Stepwise adoption of model-based solution for a full MBSE transition, an Industrial perspective

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Abstract — In this abstract we will discuss the need to provide European Space Companies and Research Institutions with a European framework for model-based engineering (MBE) and model-based system engineering (MBSE). Our assumptions will be motivated by the Lesson Learned from research programs performed by Elettronica SpA (ELT), one of the most referenced European players in the production of Electronic Warfare equipment (EW), in its transition toward model-driven engineering (MDE) and subsequently to MBSE as a mean to increase quality, to increase productivity and to reduce costs.

1 Introduction

According to the original definition given from INCOSE, Model Based System Engineering (SE) 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.
In an organization that adopt a mature model-based workflow, models at different levels of abstraction coexist in an interwoven structure held together by system-level architectures that act as a backbone for SE activities. For instance, it shall be possible to graphically navigate a system level architecture, traversing all the subsystems and visualizing inner details of software-firmware interfaces, as well as conducting Reliability, Availability, Maintainability, and Safety (RAMS) analysis in an almost automated manner by means of dedicated model-checking techniques (i.e. COMPASS toolset *https://essr.esa.int/project/compass*).

2 Adopting MBSE

From an Industrial perspective, to become an effective MBSE practitioner requires a significant investment [1] and the time needed to return from the investment can be hard to calculate in advance. In addition, this transition entails to overcome a cultural resistance to change within the organization [2]. In some cases, the road to create a Company culture on model-based technologies can be rough and steep. That is partially due to the lack of experience with formal languages and object-oriented thinking for engineers that usually have different specialties and partially to the absence of a commercial general-purpose solution capable to support every engineering domain aspect. This means that Ccompanies are often left alone with the burden to select and tailor model-based tools and methodologies on their specific needs and value chain analysis. It is therefore evident that MBSE is producing a major transformation in the way of doing system engineering, which can be probably compared with the advent of personal computers in the workplace in the late 70s and 80s.

2.1 Facing Cultural Resistances

When it turns to overcoming the cultural resistance to the adoption of models as means to enclose system and subsystem details, it should be kept in mind that models are more than just drawing:

- Models can act as single source of truth, whereas natural languages and document-based approaches are subject to interpretation and misunderstanding.
- Model based toolchains can be extended incrementally, according to perceived benefit of users and stakeholders.
- Models can be a turnkey solution to manage complexity by means of Views and filters.
- Formal languages are a powerful mean to stimulate reasoning and evaluating alternatives.
- Models can be automatically processed to produce artefacts, such as code and documentation, as well as to verify integrity and overall consistency of the finalised architecture.

One possible approach to build a Company culture around model-based engineering is to initially leverage model-driven solutions to automate processes that have a direct return on investment. Software engineers can be a key element in this first stage of the transformation process as they are usually keen to exploit model-driven solutions to automate implementation and verification of software and firmware components.

2.1 The ELT case

As described in [3], a similar approach was followed by Elettronica Spa (ELT) in his transition toward model-driven engineering (MDE). Motivated by the need to increase quality, to increase productivity and to reduce costs, ELT has decided to evolve and update the design and development process with a model-driven approach. The transition has begun in 2010 with the implementation of a Company-internal model-based toolchain to automate coding and documentation of software interfaces, operative system drivers and verification facilities such as Wireshark-dissectors, simulators and emulators.

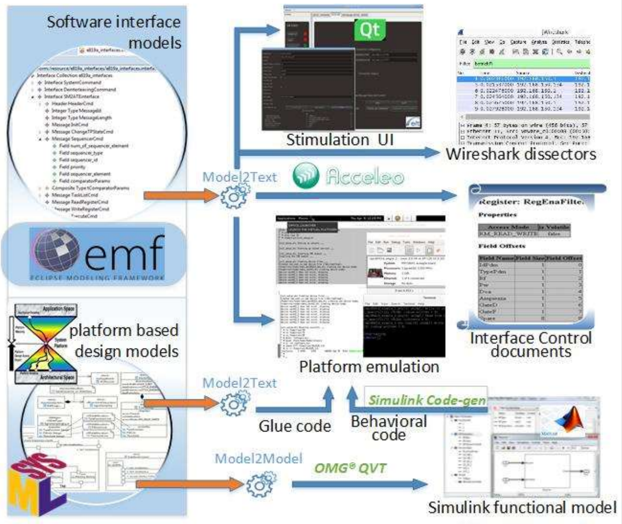

Figure 1- model-driven workflow implemented in ELT

The toolchain is also integrated with Simulink, for code-generation of behavioural code, and with IBM Rational Doors to trace architectural decisions against system and sub-system requirements. However, since ELT needs in terms of Domain Specific Languages (DSL) were peculiar to EW systems, both the metamodel and the model-based toolchain have been built from scratch leveraging the Eclipse Modeling Framework (EMF) and related Ecore technologies (Acceleo, QVT) for model to text (M2T) and model to model (M2M) transformations. The SysML models representing the System were defined according to Platform-based design (PBD) principles. As such, design elements were decomposed into three model hierarchies: a Functional architecture, an Execution Platform and a third hierarchy of elements (called Mapping model) representing the deployment of the Functional architecture onto the Execution one. The genericity of SysML model elements were partially restricted applying Stereotypes from MaRTE®, which is an OMG® Profile specific for Real-Time Embedded Systems. The implementation was conducted internally by experienced ELT software engineers in collaboration with the TeCiP institute of Scuola Superiore Sant'Anna. Although this solution enabled a first transition in the adoption of models as a mean to encapsulate and share knowledge among software stakeholders, a further transition toward System-level models required the adoption of a more tailored DSL. In fact, one of the main concerns was to introduce System Engineers to system-level modelling, adopting formal languages as a vehicle of information and as a mean to enrich technical documentation.

