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Benefiting of Digitalization for Spacecraft Engineering

Claude Cazenave (1), Luc Fancelli (2), Harald Eisenmann (3)

(1) Airbus Defence and Space
31 rue des Cosmonautes
Z.l. du Palays
31402 Toulouse Cedex 4
France
Email: claude.cazenave@airbus.com

(2) Airbus Defence and Space
31 rue des Cosmonautes
Z.l. du Palays
31402 Toulouse Cedex 4
France
Email: luc.fancelli@airbus.com

(3) Airbus Defence and Space
D-88039 Friedrichshafen
Germany
Email: harald.eisenmann@airbus.com

DIGITAL TRANSFORMATION

At the heart of the fourth industrial revolution, digitalization has become a very popular trend in all high technology industry. Based on digitization, the process of converting analogic information into computer bits, digitalization enables the automatic exchange of computer data coming from various stakeholders who contribute to a collaborative solution. As the previous industrial revolution this one is about automation. But while industrial robots have little interactions with humans, digitalization robots, aka software tools, have a lot. Those interactions are the seamless flows of information. They are exchanged along the complete system life cycle from the proposal phase to the delivery – or even beyond e.g. the on orbit phase for a satellite. Those exchanges imply all the engineering domains including product data, as well as configuration or verification data. Each of those domains has specific processes and use to define their own views on the same data independently of the needs for sharing with other domains. As a result one of the biggest challenges is not in terms of developing the tools in charge of the proper data exchange but in terms of a shared definition of the data. Moreover the definition of those data structures shall be compatible with the various processes or even more flexible enough to cope with new process definitions.

DIGITALIZATION AT AIRBUS DEFENCE AND SPACE

Digitalization is a strategic goal on Airbus level, with many actions placed. On Airbus DS level closed attention is payed to seamless End To End (E2E) integration of tools, with the seamless flow of information. At the same time, to have the efficient view on data, with views tailored for the particular use case. While in the past, the focus, was more on interdisciplinary aspects (e.g. as covered in Virtual Spacecraft Design [1]), here the clear goal is to go throughout the complete system life-cycle – or even beyond. The increasing trend of product orientation requires collecting data from projects and suppliers, to make them available, for future projects. This includes product data, as well as configuration or verification data. A key function is to support the selection of the right product and configuration, with an effective “flow” of data from the product repository, to the individual CAD tools. For this a definition of a holistic vision for the future E2E Product Life Management (PLM) environment is in progress. This vision builds on top the existing authoring tools and configuration tools, and completes this with then needed functions to obtain E2E connectivity, digital presentation of data, learning from data and improved management for the increasing “agile” projects.

