

Table of Contents

Introduction	xi
Chapter 1. Simulation: History, Concepts, and Examples	1
Pascal CANTOT	
1.1. Issues: simulation, a tool for complexity.	1
1.1.1. What is a complex system?	1
1.1.2. Systems of systems	3
1.1.3. Why simulate?	5
1.1.4. Can we do without simulation?	12
1.2. History of simulation	14
1.2.1. Antiquity: strategy games	14
1.2.2. The modern era: theoretical bases	15
1.2.3. Contemporary era: the IT revolution	18
1.3. Real-world examples of simulation	24
1.3.1. Airbus	24
1.3.2. French defense procurement directorate	26
1.4. Basic principles	29
1.4.1. Definitions	30
1.4.2. Typology	37
1.5. Conclusion	51
1.6. Bibliography	52
Chapter 2. Principles of Modeling	57
Pascal CANTOT	
2.1. Introduction to modeling	57
2.2. Typology of models	58
2.2.1. Static/dynamic	58
2.2.2. Deterministic/stochastic	59

2.2.3. Qualities of a model	63
2.3. The modeling process	66
2.3.1. Global process	67
2.3.2. Formulation of the problem	68
2.3.3. Objectives and organization	70
2.3.4. Analysis of the system	71
2.3.5. Modeling	76
2.3.6. Data collection	78
2.3.7. Coding/implementation	82
2.3.8. Verification	87
2.3.9. Validation	87
2.3.10. Execution	87
2.3.11. Use of results	89
2.3.12. Final report	90
2.3.13. Commissioning/capitalization	90
2.4. Simulation project management	91
2.5. Conclusion	94
2.6. Bibliography	94
Chapter 3. Credibility in Modeling and Simulation	99
Roland RABEAU	
3.1. Technico-operational studies and simulations	99
3.2. Examples of technico-operational studies based on simulation tools	101
3.2.1. Suppression of aerial defenses	101
3.2.2. Heavy helicopters	101
3.3. VV&A for technico-operational simulations	102
3.3.1. Official definitions	102
3.3.2. Credibility	103
3.3.3. Key players in the domain	105
3.4. VV&A issues	108
3.4.1. Elements concerned	108
3.4.2. Verification and validation techniques	114
3.4.3. VV&A approaches	123
3.4.4. Responsibilities in a VV&A process	141
3.4.5. Levels of validation	144
3.4.6. Accreditation	144
3.5. Conclusions	145
3.5.1. Validation techniques	145
3.5.2. Validation approaches	147
3.5.3. Perspectives	150
3.6. Bibliography	152

Chapter 4. Modeling Systems and Their Environment	159
Pascal CANTOT	
4.1. Introduction	159
4.2. Modeling time	160
4.2.1. Real-time simulation	160
4.2.2. Step-by-step simulation	161
4.2.3. Discrete event simulation	162
4.2.4. Which approach?	162
4.2.5. Distributed simulation	162
4.3. Modeling physical laws.	163
4.3.1. Understanding the system	163
4.3.2. Developing a system of equations	164
4.3.3. Discrete sampling of space	165
4.3.4. Solving the problem	166
4.4. Modeling random phenomena.	166
4.4.1. Stochastic processes	166
4.4.2. Use of probability.	167
4.4.3. Use of statistics	171
4.4.4. Random generators	173
4.4.5. Execution and analysis of results of stochastic simulations	175
4.5. Modeling the natural environment	178
4.5.1. Natural environment	178
4.5.2. Environment databases	178
4.5.3. Production of an SEDB	180
4.5.4. Quality of an SEDB	182
4.5.5. Coordinate systems.	183
4.5.6. Multiplicity of formats.	185
4.6. Modeling human behavior	193
4.6.1. Issues and limitations	193
4.6.2. What is human behavior?	194
4.6.3. The decision process	196
4.6.4. Perception of the environment	197
4.6.5. Human factors.	198
4.6.6. Modeling techniques	199
4.6.7. Perspectives	202
4.7. Bibliography	203
Chapter 5. Modeling and Simulation of Complex Systems: Pitfalls and Limitations of Interpretation	207
Dominique LUZEAUX	
5.1. Introduction	207
5.2. Complex systems, models, simulations, and their link with reality	209

