Contents

Foreword 1 xi

Foreword 2 xv

Preface xix

Chapter 1. Reliability and Innovation: Issues and Challenges 1
Claire LARIVOIRE, Fabien MARTY and David DELAUX

1.1. Introduction 1
1.2. Innovation: spearheading competitiveness 2
1.3. Reliability: a major issue 4
1.4. Reliability in the innovation process. 7
1.4.1. The management of innovation, the criterion of success for the innovation-reliability parallelism. 7
1.4.2. Participatory innovation between creatives and technicians. 8
1.4.3. Supporting open-innovation through collaborative projects 8
1.5. Conclusion. 9
1.6. Bibliography. 10

Chapter 2. Reliability in the Automotive World 11
David DELAUX

2.1. Introduction: a history of reliability in the automotive world. 11
2.2. The challenges of automotive reliability: complexity of systems and organizations 15

2.3. The economic stakes in automobile reliability 20
2.4. An analysis of reliability through the analysis of warranty 23
2.5. Conclusion: the future of reliability in the automotive world 23
2.6. Bibliography 24

Chapter 3. Reliability in the World of Aeronautics 27
Tony LHOMMEAU, Régis MEURET and Agnès MATHEVET

3.1. Introduction 27
3.2. Safety and reliability 32
3.3. Maintainability/availability 34
3.4. Tomorrow's challenges 35
3.5. Conclusion 38
3.6. Bibliography 38

Chapter 4. Reliability in the World of Defense 41
Henri GRZESKOWIAK

4.1. Introduction 41
4.2. Operational dependability in the world of defense 42
4.3. History of reliability in the world of defense 48
4.3.1. History of reliability in the US world of defense 48
4.4. Reliability in the field of defense in the US today 54
4.4.1. Some observations 54
4.4.2. Recommendations for improving this situation 55
4.5. Importance of taking into account influential environments in the product life profile 56
4.6. Websites dedicated to the dissemination of good reliability practices in the United States 58
4.7. French websites dedicated to the dissemination of good practices in the field of reliability in France today 65
4.7.1. France's main actors in the field of reliability in interaction with the world of defense 65
4.8. Reminder of a few real-life examples in the world of defense 69
4.8.1. Case study 1: the KURKS accident 69
4.8.2. Case study 2: missile reliability tests at Point Mugu 70
4.8.3. Case study 3: reliability tests at the CEAT (Toulouse, France) 71
4.8.4. Case study 4: the Falklands War 72
4.8.5. Case study 5: air missile and buffeting on a combat aircraft during captive flight 72

4.8.6. Case 6: incorrectly taking into account the inrush current variability of a cold start diode . . . 73
4.8.7. Lessons learned from these six case studies . . . 73
4.9. Conclusion . . . 74
4.10. Bibliography . . . 75

Chapter 5. The Objectives of Reliability . . . 77
Lambert PIERRAT

5.1. Introduction and objectives . . . 77
5.2. Genesis and problem of reliability . . . 78
5.2.1. The genesis of reliability . . . 78
5.2.2. Predictive problems . . . 79
5.3. Concepts and notions of reliability . . . 80
5.3.1. Qualitative approach to the life cycle . . . 80
5.3.2. Notions of reliability . . . 82
5.4. Components and system . . . 85
5.5. Objectives of reliability . . . 86
5.5.1. Functional characteristics . . . 87
5.5.2. Objectives of guaranteed reliability . . . 87
5.6. Adequacy of specifications . . . 88
5.6.1. Current limitations . . . 88
5.6.2. Relevance of the MTTF . . . 89
5.7. Methodological approach . . . 91
5.7.1. Formulation of the example problem . . . 91
5.7.2. All of the on-board components . . . 92
5.7.3. "Critical" component . . . 93
5.7.4. Statistical approach . . . 94
5.8. Conclusion . . . 95
5.9. Bibliography . . . 96

Chapter 6. "Critical" Components . . . 97
Lambert PIERRAT

6.1. Introduction and objectives . . . 97
6.2. Problem of reliability . . . 98
6.2.1. Components and system . . . 98
6.2.2. Concept of criticality . . . 100
6.2.3. Influence on the system's reliability . . . 101
6.3. Estimate for the lifetime of a capacitor . . . 105
6.3.1. The problem . . . 105
6.3.2. Available information . . . 107

6.3.3. Conditions and test results 108
6.3.4. The acceleration factor 109
6.3.5. Life expectancy 113
6.4. Conclusion 115
6.5. Bibliography 115

Chapter 7. Estimated Reliability Prediction 119
Rémy FOUCHEREAU, David DELAUX, Henri GREZOSKOWIAK and Daniel TRIAS