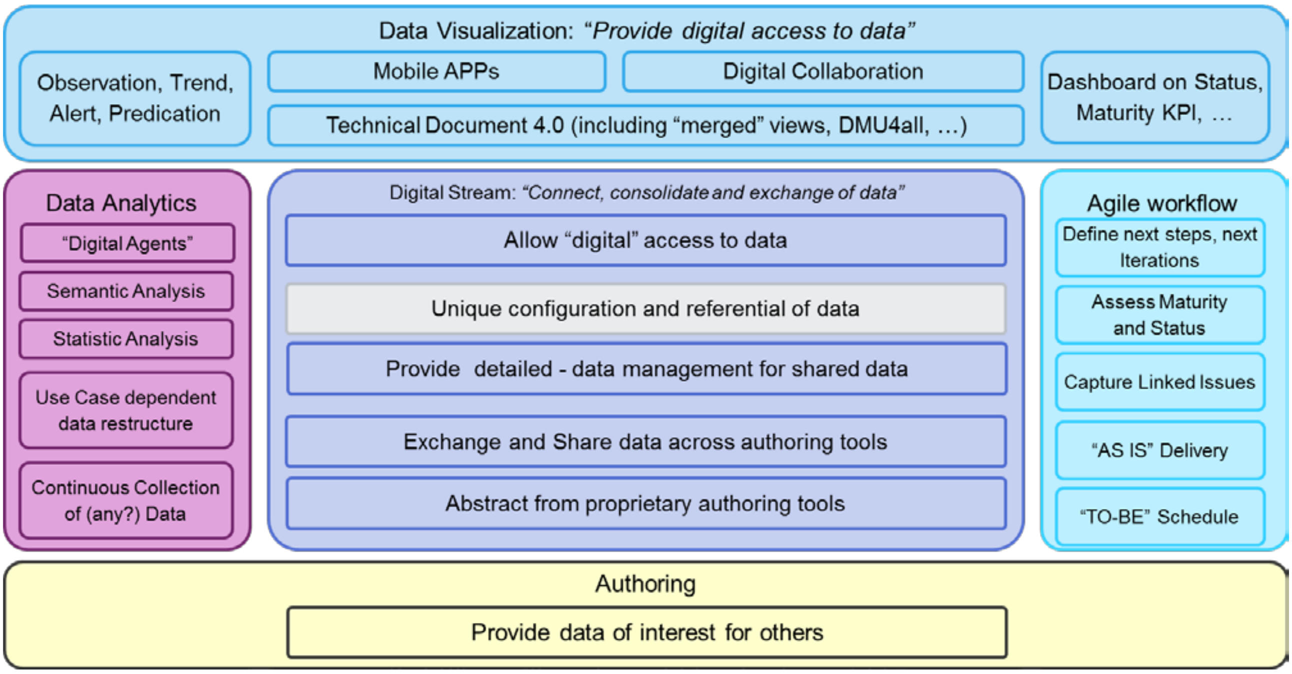

Fig. 1. Holistic E2E PLM Vision

APPROACH TAKEN FOR SPACE

Over the past years in the space part, Airbus DS significantly progressed with some key building blocks:

- As part of the PLM programme CONNECT key elements for a connected process from mechanical design, configuration control, procurement and manufacturing have been developed. This relies on classical COTS product for this purpose, like the Dassault 3D experience, PTC Windchill and SAP. For the support of manufacturing engineering and execution Solumina has been used.
- Complementary to this effort a solution has been developed supporting functional engineering. The core of it is a modular data management framework called RangeDB [2]. It has been developed, enhancing the published draft data model of ECSS-E-TM-10-23. The initial use case was the classical system database, meanwhile many different use case along the life-cycle are supported, mainly supporting functional engineering and verification.
- Dedicated for telecom process an engineering tool has been developed, called Satellite Sizing Tool. It supports telecom P/L design, starting with the bid phase, down to the design phase, where the complete configuration is defined.

Undoubtedly those key elements form essential elements of an E2E backbone. As for many other companies those elements are not sufficiently integrated. Neither the data flow between the bricks mentioned above is sufficiently supported, nor the configuration control flow.

In continuation with E2EPLM project started last year, Airbus has launched a new project dedicated to Space System spacecraft whose name is Factory 4.0. This project is not limited to digitalization but relies on this approach to increase significantly the overall efficiency of the company to design and manufacture satellites. As described in the next figure, the scope of Factory 4.0 is defined by seven collaborative platforms. It starts with a Bid collaborative platform where engineers define a preliminary solution to answer to customer needs. This preliminary solution is used for instance but not only to define the cost of the satellite. When hopefully the contract is won, this preliminary solution is finalized using the system collaborative platform. From there, in parallel functional and mechanical activities are started to define the detailed design allowing the start of manufacturing activities based on the execution collaborative platform. When spacecraft is on orbit, support activities performed with their dedicated In Orbit Support (IOS) platform are reusing data coming from the previous phases. IOS platform will also generate data for the next Bid phases benefiting of a better knowledge on the equipment to be used. Finally in parallel to all those activities a quality platform allows to monitor and control the quality at any stage.

