

Contents

Foreword	xv
Acknowledgments	xvii
Introduction	xix
Part 1. Systems Theory	1
Chapter 1. Systems Theory	3
1.1. The definition of a system	3
1.2. Definition of a complex system	5
1.3. Definition of a system of systems	6
1.4. The systems approach	7
1.4.1. The reductionist approach	7
1.4.2. The holistic approach	8
1.4.3. The analytical and systemic approach	9
1.4.4. The emergence	10
1.5. The systemic method	14
1.5.1. Systemic exploration	15
1.5.2. Qualitative modeling	17
1.5.3. Quantitative modeling	20
1.5.4. The simulation	21
1.6. How to understand the complexity of a system	22
1.6.1. Theme 1: the system is in an environment	23
1.6.2. Theme 2: the system is structured	24
1.6.3. Theme 3: the system evolves over time and has a dynamic	24
1.6.4. Theme 4: the system is controlled	25
1.7. Conclusion on systems theory	31

Part 2. Systems and Requirements Engineering	33
Chapter 2. Introduction to Systems Engineering	35
2.1. The system meets needs.	35
2.1.1. Definition of a need.	35
2.2. Definition of a stakeholder requirement	36
2.3. How to go from need to system	36
2.4. Definition of systems engineering	36
2.5. Iterative systems engineering process	38
2.5.1. Prescription and system construction	38
2.5.2. Needs analysis.	40
2.5.3. Requirements specification	41
2.5.4. Functional and logical design	41
2.5.5. Physical design	42
2.5.6. Verification and validation.	43
2.5.7. Evaluation and comparison	43
2.5.8. The requirements cycle.	44
2.6. System architecture	45
2.7. V-cycle	47
2.8. W-cycle.	48
2.9. Conclusion on systems engineering	49
Chapter 3. Introduction to Requirements Engineering	51
3.1. Definition of requirements engineering	51
3.2. The importance and challenges of requirements engineering	53
3.3. Problem domain and solution domain	54
3.4. Formalizing stakeholder needs and system requirements	55
3.5. Validate system requirements.	56
3.6. Allocate system requirements to subsystems	56
3.7. Validate the allocated requirements of the subsystems.	56
3.8. Choose the solution: define the requirements of the subsystems	56
3.9. Managing requirements	57
3.9.1. Why manage requirements?	57
3.9.2. What are the risks associated with poor requirements management?.	57
3.9.3. Managing requirement attributes	58
3.9.4. Managing the configuration of requirements	59
3.9.5. Managing changes	61
3.10. Conclusion on requirements engineering.	62

Part 3. Definition of Requirements	65
Chapter 4. Unifying Thread Example	67
4.1. Objective of the unifying thread example	67
4.2. Presentation of the raw specifications	68
Chapter 5. Needs Analysis	71
5.1. Objectives of needs analysis	71
5.2. Stakeholder identification	72
5.2.1. Definition of stakeholder	72
5.2.2. PESTEL analysis	73
5.2.3. Analysis by type of environment	74
5.2.4. Application to the unifying thread example: stakeholder identification	76
5.3. Identification of external interactions	78
5.3.1. Objectives of identifying external interactions	78
5.3.2. Application to the unifying thread example: identification of external interactions	80
5.4. Collection of needs	83
5.4.1. Why capture needs?	83
5.4.2. Methods for collecting needs	84
5.4.3. Application to the unifying thread example: formalization of needs	85
5.5. Identification of the life cycle	87
5.5.1. Building the system life cycle	87
5.5.2. Application to the unifying thread example: identifying the life cycle	89
5.6. Identification of the system's missions	91
5.6.1. Definition of the system's missions	91
5.6.2. Application to the unifying thread example: mission definition	94
5.7. Identification of operational scenarios	96
5.7.1. Defining an operational scenario	96
5.7.2. Application to the unifying thread example: definition of operational scenarios	97
5.8. Identification of services and constraints	100
5.8.1. From missions to services	100
5.8.2. Application to the unifying thread example: identification of services and constraints	101
5.9. Formalization of stakeholder needs	102
5.9.1. The input specifications	102
5.9.2. Application to the unifying thread example: formalization of needs	107
5.10. Conclusion on needs analysis	110

