Alexander Kott
Gary Citrenbaum
Editors

Estimating Impact

A Handbook of Computational Methods and Models for Anticipating Economic, Social, Political and Security Effects in International Interventions

Springer

Estimating Impact

Alexander Kott · Gary Citrenbaum
Editors

Estimating Impact

A Handbook of Computational Methods and Models for Anticipating Economic, Social, Political and Security Effects in International Interventions

Springer

Editors
Alexander Kott
Army Research Laboratory
2800 Powder Mill Rd
Adelphi, MD 20783
USA
alexander.kott1@us.army.mil

Gary Citrenbaum
System of Systems Analytics, Inc.
3877 Fairfax Ridge Rd, Suite 201C
Fairfax, VA 22030
USA
gcitrenbaum@sosacorp.com

ISBN 978-1-4419-6234-8 e-ISBN 978-1-4419-6235-5
DOI 10.1007/978-1-4419-6235-5
Springer New York Dordrecht Heidelberg London

Library of Congress Control Number: 2010936359

© Springer Science+Business Media, LLC 2010
All rights reserved. This work may not be translated or copied in whole or in part without the written permission of the publisher (Springer Science+Business Media, LLC, 233 Spring Street, New York, NY 10013, USA), except for brief excerpts in connection with reviews or scholarly analysis. Use in connection with any form of information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed is forbidden.
The use in this publication of trade names, trademarks, service marks, and similar terms, even if they are not identified as such, is not to be taken as an expression of opinion as to whether or not they are subject to proprietary rights.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Acknowledgments

This book, like most of its genre, represents a collective effort in more ways than one. Not only does it draw from the explicit efforts of its authors, but it also benefited substantially from a large support team – our teachers, advisors, coworkers, and families. We are delighted to recognize, and thank all of these individuals, who are, fortunately for us, too numerous to call out separately.

We are particularly happy to acknowledge a small set of individuals whom our authors, as individuals, have suggested warrant special recognition. Specifically:

Alex Kott, Steve Morse, and Gary Citrenbaum thank Len Hawley, former National Security Council (NSC) official, for introducing them to the ideas of Next State Planning and for sharing with them the insights he gained as senior mentor for the Integrated Battle Command (IBC) program (latter referred to as the Conflict Modeling, Planning, and Outcome Experimentation [COMPOEX] program).

Gary Citrenbaum is pleased to recognize the invaluable support of his coworkers in assembling and fleshing out this book. These include: Sara Citrenbaum, who drew, or redrew all the graphics, Gina Mansell, who assembled and proofread the manuscript, and Jordan Willcox, who developed many of the chapter summaries.

Mark Abdollahian, Jacek Kugler, Brice Nicholson, and Hana Oh acknowledge the continuous support of Sandra Seymour, Gwen Williams and Lynda Marquez at the School of Politics and Economics, Claremont Graduate University.

Ravi Bhavnani, Dan Miodownik, and Rick Riolo jointly thank Petra Hendrickson and Roman Kareev for research assistance. Ravi Bhavnani acknowledges the support of the Department of Political Science, Michigan State University. Rick Riolo acknowledges the support of the Center for the Study of Complex Systems, University of Michigan. Dan Miodownik acknowledges support from the Israel Science Foundation (Grant #33007).

Bruce Skarin acknowledges the financial support of the Air Force Research Lab (AFRL) for portions of his research.

Alan Graham acknowledges the support of PA Consulting Group's Federal and Defense Services Practice, where most of his chapter was written, and where he received much of the valuable professional experiences behind it. Without PA's generosity and professional excellence, his work would not have been possible. In particular, the collaboration with Elizabeth Farrely, Tamara Greenlaw, Donna

Mayo, Tom Mullen, Joshua Park, Whitney Pickels, Ritu Sharma, Erik Waldron, and many others was both highly productive and enjoyable.

David Jonker and William Wright wish to acknowledge the senior subject matter experts they had the privilege of working with on the DARPA COMPOEX program. These Generals, Admirals, Ambassadors and U.S. Aid leaders provided invaluable insight and visualization guidance into how they "saw" complex systems.

William Bennett thanks Ed Waltz and Pat Allen for introducing him to the challenge of modeling media effects. He also thanks Jonathan Goldstein and Howie Zhu for their support in developing data interfaces and computational modules.