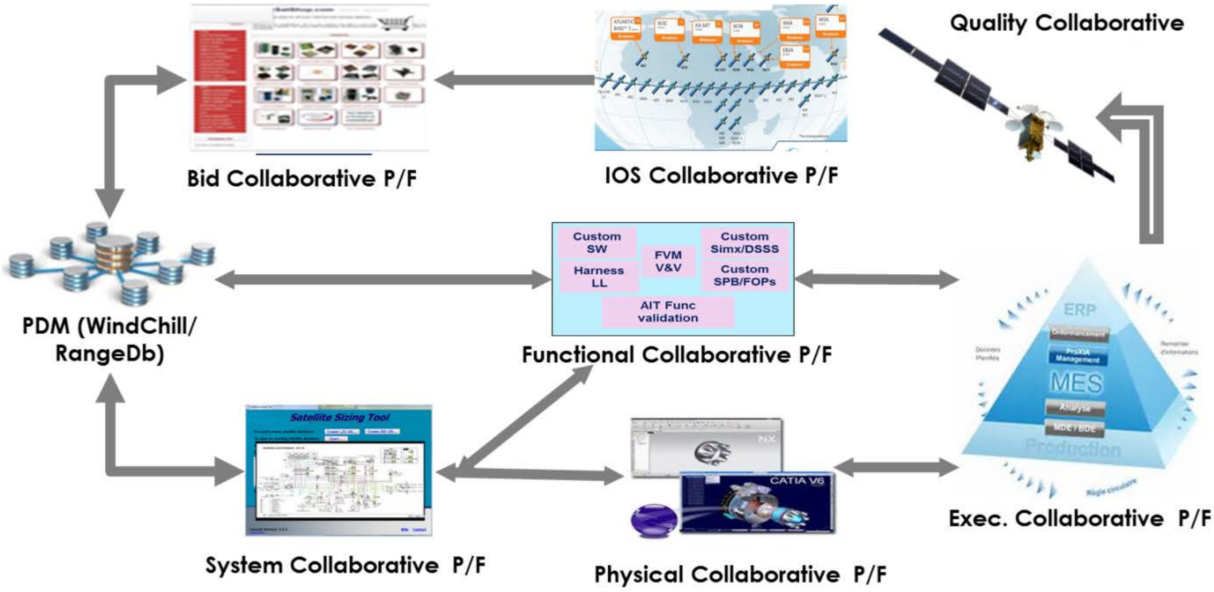

Fig. 2. Scope of Factory 4.0

To enable data exchange between these collaborative platforms, one preliminary rule is to avoid duplication of the information. This single source approach indeed greatly simplifies the problem of data consistency but keeps the need of adequate configuration control mechanisms. Those mechanisms are driven by the dynamic of the data to be exchanged. For instance is it automatic or is it human driven? Moreover different kind of data are to be exchanged with inherent various levels of complexity and accordingly there can be a need to use modelling technics to describe these complex structures. For managing all the possible cases, a strategy is required to select a limited set of technical solutions. The proposed one is based on the definition of two categories of needs and the dedicated solutions for each of them.

The first category is about engineering activities. Engineering concurrent activities are performed by several teams dealing with their own data and exchanging part of this data with other teams. The other teams have different definition of the shared data for historical reasons and because only a subset is required. Today those data exchanges are already in place but automation is not done because of this lack of shared definition of the exchanged data and because of the lack of shared configuration control solutions. Basically each domain has more or less is own solution to configure the data and exchanges between these configuration control systems are often manual. Moreover when data is sent to many consumers, there exist cases where different mechanisms are used to push the data to each consumer. Thus, the proposed solution is to reduce drastically the number of configuration control solutions. Ideally only one, a System Engineering Data Base (SEDB), would be sufficient. However two problems remain. The first one is about the move from a document centric approach, required by the customer, to a data centric approach. It is proposed to keep in parallel configuration control of documents and configuration control of data and to synchronise the two. This approach will be more described in a next chapter. The second problem is about the shared definition of the data to be exchanged. A solution is to completely and accurately define those data using a so called Conceptual Data Model (CDM). This is very robust thanks to the level of modelling that can be achieved as it has been proven when developing System Reference Data Base like RangeDB. Data are fully normalized and this limits the needs of data transformation that is always a risk for data consistency. However the definition of this single model takes a lot time and this may not be fast enough to cope with all the new needs that will arrive because for instance of new technologies. Thus a complementary solution is required based on a less normalized approach and more driven by users who can define their own data structures with ability to share them. This is typically what is proposed by RangeDB, based on ETM10-23 results, where both a CDM and user's defined data structures are managed. The less normalized approach does not prevent from any risk of duplication or from data transformation errors but has been proven as being a complementary valuable solution in the use of RangeDB.

