
Contents

Foreword by Philippe Le Poac	xi
Foreword by Antoine Grall	xvii
Preface	xxi
André LANNOY	
Acknowledgments	xxiii
André LANNOY	
Author Biographies	xxv
Chapter 1. Aims and Introduction	1
André LANNOY	
1.1. The aims of this work	1
1.2. Reliability, an application of probability theory	2
1.2.1. What is reliability?	2
1.2.2. The early days of reliability	3
1.2.3. The birth of modern reliability	5
1.2.4. The development of modern reliability 1948–1960	5
1.2.5. The advent of reliability specialists 1960–1974	6
1.2.6. The “safety culture decade” 1975–1990	7

1.2.7. Maximizing efficiency, performances and profits 1990–2007	8
1.2.8. The return to safety, risk aversion 2007–2020	9
1.3. Generating nuclear power	10
1.4. Presentation of the book's content	15
1.5. References	17
 Chapter 2. Input Data: Operation Feedback and Expertise	 21
André LANNOY and Emmanuel REMY	
2.1. The purposes of operation feedback	21
2.2. What is operation feedback?	23
2.3. The operation feedback approach	25
2.4. “Event” operation feedback	28
2.5. “Equipment” operation feedback	29
2.5.1. The maintenance model: an approach according to function	29
2.5.2. Failure analysis	31
2.5.3. Failure criteria	33
2.5.4. Data quality	33
2.6. Reliability analysis	35
2.6.1. The components studied	35
2.6.2. Data characteristics	36
2.6.3. Principles of simple reliability data estimation for PSAs	38
2.7. Conclusion	39
2.8. References	41
 Chapter 3. The Principles of Calculating Reliability in Level 1 PSAs	 43
Marc BOUSSOU	
3.1. Introduction	43
3.2. The basis of all calculations: an exponential approximation	45
3.2.1. The principle of exponential approximations	45
3.2.2. NRI exponential approximation	46
3.3. The models used	48
3.3.1. Event trees	48
3.3.2. Fault trees	51
3.4. Quantification of PSAs	54
3.4.1. Calculating the probability of UCs that are conditional on an initiator	55
3.4.2. Calculating importance factors	57
3.4.3. The uncertainty calculation	59

3.5. The question of the level of detail	60
3.6. Practical problems: model size, high probabilities	62
3.6.1. Model size and combinatorial explosion	63
3.6.2. Fire, flood and earthquake PSAs: the problem of high probabilities	64
3.7. “Cousin” models of PSA models	65
3.7.1. Event sequence diagrams	65
3.7.2. Bow tie diagram.	66
3.7.3. Boolean logic-driven Markov processes	66
3.8. How can we improve the precision of classic PSAs?	70
3.8.1. Principles of the I&AB method.	70
3.8.2. What gains does I&AB allow?	71
3.8.3. Numerical application of I&AB	72
3.9. A line of research: “dynamic PSAs”	75
3.10. Software for carrying out PSAs	76
3.11. References	78
Chapter 4. Structural Reliability: General Presentation, Applications for Nuclear Power Plants	83
Emmanuel ARDILLON	
4.1. General presentation of SRA	83
4.1.1. Why SRA?	83
4.1.2. What does SRA consist of?	86
4.1.3. Old foundations but a recent history.	87
4.1.4. SRA: from the R-S elementary case (resistance-stress method) to the general case	88
4.1.5. A brief overview of calculation methods	90
4.1.6. OpenTURNS: the processing tool for uncertainty quantifications co-developed and used at EDF	95
4.2. Structural reliability in the nuclear power generation industry	97
4.2.1. Optimizing the maintenance policy for steam generators	98
4.2.2. Risk of fast fracture of PWR reactor pressure vessels	98
4.3. The pressurizer, an example of an exploratory exercise in the application of probabilistic approaches	100
4.4. Probabilistic optimization of the maintenance of nuclear power plant steel components.	102
4.4.1. Introduction	102
4.4.2. Specifying the problem (stage A)	103
4.4.3. Uncertainty quantification (stage B).	105