On a bittersweet note, Ed Waltz, Gary Citrenbaum, and others gratefully acknowledge the pioneering vision of Dr. John G. Allen, the first Program Manager of the DARPA Integrated Battle Command (IBC) program [later referred to as the Conflict Modeling, Planning and Option Exploration (COMPOEX) program]. John's passion and direction led to the development of the first computational framework for rapidly and practically integrating PMESII models in support of analysis and planning. Without his vision and encouragement, several of the technologies discussed in this book would not be available today. Although John did not live to see this book or many of the other fruits of his labors, he and his contributions will not be forgotten.

Contents

1 Introduction: Judgment and Computation 1
Alexander Kott, Gary Citrenbaum, and G. Jiyun Kim

2 Emerging Techniques and Tools 15
Ed Waltz

3 Politics and Power 43
Mark Abdollahian, Jacek Kugler, Brice Nicholson, and Hana Oh

4 Economics and Markets 91
Alan K. Graham

5 Media and Influence 135
William H. Bennett

6 Governance and Society 179
Corey Lofdahl

7 Groups and Violence 205
Ravi Bhavnani, Dan Miodownik, and Rick Riolo

8 Insurgency and Security 239
Alexander Kott and Bruce Skarin

9 Crime and Corruption 263
Deborah Duong, Robert Turner, and Karl Selke

10 Visualization and Comprehension 285
David Jonker and William Wright

11 Verification and Validation 311
Dean Hartley and Stuart Starr

12 Conclusions: Anticipation and Action 337
Alexander Kott and Stephen Morse

Abbreviations and Acronyms..... 349

Index..... 351

About the Authors

Dr. Mark Abdollahian is cofounder and Chief Operating Office of Sentia Group, Inc. a Washington DC based consulting and software services company that utilizes social science modeling to forecast and shape political outcomes. Dr. Abdollahian is in charge of research, development and engineering efforts, including SENTURION™ political modeling software. He has been a consultant to the World Bank, the United Nations, Department of Defense and the private sector, including Arthur Andersen, Motorola, McKinsey, Raytheon, British Aerospace, Chevron, and DeBeers. His research focuses on fusing micro- and macro-social behavioral theories into business intelligence and analytic solutions. He is coauthor of Power Transitions and a number of scholarly articles on strategic decision-making and conflict. Dr. Abdollahian earned his Ph.D. in political economy and mathematical modeling from Claremont Graduate University. Dr. Abdollahian is a coauthor of Chap. 3, Politics and Power.

Dr. William Bennett has over 30 years experience modeling and analyzing information and decision systems with application to military intelligence and operations planning. He earned both a Master of Science and Ph.D. in Electrical Engineering from the University of Maryland at College Park. He has held positions in technology development and management at ALPHATECH, Atlantic Aerospace Electronics, Techno-Sciences, Inc. and US Naval Research Laboratory, and has served as adjunct faculty and advisor to chairman of the Electrical and Computer Engineering Department of University of Maryland. Dr. Bennett is a senior member of IEEE, the American Institute of Aeronautics and Astronautics and Society for Industrial and Applied Mathematics and Military Operations Research Society, Dr. Bennett currently serves as Principal Research Engineer at BAE Systems, Advanced Information Technologies. His current research addresses complex systems analysis and decision aids for sociotechnical systems, and modeling methods to support strategic communication for the US Department of Defense. Dr. Bennett is the author of Chap. 5, Modeling of Media Influence.

Dr. Ravi Bhavnani earned his Ph.D. in political science from the University of Michigan, Ann Arbor with a degree certificate from the UM's Center for the Study of Complex Systems. His thesis research, conducted under the supervision of Dr. Robert Axelrod, explored the link between intraethnic and interethnic violence.

Dr. Bhavnani is currently an Assistant Professor in the Department of Political Science at Michigan State University, where his current research focuses on the microfoundations of violence in ethnic and nonethnic civil wars using agent-based computational modeling. Recent publications have appeared in the *Journal of Politics* (2009), *Journal of Conflict Resolution* (2009), *Complexity* (2008), and *Journal of Artificial Societies and Social Simulation* (2008). Dr. Bhavnani is a coauthor of Chap. 7, Groups and Violence.

