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Andrew P. Sage, Series Editor

MODEL-BASED SYSTEM ARCHITECTURE

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WILEY

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Andrew P. Sage, Founding Editor

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Foreword

Contrary to popular myth, models are not new to systems engineering. Models are the way engineers analyze both problems and solutions, so systems models are as old as systems engineering itself. With the traditional focus on written specifications as the "source of truth," models were secondary and descriptive – sometimes reflected as simple sketches, sometimes shown in formal diagrams, partially captured in analysis packages, and often trapped in the mind of the chief engineer. The transformation of systems engineering from document-centric to model-centric practices is not about the introduction of models. It is about making models explicit and moving them to the foreground where they serve as the authoritative tool for design, analysis, communication, and system specification.

Organizations today are investing heavily in representations, standards, methodologies, and technologies to transform the practice of systems engineering through model-driven paradigms. To manage the complexity of today's problems; to keep pace with today's rapidly evolving technologies; to capture the required knowledge regarding the problem, solution, and rationale; to respond effectively to change – all require that systems engineering join the other engineering disciplines in moving beyond document-centric techniques and embracing the power of a model-based foundation. With energy and focus over the last ten years has come notable progress. The industry has advanced in the area of representations with the development of SysML as a standardized set of diagrams to complement traditional systems

representations. Numerous books – including a frequently cited guide by Tim Weilkiens – explain the details of using this notation to capture and communicate system designs to improve explicitness and alignment within the systems team. Alongside these representations have emerged countless standards and frameworks to help engineering teams develop high-fidelity models reflecting key systems dimensions.

However, for all the industry discussion regarding SysML, representations, standards, and tools, there remains a great deal of confusion. Understanding SysML notation and drawing SysML diagrams do not equate to doing model-based systems engineering. The use of disjoint models and simulation in systems engineering is also not equivalent to integrated model-based systems engineering.

Effectively moving forward with the transition to model-centric techniques requires that we step back to understand the bigger picture. Diagrams and other representations do not live in isolation but are interrelated and overlapping, communicating key aspects of the system model from specific viewpoints. System architecture and detailed analytical models are not disjoint, nor is there a single grand unified model to capture all dimensions of interest for all systems problems. To move forward, we must embrace the holistic systems perspective and apply it to model-based systems engineering, seeking out the interrelationships and developing a robust toolbox of supporting practices.

In this book, Tim Weilkiens, Jesko Lamm, Stephan Roth, and Markus Walker broaden our vision and expose us to a rich set of perspectives, processes, and methods so that we can develop an effective unified framework for model-based systems architecture. Building upon the existing industry library of textbooks on SysML, this book looks beyond the representation to address models, viewpoints, and views as part of a modern approach addressing requirements, behavior, architecture, and more. It connects to a larger framework of processes, methods, and tools key to enabling model-centric practices. And it looks beyond the technical space to the critical cultural dimensions because the transformation to model-centric techniques is far less a technical challenge than one of organizational change. Addressing the broader framework, Tim, Jesko, Stephan, and Markus bring model-centric practices together to help practitioners develop cohesive system architectures – our one chance in the life of a program to manage complexity, develop resilience, and design in critical concerns such as system security.

There is no doubt that the future of systems engineering is model-based. Document-centric techniques simply are not enough as we grapple with the challenges of today and tomorrow. Those

practitioners and organizations who are early adopters in developing a cohesive model-centric framework of processes, methods, and tools will certainly be at a competitive advantage – whether producing products themselves or delivering systems services for others. If, as a profession, we can transform from document-centric to model-based systems engineering and do so with the vision of enabling model-based engineering, we can help transform the larger product lifecycle delivering radical improvements in quality, cost, and time to market for the benefit of all.

David Long
President, Vitech Corporation
INCOSE President (2014 and 2015)

Preface

Reacting to market needs on time with systems of high quality and marketable costs is a strong competitive advantage. Once a market need has been identified, multiple disciplines are involved in developing a system toward it. They need to collaborate closely and each according to a precise understanding of the own contribution to the system development. Effective communication and the creation of understanding for the whole system of interest are keys for the success. Organizations are facing a more and more dynamic environment, and at the same time, an increasing organizational complexity of distributed teams and stakeholders, and an increasing technical complexity of more heterogeneous relationships between system components and their environment. This context requests an explicit and sustainable system architecture.

