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Implementation of MBSE Practices within Integrated PLM Solutions

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Abstract

The article provides a general analysis of the current state of information ecosystems that implement the practice of model-based system engineering. It is concluded that the largest players of the PLM-market in the strategy and tactics of development of their products lay support practices model-based system engineering. Implementation of MBSE practices within PLM solutions is considered on the example of Siemens Digital Industries Software's products

Keywords: System Engineering, Model-based system engineering (MBSE), Product lifecycle management (PLM), Capella, Modeling Tool, ARCADIA.

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1. Introduction

To create modern technical products consisting of a complex of systems representing different physical domains (mechanics, hydraulics, electrics, electronics, software code, etc.), a wide range of computer-aided design and data management tools is needed (up to 20 classes of various computer-aided design and data management systems are used in the design of a modern car, such as CAD, ECAD, CAE, PDM, ALM, CAM, QMS, etc.) All these tools have long been based on the application of models, or manage data in the form of models (usually we are talking about 3D CAD-models). Such systems are applicable only within one physical domain and do not allow to solve the problems of designing adjacent domains or multi-domain complex systems.

For System engineer responsible for the implementation of the whole system, it is essential to have a comprehensive information system, providing implementation of all processes in the life cycle of the system. The so-called PLM concept and the tools implementing it (the set of these tools will be called PLM-system) are traditionally used to manage the processes of the product life cycle. For more than 20 years, the key tasks for PLM systems have been the management of product information, in the form of electronic documents, formulations, 3D models (and their derivatives). Process for development, centralized storage, access, reuse, change management of data at all stages of the product life cycle were provided. The main emphasis was on the management of design processes and providing these processes with the necessary tools for 3D modeling and design of drawings (CAD), as well as verification and validation tools based on three-dimensional models (CAE). Implementation of such processes as requirement engineering, verification and validation management, architectural design was declared partially, and without a comprehensive vision of this process as a whole.

The complexity of technical systems, the growth of requirements, the growth of electrical and electronic components, has led to the fact that the existing tools within PLM solutions are not enough to manage the life cycle of complex and knowledge-intensive products in General, and the process of their development in particular.

2. Review of Implementation of MBSE Practices in Integrated PLM Solutions

Today, most of the major players in the PLM market (Siemens Digital Industries Software, Dassault Systemes, PTC) have realized the need for product lifecycle management based on model-based system engineering practices. This is at least evidenced by the fact that in recent years, PLM vendors have made purchases of companies developing software products for architectural design based on MBSE

In 2014, PTC acquired Atego [1], in 2017, Dassault Systemes acquired No Magic [2], and in 2018, Siemens Digital Industries Software entered into a cooperation agreement with Obeo [3].

The analysis of information materials of the designated companies (Siemens Digital Industries Software [4], Dassault Systemes [5], PTC [6]) shows the General strategy of management of processes of development of complex multi-domain systems, through multi-domain architectural model. The term multi-domain architectural model is introduced to separate the General architectural model (through which the development of the whole product is controlled) and separated architectural models designed for the development of individual system components (subsystems) using specialized software products focused on development of specific domains (electrics, electronics, etc.). This multi-domain architectural model combines the description of all systems and subsystems of the product, as well as their relationship, regardless of their physical domain, hardware or software implementation.

The key task of the multi-domain architectural model is to form a unified and at the same time multidimensional representation of the designed product (system) for all stakeholders (Fig. 1). This architecture, managed by a PLM system, provides the initial information for further detailed development of system components within their domains. The inclusion of architectural design tools in the PLM environment adds to the engineering data previously missing information on needs, stakeholders, use cases, functions, logical components, interfaces, without management of it is difficult to ensure the implementation of a successful product. Regardless of the specific developer, the architecture of the MBSE implementation within the PLM solution is illustrated in Figure 1 (example of Siemens Digital Industries Software).