Dr. Gary Citrenbaum serves as the President and Chief Scientist of System of Systems Analytics, Inc. (SoSACorp), headquartered in Fairfax, VA. He has been designing and consulting on complex systems for the United States Government for over 35 years. His specialty is concept development, as well as system design, development, utility assessment, and deployment. Dr. Citrenbaum's work has spanned a wide range of real-world problems: treaty monitoring, operations planning, intelligence collection and analysis, approaches for analyzing and mitigating international crises and to the development of tools for counterterrorism problems. His research interests include interagency planning approaches, large-scale optimization, modeling using agent-based, system dynamic, Markov approaches, system and process utility assessment, structured argumentation, and social network analysis. Dr. Citrenbaum served as coeditor of this book.

Dr. Deborah Duong earned her Ph.D. in Computational Science and Informatics from George Mason, majoring in Computational Social Science, in 2004. She currently researches modeling and simulation of irregular warfare that has created several modeling and simulation programs for the United States Government, including the Nexus Cognitive Agent-Based Simulations and the Oz Wargame Integration Toolkit; and the MICCE and Indra Natural Language Systems to extract Role ontologies from text. Her specialty is the use of AI techniques to simulate the phenomena of Interpretive Social Science. Her academic works include her dissertation work SISTER, the Symbolic Interactionist Simulation of Trade and Emergent Roles, published in JASSS. Dr. Duong is a coauthor of Chap. 9, Crime and Corruption.

Dr. Alan K. Graham earned his Ph.D. in Control Theory and Decision Science in Electrical Engineering from MIT. As faculty and staff at MIT, he was Research Director for the System Dynamics National Economic Model Project. Dr. Graham's experience includes 13 years at PA Consulting (an international management and technology consultancy) where he led teams using system dynamics models of market competition to address corporate strategy (in marketing, market forecasting, technology, and capital investment) in several industries (wireless and landline telcos, telecoms equipment, specialty and commodity chemicals, oil, pharmaceuticals, and shipping). For the government clients, Dr. Graham has led analyses for government regulation (electric power, wireless and landline telco), and government policy (counterinsurgency, strategic deterrence, economic impacts in multiple regions, and economic warfare). Coauthor of two books and numerous articles, he was on the Editorial Board of the highly cited *System Dynamics Review* for 23 years.

He is a Senior Member of the IEEE. Dr. Graham is the author of Chap. 4, Economics and Markets. Since 2009, he has been Chief Knowledge Officer for Greenwood Strategic Advisors.

Dr. Dean Hartley III is the Principal of Hartley Consulting. Previously, he was a Senior Member of the Research Staff at the Department of Energy Oak Ridge Facilities (Oak Ridge National Laboratory, Y12 Site and East Tennessee Technology Park). He is a past Vice President of the Institute for Operations Research and Management Science (INFORMS), a past Director of the Military Operations Research Society (MORS), past President of the Military Applications Society (MAS), and a member of the College on Simulation of INFORMS. Dr. Hartley is a Senior Fellow with the George Mason University School of Public Policy, a consultant for the Naval Postgraduate School (NPS), Modeling, Virtual Environments and Simulation (MOVES) Institute, and a Research Fellow with the University of Alabama in Huntsville, Center for the Management of Science and Technology (CMOST). His expertise includes modeling of combat, operations other than war (OOTW), stability and support operations (SASO), and stability, security, transition, and reconstruction (SSTR) operations, verification and validation of models, psychopharmacology modeling, and simulation. Dr. Hartley has published *Predicting Combat Effects*, contributed chapters to three other books, and written more than 150 articles and technical documents. Dr. Hartley is a coauthor of Chap. 11, Verification and Validation.

David Jonker is a Partner and cofounder at Oculus Info Inc. He is a senior system architect and senior visualization designer with over 15 years experience in visualization system research, design, and development. Mr. Jonker served as the human computer interface and visualization lead designer and technical architect on a major research program dedicated to modeling complex societal effects. He led the design and implementation of a system that helps senior decision-makers to visualize large complex social, political, and economic behaviors, to explore alternative actions in those domains, and to understand effects. Mr. Jonker is chief technical architect for Oculus main products. His research interests include high performance information visualization technical architectures, as well as visualization semiotics. He has authored papers on information visualization. Mr. Jonker earned a B.E.S. and B.Arch. from the University of Waterloo. He is coauthor of Chap. 10, Visualization and Comprehension.