4.4.4. Uncertainty propagation: calculating the overall risk of thinning points (stage C)	106
4.4.5. Using probabilistic results: determining points to repair	107
4.4.6. Conclusion and perspectives on this application.	108
4.5. Structural reliability for hydroelectricity – the reliability of penstocks: evaluation of calculation values for mechanical strength diagnostics.	110
4.6. Conclusion	112
4.7. References	113
 Chapter 5. Probabilistic and Statistical Modeling for the Reliability of Industrial Equipment.	117
Emmanuel REMY	
5.1. Introduction	117
5.2. Some general preliminary remarks	118
5.3. Nonparametric approaches	124
5.4. Parametric models	126
5.4.1. Introduction	126
5.4.2. Some models adapted to non-repairable components	127
5.4.3. Taking account of influencing factors	132
5.4.4. Imperfect maintenance models for repairable equipment	135
5.4.5. Stochastic degradation models	140
5.5. Frequentist inference	147
5.6. Bayesian statistics	153
5.7. Model validation and selection	157
5.8. Case study for illustration	160
5.9. Openings and prospects for R&D.	163
5.10. Software tools.	164
5.11. References	164
 Chapter 6. The Human and Organizational Dimensions of Reliability and Nuclear Safety.	171
Nicolas DECHY, Yves DIEN and Jean-François VAUTIER	
6.1. Introduction and historical context in the nuclear field	171
6.2. Definition of the human and organizational dimensions of dependability and nuclear safety	173
6.3. Theories on accidents and reliability	175
6.4. Human and social sciences methods for collecting and analyzing data	181

6.5. Making human activities reliable	183
6.5.1. “Human error”: man is a fallible reliability agent	183
6.5.2. Training	185
6.5.3. Applying the procedure or demonstrating skills?	187
6.5.4. Analyzing real activity and work situations	188
6.5.5. Man-machine interfaces: the case of control rooms	189
6.5.6. Consideration of HOFs during design and modifications	190
6.5.7. Operation actions and their feasibility.	191
6.5.8. Quantitative approach to human reliability	192
6.5.9. HF in maintenance interventions	193
6.6. Making the organization of work and risk management reliable.	194
6.6.1. Quality approach and safety management systems	195
6.6.2. Safety culture	196
6.6.3. Forward planning of skills and workforce – human resources management.	197
6.6.4. Managing safety on a daily basis and decision-making	198
6.6.5. Risk analysis, anticipation.	199
6.6.6. Adaptation, resilience, emergency and crisis.	201
6.6.7. Event analysis and the operating experience feedback process	202
6.6.8. Conducting organizational change.	203
6.6.9. Organizing maintenance and subcontractors’ work	204
6.7. Cross-cutting aspects	206
6.7.1. The challenges of integration, organization and time	206
6.7.2. The contribution of the systemic approach	207
6.7.3. Reflexivity and critical approach.	209
6.7.4. HOF specialists and HOF relays: the contribution of HOF networks	209
6.8. Conclusion and perspectives	210
6.9. References	211
Chapter 7. From Too Little to Too Much: The Impact of Big Data	225
André LANNOY and Emmanuel REMY	
7.1. Introduction	225
7.2. Toward a better understanding?	227
7.2.1. New ways of collecting operation feedback	227
7.2.2. The importance of pre-processing and validation	229
7.2.3. A more accurate vision of the usage profile	230
7.2.4. Toward big data methods	231
7.2.5. Reliability approaches	232
7.2.6. A posteriori processing or visualization	236

7.3. Diagnostics and prognostics	236
7.3.1. Diagnostics	236
7.3.2. The prognostics	238
7.3.3. Classical reliability models for prognostics	239
7.4. Trust	240
7.5. Conclusion and perspectives.	241
7.6. References	242
 Chapter 8. Conclusions and Prospects	245
André LANNOY	
8.1. Nuclear power plants and the progress of reliability.	246
8.2. Challenges linked to reliability?	248
8.3. Prospects for future	249
8.3.1. Operational feedback data and data quality.	249
8.3.2. On system reliability	250
8.3.3. On the reliability of structures	251
8.3.4. On data from big data and the reliability of equipment.	252
8.3.5. On the reliability of organizations and activities	253
8.4. References	255
 List of Authors	257
 Index	259