

# **SYSTEMS ENGINEERING PRINCIPLES AND PRACTICE**

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**ALEXANDER KOSSIAKOFF  
WILLIAM N. SWEET**



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# Contents

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<i>List of Illustrations</i>	<i>xi</i>
<i>List of Tables</i>	<i>xv</i>
<i>Preface</i>	<i>xvii</i>

<b>Part I Foundations of Systems Engineering</b>	<b>1</b>
<b>Chapter 1 Systems Engineering and the World of Modern Systems</b>	<b>3</b>
1.1 What is Systems Engineering?	3
1.2 Origins of Systems Engineering	5
1.3 Examples of Systems Requiring Systems Engineering	10
1.4 Systems Engineering Viewpoint	13
1.5 Systems Engineering as a Profession	19
1.6 The Power of Systems Engineering	24
1.7 Summary	26
Problems	28
References and Bibliography	30

<b>Chapter 2 Structure of Complex Systems</b>	<b>31</b>
2.1 System Building Blocks and Interfaces	31
2.2 Hierarchy of Complex Systems	31
2.3 System Building Blocks	35
2.4 The System Environment	41
2.5 Interfaces and Interactions	44
2.6 Summary	46
Problems	48
References and Bibliography	49
 <b>Chapter 3 The System Development Process</b>	 <b>50</b>
3.1 Systems Engineering Through the System Life Cycle	50
3.2 System Life Cycle	51
3.3 Evolutionary Characteristics of the Development Process	62
3.4 The Systems Engineering Method	67
3.5 Testing Throughout System Development	82
3.6 Summary	84
Problems	87
References and Bibliography	88
 <b>Chapter 4 Systems Engineering Management</b>	 <b>90</b>
4.1 Managing System Development and Risks	90
4.2 Work Breakdown Structure (WBS)	91
4.3 Systems Engineering Management Plan (SEMP)	96
4.4 Risk Management	98
4.5 Organization of Systems Engineering	106
4.6 Systems Engineering Capability Maturity Assessment	110
4.7 Systems Engineering Standards	112
4.8 Summary	112
Problems	114
References and Bibliography	115

<b>Part II    Concept Development Stage</b>	<b>117</b>
<b>Chapter 5    Needs Analysis</b>	<b>119</b>
5.1    Originating a New System	119
5.2    Operations Analysis	125
5.3    Functional Analysis	127
5.4    Feasibility Definition	130
5.5    Needs Validation	132
5.6    System Operational Requirements	133
5.7    Summary	136
Problems	137
References and Bibliography	138
<b>Chapter 6    Concept Exploration</b>	<b>139</b>
6.1    Developing the System Requirements	139
6.2    Operational Requirements Analysis	144
6.3    Performance Requirements Formulation	148
6.4    Implementation Concept Exploration	154
6.5    Performance Requirements Validation	159
6.6    Summary	161
Problems	163
References and Bibliography	164
<b>Chapter 7    Concept Definition</b>	<b>165</b>
7.1    Selecting the System Concept	165
7.2    Performance Requirements Analysis	169
7.3    Functional Analysis and Formulation	174
7.4    Concept Selection	177
7.5    Concept Validation	182
7.6    System Development Planning	184
7.7    System Functional Specifications	188
7.8    Summary	189

Problems	191
References and Bibliography	192
<b>Part III   Engineering Development Stage</b>	<b>195</b>
<b>Chapter 8   Advanced Development</b>	<b>197</b>
8.1   Reducing Program Risks	197
8.2   Requirements Analysis	202
8.3   Functional Analysis and Design	208
8.4   Prototype Development	214
8.5   Development Testing	222
8.6   Risk Reduction	231
8.7   Summary	232
Problems	234
References and Bibliography	235
<b>Chapter 9   Engineering Design</b>	<b>237</b>
9.1   Implementing the System Building Blocks	237
9.2   Requirements Analysis	242
9.3   Functional Analysis and Design	244
9.4   Component Design	248
9.5   Design Validation	260
9.6   Configuration Management	265
9.7   Summary	268
Problems	271
References and Bibliography	272
<b>Chapter 10   Integration and Evaluation</b>	<b>273</b>
10.1   Integrating, Testing and Evaluating the Total System	273
10.2   Test Planning and Preparation	280
10.3   System Integration	285
10.4   Developmental System Testing	293

10.5	Operational Test and Evaluation	300
10.6	Summary	308
	Problems	311
	References and Bibliography	312
<b>Part IV</b>	<b>Post-Development Stage</b>	<b>313</b>
<b>Chapter 11</b>	<b>Production</b>	<b>315</b>
11.1	Systems Engineering in the Factory	315
11.2	Engineering for Production	317
11.3	Transition from Development to Production	321
11.4	Production Operations	325
11.5	Acquiring a Production Knowledge Base	330
11.6	Summary	333
	Problems	336
	References and Bibliography	337
<b>Chapter 12</b>	<b>Operation and Support</b>	<b>338</b>
12.1	Installing, Maintaining and Upgrading the System	338
12.2	Installation and Test	340
12.3	In-Service Support	344
12.4	Major System Upgrades: Modernization	348
12.5	Operational Factors in System Development	352
12.6	Summary	355
	Problems	356
	References and Bibliography	357
<b>Part V</b>	<b>Special Topics</b>	<b>359</b>
<b>Chapter 13</b>	<b>Software Systems Engineering</b>	<b>361</b>
13.1	Coping with Complexity and Abstraction	361
13.2	Nature of Software Development	366



