

CONTENTS

Preface	xvii
Contributors	xxi
An Introduction to Systems Engineering and Systems Management	1
<i>Andrew P. Sage and William B. Rouse</i>	
Systems Engineering	2
Importance of Technical Direction and Systems Management	6
Additional Definitions of Systems Engineering	9
Life-Cycle Methodologies, or Processes, for Systems Engineering	23
The Rest of the Handbook of Systems Engineering and Management	31
Knowledge Map of the Systems Engineering and Management Handbook	50
The Many Dimensions of Systems Engineering	55
People, Organizations, Technology, and Architectures and System Families	56
References	62
1 Systems Engineering Life Cycles: Life Cycles for Research, Development, Test, and Evaluation; Acquisition; and Planning and Marketing	65
<i>F. G. Patterson, Jr.</i>	
1.1 Introduction	65
1.2 Classification of Organizational Processes	69
1.3 Research, Development, Test, and Evaluation Life Cycles	72
1.4 System Acquisition or Production Life Cycles	76
1.5 The Planning and Marketing Life Cycle	86
1.6 Software Acquisition life-Cycle Models	88
1.7 Trends in Systems Engineering Life Cycles	96
1.8 Conclusion	108
References	110
2 Systems Engineering Management: The Multidisciplinary Discipline	117
<i>Aaron J. Shenhar and Brian Sauser</i>	
2.1 Introduction	117
2.2 Defining Systems Engineering Management	118

vi CONTENTS

- 2.3 Activities and Roles of the Systems Engineering Manager 120
- 2.4 Toward a Comprehensive Framework for the Implementation of Systems Engineering Management: The Four-Dimensional “Diamond Taxonomy”—NTCP 123
- 2.5 Different Systems Engineering Management Roles for Various Project Types 131
- 2.6 The Skills, Tools, and Disciplines Involved in Systems Engineering Management 145
- 2.7 Developing Educational and Training Programs in Systems Engineering Management 147
- 2.8 Conclusion 150
References 150

3 Risk Management 155

Yacov Y. Haimes

- 3.1 The Process of Risk Assessment and Management 155
- 3.2 The Holistic Approach to Risk Analysis 157
- 3.3 Risk of Extreme Events 167
- 3.4 The Partitioned Multiobjective Risk Method 171
- 3.5 The Characteristics of Risk in Human-Engineered Systems 180
- 3.6 Selected Cases of Risk-Based Engineering Problems 181
- 3.7 Conclusion 200
Acknowledgment 201
References 201

4 Discovering System Requirements 205

A. Terry Bahill and Frank F. Dean

- 4.1 Introduction 205
- 4.2 Stating The Problem 205
- 4.3 What Are Requirements? 209
- 4.4 Qualities of a Good Requirement 210
- 4.5 Characterization of Requirements 216
- 4.6 The Requirements Development and Management Process 227
- 4.7 Fitting the Requirements Process into the Systems Engineering Process 243
- 4.8 Related Items 245
- 4.9 Requirements Volatility 247
- 4.10 Inspections 248
- 4.11 A Heuristic Example of Requirements 249
- 4.12 The Hybrid Process for Capturing Requirements 250
- 4.13 Conclusion 264
Acknowledgments 264
References 264

5 Configuration Management	267
<i>Peggy S. Brouse</i>	
5.1 Introduction	267
5.2 Configuration Management within the System Life Cycle	271
5.3 Configuration Status Accounting and Configuration Auditing	281
5.4 Configuration Management Responsibilities	283
5.5 Configuration Management in Process Improvement	283
5.6 Configuration Management Tools	286
5.7 Conclusion	289
References	289
6 Cost Management	291
<i>Benjamin S. Blanchard</i>	
6.1 Introduction	291
6.2 Life-Cycle Costing	291
6.3 Functional Economic Analysis	298
6.4 Work Breakdown Structure	301
6.5 Activity-Based Costing	306
6.6 Cost and Effectiveness Analysis	310
6.7 System Evaluation and Cost Control	320
6.8 Conclusion	321
References	322
7 Total Quality Management	325
<i>James L. Melsa</i>	
7.1 Introduction	325
7.2 Historical Background of the Quality Movement	328
7.3 Total Quality Management Tools	330
7.4 Total Quality Management Philosophies	332
7.5 Conclusion	349
Appendix 7A The ISO 9000:2000 Standards	350
Appendix 7B Malcolm Baldrige Award Criteria	352
Appendix 7C Deming's Quality Philosophy	356
References	358
8 Reliability, Maintainability, and Availability	361
<i>Michael Pecht</i>	
8.1 Introduction and Motivation	361
8.2 Evolution of RMA Engineering	362
8.3 Allocation	363
8.4 Design for Reliability	363
8.5 System Reliability Assessment Modeling	385