The second category is about all the data generated automatically during analysis, testing and operations activities. Compared with the previous category no human interaction is required. Data are to be stored automatically and quickly wherever they come from. There is no real configuration control but more the ability to retrieve data afterwards. The process shall be very fast and the volume of data to be considered will be much higher. This is typically what is proposed today by Big Data solutions. All the data are stored in a so called data lake to be processed later on typically to generate new values to be used for engineering activities described above. Because most often some post-processing is required, there is implicitly a need for data transformation. As a result a less normalized approach is preferable to ensure access to data coming from many not correlated sources. For instance, while it is beneficial to share the definition of TM/TC data structures in a single CDM, it is better to store directly engineering telemetry values in a big data system so that there is no more need to rely on these complex data structures when post processing spacecraft TM. To summarize the selected strategy is to mix an SEDB with strong configuration control and modelling features with a Big Data system in charge of massive data acquisition. And of course these two systems shall be well integrated to take all the benefits of those complementary approaches. The next chapters illustrate several cases.

SOME DATA CONTINUITY EXAMPLES

PDM and SEDB

As described above, for space systems, PDM is based on the well-known Windchill product. For sure this tool provides very powerful configuration control mechanisms for documents but on the other side it is rather difficult to provide to manage a data centric approach with it. Indeed there is clear lack of modelling features. On the opposite, the SEDB has been designed for this data centric approach and provides all the related configuration control mechanisms but not for documents. So the idea is to integrate the 2 systems ensuring the consistency by synchronisation mechanisms. In the SEDB as in the PDM there exists a product structure where all the available equipment are described. From an SEDB point of view, the synchronisation consists in making a link between each element of its product structure, called an Element Definition in RangeDB, and the related element in the PDM, called a part in Windchill. Once this link is established the SEDB can create references to PDM documents so that SEDB users have automatic access to these documents. But the more interesting case is when the document is an Electronic Data Sheet (EDS). Indeed the EDS is not anymore a classical document like a PDF where by reading someone can extract some numerical values. The EDS is a digitalization of the numerical values and provides direct access to them by software tools. As a result, at synchronisation time, the SEDB will detect the availability of a new version of the EDS and will directly import its content in the appropriate data structures. EDS are not yet defined for all domains, it is a work in progress, but there exists already EDS for electrical ICDs that are covering most of the equipment. This synchronisation, already been developed, is described in the next figure.

