DELING and SIMULATION SUPPORT for SYSTEM of SYSTEMS ENGINEERING APPLICATIONS

Edited by

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WILEY

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Published by John Wiley & Sons, Inc., Hoboken, New Jersey
Published simultaneously in Canada

Library of Congress Cataloging-in-Publication Data:

Rainey, Larry B.
Modeling and simulation support for system of systems engineering applications / Larry B. Rainey, Colorado Springs, CO, Andreas Tolk, SimIS, Inc., Portsmouth, VA.
pages cm
Includes bibliographical references and index.
ISBN 978-1-118-46031-3 (hardback)
1. Systems engineering–Data processing. 2. Engineering models.
I. Tolk, Andreas. II. Title.
TA168.R338 2015
620.001′13–dc23

2014022284

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Modeling and Simulation Support for System of Systems Engineering Applications

This text is dedicated to **Mr. Kevin Hibbs** of the Missile Defense Agency (MDA), an avid supporter of embracing and exercising new modeling and simulation techniques to enhance the mission of MDA, in which he recognized many system of systems related challenges and was pivotal in utilizing modeling and simulation to address these challenges.

We also remember Colonel (US Air Force, ret.) **Thomas W. O'Brien** who contributed directly as an author to this book. His insights from practical experiences and academic reflections shaped many ideas that we are taking now for granted when we study system of systems.

Foreword

System of Systems (SoS) is a maturing field, which has been described and applied in many different ways. However, at the core of different SoS descriptions and approaches is the focus on integration and coordination of multiple complex systems to achieve levels of performance, offer capabilities, or achieve purposes that are beyond the grasp of individual constituent systems. In effect, getting a set of systems that were not initially formed as a unity to come together as a unity to support a higher level (SoS) purpose. It is exciting to see the incorporation of Modeling and Simulation (M&S) presented in this volume for support and maturation of the SoS field through engineering applications.

M&S presented in this volume assists in four critical challenges facing SoS field development. First, they enable a better systems-based understanding, appreciation, and representation in the landscape of the twenty-first century enterprise. This landscape is beset with:

- Proliferation of information intensive systems and technologies, where creating interoperability extends beyond the "hard system" technical dimensions to include "soft system" dimensions such as conceptual interoperability
- Divergence in stakeholders interests and perspectives that invoke considerations for exploring and representing multiple frames of reference and their potential incompatibility
- Expectations for immediate results without long view considerations, where consequences of decisions may be significantly separated in space and time from the point of decision/action
- Scarce and dynamically shifting resources that make traditional planning forums suspect and suggest the necessity for near real time analysis of SoS level impacts stemming from dynamic shifts
- Application environments fraught with high degrees of complexity, uncertainty, emergence, and ambiguity. These "hyperturbulent" environments are subject to rapid and unexpected shifts and are no longer aberrations but are the norm
- Increasing doubt concerning the efficacy of traditional approaches based on reductionism, cause and effect certainty, absolute understanding, and results repeatability to effectively engage complex system problems

Such conditions are inevitable in the twenty-first landscape and cannot be eliminated. However, they can be managed, that is, they invoke the SoS challenge to improve effectiveness through different thinking, approaches, and applications. It is compelling that this volume offers examples of a direct assault on the SoS problem domain through application of M&S.

Second, SoS problems are inherently multidisciplinary, and they require multidisciplinary thinking and approaches for effective resolution. The SoS problem domain crosses technology, human/social, organizational, managerial, policy, and political boundaries. By their very nature, M&S applications are multidisciplinary and the array of applications in this volume attest to the capability of M&S applications to address the multidisciplinary nature of the SoS problem domain.

Third, poor decisions related to integration and coordination of SoS can have dire consequences, ranging from significant wasted resources to poor system performance, or even death. I would suggest strengthening the ability to make better decisions is the strongest contribution that M&S makes to the maturation of the SoS field. As this volume demonstrates, M&S brings the following capabilities to support better analysis and decisions in SoS: (i) systemic formulation of multidisciplinary problems through M&S driven representations, (ii) examination of the SoS behavior and responses to potential system changes in a "failsafe" setting, (iii) understanding the consequences for "poor" decisions prior to implementation and examination of alternative courses of action, and (iv) compression of time to better understand the potential long-term impacts for decisions.

Fourth, although engineering has always been about the practicality of solving problems and fulfilling unmet needs, grounding of applications in theoretical and methodological foundations is critical to maturing the SoS field. It is this grounding that will ultimately provide coherent maturation of the SoS field as well as long-term sustainability. The focused concentration of this volume on the theoretical and methodological implications for applications is laudable and makes a significant contribution to the maturing SoS field.

I have confidence that the work of this volume will be embraced for the significant weigh point it provides in the continuing journey of both the SoS and M&S fields. The contributions of this volume represent an important and decisive step forward in demonstrating the theoretical and methodological contributions of M&S to SoS through the lenses of application. The multidisciplinary breadth of applications ranging from security to transportation to space demonstrates the wide ranging applicability of SoS as informed by M&S.

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Mikhail Auguston is an Associate Professor in the Computer Science Department, Naval Postgraduate School in Monterey, California. Dr. Auguston's research interests encompass programming language design and implementation, real-time and reactive software testing and debugging automation and safety assessment tools, software and system architecture formal specification and validation, and visual programming languages. He has more than 40 years of experience in these areas and has published more than 120 papers in refereed journals, conferences, and workshop proceedings. He was PI and Co-PI in projects funded by NSF, NASA, U.S. Army Research Office, U.S. Naval Research Office, U.S. Missile Defense Agency, USMC Technology Center, TARDEC, SPAWAR/SYSCOM, and U.S. Army/Monterey TRAC.

William Dale Blair is a Principal Research Engineer with Georgia Tech Research Institute (GTRI) and is a Fellow there. He recently completed a three year assignment as the Technical Director for the C2BMC Knowledge Center of the Missile Defense Agency. Since joining GTRI in 1997, Dr. Blair has led a multiorganizational team in the development of multiplatform–multisensor–multitarget benchmarks to both air defense and ballistic missile defense. His projects at GTRI focus mostly on the modeling and simulation and algorithm assessment associated with the sensor netting for the C2BMC. Dr. Blair's research is reported in over 200 articles that include 38 refereed journals. He served as the Editor for Radar Systems for IEEE Transactions on Aerospace and Electronic Systems (T-AES) 1996-99 and Editor-in-Chief (EIC) for IEEE T-AES from 1999 to 2005. He is a Fellow of the IEEE and recipient of the 2001 IEEE Nathanson Award for Outstanding Young Radar Engineer. He is Coeditor and coauthor of the book, *Multitarget-Multisensor Tracking: Advances and Applications III*, and the author of chapter 19 "Radar Tracking Algorithms" and coauthor of chapter 18 "Radar Measurements" of the new edition of *Principles of Modern Radar*. He has served on the Board of Governors for the IEEE Aerospace and Electronics Systems Society (AESS) for 1998–2003, 2005–2010, and 2012–2014.

John Boardman has been an engineer, consultant, researcher, teacher, and public speaker. He has held academic appointments in the United Kingdom and the United States. Most recently he was a Distinguished Service Professor at Stevens Institute of Technology in the School of Systems and Enterprises where he taught graduate classes on systems thinking and enterprise architecting. His specialty subjects have covered electrical engineering, computer engineering, software, and systems engineering. He has coauthored two books, with Brian Sauser, on systems thinking. He is a Fellow of the Institution of Engineering and Technology. He now concentrates on writing and has recently completed Part I of a trilogy: "Memories live longer than dreams."

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