13.3	Software Concept Development: Analysis and Design	373
13.4	Software Engineering Development: Coding and Unit Test	385
13.5	Software Integration and Test	394
13.6	Software Engineering Management	396
13.7	Summary	404
	Problems	407
	References and Bibliography	408
<b>Chapter 14</b>	<b>Systems Engineering Decision Tools</b>	<b>409</b>
14.1	Modeling Throughout System Development	409
14.2	Modeling	410
14.3	Simulation	421
14.4	Trade-Off Analysis	430
14.5	Summary	439
	Problems	443
	References and Bibliography	443
	<i>Glossary</i>	445
	<i>Index</i>	457

# Illustrations

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1-1a	Performance vs. cost	15
1-1b	Performance/cost vs. cost	17
1-2	The ideal missile design from the viewpoint of various specialists	18
1-3	The dimensions of design, systems engineering, and project planning and control	19
1-4a	Technical orientation phase diagram	21
1-4b	Technical orientation population density distribution	22
2-1	System design hierarchy	33
2-2	Knowledge domains of systems engineer and design specialist	35
2-3	Environments of a passenger airliner	43
2-4	Functional interactions and physical interfaces	45
3-1	Comparison of system life cycle models	52
3-2	Principal stages in system life cycle	56
3-3	Concept development phases of system life cycle	57
3-4	Engineering development phases in system life cycle	59
3-5	System engineering method top-level flow diagram	70

3-6	System engineering method flow diagram	72
3-7	Spiral model of the defense system life cycle	81
4-1	Systems engineering as a part of project management	91
4-2	System product WBS breakdown structure	93
4-3	Place of SEMP in program management plans	97
4-4	Variation of program risk and cost throughout system development	99
4-5	Example of a risk mitigation waterfall chart	100
4-6	Risk decision tree for a system power deficiency	106
5-1	Needs analysis phase in system life cycle	120
5-2	Needs analysis phase flow diagram	128
6-1	Concept exploration phase in system life cycle	140
6-2	Concept exploration phase flow diagram	144
7-1	Concept definition phase in system life cycle	166
7-2	Concept definition phase flow diagram	170
8-1	Advanced development phase in system life cycle	198
8-2	Advanced development phase flow diagram	201
8-3	Test and evaluation process	227
9-1	Engineering design phase in system life cycle	238
9-2	Engineering design phase in relation to integration and evaluation	238
9-3	Engineering design phase flow diagram	241
10-1	Integration and evaluation phase in system life cycle	274
10-2	Integration and evaluation phase in relation to engineering design	275
10-3	System test and evaluation team	276
10-4	System element test configuration	287
10-5	Subsystem test configuration	289
10-6a	Operation of a passenger airliner	301
10-6b	Operational testing of an airliner	302
10-7	Test realism vs. cost	303

11-1	Production phase in system life cycle	316
11-2	Production phase overlap with adjacent phases	317
11-3	Production operations system	327
12-1	Operation and support phase in system life cycle	339
12-2	System operation history	340
13-1	Personal computer block diagram	362
13-2	Software hierarchy	362
13-3	Classical waterfall software development cycle	371
13-4	Modular partitioning	377
13-5	Data flow diagram: library checkout	378
13-6	Robustness diagram: library checkout	381
13-7	UML use Case Diagram: library loan management	383
13-8	UML class Diagram: Library Checkout	384
13-9	UML sequence Diagram: Library Checkout	385
14-1	Hierarchical system block diagram	413
14-2	Passenger airliner context diagram	414
14-3	Air defense function flow block diagrams	415
14-4	Use case diagram	418
14-5	UML activity diagram	418
14-6	System effectiveness simulation	423
14-7	Hardware-in-the-loop simulation	426
14-8	Virtual reality simulation	428

# Tables

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1-1	Examples of Engineered Complex Systems: Signal and Data Systems	12
1-2	Examples of Engineered Complex Systems: Material and Energy Systems	12
2-1	System Functional Elements	38
2-2	Component Design Elements	39
2-3	Examples of Interface Elements	46
3-1	Evolution of System Materialization Through System Life Cycle	64
3-2	Principal Participants in Typical Aerospace System Development	66
3-3	Evolution of System Representations	68
3-4	System Engineering Method over Life Cycle	80
4-1	Risk Likelihood	102
4-2	Risk Criticality	103
5-1	Status of System Materialization at Needs Analysis Phase	123
6-1	Status of System Materialization at Concept Exploration Phase	142
7-1	Status of System Materialization at Concept Definition Phase	168
8-1	Status of System Materialization at Advanced Development Phase	200