viii CONTENTS

- 8.6 Fault Trees 390
- 8.7 Design for Maintainability 390
- 8.8 Data Collection, Classification, and Reporting 392
- 8.9 Warranties and Life-Cycle Costs 393
- 8.10 Operational Readiness and Availability 393
- References 394

9 Concurrent Engineering 397

Andrew Kusiak and Nick Larson

- 9.1 Introduction 397
- 9.2 Concurrent Engineering and the Product Life Cycle 398
- 9.3 Building a Concurrent Engineering Environment: A Systems Engineering Perspective 399
- 9.4 Managing a Concurrent Engineering Environment: Tools and Techniques 425
- 9.5 Implementation 433
- 9.6 Concurrent Engineering in the Future 434
- 9.7 Conclusion 435
- Acknowledgment 435
- References 436

10 Engineering the Enterprise as a System 441

William B. Rouse

- 10.1 Introduction 441
- 10.2 Essential Challenges 442
- 10.3 Enterprise Transformation 445
- 10.4 Enterprises as Systems 451
- 10.5 Transformation Framework 454
- 10.6 Implications for Systems Engineering and Management 457
- 10.7 Conclusion 458
- References 459

11 Standards in Systems Engineering 463

Stephen C. Lowell

- 11.1 Introduction 463
- 11.2 Definition 463
- 11.3 Historical Highlights of Standards in the United States 463
- 11.4 Reasons for Using Specifications and Standards 465
- 11.5 Proper Application of Specifications and Standards 467
- 11.6 Selection and Development of Specifications and Standards 468
- 11.7 Useful Standards in the Systems Engineering Process 477
- 11.8 Locating and Obtaining Specifications and Standards 477

12	System Architectures	479
	<i>Alexander H. Levis</i>	
12.1	Introduction	479
12.2	Definition of Architectures	481
12.3	Structured Analysis Approach	483
12.4	The Executable Model	491
12.5	Physical Architecture	493
12.6	Performance Evaluation	495
12.7	Object-Oriented Approach	496
12.8	Architecture Evaluation	501
12.9	The DoD Architecture Framework	503
12.10	Conclusion	504
	Acknowledgment	505
	References	505
13	Systems Design	507
	<i>K. Preston White, Jr.</i>	
13.1	Introduction	507
13.2	What is Systems Design?	508
13.3	Steps in the Design process	508
13.4	Design Tools	517
13.5	A Brief History of Recent Design Theory	519
13.6	Design and Concurrent Engineering	521
	References	531
14	Systems Integration	535
	<i>James D. Palmer</i>	
14.1	Introduction	535
14.2	Systems Integration in Large, Complex Engineered Systems and a Systems Integration Life Cycle	538
14.3	Systems Integration Management and Technical Skills and Training Requirements	542
14.4	Systems Integration Strategy for Success	545
14.5	The Audit Trail	552
14.6	Quality Assurance in Systems Integration	555
14.7	Subcontractor Management for Systems Integration	559
14.8	Subsystem Integration and Delivery	561
14.9	Risk Management	564
14.10	The Lead Systems Integrator	568
	References	573
15	Systematic Measurements	575
	<i>Andrew P. Sage</i>	
15.1	Introduction	575

x CONTENTS

- 15.2 Organizational Needs for Systematic Measurement 577
- 15.3 Measurement Needs 578
- 15.4 Organizational Measurements 587
- 15.5 Metrics from Widely Accepted Standards, Awards, and Government Requirements 590
- 15.6 Selected Measurement Approaches 609
- 15.7 Systematic Measurements of Customer Satisfaction 617
- 15.8 Systematic Measurements of Effort, Cost, and Schedule 625
- 15.9 Systematic Measurements of Defects 625
- 15.10 Metrics Process Maturity 626
- 15.11 Information Technology and Organizational Performance Measurement 631
- 15.12 Conclusion 639
References 641