Each of the engineering disciplines contributing to system development needs specific views for obtaining the needed insight. System models enable the creation of consistent sets of stakeholder-specific views. People using them gain a fast and comprehensible understanding of the system they are developing, which can help them choose appropriate solutions for fulfilling the market needs. All the views look on the same data baseline. There is no effort to consolidate redundant data or to clarify misunderstandings of inconsistent information and the costs of resulted errors.

A system architect needs to shape the system architecture well for realizing a successful system. Multiple tasks have to be carried out, each

using an effective approach. This book provides a toolbox for the architect for his daily challenges. The scope of the book is a model-based environment, either it is already established and running or planned. The book explains how to use the SysML modeling language in obtaining model-based architecture descriptions. Nevertheless, the concepts are independent of SysML and could also be performed with other modeling languages.

This book is about people, models, and better products, based on our belief that model-based systems architecting produces better products by creating communication and insight for people involved in system development. The book presents a collection of methods and approaches which we see as ingredients for getting the system architecture work done successfully. We present model-based system architecting, which we see as a required backbone for excellent systems architecture work together with the stakeholders. We will show that involving the stakeholders means much more than running through a formalized review process.

A fundamental principle in system architecture is simplification. Without simple concepts to be communicated to the stakeholders, the system architect will not be understood and thus will fail. We advise you, dear reader, to adopt the principle of simplification and apply it to the multitude of approaches presented in the book. Feel free to only choose the approaches that are most suitable for your daily work and disregard the others, until you are in a situation where they turn out to be useful. The book is a well-stocked toolbox and not a rigid all-or-nothing process for system architects.

Our experience tells us that each organization will have a different focus area and will need different approaches. This is why we have bundled a variety of approaches we have observed being applied successfully in the industry, in the hope that you will find some pieces of information that are suitable exactly to your current activities. We have selected those approaches that we find easy to apply in daily work and are important for common model-based system architectures. We do not claim to provide a complete set. Every system architect loves to go to a hardware store to extend her toolbox. And from time to time, she has to discard one of her tools when it is no longer appropriate.

The book addresses system architects and their managers as well as engineers who are involved or interested in systems architecting. It is the first comprehensive book that combines the emergent discipline systems architecting with model-based approaches with SysML and puts

together puzzle pieces to a complete picture. Highlighted puzzle pieces are

- functional architectures and the Functional Architecture for Systems (FAS) method by Lamm and Weilkiens to derive the architecture from common use case analysis.
- the integration of the concept of layered architectures from the software discipline in the context of system architectures.
- the modeling of system variants.
- the whole picture of different architecture kinds like functional, logical, and product architectures and their relationships.
- a brief description of SysML and
- a summary of the history of the V-model and recent thinking about it in the appendix.

As a typical reader of this book, you may have no time to read all chapters in sequential order. Therefore, we have made the chapters as independent from each other as we could, in order to enable you to read them individually or out of a dedicated sequence when you like inspiration about a certain topic. You can find on-demand reference about particular topics and get inspiration for directly using the presented approaches in your daily business. The topics are demonstrated using a fictitious robot-based solution for virtual museum visits as an example system.

We like to write texts using gender-fair language. On the other hand, we avoid to clutter the flow of reading by using always both genders in the same sentence. Therefore, we have only used one gender where it was not appropriate to use gender-neutral language. Feel free to replace he by she and she by he wherever it is appropriate.

We like to thank the "FAS" and "MkS" working groups of GfSE, the German chapter of INCOSE. The work in these groups has provided us with new ideas that can now be found in this book. We thank NoMagic for their support in working with the Cameo tool family that we used to create the SysML models and diagrams we used in multiple chapters of this book. We also thank Erik Solda for allowing us to use the robot example, Martin Ruch for contributing ideas about the assessment of organizational interfaces and all the colleagues at works, who have influenced our way of thinking, helped us with foreign languages in both reading and writing or recommended literature that is today part of the foundations of this book. We furthermore thank numerous people

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who provided us with advice after we had shown or explained them little fragments of this book to hear a second opinion.

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About the Companion Website

This book is accompanied by a companion website:

www.mbse-architecture.com

The website includes:

- High resolution version of all the figures in the book.

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