Chaire industrielle

ACTE MBSE
Airbus – Université de Lorraine

Call for applications to a PhD thesis subject:

MOBSCOEF : Model-Based SoI and Manufacturing systems Co-Engineering Framework, for early concurrent architecture tradeoff

Context of the PhD work

Airbus and Université de Lorraine are two major actors in the development of practices and knowledge and in training in the field of Model-Based Systems Engineering (MBSE). They are joining their efforts to create a synergy of complementary expertise, building on fruitful past collaborations in research and teaching in MBSE.

This thesis work will be a contribution to an industrial chair. This chair involves Airbus, and two research laboratories, CRAN UMR CNRS and ERPI, from Université de Lorraine. Its main objective is to develop and experiment an Actionable Collaborative Trustworthy Executable (ACTE) MBSE framework, for early systems requirements validation and design verification and for the co-engineering of the main system and its manufacturing (or industrial) system.

Context and industrial problems

Recently, the air transport market has changed significantly, due to a high variation in demand caused by the COVID crisis and due to the emergence on the market of new low-cost airlines. These changes require aircraft manufacturers to reduce the ramp-up time, lower their production costs, reduce the time to market for their products... Hence aircraft manufacturers must review their approach for the engineering of their System of Interest (SoI, e.g. aircraft) as well as for the engineering of their key enabling systems (manufacturing (or industrial), support & services) to meet the previous goals, to achieve a global performance in terms of availability, safety and security, etc. and to maintain this performance during all their long life-cycle (more than 30 years). To keep their competitive advantage, companies will have to develop early capabilities based on digital technologies to (re)specify, (re)design, verify and validate manufacturable and operable

complex systems, in a context of deeper collaborations with multiple stakeholders, within the aircraft manufacturers and its extended enterprise.

Systems engineers use many kinds of models to represent different views of the system (operational, logical, physical, behavioral, …) and to verify the system behavior and the satisfaction of requirements such as availability, safety, mass, or power consumption... The SoI design is currently based on a descriptive MBSE approach while keeping requirement descriptions mainly textual. This current approach suffers from incompleteness, incoherence and incorrectness of the requirements and prevents them from being a robust verification reference for the system design and its implementation (SEBoK 2019). Model-Based Systems Engineering (MBSE) is "the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases" [2]. The digital transformation of development and these MBSE principles open new opportunities (Incose 2014), (SEBoK 2019) to support the development of performant, safe, manufacturable and operable complex systems with an executable MBSE (eMBSE) approach grounded on a Modeling & Simulation approach supporting System Engineering goals.

Scientific issue

An important challenge is that of concurrent engineering of the aircraft system and its closely linked contributing systems to guarantee the expected overall performance. In particular, the links between the engineering of the aircraft system and that of the manufacturing and assembly system is at the heart of this research topic. It is necessary to have a global and coherent vision of the components of the aircraft system and their interactions with the production system. It is these complex interactions that are essential to establish and maintain. Indeed, if the aircraft must be specified in detail, before developing the production system, then the time to market increases and many constraints are transfered to the manufacturing system that impact its performance. It is therefore necessary to synchronize the life cycles of the System and its Manufacturing System as early as possible, from the conceptual level in order to link, as soon as possible, both engineering phases.

The purpose of this research is to determine how far we can enforce the link between the SoI design and the manufacturing engineering. Since the 1990's, authors have worked on the design for manufacturability and the concurrent engineering of a product family and its assembly systems (Stadzisz, 1997), (Holt 2010), (Demoly 2011), (Barbosa 2013). Recent works proposed models and methods to check inconsistencies among product assembly constraints and assembly sequence planning (Perrard et al. 2012, 2013). In the context of Airbus, many projects have been led to co-design the aircraft and its manufacturing system, for instance (Pardessus, 2004) (Frankenberger, 2007) (Mas et al. 2013) (Bouissiere 2017), (Pralet et al. 2018), (Boussiere et al. 2019). These works are the first steps towards a concurrent model-based engineering approach that integrates system design and manufacturing engineering. Although based on models, this work remains very close to design models (Model Based Design) (3D numerical model, discrete event simulation models, optimization models, ...) and lacks a global system vision, essential to understand the complexity of aeronautical systems. Moreover, the simulation models developed are developed by experts, they are specific to a product and a manufacturing chain, are difficult to modify, and to verify. Thus, the MBSE is not or poorly developed for production systems engineering, which prevents synchronization of the two engineering for building a link between a description domain (static view) of the SOI and an operation domain (dynamic view) Manufacturing System (Boussiere et al. 2017). Although exchanges of information between the two domains are recommended in many works (Li et al. 2017), (Boussiere 2019), they occur too late in the development cycle.

The work developed in this thesis has as an originality to be placed in an MBSE approach for both SoI and Manufacturing System engineering and in a context of extended enterprise and industry of the future. The aim is to contribute to the synchronization of both engineering systems, in the form of specific views and this from the upstream phases of engineering (conceptualization). The synchronization will also cover the individual trade-off analyses which will be studied jointly in order to guarantee overall performance (concurrent trade-off analysis).

