FUNCTIONAL CHAIN APPROACH FOR AVIONICS MODELLING AND SIMULATION

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Abstract

Past and current avionics architectures are commonly represented by block diagrams. One representative example of this is the SAVOIR avionics reference architecture block diagram (SAVOIR is a space avionics open interface architecture resulting from an ESA initiative).

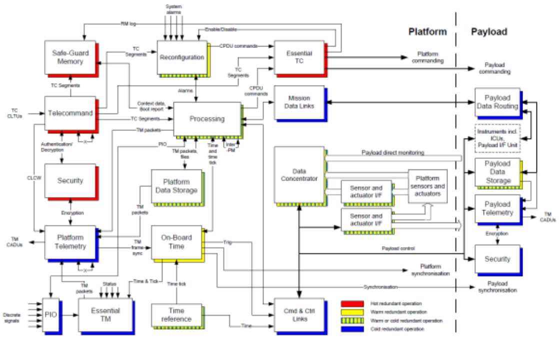

Figure 1: SAVOIR Avionics functional block diagram

In classical architectures, a specific piece of equipment, such as the On-Board Computer, the Remote Terminal Unit, the Instrument Computer Unit or the Mass Memory Unit, typically handles several of these functional blocks. But today with the rise of new kind of chips called SOCs (System On Chips), these blocks are more and more integrated and now it may no longer be relevant to represent avionics architectures like this. Instead, it is proposed to follow a functional chain approach. A functional chain will be defined here as a succession of interconnected functional blocks, translating a path followed to fulfill a particular function.

A R&T study called FATI-FC, which stands for "Future Highly Integrated Avionics: Functional Chains" was conducted in 2020-2021 by Thales Alenia Space and CNES, with the high level objective of rethinking the way to represent avionics design through functional chains and to use the result to perform traffic simulations. The study focuses on a new Thales OBC that will be built in the near future based on new technologies of SOCs. Thus, model-based approach has been chosen to model these new avionics architectures by functional chains, because it allows to highlight an anticipated increase in complexity due to SOCs. Indeed, the multi-cores processors integrated in those are embedded in a chip accompanied with some services and one FPGA part, which then implies a lower level of modelling due to the higher level of integration of the functions.

Organization and work logic

The FATI-FC study was organized in two main work packages, the first one being a model-based engineering phase in which Thales Alenia Space proposed a new methodology for representing the integrated avionics architecture, and the second being the traffic simulation of one specific functional chain, which is mainly reduced to some avionics functions interacting with each other and located respectively in the main and redundant part of the OBC.

MBSE Methodology for Functional Chains Modelling

The purpose of this part is to describe a methodology allowing to model an architecture using functional chains. To do that, Thales Alenia Space and CNES used Capella, which is the Model Driven Engineering (MDE) solution provided by Thales in Orchestra. Capella primary objectives are to define a unified engineering language, to automate engineering tasks ensuring modelling productivity and quality and to manage information consistency.

Here, the models are directly created from the Logical Architecture, each previous step having already been performed for the considered OBC system. However, note that the modelling process followed the SAVOIR architecture guidelines.

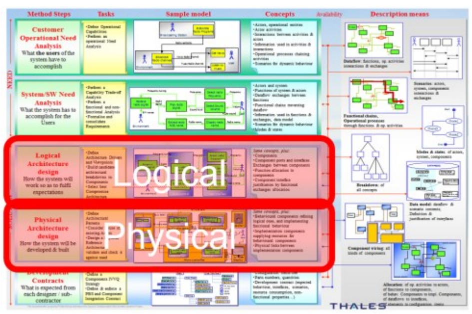

Figure 2 : Layer transition in Capella

At physical level, some physical nodes (elements of Capella) are created to depict the SOC architecture, that are different from the usual ones. Indeed, there is no board nor module here, there are only parts of the chip such as a FPGA fabric, an ARM interconnect, a processing part and even memories. This gathers the main parts of every SOC, and all the functions can be mapped directly to these physical elements in the model.