Chapter 6. Requirements Specification	111
6.1. Objective of the requirements specification process	111
6.2. Identification of the system's functional modes.	113
6.2.1. Definition and purpose of the functional modes	113
6.2.2. What to do to identify functional modes	114
6.2.3. Application to the unifying thread example: identifying the functional modes	115
6.4. Identification of system functions	116
6.4.1. What is a system function?.	116
6.4.2. What to do to identify the system functions	119
6.4.3. Application to the unifying thread example: identification of system functions	122
6.5. Identification of external interactions	123
6.6. Defining system behaviors	124
6.6.1. Objective of defining the functional behavior of the system	124
6.6.2. Application to the unifying thread example: definition of a functional scenario	124
6.7. Defining the system requirements	126
6.7.1. Why define the system requirements?.	126
6.7.2. What to do to define the system requirements	128
6.7.3. How to define system requirements: application to the unifying thread example.	130
6.8. System specification.	134
6.8.1. The specification document	134
6.8.2. Application to the unifying thread example: system specification	138
6.9. Conclusion on requirements specification	140
Chapter 7. Requirements Validation	143
7.1. General process	144
7.2. Selecting methods and defining validation procedures.	145
7.3. Establishing requirements traceability	145
7.3.1. Establishing traceability from needs to requirements	145
7.3.2. Establish traceability from requirements to needs	145
7.4. Analysis of assumptions and induced requirements	146
7.4.1. Analysis of assumptions	146
7.4.2. Analysis of induced requirements	146
7.5. Rolling out the validation	146
7.5.1. Checking the requirements individually (correctness).	147
7.5.2. Globally checking the requirements (consistency).	147
7.5.3. Validating requirements against needs	148

7.6. Identifying and resolving gaps between needs and requirements	148
7.6.1. Identifying gaps and conflicts	148
7.6.2. Assessing conflicts	148
7.6.3. Study of trade-offs	149
7.6.4. Identifying trade-offs and impacts.	149
7.7. Saving a database of validated requirements	149
7.8. Conclusion on requirements validation	150
Part 4. System Design	151
Chapter 8. Functional and Logical Design	153
8.1. Design and functional architecture	153
8.1.1. Static functional architecture.	153
8.1.2. Dynamic functional architecture.	154
8.1.3. Behavioral functional architecture.	156
8.2. Identifying the sub-functions of the system and their interactions.	157
8.2.1. Purpose of identifying sub-functions	157
8.2.2. Functional chain analysis approach	158
8.2.3. Implementation of the unifying thread example: identification of sub-functions	161
8.2.4. The outputs of the static architecture	164
8.2.5. Rules on the quality of a functional decomposition	167
8.3. Functional interface analysis	168
8.3.1. The coupling matrices	168
8.3.2. Characterizing functional interfaces.	171
8.4. Consolidation of functional modes	171
8.4.1. Objective of consolidating functional modes.	171
8.4.2. What to do to identify the functional sub-modes.	172
8.4.3. Application to the unifying thread example: resumption of the functional modes	174
8.5. Resuming system functioning	176
8.5.1. Objective of the system recovery	176
8.5.2. Implementation of the unifying thread example: resumption of the system functioning.	178
8.6. Propose groupings of sub-functions into logical components	180
8.6.1. The use of logical components.	180
8.6.2. Proposing a schematic diagram of the solution.	180
8.7. Allocate functional requirements to sub-functions	180
8.7.1. Objective of the allocation of system requirements to sub-functions.	180
8.7.2. Application to the unifying thread example: allocation of system requirements to sub-functions	182
8.8. Conclusion on functional design	184

Chapter 9. Verification and Validation of the Functional Architecture . . .	185
9.1. Verification of the functional architecture	185
9.2. Validation of functional architecture	186
9.2.1. Selecting methods and defining validation procedures	187
9.2.2. Establishing traceability	187
9.2.3. Analysis of assumptions	187
9.2.4. Unrolling the validation	188
9.2.5. Performing the revalidation	188
9.2.6. Recording the results of the functional architecture's validation	188
9.3. Conclusion on the verification and validation of functional design	188
Chapter 10. Physical Design	191
10.1. Purpose of physical design	191
10.2. Identification of physical components	193
10.2.1. Identifying components and allocating technical functions	194
10.2.2. Completing the identification of the components with the missions of the system.	195
10.2.3. Completing the identification of components with non-functional requirements	195
10.2.4. Identification of variants in the physical architecture	195
10.2.5. Building physical architectures with a product line approach	196
10.2.6. Building physical architectures from a logical architecture	197
10.2.7. Application to the unifying thread example: identification of components	198
10.3. Decomposition of the components	201
10.3.1. Architecture principles	202
10.3.2. Coupling matrix	205
10.3.3. Global coupling quality of an architecture	206
10.3.4. The physical tree structure	209
10.3.5. The architecture of the components	211
10.3.6. Application to the unifying thread example: components and interfaces.	212
10.4. Characterization of interfaces	215
10.5. Identification of system configurations.	218
10.5.1. Definition of a technical configuration	218
10.5.2. Activities to identify technical configurations	219
10.5.3. Application to the unifying thread example: identification of configurations	220
10.6. Identifying the physical functioning of the system	222
10.6.1. Definition of the physical functioning of the system	222
10.6.2. Application to the unifying thread example: constructional scenario . . .	223
10.7. Allocation and definition of subsystem requirements.	224
10.7.1. Emergence of properties	224