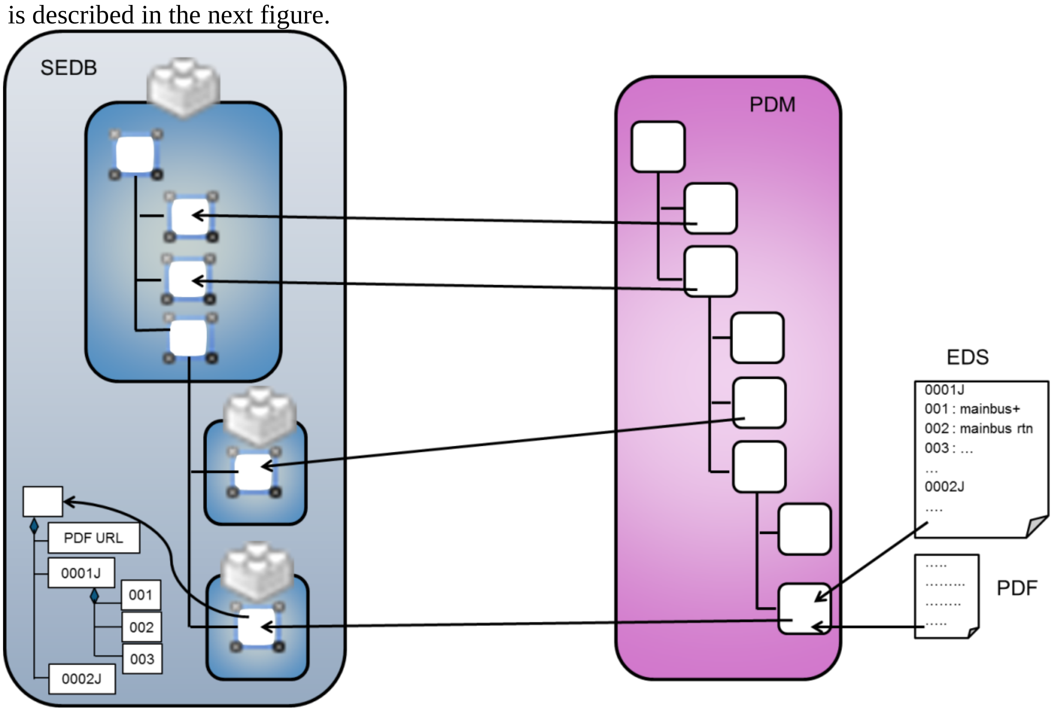

Fig. 3. SEDB and PDM synchronisation

Proposal phase to design phase

During proposal/Bid phase it is required to quickly select the equipment to be used. This selection is based on many criteria and the trade-offs are not limited to the comparison of one equipment with on other but also by comparing a set of equipment that fit together with another set. This activity has two main data continuity problems. First is to retrieve all the characteristics of all those equipment during trade-offs and to maintain the consistency by keeping up to date those data. Second is to enable the reuse of this selection to start the actual design when project is won. The implemented solution is a web interface for the bid phase pre design. This looks very close to e-market approach so that people have a quick buy in. On the background RangeDB, the SEDB, provides all the mechanisms required to share the data with this interface on one side and to configure and control those data on the other side. Once equipment have been selected, their references are sent to Satellite Sizing Tool, the Airbus system design tool for spacecraft. This tool is also relying on RangeDB to retrieve all the data of the selected equipment. The design can start and all the work performed will be also stored in the SEDB. So that, all the next concurrent engineering activities will rely, seamlessly, on the initial Bid phase results. It is also important to note that equipment characteristics are not limited to supplier data (ideally delivered through EDS). There is also data coming from testing and on orbit results. All of them are stored in a data lake and with dedicated processing will feed the SEDB with more accurate or complementary information.