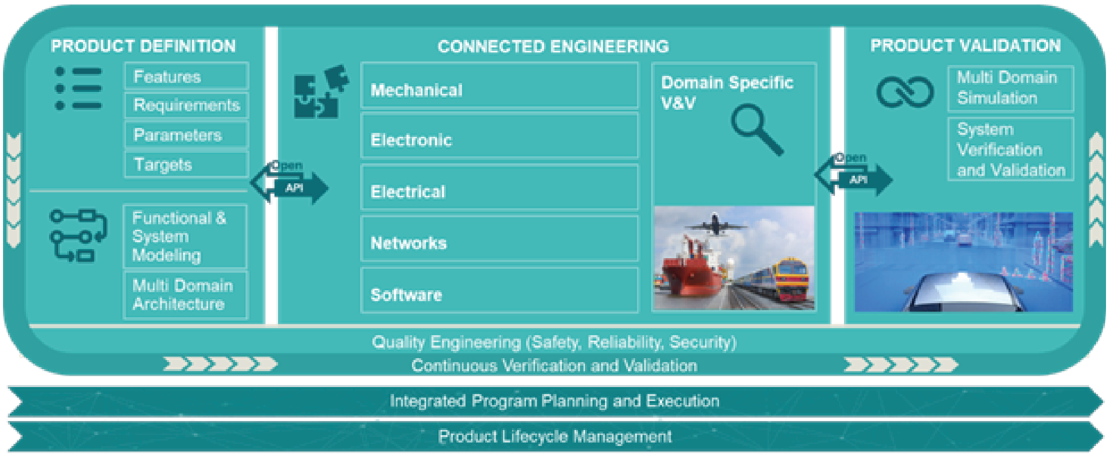

Figure 1: Architecture of MBSE implementation in PLM systems

The functional for definition of a product is allocated, within which there is a definition of the purposes, needs, requirements, parameters, both for a product, and for group of products. The architectural description of the product (multi-domain architectural model) is performed in the form of a set of interrelated models (functions, functional relationships, logical and physical components, their interfaces are defined, usage scenarios are described). To build a multi-domain architectural model, architectural modeling tools (System Modeling Workbench, Windchill Modeler, Cameo Systems Modeler) using The SysML language or its modifications are used.

Requirements are traced to the elements of the multi-domain architectural model, which are stored and managed by the PLM system as objects. Elements of the architectural model are subsequently traced with other PLM-system objects that arise as a result of detailed design of individual system components. Such an information link between requirements, architecture and design results within a PLM system is an important step in the development of modern PLM solutions, and allows to eliminate the information gap that existed in the separate use of requirements, architecture and design management tools

Information links, both between objects within a multi-domain architectural model and with requirements, form a sufficient set of input information to begin detailed design of system components of selected systems.

Further design of system components within their domains is implemented by specialized tools. Such tools include CAD, EDA, ECAD-systems, solutions for the development of control systems and embedded software, etc. These tools can apply elements of multi-domain architecture at the input, or develop their own architectural models necessary for the design of their domain (for example, the architecture of the control system). The output of such tools is detailed data for the implementation process (production or procurement).

Verification and validation procedures are planned for each requirement separately, followed by linking these requirements to the tasks of the schedules, depending on the specific PLM-solution, the implementation of this process may differ. Verification and validation activities are performed according to the plans.

As part of the design data, the verification and validation procedure can be subject to multi-domain architecture, and the results of detailed design within individual domains. The key trend is to ensure a continuous process of verification and validation within the design processes.

The development of a multi-domain architecture, as a rule, is carried out by its gradual decomposition from the level of the entire system as a whole to the level of its system components of various levels of nesting. For each level of decomposition, techniques and implementing it tools for multi-domain verification and validation are used, for example, 1D-analysis, FMEA, RAMS. Most of the data they need is extracted from the architectural model (functions, functional relationships, function flows, etc.). In this regard, there is a General tendency to include relevant tools in complex PLM-solutions, by integrating them into the PLM-environment. One of the trends of the component integration process for MBSE is the integration of multi-domain architectural model development systems with the simulation tools of multi-physical systems based on 1D models (Simcenter Amesim, Simulink, Simulation X, Twin Builder). For verification and validation design results apply different CAE-analysis tool based on geometric data (Simcenter 3D, ANSYS, Abaqus, etc.). The results of such verification and validation serve as initial data to refine the multi-domain system architecture, on the basis of which the simulation 1D model is refined. Verification and validation results are linked to requirements to ensure feedback and traceability of the process.

3. Example of Implementation of MBSE in Siemens Digital Industries Software Tools

The Central component of SPLM's PLM- solution is the PDM-system Teamcenter, which provides centralized data storage, management, and access. System Modeling Workbench (Capella integrated into Teamcenter environment) is the main tool for creating a multi-domain architectural model within PLM-solution of Siemens Digital Industries Software. The development of a multi-domain architectural model in SMW is based on the ARCADIA methodology developed by TALES to solve their internal engineering problems.

The development of the architecture according to the ARCADIA methodology consists of five steps: Operational analysis, System analysis, Logical architecture, Physical architecture, Contracts for Development) [7].

A multi-domain architectural model is stored by Teamcenter to provide access to information for all stakeholders. Allocation of requirements is performed on functions, logical, physical components, their interfaces. The requirements structure is created and managed by Teamcenter, and tracing is provided by built-in integration between Teamcenter and SMW.