16 Human Supervisory Control 645

Thomas B. Sheridan

- 16.1 Introduction 645
- 16.2 Task Analysis and Function Allocation 648
- 16.3 The Phases of Supervisory Control 652
- 16.4 Examples of Supervisory Control Applications and Problems 662
- 16.5 Adaptive Automation 674
- 16.6 Overview Considerations of Supervisory Control 676
- 16.7 Conclusion 685
References 685

17 Designing for Cognitive Task Performance 691

Judith M. Orasanu and Michael G. Shafto

- 17.1 Introduction 691
- 17.2 Cognitive Constraints on System Design 693
- 17.3 Reduction to Practice 705
- 17.4 Conclusion 715
Acknowledgments 716
References 716

18 Modeling Organizational and Individual Decision Making 723

Kathleen M. Carley and Terrill L. Frantz

- 18.1 Introduction 723
- 18.2 Computational Organization Theory 726
- 18.3 Modeling the Individual 730
- 18.4 Modeling the Organization 741
- 18.5 Computational Tools 745

- 18.6 Implications for Systems Engineering and Management 747
- 18.7 Conclusion 748
- References 750

19 Organizational Simulation 763

William B. Rouse and Douglas A. Bodner

- 19.1 Introduction 763
- 19.2 Scope of Organizational Simulation 764
- 19.3 State of the Art 766
- 19.4 Case Studies 768
- 19.5 Conclusion 790
- References 790

20 Organizational Change: The Role of Culture and Leadership 793

Charles S. Harris, Betty K. Hart, and Joyce Shields

- 20.1 Introduction 793
- 20.2 Setting the Context: Culture 795
- 20.3 The Role of Leadership 800
- 20.4 Applying the Change Model 804
- 20.5 Profiles in Change 824
- 20.6 Conclusion 831
- References 833

21 Model-Based Design of Human Interaction with Complex Systems 837

Christine M. Mitchell and David W. Roberts

- 21.1 Introduction 837
- 21.2 Human Interaction with Complex Systems: The Systems, Tasks, and Users 837
- 21.3 Emerging Technology and Design 838
- 21.4 Human–System Interaction Issues 840
- 21.5 Model-Based Design: Operator 847
- 21.6 Model-Based Design Using the Operator Function Model 860
- 21.7 Ofm-Based Design: Illustrative Applications 875
- 21.8 Team-OFM 889
- 21.9 Basic Research and Operational Relevance to Real-World Design 894
- 21.10 Conclusion 899
- Acknowledgments 900
- References 900

22 Evaluation of Systems 909

James M. Tien

- 22.1 Introduction 909

xii CONTENTS

- 22.2 Evaluation Field 910
- 22.3 Evaluation Framework 911
- 22.4 Evaluation Design Elements 914
- 22.5 Evaluation Modeling 918
- 22.6 Conclusion 920
- References 921

23 Systems Reengineering 923

Andrew P. Sage

- 23.1 Introduction 923
- 23.2 Definition of and Perspectives on Reengineering 925
- 23.3 Overview of Reengineering Approaches 931
- 23.4 Conclusion 1013
- References 1020

24 Issue Formulation 1027

James E. Armstrong, Jr.

- 24.1 Introduction: Problem and Issue Formulation 1027
- 24.2 Situation Assessment 1027
- 24.3 Problem or Issue Identification 1032
- 24.4 Value System Design 1043
- 24.5 Iteration of The Design 1053
- 24.6 Generation of Potential Alternatives or System Synthesis 1070
- 24.7 Alternatives and Feasibility Studies 1082
- 24.8 Conclusion 1085
- References 1088

25 Functional Analysis 1091

Dennis M. Buede

- 25.1 Introduction 1091
- 25.2 Elements of Functional Analysis 1091
- 25.3 Functional Decomposition 1092
- 25.4 The Systems Engineering Requirements Statement and Functional Analysis 1096
- 25.5 Diagrams and Software for Functional Analysis 1109
- 25.6 Conclusion 1125
- References 1125

26 Methods for the Modeling and Analysis of Alternatives 1127

*C. Els Van Daalen, Wil A. H. Thissen, Alexander Verbraeck,
and Pieter W. G. Bots*