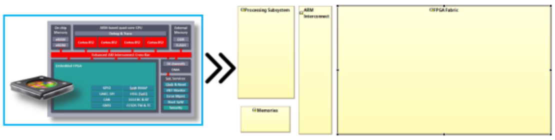

Figure 3: Proposition of Physical nodes representing the SOC architecture

The functional chain strategy was applied at this step to model the PABs (Physical Architecture Blanks). Indeed, several PABs are created based on this SOC physical architecture, in order to devote each of them to one specific functional chain. Basically, the process consists in focusing on one specific functional chain at a time, by adding only the elements (functional blocks) of interest in a dedicated PAB, in order not to overload the global model and to easily handle the complexity. Because on a same arcadia layer all the changes also impact the other diagrams, this methodology also allows to automatically update a more comprehensive PAB.

Focus on the TC Functional Chain: diagram resulting from the methodology

In this paper, not all the functional chains are going to be detailed in order to simplify the understanding and to improve the reading fluidity. Here, only the Telecommand functional chain will thus be presented, but the process is the same for every other chain.

Also note that during this study, only a few avionics functions have been studied with high amount of details, i.e. with definition of all the functions and functional exchanges. These were the telecommand function, the telemetry function and the reconfiguration function (more information about these specific functions can be found in the SAVOIR reference architecture related documents).

For the TC (Telecommand) function, there are several particular paths that have been represented in the Capella model (appears in blue on *Figure 4: TC functional chain to OBSW*). In fact, we had to consider options and variability of the TC functional chain: with or without encryption? internal or external encryption? etc. A classical TC flow would be the following: coming from the transponder, the data goes to the TC Decoder (behavioural component in blue) after detection of a TC signal. After that, the data transits to the decryption function and comes back in a clear segment to the TC Decoder. Then, depending on the target of the TC, the correct routing is done. Hereafter is presented one of the possible paths in the Capella model with a “Functional Chain” Capella element (not to confuse with the functional chain approach for modelling, which consists in only adding elements that translate TC-related functionalities in the diagram)

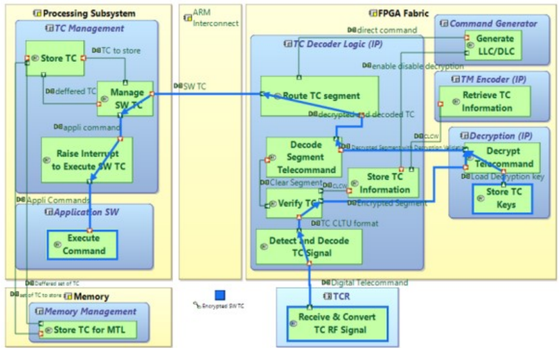

Figure 4: TC functional chain to OBSW

There are different targets for the TC and so there are several paths, basically one for each target. For instance, the direct TC is executed by the command generator when the TC is tagged with a MAP 0. The other MAP often used is the MAP 1 which corresponds to a TC routed to the SW. All the other TCs than MAP 0 and 1 are routed to the other avionics functions, mainly the Safeguard Memory and the Reconfiguration Module. Each TC corresponds to one Functional Chain Capella element (such as the blue path, again not to confuse with the functional chain modelling approach but which completes the representation of the functional chain itself).

First use-case: Functional Chain Traffic Simulation

The second part of the study was linked to the model-based engineering process that was conducted. The objective was to use the models which define the functional exchange and consequently define the traffic with the corresponding data flows of each Capella element. This enables to simulate the interactions between the different functions. Here the example of the nominal and the redundant part of the OBC has been chosen. So basically, the topology and the traffic simulated represent all the functional exchanges that are shared by the nominal and redundant OBC modules.

The purpose of this simulation was to estimate and to validate the traffic generated by the avionics functions in the case of using SOCs with new assorted communication links. The definition of period, data length and data type was preliminary assessed and not fully consolidated but led to a comprehensive basis for simulations. Starting from the Capella model with the functional chains, a transposition led to the description of the following topology in the simulation tool, with the hypothesis of having a simulation router representing the SOC Interconnect.