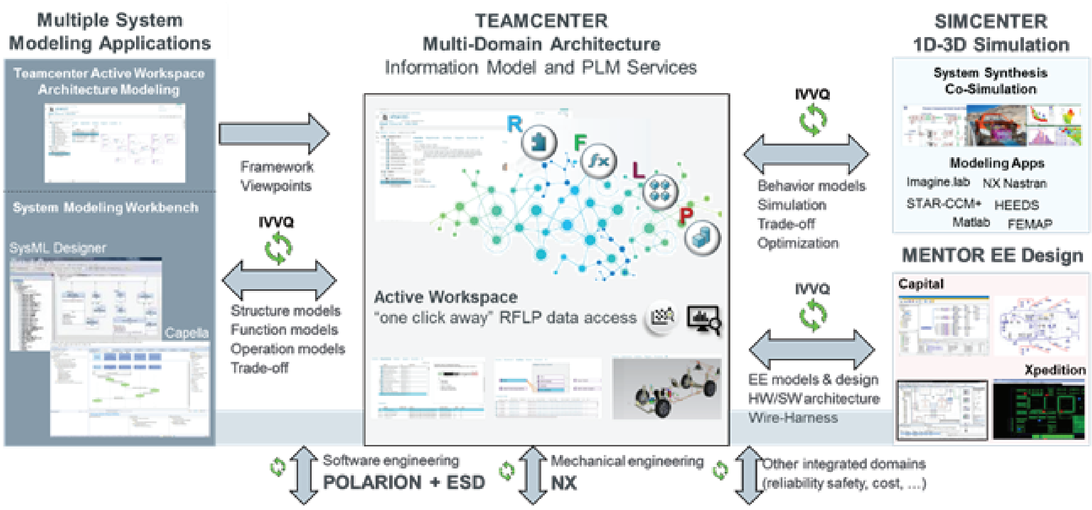

Figure 2: General scheme of MBSE implementation within PLM-solution of Siemens Digital Industries Software

The multi-domain architecture in SMW provides the basis for detailed design of system components within their domains.

The mechanical part is developed in the NX CAD system, the input to this process is the decomposition from the physical architecture level, and the output from the electrical and electronics design systems. The output is a detailed geometry in the form of an electronic model of the entire product.

Electrical and electronics design is implemented by means of the Mentor product line (Capital and Xpedition), the input to this process is the architecture of electrical and electronic systems, separated from the general multi-domain architectural model, from the level of the physical architecture of SMW. The output is new system requirements, electrical system model, wiring diagram, PCB topology. Part of this data is used in the NX CAD system for 3D modeling of electrical and electronic components (cables, harnesses, connectors, printed circuit boards, etc.) as part of the overall electronic model of the entire product.

Firmware development is performed in conjunction with Simcenter Embedded Software Designer and ALM system Polarion. Requirements and multi-domain architecture are the entry points for software development. This solution closes the full cycle of tasks for the development and life cycle management of embedded software, so the subsequent decomposition and management of system requirements, software architecture development, planning and implementation of tests, versioning software development is performed by Polarion and Simcenter Embedded Software Designer. The output is a specific release of software code.

All information coming out of the designated systems is grouped around Engineering Bill of materials (EBOM) within the Teamcenter.

For each Teamcenter requirement, a verification and validation method is defined. Numerically controlled parameters can be represented as a separate object of type ”Attribute” with indication of its nominal value, as well as possible deviations. Verification of numerical requirements can be implemented in automated mode, when a running verification process (in a verification tool) compares the received and planned values and returns the received status of the Teamcenter requirement.

Verification and validation activities are planned for each requirement, either in the form of consolidated milestones or in the form of request for analysis implemented through business processes.

Verification and validation is performed by a whole set of specialized tools. Some of the verification and validation tools are built into design systems, such tools are available in Capital, Xpedition, NX.

For verification and validation of multi-domain architecture or its individual system components, the method of 1D-analysis is applied, within the framework of Siemens Digital Industries Software products, this task is solved by a set of Simcenter System Simulation products (primarily System Architect and Simcenter Amesim). Input are requirements, multi-domain architectural model from SMW, results of other processes (for example, 3D CAE analysis taking into account geometric characteristics of the system, control program code).

Part of the requirements can be verified by NX means (e.g. compliance with mass requirements; compliance with geometry requirements (connection, dimensions); compliance with manufacturability requirements).

For verification and validation based on geometric data, the Simcenter CAE Simulation product group is used, which includes such products as Simcenter STAR-CCM+, Simcenter 3D, NX Nastran, Simcenter Flotherm, etc.

To assess reliability and safety using techniques such as RAMS and FMEA, the MADe (PHM Technology) solution is used, using as input the requirements for reliability and safety, as well as the functional model from SMW. The output is to assess compliance with the requirements for reliability and security, as well as data to adjust the architecture and design. Separately, the FMEA module of the Opcenter Quality QMS system can be used for FMEA analysis.

The results of design process verification and validation are linked to Teamcenter requirements. Users have access to a separate interface that provides control over the process of fulfilling requirements, with the fixation of completed or not completed tests, received values, responsibilities, deadlines and other information.

4. Conclusion

Leading PLM vendors see MBSE as a means to ensure successful product implementation processes, and actively use MBSE methods and tools in their solutions. Already today, Siemens Digital Industries Software, PTC and Dassault Systemes offer their customers tools that implement MBSE practices. Despite the active work in this direction, it is too early to talk about the full integration of MBSE-tools with classic PLM-components. However, the speed and pace of development allow us to state that in the next 5 years, leading PLM vendors will receive comprehensive PLM solutions implementing MBSE practices.

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