# GRAND CHALLENGES IN HYBRID MODELLING

Navonil Mustafee

Centre for Simulation, Analytics and Modelling
The Business School
University of Exeter
Exeter, EX4 4ST, UK

Andreas Tolk

Modeling, Simulation, Experimentation & Analytics
The MITRE Corporation
1001 Research Park Blvd # 220
Charlottesville, VA 22911, USA

Steffen Straßburger

Info. Technology in Production & Logistics
Ilmenau University of Technology
P.O. Box 100 565
Ilmenau, 98684, GERMANY

Varun Ramamohan

Department of Mechanical Engineering
Indian Institute of Technology Delhi
Hauz Khas
New Delhi, 110016, INDIA

Alison Harper

PenCHORD, PenARC
University of Exeter Medical School
Exeter EX1 1TE, UK

## ABSTRACT

The combined application of simulation techniques such as discrete-event simulation, system dynamics and agent-based simulation is referred to as Hybrid Simulation (HS). Distinct from HS, Hybrid Modelling (HM) is the use of simulation in conjunction with theories and frameworks, methodologies, tools and techniques from Social Sciences, Engineering, Computer Science and other disciplines. Like M&S, these approaches were developed, tested, applied and refined and continue to evolve within disciplinary confines, and there exists an opportunity for the realization of synergy through the combined application of techniques! There are several examples of HM studies using simulations with analytical models or Soft OR approaches, however, such cross-disciplinary inquiry lacks saturation. Through the Grand Challenges panel, we seek to generate interest in HM research and practice, which embraces the most appropriate approaches irrespective of their disciplinary origins and paves the way for increased collaboration among scientific disciplines.

## 1 INTRODUCTION

The deployment of knowledge from various disciplines has become imperative with the increasing scale of problems that face humanity (e.g., climate change) and the complexity of phenomena for which we seek better understanding (e.g., the formation of the Universe). The term *E-Science* became popular in the early part of the new millennium. It referred to collaborative scientific inquiry that required massive amounts of computing power, large datasets and distributed e-Infrastructure technologies such as HPC resources, remote instrumentation and grid computing. A key element of e-Science were the so-called virtual research

communities (VRCs). VRCs consisted of experts from different organizations and disciples, working predominantly through highly distributed environments with specialist software and hardware. The constitution of the VRCs was largely based on the e-Science application in question. For example, analysis of data from experiments conducted in CERN's *Large Hadron Collider* would predominantly require Physicists. e-Infrastructures enabled the e-Science applications to execute (these were mostly computer simulations), and the analysis was done by the VRCs (Mustafee et al., 2020). M&S e-Science applications were examples of hybrid modelling as they leveraged research on e-Infrastructure, primarily the domain of Computer Science and Networking disciplines.

HMs, such as the one described above, could be classified as either multidisciplinary HM (integratability of infrastructures for enabling data exchange) or interdisciplinary HM (both integratability and interoperability allowing for data exchange) (Tolk et al., 2021). Examples include studies that have executed simulations over parallel and distributed computing resources for speed-up (Parallel and Distributed Simulation). However, assessing hybridity only through the lens of *integratability* and *interoperability* limits the exploration of opportunities that exist in combining disciplinary approaches along with M&S. These combined approaches should extend mere model execution. Indeed, a M&S study, especially in the context of Operations Research/Management Science (OR/MS), includes several well-defined stages, for example, problem formulation and conceptual modelling, input data analysis, model building, verification and validation, scenario development and experimentation. The distinct stages provide opportunities for the combined application of M&S techniques, including HS, with frameworks, methods, techniques and research approaches that have been developed in disciplines outside M&S (Powell and Mustafee, 2017). A transdisciplinary approach for HMs could aim for the overarching synthesis of M&S with other disciplines, whereby new methodological and theoretical frameworks would enable the co-production of knowledge within those disciplines, leading to composability of conceptualizations and systemic integration of the knowledge components (Klein, 2014).

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Within this overall context of (1) multi-, inter- and transdisciplinary HMs, and (2) the life cycle of a typical M&S study, the panel will discuss five Grand Challenges that primarily focus on methodological perspective and two challenges that are on application:

- Grand Challenge in the conceptualization of HMs
- Grand Challenge on HM implementation
- Grand Challenge in the integrability and execution of HM
- Grand Challenge on output evaluation and presentation of the result of a HM study
- Grand Challenge on Trust in HM
- Grand Challenge on inclusivity modelling in HM
- Grand Challenge on HM for sustainable development goals, including climate action

The seven challenges are based on the panelists' research interests. However, these are by no means the definite set of challenges. The panel will seek contributions from the audience to help refine the challenges and to articulate new directions for future research in HM!

## ACKNOWLEDGEMENTS

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