The study and formalization of exchanges in the collaboration between business domains is the second innovative point of this research, with a particular focus on the sharing of models and views, exploiting the concepts of model architect (for architecting the models) and intention models (Retho 2015), model identity card, (Sirin 2015) to architect the models. The works on the topic of collaboration between different systems engineering specialties (Bouffaron 2014, 2016), should be extended to collaboration between engineering departments.

Finally, to increase confidence in models and simulations, the transformation of system models into production system design models will be studied, following the example of what has been proposed in the field of safety (Mauborgne 2016), or in logistic (Batarseh 2012).

Research objectives and action plan

Our objective is to propose a methodological framework for **Model-Based Systems Co-engineering of the aircraft (SoI) and its manufacturing and assembly system**, for an early concurrent architecture tradeoff, in order to guaranty the overall performance of SoI and Manufacturing System. The primary objective is to enable aircraft system engineers (resp. industrial system engineers) designing a system that is performant while taking its manufacturability (resp. aircraft capabilities) characteristics into account.

For that matter, this thesis will address:

- The aircraft system architecture, the industrial system architecture and the manufacturing processes with an MBSE approach as a potential solution to contribute to the overall synchronization of both architectures. The interest of having a system referential to support early architecture analyses will be studied, in particular to provide architectural concepts and V&V evidence of functional architectures. A particular attention should be paid on the top program objectives/requirements validation, the upstream global optimization of the proposed architectures, the impact analysis and the ensured consistency for integration.
- The synchronization will cover the trade-off analyses that will be studied jointly in order to guarantee overall performance of both systems. A particular attention should be paid on the formal links between system operational scenarios, functions and requirements. The formalization of model exchanges between development departments will focus on the sharing of models and views, and on model architecture (concepts of model architect, intention models (Retho 2015), model identity card (Sirin 2015). Our previous works on collaboration between SE and specialties should be extended to collaboration between development departments. In particular it is important to characterized the aircraft-centric view of the industrial system (resp. the industrial system-centric view of the aircraft) as a variable manufacturing (resp. aircraft) model used to discuss the manufacturability (resp. product to be done) in regards to existing capabilities.
- Address the industrial system design for a product family set or different product types (Gupta, 2013), considering the flexibility needed in the system lifecycle. For the product system design, one product or a product family will be considered including the modularity or flexibility that could be integrated towards manufacturability. The nature of the systems dependency related to the lifecycle phase should be address as part of this exercise.

The action plan may be structured as follows:

- Literature review on industrialization process, design for manufacturing and assembly, models for impact and tradeoff analyses, MBSE for manufacturing and assembly engineering, architecture of models, intention model, system model transformations for performance assessment or impact analysis.
- Analysis of the exchanges between different engineering departments based on use cases of industrial applications (internal to Airbus and to be identified).
- Formalization of these exchanges in a co-engineering process based on SE standards (ISO 15288, ARP4754…), identification of models to build, of common engineering artefacts, of data to be exchanged and views to share.

- Development of the system models for SoI and its manufacturing system (e.g. with SysML).
- Development of methods and models to support performance evaluation and trade-off analysis (mathematical or constraints programming, optimization methods or multiple-criteria decision making methods), all along the co-engineering process and to support impact analysis between both domains (design structure matrix [5], [10], causal graphs).
- Implementation of the process, methods and models, and application to several industrial case studies to verify the applicability of the proposals and to validate them.

Particular attention will be paid to the ability of systems engineers to learn, use and accept such an innovative approach. The research should lead to the development of an innovative framework for model-based systems co-engineering, but this contribution will only be adopted if the benefits associated with it are understood and the efforts for its implementation are perceived as realistic.

The objective of this PhD work is to increase the systems engineering body of knowledge in a model-based systems co-engineering and to convince systems engineers to use model-based approaches, to train and coach them to these innovative practices.

Application

Partners : AIRBUS, Université de Lorraine (Laboratory CRAN, UMR CNRS 7039 and Laboratory ERPI). The PhD student will be hired by the Université de Lorraine, for a 3-year period.

Location: mainly at AIRBUS, Toulouse, France. Travel fees to Nancy will be in charge of the laboratory CRAN.

Beginning date: November 2021

Funding: Industrial Chair between Airbus and Université de Lorraine. **Net salary: about 1800€.**

Applicant's profile. With a master degree in engineering or with an engineer degree. Will be appreciated knowledge in the field of: systems engineering, MBSE, manufacturing and assembly processes, aeronautical engineering or mechanical engineering.

Professional skills and motivation: autonomy, good writing in English, good interpersonal skills, motivation for action-research in aeronautics design offices.

Deadline for applications: October 01st, 2021

Date of answer to applicants: October 8th, 2021 (possibly after an interview and a recruitment exam)

Contacts and applications: CV, motivation letter, transcript of marks for Master degree and Master thesis should be sent to :

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