

Preface

A two-day workshop was held on January 13–14, 2016, at the National Science Foundation in Arlington, Virginia, with the goal of defining directions for future research in modeling and simulation and its role in engineering complex systems. The workshop was sponsored by the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the Air Force Office of Scientific Research (AFOSR), and the National Modeling and Simulation Coalition (NMSC) in conjunction with its parent organization the National Training and Simulation Association (NTSA). This book documents the findings emanating from this workshop.

The goal of the workshop was to identify and build consensus around critical research challenges in modeling and simulation related to the design of complex engineered systems—challenges whose solution will significantly impact and accelerate the solution of major problems facing society today. Although modeling and simulation has been an active area of study for some time, new developments such as the need to model systems of unprecedented scale and complexity, the well-documented deluge in data, and revolutionary changes in underlying computing platforms are creating major new opportunities and challenges in the modeling and simulation (M&S) field. The workshop focused on four main technical themes: (1) conceptual models, (2) computational issues, (3) model uncertainty, and (4) reuse of models and simulations.

The workshop resulted in large part from an initiative led by the research and development committee of the National Modeling and Simulation Coalition (NMSC) aimed toward defining a common research agenda for the M&S research community. Recognizing that the modeling and simulation community is fragmented and scattered across many different disciplines, communities, and constituencies, there is a need to gather individuals from different communities to articulate important research problems in M&S. Presentations and panel sessions at several modeling and simulation conferences were held leading up to and following the January workshop to raise awareness of this activity.

Detailed planning began in September 2015 with the formation of the workshop steering committee consisting of Richard Fujimoto (chair, Georgia Tech, and then

NMSC Policy Committee chair), Steven Cornford (NASA Jet Propulsion Laboratory), Christiaan Paredis (National Science Foundation), and Philomena Zimmerman (Office of the Secretary of Defense). An open call was developed and disseminated that requested nominations of individuals, including self-nominations, to participate in the workshop. A total of 102 nominations were received. The steering committee reviewed these nominations, and several rounds of invitations were made until the workshop capacity was reached. Selection of participants focused on goals such as ensuring balance across the four technical theme areas, broad representation from different research communities, inclusion of senior, distinguished researchers in the field, and ensuring inclusion of individuals from underrepresented groups.

A total of 65 individuals attended the workshop. Four working groups were formed, each representing one of the technical theme areas. Participants were initially assigned to one of the working groups; however, attendees were free to participate in a group different from that which the individual was assigned (and some did so), and some chose to participate in multiple groups throughout the course of the two-day workshop. Three individuals within each group agreed to organize and facilitate discussions for that group and help organize the workshop findings.

Each group was charged with identifying the four or five most important research challenges in the specified technical area that, if solved, would have the greatest impact. It was anticipated that within each of these main challenges, there would be some number of key subchallenges that would need to be addressed to attack the research challenge.

Prior to the workshop, several read-ahead documents concerning research challenges in M&S were distributed to the participants. These read-ahead materials included the following:

- National Science Foundation Blue Ribbon Panel, “Simulation-Based Engineering Science,” May 2006.
- National Research Council of the National Academies, “Assessing the Reliability of Complex Models, Mathematical and Statistical Foundations of Verification, Validation, and Uncertainty Quantification,” 2012.
- A. Tolk, C.D. Combs, R.M. Fujimoto, C.M. Macal, B.L. Nelson, P. Zimmerman, “Do We Need a National Research Agenda for Modeling and Simulation?” *Winter Simulation Conference*, December 2015.
- J.T. Oden, I. Babuska, D. Faghihi, “Predictive Computational Science: Computer Predictions in the Presence of Uncertainty,” *Encyclopedia of Computational Mechanics*, Wiley and Sons, to appear, 2017.
- K. Farrell, J.T. Oden, D. Faghihi, “A Bayesian Framework for Adaptive Selection, Calibration and Validation of Coarse-Grained Models of Atomistic Systems,” *Journal of Computational Physics*, 295 (2015) pp 189–208.
- Air Force Office of Scientific Research and National Science Foundation, “Report of the August 2010 Multi-Agency Workshop on Infosymbiotics/DDDAS: The Power of Dynamic Data Driven Application Systems” August 2010.

In addition, workshop attendees were invited to submit brief position statements of M&S research challenge problems or areas that should be considered for discussion at the workshop. Each proposal was assigned to one of the four technical theme areas and distributed to attendees prior to the meeting.

The workshop program included five application-focused presentations on the first day that described important areas where technical advances in M&S were needed within the context of these domains: sustainable urban growth (John Crittenden), healthcare (Donald Combs), manufacturing (Michael Yukish), aerospace (Steven Jenkins), and defense (Edward Kraft). These presentations, the read-ahead materials, and research challenge proposals submitted by workshop participants were the main inputs used in the workshop.

The remainder of the workshop focused on breakout groups and cross-group discussions with the goal to build consensus around key research challenges that could form the basis for a common research agenda. The first day focused on collecting and consolidating views concerning important research challenges. The second day included brief presentations and discussions reporting progress of the four groups, and further discussion to refine and articulate recommendations concerning research challenges in each of the four technical areas.

This document describes the main findings produced by the workshop. We would like to thank the many individuals and organizations who helped to make this workshop possible. First, we thank the workshop sponsors, especially NSF (Diwakar Gupta) and NASA (John Evans) who provided the principal funding for the workshop. NMSC/NTSA (RADM James Robb) sponsored a reception held at the end of the first day of the workshop, and AFOSR (Frederica Darema) participated in events leading up to the workshop and provided valuable guidance as the workshop was being developed. The five plenary speakers (John Crittenden, Donald Combs, Michael Yukish, Steven Jenkins, and Edward Kraft) provided outstanding, thought-provoking presentations regarding the impact of M&S in their respective application areas. Administrative support for the workshop was provided by Holly Rush and Tracy Scott, and Philip Pecher helped with the development of the final report and Alex Crookshanks help with the graphics used in some of the figures.

Finally, we especially thank the many participants who devoted their time and effort to participate and help develop this workshop report. We thank the group leads for carefully managing the discussions of their groups as well as efforts to organize and, in many cases, write much of the text that is presented here.

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