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Heterogeneous simulation and interoperability of tools applied to the design, integration and development of safety critical systems

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ABSTRACT

A key issue of the assessment of the Model Based Systems Engineering (MBSE) is the integration between the requirement, functional and physical analyses. It turns out into a full capability of correlation and data exchange among the tools currently available to manage those three activities and, in particular, into a tight cooperation between the functional modeling and the physical one, being based on several methods of engineering, widely applied since longtime (mathematical, analytical, numerical and experimental). A successful accomplishment of this task within the frame of the development of the MBSE represents a milestone for both the methodology and the tools of the Systems Engineering.

The application of models and simulations to support the engineering activities has spread over different domains and is strictly related to the decision making process applied to finalize an effective system design. Many kind of models are often performed to develop the systems currently populating the wide scenario of complex and smart products. When the product is a result of a material processing, some geometrical models allow describing shape and properties of the manufactured product, whose behavior is then predicted by resorting to some numerical discretization funded on a set of equations to be solved. Those models mainly describe the real nature of system, not only as is designed but even as is manufactured, thus allowing the required verification and validation activities. Due to this motivation those models belong the so–called physical modeling, whose key targets are both a mathematical modeling and a quantitative evaluation of performance.

According to the MBSE the above described activity is never sufficient to completely define the details of the system under design and development. Moreover, to face the inherent complexity of new systems, being characterized by a number of functions, components and interfaces, a clear traceability from requirement to numbered part is needed. A bright allocation of each requirement to the system functions first, and to its logical blocks then, is definitely a key issue of the proposed approach. Those two main goals require a preliminary functional modeling activity, never characterized by numbers, while is dominant a prediction of system operation, behavior, interaction with other systems and stakeholders, and even a preliminary definition of well assessed requirements to motivate a consequent set of proposed layouts, based on some selected technology.

As a matter of facts, a current need of industry to develop complex and safety critical systems is the availability of a tool chain, composed by different tools allowing to perform the whole modeling activity previously described, by resorting to a common platform, to be shared among partners and operators, interconnected in a such a way that a complete interoperability could be assured, i.e. each tool can exchange in input and output the data to perform the required analysis, without any lack of information and by overcoming all the technical obstacles of connection. If a common environment is built up to model and simulate the system behavior in both terms of qualitative functionality and quantitative response, under a defined configuration of its properties and of operating conditions, the goal of providing a suitable tool for the so–called "heterogeneous simulation" could be completely achieved.

Practically speaking, the MBSE allows to predict the system behavior in several operating conditions, potentially enabling the creation of a consistent view over its evolution during the whole lifecycle phases. This process assures a high capability of replication and a significant reusability of models, since they are built up through the implementation of a structured framework. However, tools currently used are many, exploiting several technologies and providing a number of analysis and features. Very often they were conceived to be used separately to investigate specific issues of analysis. To reach the target of a simplified and harmonized heterogeneous simulation, this approach might currently lead to a definition of too many models, thus collecting a large number of inhomogeneous results, being analyzed separately. A better way to face this problem is enforcing the tools integration, by overcoming some problems related to connection among different software products, being sold by different vendors. Pursuing the instantiation of an heterogeneous simulation, i.e. a simulation based on interoperability standards, being capable of enabling the communication among tools, is currently a key focus of the research activity as well as of the commercial development of the MBSE tools.

In this contribution a preliminary overview on the main focus of how the MBSE approach could be straightly implemented within the system design and development is provided. Some examples are proposed to discuss several issues of the integration of functional and numerical modeling activities, as they were developed by the speakers in dealing with some dedicated projects, concerning the aerospace, automotive, steelmaking and maritime engineering applications.

A preliminary analysis of the current implementation of the MBSE applied to those fields is proposed to define the context of industrial application. It might be remarked that a main framework includes a clear investigation of needs at the very beginning of activity. It is then followed by a recursive assessment of requirements, through a functional, operational and architectural analysis, tightly interoperated with a physical analysis, which is correlated to the design synthesis and the safety and reliability assessment. Aside this main driveline, industry indentifies in the functional product breakdown, product breakdown and product definition three main steps of documentation and modeling for the whole system lifecycle development. Engineering methods widely used to perform the above described activity are the preliminary trade–off of the system architecture and the verification and validation.

To detect some current challenging issues of the development of the MBSE in terms of interoperability, some examples are developed and shown to describe how the tools currently available on market could be integrated to realize the heterogeneous simulation. Needs of the tool chain are first explored. Functions and logical elements are then described. Examples of the platform are finally presented. Interoperability is investigated even from the point of view of connection among tools and solution oriented implementation. Some key results are shown, by resorting to the development of an aeronautical, physical and on board unit, like a de–icing system, to be integrated on a civil aircraft, for regional transportation. Integration between an avionic monitoring control unit and a physical one like the fuel system is then analyzed to show some peculiarities of the coupling between avionic and mechanical systems, respectively.

Some additional remarks are finally introduced to describe the interoperability between safety and reliability analyses and product development. Moreover, a preliminary discussion of heterogeneous simulation to be performed in case of some mechatronic autonomous systems, like a steelmaking plant or a controlled ship gun, is even included, within the constraints of non-disclosure, covering some specific details of those applications.

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Eugenio Brusa is full professor of Machine Design at the Politecnico di Torino, Italy, where he graduated in Aeronautical Eng. (1993) and received the Ph.D. in Mechanical and Machine Design (1997). Since 2002 to 2008 he was associate professor at the University of Udine (Italy) and technical director of the Master on Project Management and Systems Engineering (2005-2007). At the Politecnico di Torino he was instructor of Fundamentals of Strength of Materials (B.Sc.), while nowadays he teaches Fundamentals of Machine Design and Drawing (B.Sc.), Machine Design (M.Sc.) and Tools and Applications of Systems Engineering (Ph.D.). He is currently Coordinator of the B.Sc. and M.Sc. degrees in Mechanical Engineering at the Politecnico di Torino. He is active within the Structural mechatronics (rotors, vehicles, MEMS); Design of Industrial Equipment and Machine (aerospace, manufacturing, steelmaking) and leads a group focused on the ‘Model-Based Industrial Systems Engineering’. He taught ‘Structural Mechatronics and Micromechatronics’ as an invited lecturer at TU Delft (2000), TU Helsinki (2002), Univ. “Blaise Pascal”, Clermont Ferrand (2005), CNRS, Paris (2007), Ecole EPF, Sceaux (2007, 2010), TU Munich (2009), Institut Marie Curie, Paris (2010), University of Toronto (2016), being also instructor at the Int. School of “Microsystem Mechanical Design”, CISM, Italy (2004) and “1st Eur. School on Mechatronics and Microsystems”, TU Braunschweig (2006). He was deputy chair first (2010-2014) then chair (2014-2015) of the Italy Section of the American Society of Mechanical Engineers (ASME). He is author of about 180 publications and some patents.

Davide Ferretto received the B.Sc. (2012) and M.Sc. (2014) degrees in Aerospace Engineering from the Politecnico di Torino, Italy. Since 2014 to 2016 was Research Assistant at the Dept. of Mechanical and Aerospace Engineering of the Politecnico di Torino. His research activities concern the design of aeronautical and aerospace systems, aircrafts and spacecrafts as well as methods and tools of the Systems Engineering. He was involved in the research activity performed within the frame of the ARTEMIS JU – Project “CRYSTAL – CRitical sYStems engineering AcceLeration” (2013–2016) for the assessment and standardization of the MBSE approach and related tools. Currently he is performing the Ph.D. in Aerospace Engineering, dealing with innovative configurations of hypersonic transportation systems, designed through the MBSE.