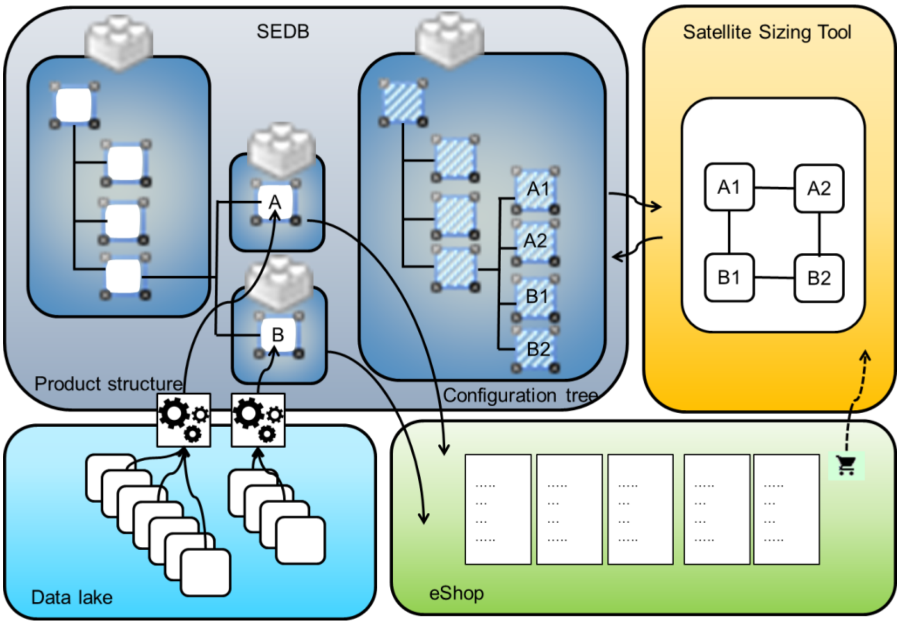

Fig. 4. SEDB, data lake, eShop and SST

Design phase to accommodation

Satellite Sizing Tool, SST, is used to define the complete design of the spacecraft. Once equipment have been selected , including the quantity of equipment, the equipment are connected together at functional level. The SEDB again is used to configure and control all this information so that other disciplines can use it in a safe way. The PDM at first will receive the configuration tree of RangeDB to elaborate the spacecraft hardware matrix. Then, among activities to be performed one consists in a preliminary accommodation of the equipment on the spacecraft. This consists in the definition of each equipment position taking into account all the constraints such as structure, deployments and connections between equipment. This position will be refined later on by the mechanical design office but here the objective is only to have a preliminary design based on various methods including for instance optimization algorithms. In order to achieve that an interface with the Digital Mockup, the DMU, is required to have access to simplified geometries of the parts to be assembled and to exchange preliminary and final mechanical assemblies definition. Thanks to the link between the SEDB and the PDM on one side and the link between the DMU and the PDM on other side, there is unique definition of the parts and geometries can be retrieved automatically by using a shared area provided by the DMU. This also applies to the assemblies definition as described in the next figure.

