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Extended abstract

Beyond SysML models to describe Airbus Space missions in an extended MBSE environment for system architecting.

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The paper attempts to address the workshop objectives as follows:

ID	Specific workshop objectives at operational level	Paper contribution to objectives
O-1	Successful applications with emphasis on reporting perceived return-on-investment	The proposed approach is currently developed, tested and partially deployed on Airbus Space projects. For the RoI assessment criteria were defined and savings estimated.
O-2	Limitations of current MBSE approaches and ways to circumvent or resolve these (e.g. through customization of processes and tools)	The presented solution for system architecting is integrating different aspects relevant for a robust preliminary system definition like the mission, operations, functions, logical and technical decompositions, system variants with budget and the relations to the requirements.
O-3	Sustaining MBSE after first adoption (e.g. long term maintenance and model evolution, application / re-use in the next project, identified non-technical and governance aspects [see also tactical and strategic level])	The solution integrates the management of generic models for supporting the generation of specific system architectures required for a given mission. The overall governance is managed in the Airbus DDMS (Digital Design Manufacturing and Services) transformation program.
O-4	Leveraging MBSE results to improve the definition and development of other downstream applications and use cases	Not explicitly described in this paper but part of Airbus DDMS (Digital Design Manufacturing and

	(e.g. simulation, validation and verification, operations)	Services) program addressing the long term maintenance aspects.
O-5	Experience reports on sharing models and data ("doing MBSE together") Across projects Across engineering domains Across life-cycle phases With customers With suppliers	The paper reports that the most important aspects to effectively deploy the MBSE solution and share models are an abstract system engineering meta-model and a direct and continuous coaching of the projects by experts.

ID	Specific workshop objectives at tactical level	Paper contribution to objectives
T-1	Discuss enablers and hurdles to introduce MBSE in industrial practice also considering non-technical aspects (e.g. change and engineering management, organizational embedding, infrastructure and security, workforce training/evolution)	This aspect is described in the paper mentioning the need for a common referential like the abstract system engineering meta-model called SECAM©, a modelling method called MOFLT©, as well as training and close coaching.
T-2	Discuss the next "big challenge" to address to improve digital continuity; what is needed to achieve a truly end-to-end digital workflow	Not addressed in this paper but part of the Airbus DDMS (Digital Design Manufacturing and Services) transformation program.
T-3	Showcase novel approaches to MBSE that have the potential to significantly improve the state-of-practice in space mission design and development; both innovative approaches from industry and academia are welcomed, but with a clear focus on application potential at scale	The proposed system architecting solution has the ambition to integrate the main aspects of mission and system architecture definition completed by the management of the system parameters and system budgets. It gives in addition the possibility to visualise the main system parameters in a browser directly accessible by the project stakeholders to get a coherent view on the mission and system definition. Further, the solution addresses the connection to business models to establish a robust and coherent transition between the business needs w.r.t. system capabilities and the generation of the engineering solution.
T-4	Discuss the role of existing, evolving and emerging standards to address interoperability and semantic modelling to support digital continuity	Not addressed

ID	Specific workshop objectives at strategic level	Paper contribution to objectives
S-1	The vision for (model based) systems and software engineering in the next decade; opportunities and challenges, risks and rewards	One additional aspect of the vision would be to also connect business models described in UAF to the system engineering models as described in the paper.

S-2	Current and future R&D programmes with focus on MBSE, digital spacecraft, big data, machine learning and artificial intelligence	Not addressed
S-3	Collaboration in an international, competitive and heterogeneous market place (e.g. evolution and adoption of standards and tools, legal and contractual aspects, data governance)	Not addressed
S-4	Lessons learned from other application domains dealing with complex system design (e.g. aeronautics, automotive, railway etc.) with focus on potential of knowledge transfer to the space domain	Not addressed