10.7.2. Architecture sizing	226
10.7.3. Allocating non-functional requirements	227
10.7.4. Definition of subsystem requirements	228
10.8. Conclusion on the physical design	230
Chapter 11. Verification and Validation of the Physical Architecture	231
11.1. Verification of the physical architecture	231
11.1.1. Defining physical design verification procedures.	232
11.1.2. Performing physical design verification.	232
11.1.3. Rechecking the physical design	233
11.1.4. Recording the results of the physical design verification	233
11.2. Validation of the physical architecture	233
11.3. Conclusion on the verification and validation of the physical architecture	235
Chapter 12. Evaluation and Comparison of Solutions.	237
12.1. Evaluation of architectures	237
12.1.1. Selection of common criteria	237
12.1.2. Value criteria.	237
12.1.3. Risk and cost criteria	238
12.2. Comparison of architectures.	239
12.2.1. Selecting stakeholders.	239
12.2.2. Characterizing the weight of each criterion	239
12.2.3. Getting stakeholders to vote	240
12.2.4. Comparing architectures	240
12.2.5. Justifying architectural choices.	241
12.3. Conclusion on the evaluation and comparison of the architectures	241
Part 5. Virtual System Integration	243
Chapter 13. Integration on a W-Cycle	245
13.1. Virtual integration and real integration.	245
13.2. Simulation models	247
13.3. Conclusion on integration on a W-cycle	249
Chapter 14. Creating a Simulable Design Model	251
14.1. Defining the simulation objectives	251
14.2. Simulation and the systemic approach	251
14.3. Analysis and modeling of system architecture.	252
14.4. Analysis and causal modeling	254
14.4.1. Extracting simulation variables.	254
14.4.2. Relationships between variables	255

14.4.3. Feedback loops	255
14.4.4. Application to the unifying thread example: causal analysis	258
14.5. Formalizing the simulation model	261
14.5.1. Classification of variables	261
14.5.2. Dynamic modeling	262
14.5.3. Application to the unifying thread example: formalization of the causal model	265
14.6. Running the simulation	266
14.6.1. Identifying and configuring equations	266
14.6.2. Configuring the simulation	266
14.6.3. Application to the unifying thread example: simulation	266
14.7. Analyzing the results.	268
14.7.1. Purpose of the analysis of the results	268
14.7.2. Application to the unifying thread example: analysis of the results.	268
14.8. Conclusion on the realization of a simulable design model.	269
Chapter 15. Making a Simulable Specification Model	271
15.1. The monitoring model	271
15.1.1. Why make a monitoring model?	271
15.1.2. How to build a monitoring model	272
15.2. Writing structured requirements	273
15.2.1. Reminder on the structure of a requirement.	273
15.2.2. Application to the unifying thread example: selecting structured requirements.	274
15.3. Formalizing property requirements	274
15.3.1. Properties.	274
15.3.2. How to formalize a property	275
15.3.3. Application to the unifying thread example: formalization of properties	276
15.4. Building a monitoring model	278
15.4.1. Application to a property	278
15.4.2. Creating the specification model	279
15.5. Running the simulation	280
15.5.1. Connecting the specification model	280
15.5.2. Application to the unifying thread example: running the specification model.	281
15.6. Analyzing the results.	283
15.6.1. Result from the specification model	283
15.6.2. Application to the unifying thread example.	283
15.7. Conclusion on the realization of a simulable specification model	288

Part 6. System Integration	289
Chapter 16. Using Models	291
16.1. Models in systems engineering	291
16.2. Typology of models	291
16.3. Analytical behavioral models	292
16.3.1. Using the behavioral model in V&V	293
16.3.2. Model-based design	293
16.4. Business analytical models	296
16.4.1. Using the business model in V&V	296
16.5. Conclusion on the use of models	296
Chapter 17. System Integration, Verification and Validation	297
17.1. System integration	297
17.1.1. Receiving subsystems	298
17.1.2. Assembling subsystems	299
17.2. Checking the system	299
17.2.1. Defining the system verification strategy	300
17.2.2. Defining the system verification procedures	302
17.2.3. Performing the system check	303
17.2.4. Establishing system compliance	304
17.3. System validation	304
17.3.1. Preparing for validation	305
17.3.2. Performing validation	306
17.3.3. Analyzing the results	307
17.3.4. Saving validation results	307
17.4. Conclusion on system integration, verification and validation	308
General Conclusion	309
References	311
Index	315