5.2.1. Systems	209
5.2.2. Complexity	211
5.2.3. The difficulty of concepts: models, modeling, and simulation	215
5.3. Main characteristics of complex systems simulation	218
5.3.1. Nonlinearity, the key to complexity	218
5.3.2. Limits of computing: countability and computability	223
5.3.3. Discrete or continuous models	226
5.4. Review of families of models	228
5.4.1. Equational approaches	229
5.4.2. Computational approaches	232
5.4.3. Qualitative phenomenological approaches	237
5.4.4. Qualitative structuralist approach: application of category theory	240
5.5. An example: effect-based and counter-insurgency military operations	244
5.6. Conclusion	246
5.7. Bibliography	249
Chapter 6. Simulation Engines and Simulation Frameworks	253
Pascal CANTOT	
6.1. Introduction	253
6.2. Simulation engines	254
6.2.1. Evolution of state variables	254
6.2.2. Management of events and causality	255
6.2.3. Simulation modes	256
6.2.4. Example	258
6.3. Simulation frameworks	260
6.3.1. Some basic points on software engineering	260
6.3.2. Frameworks	268
6.3.3. Obstacles to framework use	270
6.3.4. Detailed example: ESCADRE	272
6.4. Capitalization of models	290
6.5. Conclusion and perspectives	291
6.6. Bibliography	292
Chapter 7. Distributed Simulation	295
Louis IGARZA	
7.1. Introduction	295
7.1.1. The principle	295
7.1.2. History of distributed simulations	297
7.1.3. Some definitions	298
7.1.4. Interoperability in simulation	300

Table of Contents ix

7.1.5. Standardization	302
7.1.6. Advantages and limitations of distributed simulation.	303
7.1.7. Other considerations	303
7.2. Basic mechanisms of distributed simulation	305
7.2.1. Some key principles	305
7.2.2. Updating attributes	306
7.2.3. Interactions	307
7.2.4. Time management	308
7.2.5. Dead reckoning	309
7.2.6. Multi-level modeling.	310
7.2.7. Section conclusion	311
7.3. Main interoperability standards	312
7.3.1. History	312
7.3.2. HLA.	313
7.3.3. DIS	319
7.3.4. TENA.	321
7.3.5. The future of distributed simulation: the LVC AR study.	324
7.3.6. Other standards used in distributed simulation.	325
7.4. Methodological aspects: engineering processes for distributed simulation	326
7.4.1. FEDEP	327
7.4.2. SEDEP	329
7.4.3. DSEEP	330
7.5. Conclusion: the state of the art: toward “substantive” interoperability	331
7.6. Bibliography	331
Chapter 8. The Battle Lab Concept	333
Pascal CANTOT	
8.1. Introduction	333
8.2. France: Laboratoire Technico-Opérationnel (LTO)	336
8.2.1. Historical overview.	336
8.2.2. Aims of the LTO	337
8.2.3. Principles of the LTO	338
8.2.4. Services of the LTO	341
8.2.5. Experimental process	342
8.2.6. Presentation of an experiment: PHOENIX 2008	345
8.2.7. Evaluation and future perspectives of the LTO	349
8.3. United Kingdom: the Niteworks project	350
8.4. Conclusion and perspectives.	351
8.5. Bibliography	352

Chapter 9. Conclusion: What Return on Investment Can We Expect from Simulation?	355
Dominique LUZEAUX	
9.1. Returns on simulation for acquisition	355
9.2. Economic analysis of gains from intelligent use of simulations	357
9.2.1. Additional costs of the SBA	358
9.2.2. Additional costs from unexpected events or bad planning	364
9.3. Multi-project acquisition	367
9.4. An (almost) definitive conclusion: conditions for success	368
9.5. Bibliography	371
Author Biographies	373
List of Authors	375
Index	377