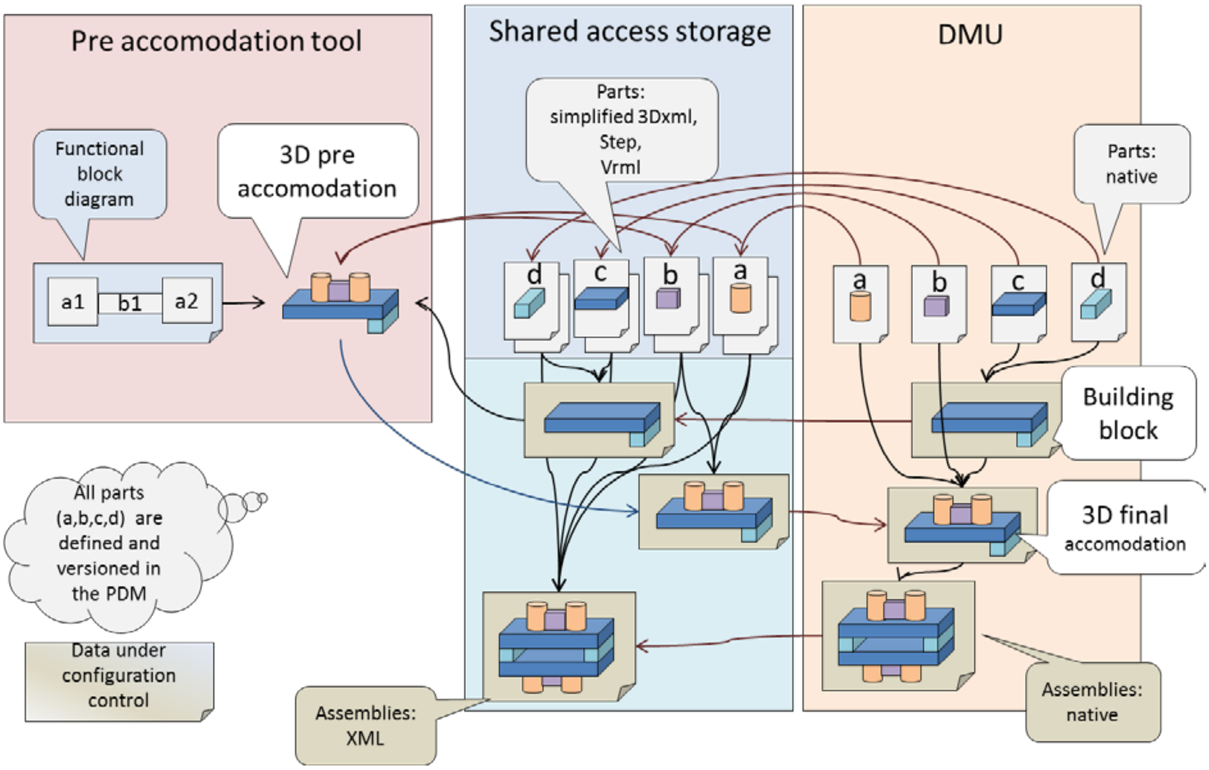

Fig. 5. Automatic exchange of 3D simplified geometries and mechanical assemblies

Design to verification

This chapter presents two examples to illustrate how the digitalization approach is benefiting to the verification phase. The fist example is about the simulation systems used for the verification of the spacecraft. The goal is to generate automatically the configuration of the simulator according to the definition of the design. In the SEDB the selected equipment, their quantities, and their connections are directly used to generate configuration files of the simulator. These configuration files provide the number and types of each simulation model to be instantiated and the connection between the models. For instance connections between models for the electric part are computed by the SEDB according to functional electrical design. This is achieved by importing the design of the model into the SEDB so that links between the simulation model elements (data, ports,…) can be performed with the functional design of the equipment already stored in the SEDB. According to these links simulation model parameters and connections are derived as described here under.

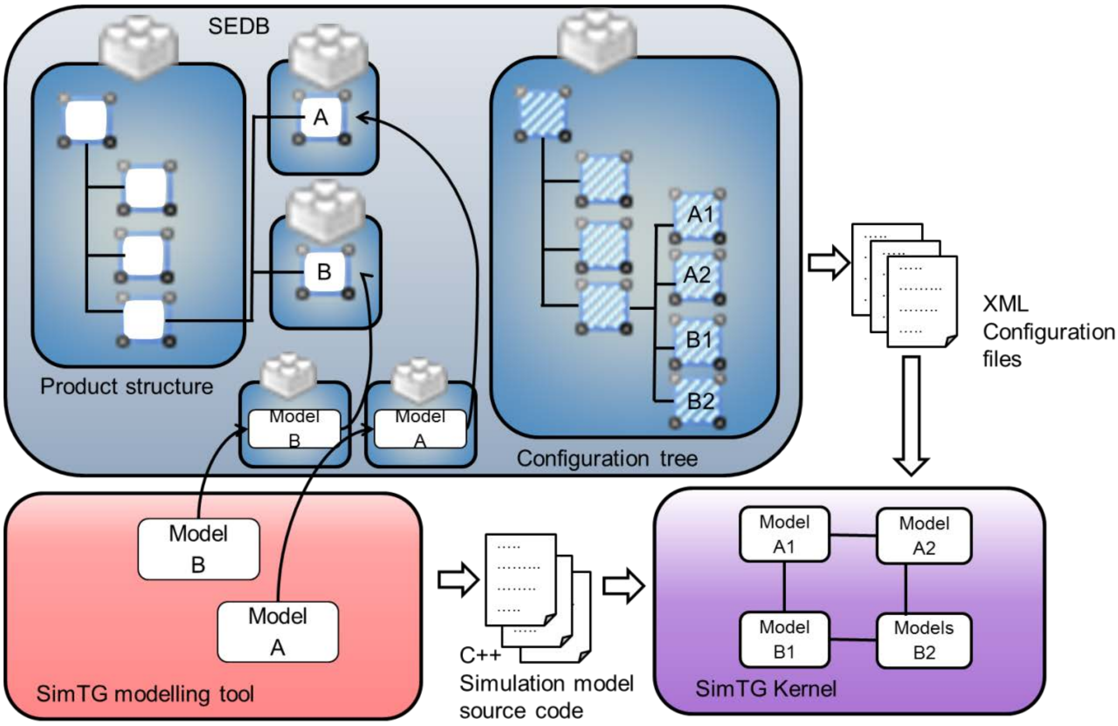

Fig. 6. Simulation automatic configuration using SimTG[3] the Airbus spacecraft simulation infrastructure

