

Table of Contents

1	Systems Engineering Handbook Scope	1
1.1	Purpose	1
1.2	Application	1
1.3	Contents	1
1.4	Format	3
1.5	Definitions of Frequently Used Terms	4
1.6	References	6
2	Systems Engineering Overview	7
2.1	Introduction.....	7
2.2	Definition of Systems Engineering.....	7
2.3	Origins of Systems Engineering	8
2.4	The Hierarchy <i>Within A System</i>	9
2.5	Systems of Systems	11
2.6	Use of Systems Engineering.....	14
2.7	Value of Systems Engineering	17
2.8	An Allegorical Tale	18
2.9	References.....	19
3	Generic Life-Cycle Stages	21
3.1	Introduction.....	21
3.2	Life Cycle Characteristics	22
3.3	Life-Cycle Stages	24
3.4	Life Cycle Approaches.....	32
3.5	What is Best for Your Organization?	43
3.6	Introduction to Three Case Studies	44
3.7	References.....	51
4	Technical Processes.....	55
4.1	Stakeholder Requirements Definition Process	56
4.2	Requirements Analysis Process	71
4.3	Architectural Design Process	96
4.4	Implementation Process.....	115
4.5	Integration Process.....	120
4.6	Verification Process	126
4.7	Transition Process	131
4.8	Validation Process	135
4.9	Operation Process	139
4.10	Maintenance Process	142
4.11	Disposal Process	145
4.12	Cross-Cutting Technical Methods.....	149
4.13	References.....	174
5	Project Processes	177
5.1	Project Planning Process	178
5.2	Project Assessment and Control Process.....	197
5.3	Decision Management Process.....	202
5.4	Risk Management Process.....	215
5.5	Configuration Management Process	228
5.6	Information Management Process	237

5.7	Measurement Process.....	242
5.8	References.....	250
6	Agreement Processes	253
6.1	Acquisition Process	255
6.2	Supply Process.....	261
6.3	References.....	265
7	Organizational Project-Enabling Processes	267
7.1	Life Cycle Model Management Process.....	268
7.2	Infrastructure Management Process.....	280
7.3	Project Portfolio Management Process.....	284
7.4	Human Resource Management Process.....	289
7.5	Quality Management Process	295
7.6	References.....	301
8	Tailoring Processes.....	303
8.1	Tailoring Process	303
8.2	References.....	310
9	Specialty Engineering Activities	311
9.1	Design for Acquisition Logistics – Integrated Logistics Support	311
9.2	Cost-Effectiveness Analysis	316
9.3	Electromagnetic Compatibility Analysis	317
9.4	Environmental Impact Analysis	317
9.5	Interoperability Analysis.....	318
9.6	Life-Cycle Cost Analysis	319
9.7	Manufacturing and Producibility Analysis.....	323
9.8	Mass Properties Engineering Analysis.....	324
9.9	Safety & Health Hazard Analysis	325
9.10	Sustainment Engineering Analysis.....	327
9.11	Training Needs Analysis.....	327
9.12	Usability Analysis/Human Systems Integration.....	328
9.13	Value Engineering	340
9.14	References.....	346
	Appendix A: System Life-Cycle Process N ² Chart.....	347
	Appendix B: System Life-Cycle Process Mappings	349
	Appendix C: Acronym List.....	357
	Appendix D: Terms and definitions	361
	Appendix E: Acknowledgements	367
	SEHv3.2.1 Contributions	367
	SEHv3.2 Contributions	368
	SEHv3.1 Contributions	369
	SEHv3 Contributions	370
	Appendix F: Comment Form	371
	Index	373

