MODEL-BASED SYSTEM ENGINEERING FOR AVIONICS PROCESSES.

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***ABSTRACT* – In the space domain, avionics is by nature a challenging part of the system, as it is distributed over different sub-systems and involves different disciplines (DHS, AOCS, FDIR, SW, HW, RAMS, …). For many years, Thales Alenia Space has been using Model-Based System and Software Engineering, and in particular Capella, to cope with this complexity in different steps of the lifecycle and via different approaches. Thanks to its experience and its continuous efforts in this area, it can draw a global picture of how MBSE can be used in the avionics design process.**

KEYWORDS – MBSE, Capella, Avionics

1. Introduction

The avionics architecture of a spacecraft can be well summarized at functional level by the SAVOIR reference architecture:

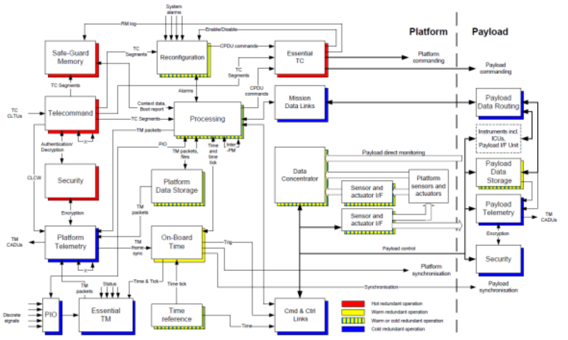

Figure 1: SAVOIR Avionics functional block diagram

Classically, there are several units which handle all these avionics functions : On-Board Computer, Remote Terminal Unit, Instrument Computer Unit, Mass Memory Unit… This diagram only gives a glimpse at a very complex design architecture which is then formally converted in an avionics design process, starting from the expression of functional needs to the HW and SW implementation with a lot of interactions between engineering disciplines (RAMS, SW, HW, …).

Model-Based System Engineering has provided development and improvement of engineering processes in the industry [1]. The space domain and more specifically the avionics world expressed its interests in using this approach in order to optimize the work performed by using models as references for discussions and traceability, but also to perform some analyses.

This paper explains and summarizes how Thales Alenia Space is coordinating Model-Based activities for avionics and how the extensibility of Capella is exploited to develop various tooled approaches making use of these models.

2. Leveraging on MBSE for Information Exchanges

Historically, the first way to interact between engineers and different entities is to share design descriptions on one hand and a set of specifications on the other. With the increase of complexity and the amount of documentation, it is not always clear and obvious where to find the relevant information and to enter in a program with a history and with a mountain of documents. Even though textual explanations are sometimes needed, models are a more formal and unambiguous way to share information. They act as a single source of truth, on which queries are made and design iterations performed. Furthermore, while documents are still required in most cases, some of them can be generated from those models.

In Thales Alenia Space, the main tool used for system engineering activities is Capella. The Capella model acts as a basis, a reference in the engineering process, and its use brings consistency and enables to have modifications with more flexibility [2].

However, models can have different goals depending on the work and the field of applicability. To extend the features of Capella, Thales Alenia Space develops add-ons which allow to add properties and make the link with other tools. To have a coherent modelling approach despite those different goals, Thales Alenia Space also defined some modelling guidelines for Capella.

3. Model for Requirement Checking

The first use of a Capella model which brings consistency to the process is the mapping of the requirements to the model. Two Capella layers are mainly used for the avionics field: the Logical Architecture which gathers logical functions answering to the need, and the Physical Architecture representing the implementation including the physical nodes and physical functions.

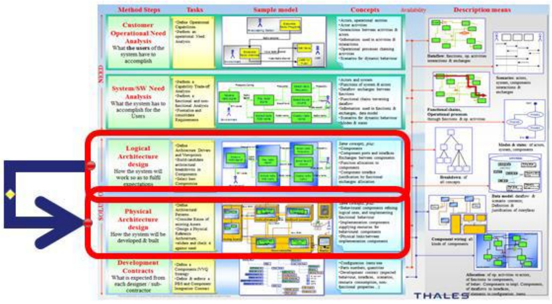

Figure 2. Capella layers used

The process to integrate requirements in the model is well mature and once they are loaded in the model, it remains to build the link with functions that fulfil the corresponding requirement. Thanks to that, interesting outcomes can result such as the compliance matrix or the requirement traceability with parents requirements.