The second example is related to management of all the verification activities. A dedicated tool, Functional Verification Manager[4] (FVM), has been developed to define the test specifications, to link them to the test procedures and to check test execution results. Test specifications cover all user requirements and as an outcome of FVM a Verification Control Document (VCD) can be automatically generated to prove how each user requirements have been verified. In addition to this verification matrix, FVM can define the manufacturing phases where each test has to be performed and with the required configuration of the system. This is the so called Overall Test Matrix (OTM). All the information elaborated within FVM are connected, when appropriate to the system design stored in the SEDB. For instance, as described in the next figure, requirements to be verified are the ones stored in the SEDB (optionally imported from DOORS) and spacecraft configuration is also directly referenced to define efficiently each test configuration.

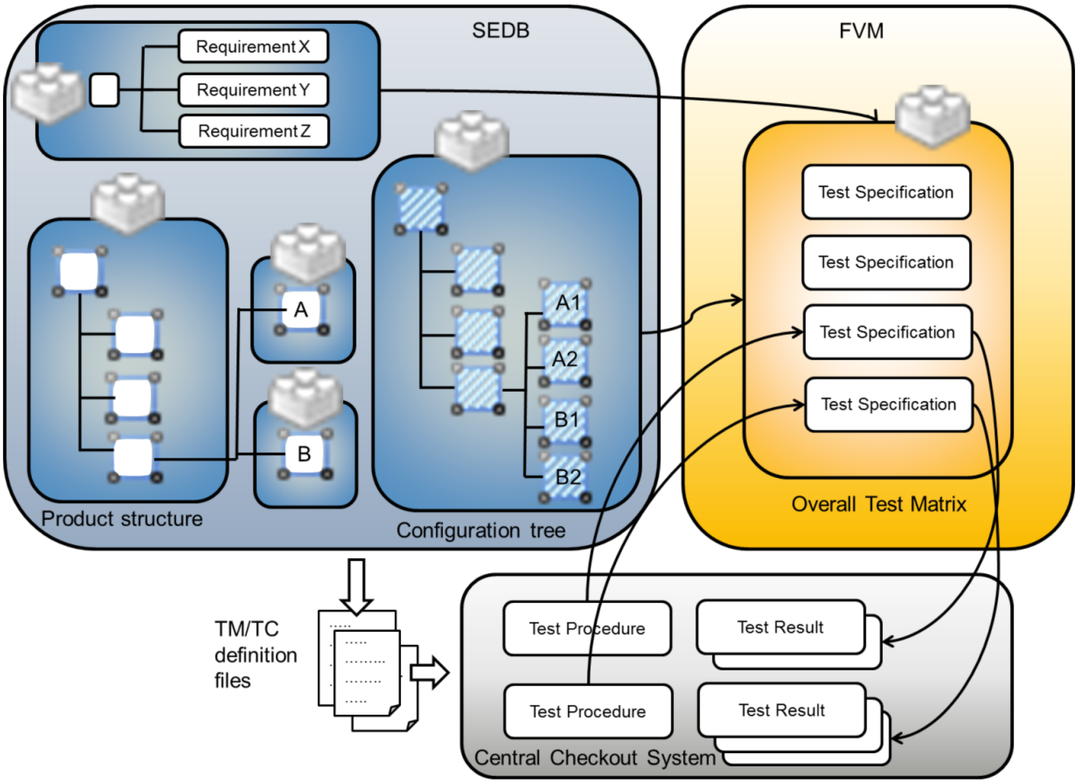

Fig. 7. Functional Verification Manager data continuity

CONCLUSION

As seen above, through this list, not exhaustive, many digitalization activities are ongoing. A strategy is in place, tools development and adaptations are progressing under the lead of several improvement programs such as E2EPLM and Factory 4.0. This is a major change in our industry where the main difficulty is to keep all engineers on board, to ensure their complete buy-in and to support them during the transition phases.

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