8-2	Development of New Components	206
8-3	Selected Critical Characteristics of System Functional Elements	210
8-4	Some Examples of Special Materials	216
9-1	Status of System Materialization at Engineering Design Phase	240
9-2	Configuration Baselines	266
10-1	Status of System Materialization at Integration and Evaluation Phase	278
10-2	System Integration and Evaluation Process	279
10-3	Parallels Between System Development and T&E Planning	281
13-1	Categories of Software-Dominated Systems	364
13-2	Differences Between Hardware and Software	365
13-3	System Life Cycle and the Waterfall Model	371
13-4	Commonly Used Computer Languages	388
13-5	Some Special-Purpose Computer Languages	389
13-6	Characteristics of Prototypes	391
13-7	Comparison of Computer Interface Modes	392
13-8	Capability Maturity Levels and their Key Process Areas	399
14-1	Trade-Off Matrix	437

# Preface

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Learning how to be a successful systems engineer is entirely different from learning how to excel at a traditional engineering discipline. It requires developing the ability to think in a special way,—to acquire the “systems engineering viewpoint,” and to make the central objective the system as a whole and the success of its mission. The systems engineer faces in three directions—the system user’s needs and concerns, the project manager’s financial and schedule constraints, and the capabilities and ambitions of the engineering specialists who have to develop and build the elements of the system. This requires learning enough of the language and basic principles of each of the three constituencies to understand their requirements and negotiate balanced solutions acceptable to all. The role of interdisciplinary leadership is the key contribution and principal challenge of systems engineering, and it is absolutely indispensable to the successful development of modern complex systems.

## 1.1 OBJECTIVES

“Systems Engineering Principles and Practice” is a textbook designed to help students learn to think like systems engineers. Students seeking to learn systems engineering after mastering a traditional engineering discipline often find the subject highly abstract and ambiguous. To help make systems engineering more tangible and easier to grasp, the book provides several models: 1) a hierarchical model of complex systems, showing them to be composed of a set of commonly occurring building blocks or components, 2) a system life

cycle model derived from existing models, but more explicitly related to evolving engineering activities and participants, 3) a model of the steps in the systems engineering method, and their iterative application to each phase of the life cycle, 4) a concept of “materialization” that represents the stepwise evolution of an abstract concept to an engineered, integrated and validated system, and 5) repeated references to the specific responsibilities of systems engineers as they evolve during the system life cycle, and to the scope of what a systems engineer must know to perform these effectively. The book’s significantly different approach is intended to complement the several excellent existing textbooks that concentrate on the quantitative and analytical aspects of systems engineering.

Particular attention is devoted to systems engineers as professionals—their responsibilities as part of a major system development project, the knowledge, skills and mind-set they must acquire to be successful. The book stresses that they must be innovative and resourceful, as well as systematic and disciplined. It describes the special functions and responsibilities of systems engineers in comparison to those of system analysts, design specialists, test engineers, project managers and other members of the system development team. While the book describes the necessary processes that systems engineers must know and execute, it stresses the leadership, problem-solving and innovative skills necessary for success.

The function of systems engineering as defined here is to “guide the engineering of complex systems”. To learn how to be a good guide requires years of practice, and the help and advice of a more experienced guide, who knows “the way”. The purpose of this book is to provide a significant measure of such help and advice through the organized collective experience of the authors and other contributors.

This book is intended for graduate engineers or scientists who aspire to or are already engaged in careers in systems engineering, project management or engineering management. Its main audience is expected to be engineers educated in a single discipline, either hardware or software, who wish to broaden their knowledge so as to deal with system problems. It is written with a minimum of mathematics and specialized jargon so that it should also be useful to managers of technical projects or organizations, as well as to senior undergraduates.

## **1.2 ORIGIN AND CONTENTS**

The main portion of the book has been used for the past five years to support the five core courses of the Johns Hopkins University Master of Science program in Systems Engineering, and is thoroughly class-tested. It has also been used successfully as a text for distance course offerings. In addition, the book is well suited to support short courses and in-house training.



The book consists of 14 chapters grouped into five parts:

Part I. The Foundations of Systems Engineering, consisting of Chapters 1 through 4, describes the origin and structure of modern systems, the step-wise development process of complex systems, and the organization of system development projects.

Part II. Concept Development, consisting of Chapters 5 through 7, describes the first stage of the system life cycle in which a need for a new system is demonstrated, its requirements are developed and a specific preferred implementation concept is selected.

Part III. Engineering Development, consisting of Chapters 8 through 10, describes the second stage of the system life cycle, in which the system building blocks are engineered and the total system is integrated and evaluated in an operational environment.

Part IV. Post-Development, consisting of Chapters 11 and 12, describes the role of systems engineering in the Production, Operation, and Support phases of the system life cycle, and what domain knowledge of these phases in the system life cycle a systems engineer should acquire.

Part V. Special Topics consists of Chapters 13 and 14. Chapter 13 describes the pervasive role of software throughout system development, and Chapter 14 addresses the application of modeling, simulation, and trade-off analysis as systems engineering decision tools.

Each chapter also contains a summary, homework problems, and a bibliography. A Glossary of important terms is also included. The chapter summaries are formatted to facilitate their use in lecture viewgraphs.

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ALEXANDER KOSSIAKOFF  
WILLIAM N. SWEET