Preface

Mastering the complexity of innovative systems currently looks a challenging goal of design and product development as well as embedding a suitable degree of smartness in devices, machines, and equipment to make them able of adapting their operation to variable conditions or effects of a harsh environment. This goal is achieved through a continuous monitoring of the system in service, an effective control of its behavior, and a wide connectivity toward many other systems. Only an effective system design and manufacture, able to cover all the required actions, can assure this kind of assessment overall the life cycle since a very early concept of the product to a full disposal and service.

Complexity makes hard managing the product development, because of the number of functions, subsystems, components, and related interfaces usually involved, like in motor vehicles, robots, railway systems, aircrafts, and spacecrafts as well as in large industrial manufacturing systems or very innovative microsystems and bioinspired devices. A crucial issue in this activity is performing a bright and complete elicitation of requirements, which need to be fully and suitably allocated to the system components, through a clear traceability, especially in systems produced as a result of material processing and assembling of parts. Moreover, the product must fit the requirements associated with some customer needs, innovation targets, and technical standards and be compatible with the manufacturer's capabilities.

As it looks clear from the current state of the art, since several years, the Systems Engineering assures a suitable answer to the needs above mentioned. It provides a methodology to drive the product lifecycle assessment that is implemented through a well-defined process, being based on some specific and graphical languages and even formalized in several tools enabling the required analyses, taking advantage of the capabilities of some dedicated commercial software. Those contents lead to create a platform, consisting of a sort of tools chain, which might be used and shared among different industrial and professional partners to digitalize both the information and even the whole industrial product development, as far as the current strategy referred to as "Industry 4.0/The Factory of the Future" brightly suggests and supports. The so-called *Model-Based Systems Engineering* (MBSE) is

then successfully proposing an effective and modern alternative to the document-based approach, using data models as a main element of the design process. Some technical standards already drive the user in implementing the Systems Engineering, thus leading to develop a systematic approach the design aimed at satisfying the customer needs. Suitable capabilities in the manufactured system are assured by the so-called architectural frameworks, which support the system development and integration.

The Model-Based Systems Engineering allows proceeding with a modeling activity which investigates requirements, behavior, and architecture through a combined operational, functional, and logical analysis, being linked and interoperated with a mathematical and physical modeling, which is typically more known and widely used within the industrial engineering. A full integration of all the activities of the *Product Lifecycle Management* (PLM) is currently going on, to include the system architecture definition and its *Application Lifecycle Management* (ALM) as well as the *Product Data Management* (PDM), i.e., the design activity together with the tasks of production, testing, homologation, and service. A recognized standard certification to qualify the Systems Engineer is even available as the *International Council on Systems Engineering* (INCOSE) provides.

The scenario above described is strongly integrated with the increasing development of both the network and the cyber-physical systems, for a fully distributed connectivity, to be exploited in advanced smart systems and devices as well as in intelligent manufacturing, according to the most recent strategies of innovation as the "Industry 4.0" initiative and the "Lean manufacturing" idea. Simultaneously, the system smartness and connectivity together increase the demand of data transmission and elaboration, thus linking this topic to the technology of big data management, while they benefit of the progress in information technology, through a secure cloud based on the network.

The context just described motivates the fast diffusion of the Model-Based Systems Engineering as a tool for innovating all the production processes. The increasing demand of specialized software and of educational activities as well as the number of workshops and conferences focused on this topic confirm this trend. However, it might be remarked that several contributions to the literature about the Systems Engineering widely grew up during the last years, thus making the Reader sometimes confused, especially when approaching this topic at first.

The Systems Engineering topics are so many that it looks rather difficult mastering its skills, without a preliminary classification of contents. Technical domains involved are mainly those of engineering and computer science, although many other ones play the role of a daily user of this methodology. According to the most recent development of the Systems Engineering, whose typical application fields were the software and electronic systems even for space missions, the current focus consists of several industrial systems, being gradually innovated by introducing the tailored solutions of mechatronics. It is worthy noticing that a significant advancement was introduced between the very early implementation of the Systems Engineering and its recent evolution, since several new applications are focused on the production of systems, which need to be manufactured through a material processing.

Usually, they exhibit some attributes related both to their physical nature and to the functions performed, thus requiring to model both their functional and physical behaviors together. This need is changing the scenario of the typical applications of the Systems Engineering as software design.

This handbook expressively avoids to cover all the typical contents of the specialized literature of the Model-Based Systems Engineering, while is aimed at making easier a first approach to this topic and sharing a preliminary experience performed by the authors within some industrial domains, by proceeding in the modeling activity in a real industrial environment. The main goal is drawing a sort of simple and hopefully clear roadmap in modeling and developing the industrial and material systems and in implementing the Systems Engineering, particularly in the design activity. Therefore, the target audience of this handbook includes professional engineers, scientists, and students dealing with the ALM and the system architecture assessment, more than the PDM or the whole PLM.

The approach followed is that of introducing some examples of implementation of the Systems Engineering, by proceeding step by step from the screening of needs and the elicitation of requirements till a synthesis of the system design. Each action will be referred to the literature, related to the implementation of the *Systems Modeling Language* or *SysML* and to the use of some tools available on market, thus highlighting benefits, drawbacks, and current limitations of some dedicated software or even of some proposed methodologies. Several comments will be provided to describe the troubles shared among some users of the Systems Engineering as they were detected in daily practice by the authors. They wish that this handbook could briefly and gradually provide the Reader with a preliminary guideline to approach professionally the Model-Based Systems Engineering, by understanding its main contents and applying it to the industrial environment. As a desired result, this work might be considered as an integration of some textbooks of Machine Design, and it is aimed at completing the education within Engineering Design or at simply providing a friendly introduction to the Systems Engineering.

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