- 26.1 Introduction 1127
- 26.2 Quantitative Models and Methods 1128

26.3	Physical System Models	1134	
26.4	System Dynamics	1141	
26.5	Discrete-Event Simulation Models	1145	
26.6	Agent-Based Models	1150	
26.7	Economic Models of Costs and Benefits	1155	
26.8	Evaluation and Discussion	1161	
	Acknowledgments	1165	
	Appendix: Modeling and Simulation Software	1165	
	References	1166	
27	Operations Research and Refinement of Courses of Action		1171
	<i>Keith W. Hipel, D. Marc Kilgour, Siamak Rajabi, and Ye Chen</i>		
27.1	Introduction	1171	
27.2	Operations Research	1171	
27.3	Operations Research and Systems Engineering	1176	
27.4	Operations Research Methods	1178	
27.5	Generating and Screening Actions	1189	
27.6	Multiple-Criteria Decision Making	1192	
27.7	Multiple-Participant Decision Making	1202	
27.8	Heuristic Programming	1210	
27.9	Conclusions	1214	
	References	1215	
28	Decision Analysis		1223
	<i>Craig W. Kirkwood</i>		
28.1	Introduction	1223	
28.2	Structuring Objectives	1223	
28.3	Developing Alternatives	1228	
28.4	Value Analysis	1232	
28.5	Decisions With Uncertainty	1238	
28.6	Multiple Objectives and Uncertainty	1245	
28.7	Decision Analysis Software	1246	
28.8	Conclusion	1247	
	References	1248	
29	Project Planning: Planning for Action		1251
	<i>Ruth Buys</i>		
29.1	Introduction	1251	
29.2	Network-Based Systems Planning and Project Management	1253	
29.3	Pricing and Estimating	1256	
29.4	Risk and Cost Control	1260	
29.5	Maintenance and Support	1267	

xiv CONTENTS

- 29.6 Software for Planning Support 1269
- 29.7 Presentation and Communication of Results of Systems Planning 1272
- 29.8 Project Planning Pitfalls 1275
- 29.9 Conclusion 1279
- References 1280

30 Complex Adaptive Systems in Systems Engineering and Management 1283

Sarah Sheard

- 30.1 Introduction 1283
- 30.2 Order: Newtonian and Mechanical Systems 1286
- 30.3 History and Principles of Chaos 1289
- 30.4 Between Order and Chaos 1291
- 30.5 Complexity and Complex Systems 1292
- 30.6 Complex Adaptive Systems 1294
- 30.7 Small Worlds, Scale-Free Networks, Power Laws, and Evolving Fitness Landscapes 1297
- 30.8 Principles of Complex Systems for Systems Engineering 1303
- 30.9 Principles for Management of Complex Adaptive Systems Engineering Efforts 1309
- 30.10 Conclusion 1315
- References 1316

31 Human Systems Integration 1319

Harold R. Booher, Robert J. Beaton, and Frances Greene

- 31.1 Introduction 1319
- 31.2 HSI Concept 1320
- 31.3 HSI Assessment Principles and Factors 1326
- 31.4 HSI Business Case 1332
- 31.5 HSI Process in Systems Engineering 1339
- 31.6 Conclusion 1355
- References 1356

32 Model-Based Systems Engineering 1361

David W. Oliver, James F. Andary, and Harold Frisch

- 32.1 Introduction 1361
- 32.2 A Selected History of The Modeling of Systems 1364
- 32.3 A Semantic Glossary and Model for Systems Engineering Concepts 1370
- 32.4 Product Data Management 1393
- 32.5 Ontologies 1396
- 32.6 Conclusion 1398
- References 1399

33 Using the Design Structure Matrix to Design Program Organizations	1401
<i>Tyson R. Browning</i>	
33.1 Introduction	1401
33.2 A Framework for Organizational Integration	1403
33.3 Organizational Integration Analysis with the Design Structure Matrix	1405
33.4 A Systematic Approach to Designing Programs for organizational Integration	1413
33.5 Implementation barriers	1420
33.6 Conclusion	1420
References	1421
34 Information Technology and Knowledge Management	1425
<i>William B. Rouse and Andrew P. Sage</i>	
34.1 Introduction	1425
34.2 Trends	1428
34.3 Scenarios	1433
34.4 Eleven Challenges	1437
34.5 Ecological Approaches to the Challenges	1450
34.6 Conclusion	1457
References	1457
Index	1463