Dr. G. Jiyun Kim earned his doctoral degree in Political Science, together with a graduate certificate in Complex Systems, from the University of Michigan, where he specialized in political transitions and conflict resolution. He was a postdoctoral researcher at the University of Pennsylvania in the Department of Electrical and Systems Engineering. His research involved: 1) building and empirically validating virtual countries using a multi-resolution, agent-based model; and 2) building an international crisis simulator to monitor and assess the North Korean nuclear crisis. He is currently an Adjunct Professor in the Department of Politics at New York University. His current research and teaching focus on the economic and financial

ramifications of political instability in emerging markets. Dr. Kim is a coauthor of Chap. 1, Introduction, Judgment and Computation.

Dr. Alexander Kott currently serves as a Division Chief at the United States Army Research Laboratory (ARL). Prior to joining ARL he worked at the Defense Advanced Research Projects Agency (DARPA) – the central R&D organization of the United States Department of Defense. At DARPA, he initiated and managed several large-scale research programs, including the Conflict Modeling, Planning and Outcomes Exploration (COMPOEX) program. His research interests include modeling of societal systems, phenomena in social and information networks, dynamic planning in rapidly changing, uncertain, and adversarial environments, and instabilities in decision-making systems. Dr. Kott has published over 70 technical papers and has served as the editor and coauthor of several books, including *Information Warfare and Organizational Decision Process*, *Adversarial Reasoning*, and *The Battle of Cognition*. Dr. Kott served as senior editor of this book and coauthored Chap. 1, Introduction: Judgment and Computation, Chap. 8, Insurgency and Security, and Chap. 12, Conclusions: Anticipation and Action.

Dr. Jacek Kugler is the Elisabeth Helms Rosecrans Professor of International Relations at the School of Politics and Economics, Claremont Graduate University, where he has also served as Chair. He is a cofounder of Sentia Group Incorporated. Dr. Kugler is the editor of *International Interactions*, a past president of the International Studies Association and the Peace Science Society. His numerous publications in world politics and political economy are widely available in scholarly journals. He is the coauthor of *The War Ledger*, *Births, Deaths, and Taxes*, and *Power Transitions* as well as the coeditor of *Parity and War*, the *Long Term Stability of Deterrence*, and *Political Capacity and Economic Behavior*. Dr. Kugler earned his Ph.D. in world politics from the University of Michigan. Dr. Kugler is a coauthor of Chap. 3, Politics and Power.

Dr. Corey Lofdahl is a Consulting Engineer at IGEN Corporation in Carlisle, Massachusetts where he uses advanced simulation and statistical techniques to analyze hard policy and strategy problems and develops supporting software. He was the conflict economics modeler for DARPA's Integrated Battle Command (IBC) project. Dr. Lofdahl earned degrees in electrical engineering, computer science, and international relations from the University of Colorado at Boulder, Brown University, and MIT, and is the author of *Environmental Impacts of Globalization and Trade: A systems study* (MIT Press, 2002). Dr. Lofdahl is the author of Chap. 6, Governance and Society.

Dr. Dan Miodownik earned his Ph.D at University of Pennsylvania, Political Science Department. He currently serves as an assistant professor in the Departments of Political Science and International Relations at the Hebrew University of Jerusalem, where he studies the emergence, unfolding and regulation of antiregime mobilization, protest behavior, ethnic polarization, and civil wars. Dr. Miodownik also has significant interest in the development of computer simulations – Agent-Based Modeling in particular – to assist comparative political analysis of these and

other complex social phenomena. His work has been published in journals such as the *American Political Science Review*; *Journal of Conflict Resolution; Comparative Politics; Studies in Comparative International Development; Nationalism & Ethnic Politics; Social Science Computer Review;* and *Journal of Artificial Societies and Social Simulations*. Dr. Miodownik teaches courses on ethnic conflict and mobilization, civil wars, the study of politics and research methods. Dr. Miodownik is a coauthor of Chap. 7, Groups and Violence.

Dr. Stephen Morse has over 30 years of experience as a technical consultant to various institutions of the U.S. Government. His contribution to the current volume is based on his research in use of model predictive control for optimized decision-making in complex dynamic environments. His other relevant efforts include: PMESII modeling; rapid optimization algorithms for adaptive replanning; remote sensing; high performance computing and parallel processing; and data mining on very large data warehouses. Dr. Morse is the author of two books and numerous technical articles and presentations. Dr. Morse is a coauthor of Chap. 12, Conclusions: Anticipation and Action.