3 A project example with MBSE

Bolstered by the achieved consensus with MDE, ELT has experimented MBSE on internal pilot projects (partially or totally self-financed) in the context of the Company innovation process named BELT (short form of Building ELT together). The System of Systems (SoS) adopted as use-cases for the modelisation are aimed to support armed forces in the operations of integrated missions that cover the following domains:

- Electronic Warfare
- Spectrum Management
- Signal intelligence
- Cyber Operation

In this context, MBSE can provide a consistent advantage to manage the complexity caused by: the intrinsic scalable and reconfigurable shape of these SoS; the high number of actors (internal and external to the System); the high number of program's stakeholders with vested interest to be kept into consideration along the project lifespan.

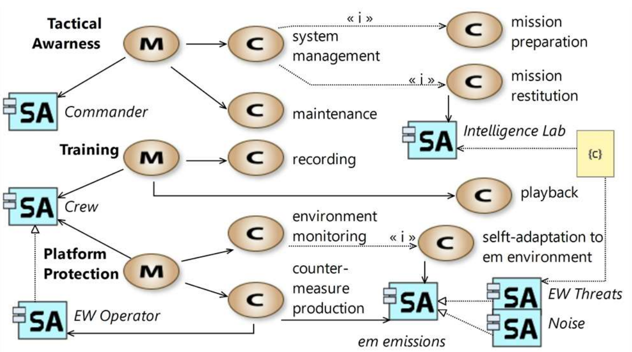

Figure 2- EW Mission/Capability example diagram

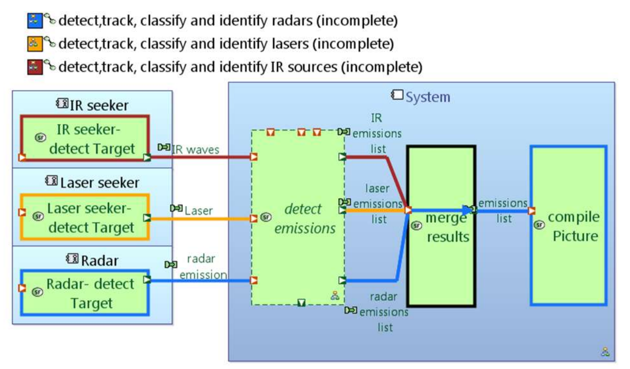

Figure 3- System Architecture diagram with functional chains

The model-based approach selected for this purpose was ARCADIA (ARChitecture Analysis and Design Integrated Approach) with its open-source model-editor Capella and the Requirements Viewpoint to import requirements from IBM Doors. In one of the MBSE experimentations performed within BELT, a team of six system-engineers with different specialties and not prior knowledge of modelling based languages, supported by one Modeling Expert and one Project Manager, managed to enclose a portion of the system knowledge into a model-based representation with enough details to run basic model-checking activities on it. The Mission/Capability diagram in figure 2 shows some of the classical challenges that EW SoS are required to perform in a reliable and accurate manner: self-adaptation to the electromagnetic (e.m.) environment, tactical awareness, mission and data management and platform protection. The System Architecture diagram provided as example in figure 3 provides a quick overview of three simplified Functional Chains associated to environment-monitoring Capability. Specifically, the detection, classification and identification of Infrared (IR), Laser and Radar guided weapons (also called Targets) in a synthetic representation of the electromagnetic environment (Picture Compilation). Adoption of models resulted in the following outcomes:

- Mapping of targeted use cases toward the developed architecture.
- Inheriting interfaces from high-level to system-level architecture.
- Automatic verification of interfaces consistency.
- Justification of the physical architecture toward the functional one.
- Impact analysis to evaluate complete and consistent propagation of requirements toward the final architecture.

In particular, at the end of the medialisation activity it had been possible to investigate a number of issues just by validating the model. We identified the absence of a physical connection to carry data exchanged among functions originally thought to be deployed on two unconnected nodes. This issue were tackled restructuring functional deployment and physical architecture so as to optimise the overall design in terms of costs and performances. The Arcadia methodology and Capella model-editor resulted of easy understanding for the team. An initial two-weeks training period was enough to make the team self-confident and autonomous in the basic modelling activities, which were performed in accordance to processes specific for a document-centric SE workflow. This experience demonstrated how the adoption of formal notations could support System Engineers to reason about architectural choices and their impact on Stakeholders.

4 Conclusions

A takeaway message from this experience is the possibility to use model-driven solutions to automate processes that have a direct return on investment and do not need the full MBSE to be implemented at the beginning. Given the additional cost of creating models, it is of primary importance to create a modelling ecosystem in which models can be exploited to automatically produce valuable artefacts such as low-level embedded code, documentation, adapters, simulators and other supporting facilities for Validation & Verification purposes. As a way forward, the availability of model-based solutions readily available to European Space Companies, such as the Open-Source Reference Architecture (OSRA), could enable a quicker transition to MBE and MBSE as a strategy to increase quality and productivity while reducing development and maintenance costs.

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