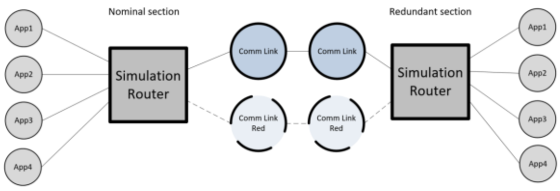

Figure 5: Topology of the simulation

The simulator was developed internally under ESA funding and is called MOST (Modelling of On-board Space Traffic). To build the simulation topology, the Capella model was used only as a visual base, but Thales is now developing a bridge allowing MOST to interpret Capella diagrams to make them act as a graphic user interface for the tool.

After that, a traffic has been defined to be representative to the reality. In addition to that, some assumptions had to be made to match the new types of traffic imposed by SOC-based architectures.

The results were that for the basis of important data, the communication links handle well the avionics function exchanges between the two OBC slices. Subsequently, this process enables also to push the system to the limit with a denser traffic.

Second use-case: requirement coverage analysis

At the same time than the FATI-FC study and in the SAVOIR context, CNES launched a smaller researched activity with the objective to investigate the impacts of the new SOC-based integrated avionics architectures on the SAVOIR requirements by using an MBSE approach. The main objective of this study was to build two avionics architectural models: one classical avionics architecture model based on the SAVOIR documentation, and one highly integrated architecture model based on new possibilities offered by SOCs. Eventually the objective was to use these two models in order to compare them and to perform an impact analysis. Indeed, SAVOIR requirements are initially designed for classical avionics architectures and may not be applicable to SOC-based architectures. It is then important to point out which requirements are too technology-oriented, and by doing this, highlighting the requirements that should be reviewed.

In order to build these two models, the same functional chain approach was used, which allowed to better manage the complexity and the readability of the diagrams.

A Capella add-on was used for advanced requirements management inside the tool. It allowed to try mapping every SAVOIR requirement to Capella model elements, thus allowing to study the ability of the requirements to cover a classical avionics architecture or a SOC-based architecture. With the help of another add-on enabling automated document generation called M2Doc, some requirement allocation coverage tables were generated, allowing to study the requirements that are not applicable in an integrated architecture. Indeed, if a requirement cannot be matched with any Capella element, it may mean that it is too oriented (towards a specific physical implementation) and that it should be generalized.

Requirement	Allocation status (If field is empty, then no allocation)
SAVOIR.OBC.TC.10 *No of TC Decoders*	**Allocation OK** *Handle Telecommand* *(ID : eb3b8dfb-fb28-4dfa-a371-0ae72f641f5f)* **Allocation OK** *Redundancy type* *(ID : 18b7768d-9030-450d-b127-6b0d270ffd27)*
SAVOIR.OBC.TC.20 *Input selection mechanism*	**Allocation OK** *Select TC receiver inputs* *(ID : 5c055089-0051-4dc0-a1b0-7b6184fcd673)*
SAVOIR.OBC.TC.30 *TC Decoder function*	**No allocation**
SAVOIR.OBC.TC.40 *TC Decoder function*	**Allocation OK** *Decode TC segments* *(ID : 7fdf1ec3-d8e4-4532-968f-6d2175025ab6)*

Figure 6 - Requirements Allocation Document Extract

Conclusion

This study brought a good support and a new philosophy to the current OBC based on new SOCs that is in development at Thales Alenia Space.

The main benefit of this methodology is that it really helps to manage complexity brought by the new highly integrated types of architectures as well as by the multiple new possibilities offered by these regarding avionics functions physical integration.

It also helps to develop new applications based on models such as traffic modelling. In our study, we showed that the traffic generated by different avionics functions fits well the limitation imposed by the communication links between the nominal and redundant part of the OBC. Here the functional chain modelling approach was not mandatory but helped to study specific paths for the TCs and other avionics functions not presented in this paper.

The methodology was also used for requirement coverage analysis, again showing its utility for improving the complexity management of a model, thus allowing to focus more on the objective of the study.