the specification (an exchange without associated data structure has to be completed).

3) Regarding the generation process, using the M2Doc tool (that allow the generation of Word documents including modelling items), we were able to mainly generate the traditionally manually filled document, the non-formal schema of the original document being replaced by formal Capella diagrams.

Due to the encouraging results of this first project, a second one, in an operational field, was dedicated to the capture of the V&V specification.

4 MBSE-driven V&V

Based on the models realized during the first project, the goal was to specify the V&V objectives and the corresponding tests sequences using modelling activities. As references, some test procedures of other CNES project were analysed and working session gathering Artal and the CNES allowed the identification of the V&V modelling needs. A dedicated Artal Capella viewpoint (called VVO) was customized to answer these needs.

First of all, the validation needs must be expressed by defining Functional Chains (succession of functional exchanges), each one representing one behaviour of the system to validate. Then, the definition of global validation objective (VVO) allows to groups them. For example, to validate the communication between two components (example of VVO), it will be necessary to satisfy a set of validation needs (e.g. all the possible connections between these components). In the context of a VVO, each function chain can then be derived in order to convert "abstract test objective" into "concrete test sequence". This step allows to specify the executable version (boxed in Figure 4) of a part of the validation sequence to be simulated (in purple in Figure 4).

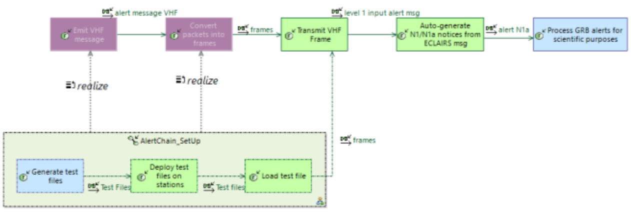

Figure 4. Concretization of the test

Using this data, an embedded tool allows the generation of a test sequence that can be annotated in order to specify the interactions steps and the success criteria to be manipulated by the test operator. Each step or criteria can embeds configuration parameter that will be valued during the test sequence instantiation.

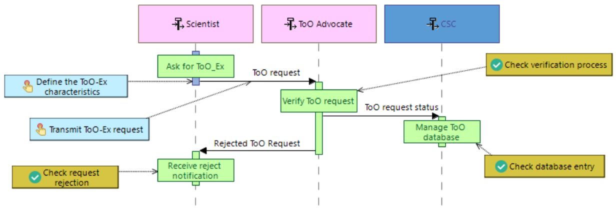

Figure 5. Annotated concrete test sequence

Using this toolchain, it was possible to capture all required validation data, the evidence being that all the required V&V specification document were fully generated from the model. Indeed, all along this collaboration, the MBSE has gained ground gradually. Initially, it was experimented in parallel of the classical process, in order to prove its worth. Then we planned to gather the two "ways of working" by generating, from the model, the document usually manually filled. The proof having been provided, progressively, the CNES engineers relied on the model and used it as data reference to conceive the V&V data, which were then integrated in the model. Finally the writing of the operationally used V&V specification document was fully delegated to the implemented tools.

The SVOM experts, MBSE and Capella inexperienced people, received this new process positively and were unanimous regarding the benefits of such approach. The operational gain was notable thanks to the strong stakeholders' involvement in this project and the real consideration of the model as the specification reference.

5 Going further

Around this main flow, several "on-the-edge" points were considered. First of all, we confronted the model and the 579 textual requirements in order to evaluate their overlap. Less than half of them can be strongly linked to the model (either fully covered by it or completing it, by adding performance constraints for example), the others being either too technical or, on the contrary, too abstract. An independent and autonomous requirement engineering process remains then needed and cannot be fully integrated to this described MBSE process.

Another point consists in the managing of specification version. In the original CNES process, the produced documents themselves embed their version and the change tracking report (manually filled). To transpose such capability in the MBSE world requires to being able to support such feature:

- The versioning of each stage of the model by saving the model stable copies.
- Storing the description of the changes associated to a new model version in order to facilitate impact analysis and to carry out reviews on a limited scope.
- Tracking the author and the modification dates.

The usage of some tools and connectors gravitating around the Capella platform (Github, Jira, Mylyn…) associated to the suitable method seems to be a satisfying answer.

Finally, in order to ensure a complete data continuity along the development process, it would be necessary to link the experimented modelling phase with the following steps namely the system building including software implementation. Concerning such goal, only a small incursion concerning the link with the satellite database was achieved. Starting from the Capella model, we well generated a skeleton of it (which has to be filled manually). Based on the "Mapping" API, this demonstrator supports iterative processes, in other words : allowing to progressively update the database content according to the successive version of the Capella model, while allowing manual database edition in parallel. A specific interface being dedicated to conflict resolution.

6 Conclusion

The smooth incursion of MBSE in CNES engineering process was undeniably well received. The SVOM experts were converted to this new way of working. Even if their professional schedule were fully charged, they did not hesitate to invest time to completely follow this experience until the end. The building of an operational model-based toolchain to capture the VV specification is an achievement which opens the door to a wider reach of MBSE within CNES. The data continuity is a powerful help in order to track inconsistence and to compute impact.

The three identified MBSE pillar seems to enter into resonance with the CNES needs:

- The communication between engineers will be lightened while remaining rigorous.

- The specification process will be secured thanks to the generalization of data continuity including a strong link between the validation specification and the system under test specification itself.

- All required documents will be automatically generated from the model, avoiding time waste in the heavy task of writing document.

Capella perfectly answered the CNES needs in this context and could be easily incorporated in a larger engineering framework to cope with transversal engineering concerns that rapidly arise.

Acknowledgement to SVOM project including CNES and SECM

References

[1] VOIRIN, Jean-Luc. *Model-based System and Architecture Engineering with the Arcadia Method.* Elsevier, 2017.

[2] ROQUES, Pascal. *Systems Architecture Modelling with the Arcadia Method: A Practical Guide to Capella.* Elsevier, 2017.