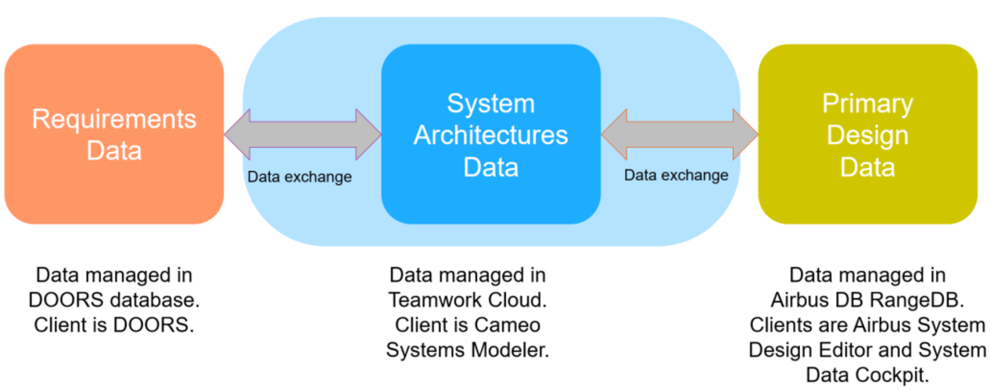
Airbus has been developing in the past few years an abstract system engineering meta-model called SECAM© (Systems Engineering Core Architecture Model), which is the basis for the Airbus MBSE digital continuity, for all Airbus divisions. This meta-model defines the profile used to model systems in SysML. The related modelling method MOFLT© (Mission Operations Functions Logical Technical) is based on ISO 15288 and is providing all the steps needed to advance from the mission to the operations definition, to trace the definition of the functions from the operational main use cases, to perform the functional analysis, to finally allocate the functions to the logical and technical architectures. Airbus projects like e.g. EL3 (ESA), PERIOD (EU), LISA (ESA), CLTV (ESA), XRF (ESA) or MSR-ERO (ESA) are benefiting from the provided Airbus MBSE infrastructure including the profile, the method and the trainings. For some of these projects the generated models are deliverables to the study reviews. An internal saving analysis came to the conclusion that applying this MBSE level could already generate savings in projects in the order of 8 to 10% in early project phases. The main limitations for the adoption of MBSE in the projects are more of cultural and generational nature. To overcome this, different levels of training are proposed at Airbus and even more important a direct coaching is assured by experts directly in the project teams to apply MBSE.

To leverage the MBSE initial results based on the SysML modelling, the internal Airbus DDMS (Digital Design Manufacturing and Services) transformation program, is enlarging the MBSE perimeter to connect the SysML models to adjacent domains. For the system architecting perimeter, SysML models are connected to the following additional system engineering databases:

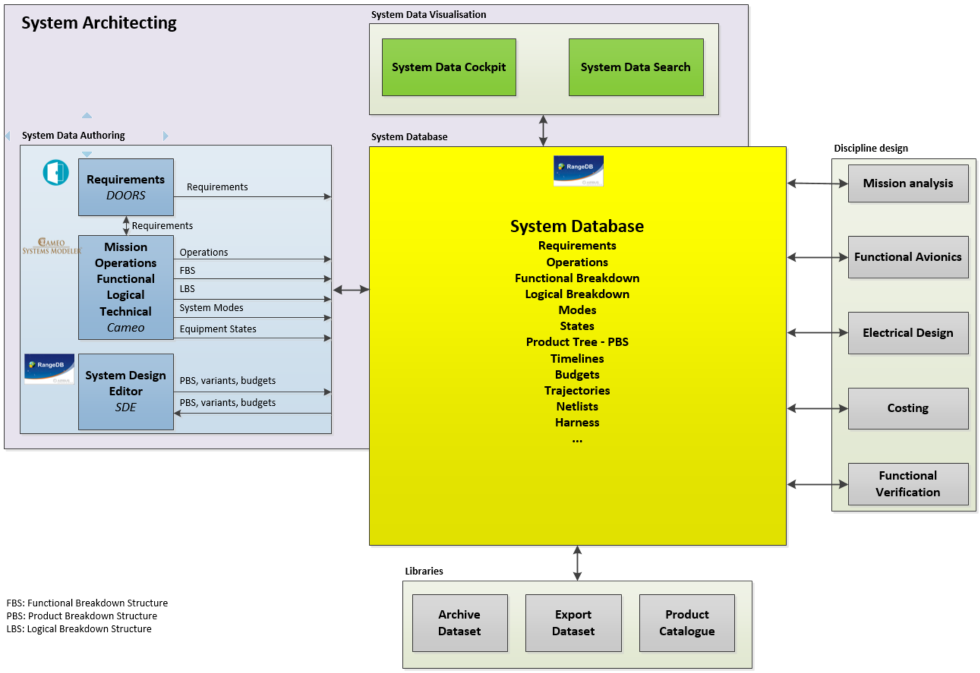
1. Import of requirements into the SysML models to establish relationships to the architecture models. The MOFLT architecture modelling in itself will allow the definition of consistent and coherent architectures through the generation of dependencies between the adjacent architectures (e.g. allocation of functions to logical components). In addition to the relations between architectures, a tracing between the architectures and the requirements is implemented to support a proper and concise definition of the requirements. This step is implemented based on the commercial tool CAMEO DATAHUB to synchronize requirements in DOORS with the architecture models in Cameo Systems Modeller.
2. Generation of documentation. In addition to the MOFLT profile and method, Airbus has developed a toolbox called MBSELab; one feature is to define a document structure and its mapping to the model ontology. MBSELab is able to generate documentation from the model, for instance for the design file or the mission description. This feature provides to the teams an additional motivation for developing the models.

