Contents

List of Acronyms Preface			xi xv
PA	ART I	Introduction	1
1	Intr	oduction	3
	1.1	The evolution of medical purpose software	3
	1.2	Product quality and software quality	4
	1.3	On the need for quality in medical purpose software	7
	1.4	Regulatory environments	11
	1.5	Verification and validation	13
	1.6	Structure of the book	14
PA	RT I	I Regulations	17
2	EUI	MDD 93/42/EEC	19
	2.1	Background	19
	2.2	Content of the Directive 93/42/EEC	20
	2.3	The approval process for software as a medical device	24
		2.3.1 Qualification	25
		2.3.2 Classification	28
		2.3.3 Selection of the Authorized Representative and notified body	29
		2.3.4 Implementation of a quality management system	29 29
		2.3.4 Implementation of a quarty management system 2.3.5 Documenting software as a medical device	29
		2.3.6 Auditing by the notified body	30
		2.3.7 Display of the CE marking	30
		2.5.7 Display of the CE marking	50
3	FDA title 21 of US CFR		
	3.1	The role of the Food and Drug Administration	31 32
	3.2	Content of the Codes of Federal Regulation 21 CFR	
	3.3	The approval process for Software as a Medical Device	35
		3.3.1 Qualification	35
		3.3.2 Classification	37
		3.3.3 Implementation of a Quality Management System	38
		3.3.4 Documenting the Software as a Medical Device	39
		3.3.5 FDA clearance and premarket approval	40

vi	Eng	gineering high quality medical software	
4	Reg	ulations for other markets	43
	4.1	Regulatory environment and approval process in Aust	tralia 43
	4.2	Regulatory environment and approval process in Braz	zil 44
	4.3	Regulatory environment and approval process in Cana	ada 46
	4.4	Regulatory environment and approval process in Chir	
	4.5	Regulatory environment and approval process in Japa	
	4.6	Regulatory environment and approval process in Russ	sia 49
PA	RT I	III Standards	51
5		13485: medical devices—quality management syste	
	-	uirements for regulatory purposes	53
		Introduction	53
	5.2	Contents	54
		5.2.1 The Quality Management System	55
		5.2.2 Management responsibility	57
		5.2.3 Resource management	58
		5.2.4 Product realization	58
	5 2	5.2.5 Measurement, analysis, and improvement	59
		ISO 13485:2016 versus other Quality Systems ISO 13485 certification	60 65
			66
	5.5	Use of 150 15485 in each jurisdiction	00
6		14971: medical devices—application of risk man	•
		lical devices	69
		Introduction	69
		Contents	70
		1 11	74
	6.4		
	(5	hazardous situations	76
	6.5	Risk-management methods and tools	78 78
		6.5.1 Failure mode effects analysis6.5.2 Failure mode, effects, and criticality analysis	78 79
		6.5.3 Fault tree analysis	81
		6.5.4 Hazard analysis and critical control points	81
		6.5.5 Hazard operability (HAZOP) analysis	82
		6.5.6 Preliminary hazard analysis	82
		6.5.7 Markov analysis	82
	6.6	•	84
		, i i i i i i i i i i i i i i i i i i i	
7	IEC	C 62304: medical device software—software life-cycle	-
	7.1	Introduction	87
	7.2	Content	89
		7.2.1 Software Development Process	89
		7.2.2 Maintenance process	90

		7.2.3	Software risk management process	90
		7.2.4	Software configuration management process	92
		7.2.5	Software problem resolution process	92
	7.3	Use of	TEC 62304 in each jurisdiction	92
8	IEE	E 1012 :	and ISO/IEC 29119: standards for software verification	95
	8.1	IEEE S	Std 1012 for system and software verification and validation	95
		8.1.1	Integrity levels	97
		8.1.2	Common V&V activities	97
		8.1.3	Software V&V activities	97
	8.2		EC 29119 software testing	99
			ISO/IEC 29119-1: concepts & definitions	100
			ISO/IEC 29119-2: test processes	100
			ISO/IEC 29119-3: test documentation	104
			ISO/IEC 29119-4: test techniques	104
		8.2.5	ISO/IEC 29119-5: keyword-driven testing	105
PA	RT I	V Ver	ification and validation techniques	107
9		c testin		109
			uction and background	109
		Static		110
	9.3		analysis	111
			Control flow analysis	111
			Data dependence analysis	114
		9.3.3	Control dependence analysis	120
10	•	amic te	0	121
		Introdu		121
	10.2	-	ication-based testing technique	122
			Equivalence partitioning	122
			Boundary value analysis	123
			State transition testing	124
			Cause–effect graphing and decision table testing	125
			Syntax testing	127
			Combinatorial test techniques	128
			Scenario testing and use case testing	131
	10.2		Random testing	132
	10.3		ure-based testing technique	132
			Statement testing	132
			Branch/decision testing	133
			Condition testing	135
	10.4		Data flow testing	135
	10.4		guessing testing technique	136
		10.4.1	Error-guessing	136