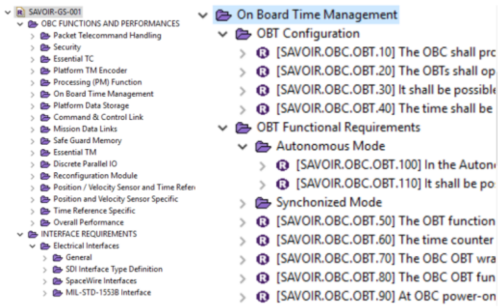

Figure 3. Requirements linked in the model

4. From Modelling to Simulation

A second interesting use of the Model-Based engineering in avionics is the possibility to use Capella as an entry point for simulation tools. Thales Alenia Space is currently involved in the ESA study called OSRA-ION, which aims at linking Capella to a protocol simulation tool that is able to simulate the protocols used in space.

In fact, the evolution of the number of protocols in the space community (MIL-STD 1553, CAN, SpaceWire, SpaceFiber, TTEthernet, TSN,…) reveals the need for standardizing the high-level avionics communication means. The SAVOIR On-board Communication System Requirement Document elaborates generic specifications for any on-board communication system with generic concepts that are used for all the protocols. Consequently, the idea to generate a link in the engineering process between early design with a Model-Based tool like Capella, and a simulation protocol tool, called MOST (Modelling of On-board Space Traffic), seemed natural.

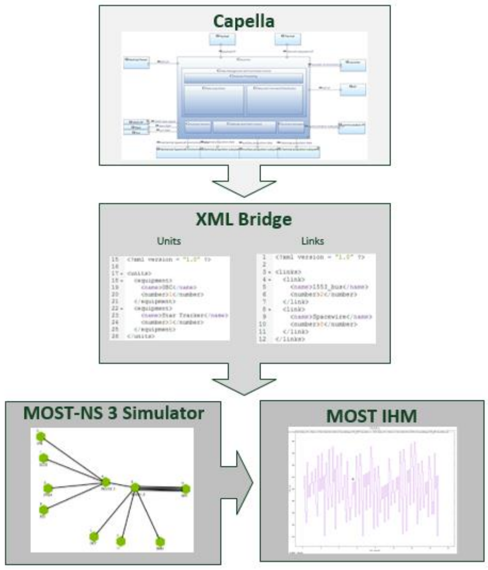

Figure 4. From Modelling to Simulation

This enables to model and define the avionics architecture and to insert the communication requirements. An engineer can then assess statically with the model alone, or dynamically with a simulation tool, whether the communication means answer well the need. If simulation is needed for a detailed analysis, an automatic transition of the topology, traffic and requirements defined in Capella enables to simulate the traffic and validate the requirements with accurate results.

5. Model for FDIR Process

In the avionics process, the Failure, Detection, Isolation and Recovery (FDIR) is one domain of the avionics design which often comes late in the project once the overall design is already done. The reason is that the FDIR design currently requires the existence of the Spacecraft Data Base. This prevents the deployment of early verification and validation analysis which are key to optimise the FDIR design, manage the complexity, and de-risk the test activities, avoiding discovering issues late in the process, which can have a significant impact and generate additional costs and planning overheads. This is why Thales Alenia Space is putting a significant effort in de-risking the use of a Capella based Model-Based FDIR Design approach, opening the door to early verification and validation thanks to Model Checking and Simulation in the near future. This is done in the frame of an on-going GSTP activity, exploring the approach based on a PLATO case-study.