7.1. Introduction 119
7.1.1. Historical benchmarks for the methods and standards of reliability prediction for electronics 120
7.1.2. The MIL-HDBK-217F handbook 122
7.1.3. The RIAC-HDBK-217+ handbook 123
7.1.4. RDF 2000 (UTE C80-810) Reliability Data Handbook . . . 125
7.1.5. FIDES guide 125
7.1.6. What are the main differences between the handbooks? . . . 127
7.1.7. Conclusion 128
7.2. Reliability prediction for four critical components 128
7.2.1. General remarks 128
7.2.2. Electrolytic capacitor 129
7.2.3. Film capacitor 133
7.2.4. IGBT 133
7.2.5. Power inductance 136
7.2.6. Power components, which handbooks? 137
7.3. Conclusion 139
7.4. Bibliography 139

Chapter 8. Simulation of Degradation Phenomena in Semiconductor Components in order to Ensure the Reliability of Integrated Circuits 143
Insaf LAHBIB, Aziz DOUKKALI, Patrick MARTIN, Guy IMBERT, Philippe DESCAMPS and Dominique DEFOSSEZ

8.1. Introduction 144
8.1.1. History of reliability 146
8.1.2. Designing for reliability 147
8.2. Mechanisms of degradation in active semiconductor components 149
8.2.1. Degradation in MOS transistors 149
8.2.2. Degradation in bipolar transistors 165
8.2.3. Conclusion 176

8.3. Study on the degradation of a ring oscillator 177
8.3.1. Introduction 177
8.3.2. Presentation of the oscillator 177
8.3.3. Study on the aging of the circuit according to these modes of operation 178
8.4. Conclusion 183
8.5. Bibliography 184

Chapter 9. Estimation of Fatigue Damage of a Control Board Subjected to Random Vibration 187
Mayssam JANNOUN, Younes AOUES, Emmanuel PAGNACCO, Abdelkhalak EL HAMI and Philippe POUGNET

9.1. Introduction 187
9.2. Description of the methodology 187
9.3. Finite element modeling 188
9.3.1. Geometry, boundary conditions and mechanical properties of materials 189
9.3.2. Modal analysis 191
9.4. Spectral analysis of random vibrations 196
9.4.1. Highly accelerated life tests (HALT) 196
9.4.2. Numerical simulations 198
9.5. Application of a stationary Gaussian random load 203
9.5.1. FE model and sub-modeling technique 205
9.6. Estimated fatigue damage 207
9.6.1. Time domain study 207
9.6.2. Frequency domain study 207
9.6.3. Calculation of fatigue damage and comparison of methods 208
9.7. Conclusion 209
9.8. Bibliography 210

Chapter 10. Study on the Thermomechanical Fatigue of Electronic Power Modules for Traction Applications in Electric and Hybrid Vehicles (IGBT) 213
Abderahman MAKHLOUFI, Younes AOUES, Abdelkhalak EL HAMI, Bouchaib RADI, Philippe POUGNET and David DELAUX

10.1. Introduction 213
10.2. Presentation of the power module (IGBT) 214
10.3. Different modes of failure for power modules under the effect of thermal cycling 216
10.3.1. Breakdown of ceramic substrates 216

10.3.2. Solder fatigue: chip–substrate and substrate–base plate . . . 217
10.3.3. Fatigue of the metallization in the aluminum of the component . . . 218
10.4. The physical phenomena involved . . . 218
10.4.1. Thermal phenomena . . . 218
10.4.2. Electrothermal phenomena . . . 222
10.4.3. Mechanical phenomena . . . 224
10.5. Modeling of physical phenomena (simulation through the finite element method) . . . 228
10.5.1. Strong coupling of electro-thermomechanical modeling . . . 229
10.5.2. The weak coupling of electro-thermomechanical modeling . . . 233
10.6. Digital models of IGBT power demonstrator failure . . . 235
10.6.1. Failure model of electrical wires by thermal fatigue . . . 235
10.6.2. Failure model of solder by thermal fatigue . . . 246
10.7. Conclusion . . . 249
10.8. Bibliography . . . 250

Chapter 11. Exploration of Thermal Simulation Aimed at Consolidating the Reliability Approach of Mechatronic Components . . . 253
Sébastien YON and Eric ROULAND

11.1. Introduction . . . 253
11.2. Modeling, input data and boundary conditions . . . 254
11.2.1. Inverter converter and heat sink . . . 254
11.2.2. Thermal modeling of the component . . . 256
11.2.3. Fluid modeling . . . 258
11.2.4. Global modeling of the system . . . 259
11.2.5. Boundary conditions and input data . . . 260
11.3. Operation results of the digital model . . . 263
11.3.1. Results of the digital simulations . . . 263
11.3.2. Reliability laws . . . 270
11.4. Digital tool: EleXTherm . . . 273
11.5. Bibliography . . . 273

Appendix . . . 275

List of Authors . . . 279

Index . . . 281