3. Export of SysML architecture models to the Airbus system database. Airbus has been developing and deploying in the past 10 years the RangeDB system database to manage the detailed system design with the definition of the TM/TC database and also for supporting the AIT activities. The SysML architecture models are imported in this system database to support the definition of the product tree and configuration trees based on an Airbus proprietary solution. A configuration tree represents a variant of the system with the selection of specific equipment from the product tree. From the configuration tree, the system budgets like e.g. mass and power are created and maintained to support the system analyses. As well, the system parameters can be exported from the system database to provide valid parameters for additional discipline specific analyses.
4. Visualisation of the system parameters and architectures in a system data cockpit. Altogether, 3 system databases are used for the system engineering work (requirement database in DOORS, architecture SysML database in Cameo Teamwork Cloud and system database in proprietary Airbus RangeDB) with data exchange possibilities between the databases. In addition, several authoring tools are used by the teams to provide and manage the various system data. To ease the communication within the team, the customer and the project partners, a system data cockpit is in development at Airbus to provide in a browser direct access to the system data without the need to open the specific authoring tools (which may anyway not be available on customer and partner side). The system data cockpit could provide access to the system parameter definition, to the function tree, product tree and configuration trees as well as to their respective architectures. An extension of the system data cockpit would be a search engine able to process the dependencies defined between the architecture elements to answer questions on the system like: "show all active functions in this operational phase". Such a search engine would allow to get a much deeper understanding on the system and its behavior.

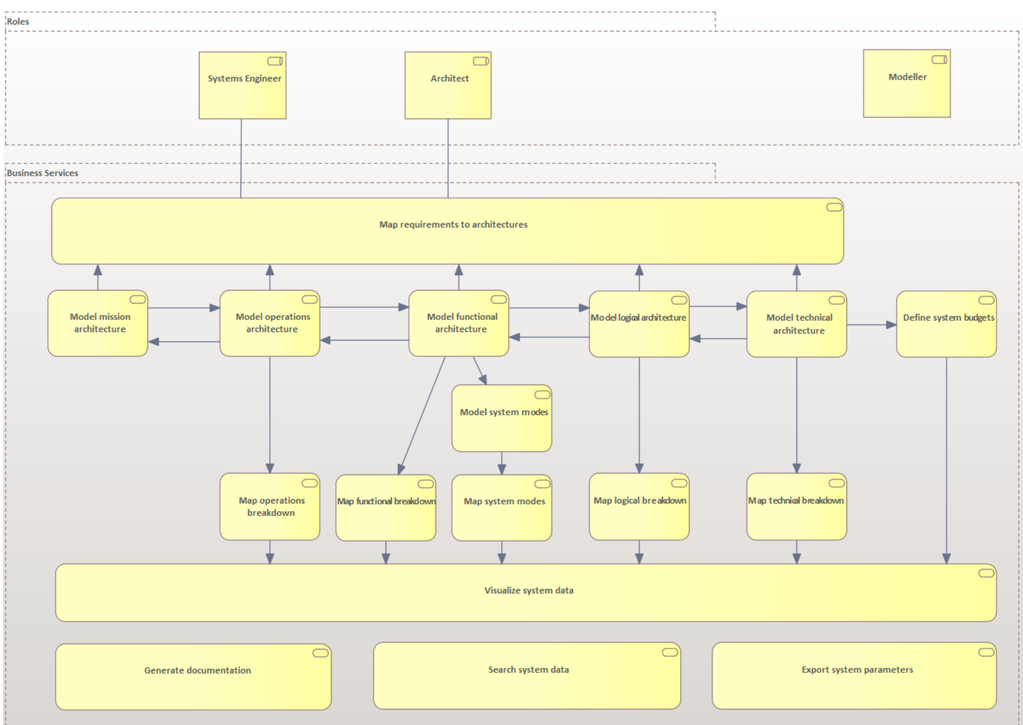
This extended MBSE environment for system architecting is currently in development and test phase for different Airbus Space projects. The validation of the extended MBSE environment for system architecting will take place in autumn 2022 for a planned operational deployment in some projects by the end of 2022. The integration of MBSE in an end-to-end approach will allow to increase the benefits and savings of this collaborative and efficient system engineering process. The next challenge is the integration of this system architecting process in a bigger perimeter integrating system of systems, electrical design, configuration management and production. Another area is related to the definition of business models based on UAF including the enterprise goals, required enterprise capabilities and high level mission operations to support the proper transition from the business perspective to the mission definition on the system engineering side. Direct coaching in the projects remains the main mean to accompany this deep transformation of the digital and collaborative way of working, a fundamental transformation that requires a lot of patience and endurance.



The main motivation is to build the Mission, Operations, Functional, Logical and Technical architectures that are consistent and well aligned with the Requirements and the System Preliminary Design.



The extended MBSE environment for system architecting allows defining, maintaining and exchanging the system data in specific authoring tools. This is mainly relying on the system database, interfacing the requirements database (DOORS) and the architecture definition database (Teamwork Cloud).



The extended MBSE environment for system architecting hosts interacting MBSE services that serve the main MBSE processes to generate consistent mission and system architectures.