6. Model for RAMS Analysis

In the current mission assurance process, the dependability analysis is in most of cases performed once the design has already been chosen, or sometimes even frozen, since the information needed to assess the quality of the architecture (e.g. its reliability, availability, failure tolerance, etc.) are gathered from engineering documents that are made available only in late phases. Thus Reliability, Availability, Maintainability and Safety (RAMS) analyses are sometimes performed 'only' as a proof of a design properly done, meaning compliant to the client requirements, but should be used instead as an engineering parameter to make multidisciplinary trade-off in the design. Using the units, avionics or even the satellite Capella models represents an opportunity to assess the quality of the design since the early phases of the satellite development and to take into account RAMS recommendations in the final selection of the most suitable architecture. For this purpose a Mission Assurance Model Based (MBMA) approach has been envisaged by Thales Alenia Space and different RAMS viewpoints have been and also will be developed in the frame of ESA R&D studies in order to support RAMS engineers in performing their domain specific analyses starting from the Capella models provided by engineering.

7. From Avionics Architecture to Software

Avionics and Software are closely related, as the first produces specifications for the second. In order to improve co-engineering between avionics teams and SW teams, Thales Alenia Space has been working on a model-based toolchain called Sys2Soft. This tooled process is based on Capella/Melody Advance for the avionics design, and CCM4Space (an internal proprietary tool) for the On-Board Software (OBSW) design. Sys2Soft provides a Capella Viewpoint that enables avionics and SW co-engineering for design consolidation, a tooled transformation allowing to save modelling effort on SW side by initiating a correct by construction architecture, as well as partial code generation for equipment managers.

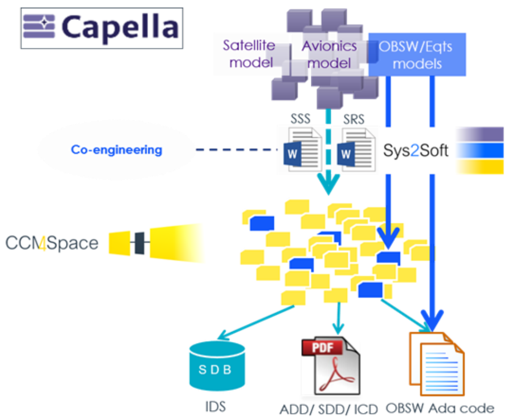

Figure 5. Avionics to Software implementation flows

In the end, avionics and SW co-engineering is a key topic for MBSSE, and in Thales Alenia Space, Capella is the backbone of the System/SW Factory, in which Avionics has a central role. In addition to Sys2Soft, some R&D activities aim at enriching the link between avionics and OBSW in the development process. Indeed, Electronic Datasheets and their role in this process is an important topic, and a transition from Capella to the SAVOIR On-Board Software Reference Architecture (OSRA) is also being explored in the frame of the ESA study Capella2OSRA.

8. Conclusion

The avionics domain is wide and complex considering its importance and all the functions associated to it, as it is considered as the heart of the spacecraft. Thales Alenia Space has put considerable efforts in MBSE over the past years, and is now in line with ESA which integrated this approach in its roadmap, making use of Capella's features and of its extensibility to address different problematics in the avionics design (traceability, information exchanges, simulation, analyses, etc.). Moreover, Thales Alenia Space is currently involved in several studies to continue to enrich this approach: Model-Based Avionics, OSRA-ION, Model-Based FDIR Design, Capella2OSRA, …
However, the ultimate challenge is to reach a digital continuity that would federate all the different approaches into a global model-based process. Indeed, Capella is often used with a precise goal in mind by the different disciplines, and models are not always shared between them.
Taking advantage of its experience in projects and its R&D activities, Thales Alenia Space addresses this challenge by coordinating its efforts to ensure a common approach, that will hopefully tend to this digital continuity.

Acknowledgments
The authors would like to acknowledge the support of

the European Space Agency, the involvement of Technical Officers in the studies, their advises and their confidence in Thales Alenia Space MBSE teams. This enabled to make the MBSE community grown and having coherency between tools to be used by programs.

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