Brice Nicholson is a Ph.D. student at Claremont Graduate University, where his research interests include systems dynamics applied to security, stability, transition, and reconstruction operations (SSTRO), and integration. His most recent project was the development of a formal model of stabilization and reconstruction operations while working at the National Defense University. Mr. Nicholson earned his B.A. in Political Science and History from California State University Northridge and his M.A. in International Political Economy from Claremont Graduate University. Mr. Nicholson is a coauthor of Chap. 3, Politics and Power.

Dr. Hana Oh earned her Ph.D. in political economy and comparative politics from Claremont Graduate University. She has worked with the World Bank, the United Nations, and the private sector, and is currently a Senior Analyst at Sentia Group, where she is responsible for political risk analysis and mitigation strategies. Her research spans computational modeling, social network analysis, and behavioral game theory applied to real world policy problems, and she has published articles on social and dynamic modeling of human behavior. Dr. Oh is a coauthor of Chap. 3, Politics and Power.

Dr. Rick Riolo earned his Ph.D. in Computer Science at the University of Michigan (UM) for research focused on genetic algorithms and classifier systems. He currently works at the UM's Center for the Study of Complex Systems, where he provides agent-based modeling expertise in support of interdisciplinary research projects involving topics such as urban sprawl and its ecological impacts; decision making in closed political regimes; the evolution of cooperation, supply chain dynamics, coordination of agents competing for limited resources; the relationship between phenotype plasticity and the structure and dynamics of food webs; and the spread of antibiotic resistance in nursing homes and other nosocomial settings. Dr. Riolo is a member of the Swarm Board of Directors (SDG) and the Repast Organization for Architecture and Development (ROAD), groups responsible for the development and

distribution of Swarm (see http://swarm.org) and Repast (http://repast.sourceforge.net), software packages for creating agent (individual)-based models (ABM/IBM). Dr. Riolo is a coauthor of Chap. 7, Groups and Violence.

Karl Selke is currently a Senior Systems Scientist for the Center for Complexity Analysis (CCA), a second year Ph.D. student at George Mason University's Center for Social Complexity, and works as an irregular warfare analyst for a U.S. government organization. Before joining CCA in August 2008, he spent 2½ years as a Systems Engineering Analyst at Evidence-Based Research, Inc. on several projects involving numerous clients such as the Defense Advanced Research Projects Agency, the Defense Information Systems Agency, and the Navy's Second Fleet. Mr. Selke has a BS in political science from Lake Superior State University and a MS in systems engineering focusing on operations research and management science from George Washington University. His area of research is focused on the processes and techniques for integrating computational social science models into strategic-operational wargaming. Mr. Selke is a coauthor of Chap. 9, Crime and Corruption.

Bruce Skarin is a Simulation Scientist leading projects that utilize computational models to aid decision making, collaboration, and knowledge management at Aptima, Inc. Mr. Skarin is also a part-time MS student at Wocester Polytechnic Institute where he earned a BS in System Dynamics. His experience includes system dynamics, agent-based, and discrete event modeling with a focus on simulating sociocultural behavior, social networks, and organizational dynamics. While at Aptima he has designed and built an agent-based model that forecasts changes in local populations that is used to assist ongoing strategic planning. He is a coauthor of Chap. 8, Insurgency and Security.

Dr. Stuart H. Starr is a Distinguished Research Fellow at the Center for Technology and National Security Policy (CTNSP), National Defense University (NDU). Concurrently, he serves as President of Barcroft Research Institute (BRI), where he consults on Command and Control (C2) and Modeling and Simulation (M&S) issues (e.g., The Institute for Defense Analyses (IDA)), lectures to audiences world-wide on C2 and M&S issues, and participates on Blue Ribbon panels (e.g., member of the Army Science Board). Prior to founding BRI, Dr. Starr was Director of Plans, The MITRE Corporation; Assistant Vice President for C3I Systems, M/A-COM Government Systems (currently a unit of SAIC); Director of Long Range Planning and Systems Evaluation, OASD(C3I), Office of the Secretary of Defense (where he was member of the Senior Executive Service); and Senior Project Leader, IDA. Dr. Starr earned his Ph.D. and MS in Electrical Engineering from the University of Illinois, a BSEE from Columbia University, and a B.A. from Queens College. He has received the Clayton Thomas medal (2004) and the Vance Wanner medal (2009) from the Military Operations Research Society (MORS) for lifetime accomplishments in operations analysis. Dr. Starr is a coauthor of Chap. 11, Verification and Validation.

Robert Turner leads the systems analysis efforts at IMAG in the Office of the Secretary of Defense. He has over 30 years of experience in systems analysis,