Table of Figures

Figure 1-1 System Life-cycle Processes Overview per ISO/IEC 15288:2008.....	2
Figure 1-2 Sample of Context Diagram for Process	4
Figure 2-1 Hierarchy Within a System	11
Figure 2-2 Example of the multitude of perceivable systems of interest in an aircraft and its environment of operation within a Transport system of Systems.....	12
Figure 2-3 Digital Camera and Printer System of Systems.....	13
Figure 2-4 Committed Life-cycle Cost against Time.....	15
Figure 2-5 In the last century, the time from prototype to significant market penetration is dramatically reduced.....	16
Figure 2-6 Technology acceleration over the past 140 years	17
Figure 2-7 Cost and schedule overruns correlated with SE effort	18
Figure 3-1 Generic business Life-cycle.....	22
Figure 3-2 SE level of effort across life-cycle stages	26
Figure 3-3 Comparisons of life-cycle models	26
Figure 3-4 Vee model	27
Figure 3-5 Left side of the Vee model.....	28
Figure 3-6 Importance of the Concept Stage.....	30
Figure 3-7 Right side of the Vee Model	31
Figure 3-8 IID and Evolutionary Development.....	34
Figure 3-9 Lean Development Principles	38
Figure 3-10 Hierarchical Baseline Elaboration	41
Figure 3-11 Non-hierarchical Baseline Elaboration	41
Figure 4-1 Key SE Interactions	56
Figure 4-2 Context Diagram for Stakeholder Requirements Definition Process	57
Figure 4-3 Requirements elicitation captures the needs of stakeholders	61
Figure 4-4 Context Diagram for the Requirements Analysis Process.....	73
Figure 4-5 Sources of Requirements	77
Figure 4-6 Requirements Derivation, Allocation, and Flowdown	84
Figure 4-7 Quality Function Deployment (QFD): The House of Quality	86
Figure 4-8 Example Project Specification Tree, also known as a Product Breakdown Structure	90
Figure 4-9 Context Diagram for the Architectural Design Process.....	96
Figure 4-10 Example of Alternative Architectural Concepts	100
Figure 4-11 System Architecture Synthesis Process Flow	102
Figure 4-12 Context Diagram for the Implementation Process	116
Figure 4-13 Context Diagram for the Integration Process	121
Figure 4-14 Context Diagram for the Verification Process	127
Figure 4-15 Test platform for analyzing battery performance at high loads	130
Figure 4-16 Context Diagram for the Transition Process	132
Figure 4-17 Context Diagram for the Validation Process.....	136
Figure 4-18 Context Diagram for the Operation Process.....	140
Figure 4-19 Context Diagram for the Maintenance Process	143
Figure 4-20 Context Diagram for the Disposal Process.....	146
Figure 4-21 Functional Analysis/Allocation Process	160
Figure 4-22 Alternative Functional Decomposition Evaluation and Definition	161
Figure 4-23 Sample FFBD and N ² Diagram.....	166
Figure 4-24 Foundation of OOSEM	168
Figure 4-25 OOSEM Activities in the Context of the System Development Process	169
Figure 4-26 OOSEM Activities and Modeling Artifacts	170
Figure 4-27 SysML™ Diagram Types	171
Figure 5-1 SE/Project Planning and Control Overlap	177
Figure 5-2 Context Diagram for the Project Planning Process	179
Figure 5-3 Examples of Complementary Integration Activities of IPDTs.....	193

Figure 5-4 Context Diagram for the Project Assessment and Control Process	198
Figure 5-5 Context Diagram for the Decision Management Process.....	203
Figure 5-6 Decision Tree for a “Bid – No Bid” Decision	207
Figure 5-7 Weighted Scores for Each Criterion for Each Alternative.....	213
Figure 5-8 Sample Trade Study Report Format	214
Figure 5-9 Context Diagram for the Risk Management Process.....	217
Figure 5-10 Level of risk depends upon both likelihood and consequences	221
Figure 5-11 Typical Relationship among the Risk Categories	222
Figure 5-12 Intelligent Management of Risks and Opportunities.....	227
Figure 5-13 Context Diagram for the Configuration Management Process	229
Figure 5-14 Requirements changes are inevitable	232
Figure 5-15 Context Diagram for the Information Management Process	239
Figure 5-16 AP233 facilitates data exchange	242
Figure 5-17 Context Diagram for the Measurement Process	243
Figure 5-18 TPM Monitoring	250
Figure 6-1 Acquisition Process Context Diagram.....	256
Figure 6-2 Supply Process Context Diagram.....	261
Figure 7-1 Life-Cycle Model Management Process Context Diagram	269
Figure 7-2 Standard SE Process Flow	274
Figure 7-3 Infrastructure Management Process Context Diagram.....	281
Figure 7-4 Project Portfolio Management Context Diagram	286
Figure 7-5 Human Resource Management Process Context Diagram	290
Figure 7-6 Shorter delivery time with concurrent development vs. traditional	295
Figure 7-7 Quality Management Process Context Diagram	296
Figure 7-8 Banner from Ford quality campaign.....	300
Figure 8-1 Tailoring requires balance between risk and process	304
Figure 8-2 Tailoring Process Context Diagram	304
Figure 9-1 Acquisition Logistics Activities.....	312
Figure 9-2 The Spitfire: A perfect balance of -ilities?	316
Figure 9-3 Life-Cycle Cost Elements (not to scale)	322
Figure 9-4 System safety focus during the system life cycle	325
Figure 9-5 Protective clothing for Hazmat Level A and bird flu.....	326
Figure 9-6 Sample Function Analysis System Technique (FAST) Diagram	345

Table of Tables

Table 1-1 Frequently Used Terms	5
Table 2-1 Important Dates in the Origins of SE as a Discipline	8
Table 2-2 Evolution of SE Standards.....	9
Table 3-1 Generic life-cycle stages, their purposes, and decision gate options	25
Table 5-1 Acronym List.....	178
Table 5-2 Types of IPDTs, their Focus and Responsibilities	191
Table 5-3 Ten Techniques for High Performance in Integrated Product Development Teams.....	196
Table 5-4 Pitfalls of using IPDT	196