11 Formal verification	137
11.1 Introduction and background	137
11.2 Formal specification	138
11.2.1 Ambient calculus and ambient logic	138
11.2.2 Linear temporal logic	142
11.3 Model checking	143
11.4 Static and dynamic (formal) verification	145
11.5 Summary	145
PART V Techniques, methodologies, and engineering	
tasks for the development, configuration,	1.47
and maintenance	147
12 Prescriptive software development life cycles	149
12.1 Software as a product	149
12.2 Software development strategies	150
12.3 Waterfall models	152
12.3.1 The waterfall	152
12.3.2 The V-model	153
12.4 Evolutionary models	154
12.4.1 Prototype models	154
12.4.2 The incremental model	156
12.4.3 The spiral model	156
12.5 Choosing the best software development model	159
13 Agile software development life cycles	161
13.1 The Agile Manifesto	161
13.2 Scrum	164
13.2.1 Roles	164
13.2.2 Events	165
13.3 Agile testing practices	166
13.3.1 Test-Driven Development	166
13.3.2 Acceptance Test-Driven Development	168
13.3.3 Behavior-Driven Development	169
13.4 Agile in a regulated environment	170
14 Project management	173
14.1 Introduction	173
14.2 Initiating	175
14.3 Planning	177
14.3.1 Setting the goals	177
14.3.2 Assigning the responsibilities	178
14.3.3 Defining the scope	178
14.3.4 Planning time and costs	182
14.4 Executing	184

		Contents	ix
	14 C N C 1 1 1 1 1 1		100
	14.5 Monitoring and controlling		186
	14.6 Closing		187
15	Risk management		189
	15.1 Risk assessment overview		189
	15.2 Risk assessment workflow		192
	15.3 Static versus dynamic safety risk scenarios		196
	15.4 Probabilistic risk model		199
	15.5 Application to the case study		200
	15.5.1 Safety critical factor identification		200
	15.5.2 Risk analysis		201
	15.5.3 Risk scenario development		202
	15.5.4 Probabilistic risk model		204
	15.5.5 PRM analysis and risk evaluation		206
16	Requirements management		209
10	16.1 Background		209
	16.2 Types of requirements		210
	16.3 Requirements development		213
	16.3.1 Requirements elicitation		213
	16.3.2 Requirements specification		214
	16.3.3 Requirements verification and validation		217
	16.4 Requirements traceability		217
17	Design controls and development management		219
1/	17.1 Background		219
	17.2 Design controls		220
	17.3 Design control and development templates		221
	17.3.1 Intended use template		222
	17.3.2 Risk management file template		224
	17.3.3 Software development plan template		224
	17.3.4 Software requirements specification template		225
	17.3.5 Software architectural design template		226
	17.3.6 Software detailed design template		227
	17.3.7 Test plan template		228
	17.3.8 Test case specification template		229
	17.3.9 Test procedure specification template		229
	17.3.10 Test incident report template		230
	17.3.11 Test summary report template		231
	17.3.12 Review report template		231
	17.3.13 Meeting report template		231
18	Test management and defect management		233
	18.1 Software testing principles		233
	18.2 Software testing strategies		234

x Engineering high quality medical software

18.3 A software testing process	235
18.3.1 Test planning, monitoring, and control	236
18.3.2 Test analysis	237
18.3.3 Test design	237
18.3.4 Test implementation	238
18.3.5 Test execution	238
18.3.6 Test evaluation exit criteria	239
18.3.7 Test closure	239
18.4 Test metrics	239
18.5 Defect management	243
19 Change management, configuration management, and	
change management	245
19.1 Change management	245
19.2 Configuration management	249
19.3 Incident management	251
PART VI Conclusions	255
20 Conclusions	257
20.1 Perspectives	257
20.2 Criticality	262
20.3 Conclusions	265
References	267
Index	271