Preface to the 8th Edition

This book shows how to build in and assess reliability, availability, maintainability, and safety (RAMS) of components, equipment & systems. It presents the state-of-the-art of reliability (RAMS) engineering, in theory & practice, and is based on over 30 years author's experience in this field, half in industry and half as Professor of Reliability Engineering at the ETH, Zurich.

The request for a Chinese translation of this book and the very high eBook requirements were the motivation for this final edition, the 13th since 1985, including German editions [6.5]*. Extended and carefully reviewed to improve accuracy, it represents the continuous improvement effort to satisfy the reader's needs & confidence, and is more worthy now of appreciation's expressed in the book reviews mentioned on the book cover [1.17, 1.0]. It remains the author's aim, to concentrate research results in a book, to facilitate consultation and reduce publications flow. The launching of the 6th English Edition was celebrated with a special Session at the 12th Int. Conference on Quality and Dependability CCF2010 held in Sinaia, 22-24 Sept. 2010 [1.0 (2010)].

The structure of the book has been maintained through all editions, with main Chapters 1 to 8 and Appendices A1 to A11 (A10 & A11 since the 5th Edition 2007). Chapters 2, 4 & 6 (230 pp.) deal carefully with analytical investigations, Chapter 5 (25 pp.) with design guidelines, Chapters 3 and 7 (90 pp.) with tests, and Chapter 8 (15 pp.) with assurance activities during the production phase. Appendix A1 (15 pp.) defines and fully comments on the terms commonly used in reliability (RAMS) engineering. Appendices A2 - A5 (30 pp.) have been added to Chapter 1 (25 pp.) to support managers in answering the question of *how to specify & achieve high reliability (RAMS) targets for complex equipment & systems*. Appendices A6 - A8 (150 pp.) are a careful introduction to probability theory, stochastic processes, and mathematical statistics, as necessary for Chapters 2, 4, 6, and 7, consistent from a mathematical point of view but still with reliability engineering applications in mind (demonstration of established theorems is referred, and for all other propositions or equations, sufficient details for a complete demonstration are given). Appendices A9 - A11 (20 pp.) include statistical tables, Laplace transforms, probability charts, basic technological component's properties, and problems for homework.

This book structure allows rapid access to practical results. Methods and tools are given in a way that they can be tailored to cover different reliability (RAMS) requirement levels, and be used for risk management analyses too. Thanks to Appendices A6 - A8 the book is mathematically self contained, and can be used as text book or as desktop reference with a large number of tables (60), figures (210), and examples/exercises (220, of which 80 as problems for homework). Writing and rewriting was necessary in some places, so as to improve readability and coherence.

The book has grown from 420 to 650 pages (incl. References & Index), with important extensions, in particular, since the 4th Edition (2004):

- 4 th Edition: Introduction to imperfect switching, incomplete coverage, fault tolerant reconfigurable systems (time & failure censoring), items with more than two states, Monte Carlo approach for rare events, nonhomogeneous Poisson processes with applications to reliability tests.
- 5 th Edition: Introduction to common cause failures, Petri nets, dynamic FTA, availability tests for continuous operation, trend tests, particular nonregenerative processes, homework problems.
- 6 th Edition: Proof of Eqs. (6.88) & (6.94), introduction to network reliability, event trees & binary decision diagrams, extension of maintenance strategies & incomplete coverage, conditions to have $\tau_1 = A\tau_2$ in accelerated tests, refinements for complex systems & approx. expressions.
- 7 th Edition: Strategy to mitigate incomplete coverage, introduction to human reliability with design guidelines & new models, refinement of reliability allocation & design guidelines for maintainability, and writing relevant statements and rules *italics and centered on the text*.

New in this 8 th and final edition are, in particular:

- an introduction to risk management and to the concept of mean time to accident with structurally new models based on a novel subclass of semi-Markov processes, introduced for investigations on human reliability in Section 6.10 of the 7 th Edition, and further refined (pp. 299 - 310);
- reliability & availability calculation of a $k-out-of-n$ redundancy for $n-k=2$, constant failure & *arbitrary repair rates,* only one repair crew, and no further failures at system down (pp. 528 - 29);
- refinement of compound failure rate models for *multiple failure mechanisms* (pp. 64 - 65, 343 - 44);
- refinement of *spare parts provisioning* (pp. 128 - 30);
- refinement of necessary & sufficient conditions to have a *regeneration point* at the end of a repair, with respect to the state considered (pp. 386, 239 - 40, 353, 393, 522 & 526, footnote on p. 220);
- improved discussions / refinements on the:
  - procedure for calculating $MTTF_S$ & $PA_S = AA_S$ of *large complex systems* (pp. 293 - 94);
  - models building / verification (pp. 102, 168, 220, 238-40, 252, 343-44, 363, 368, 406, 536);
  - use of $MTBF \equiv 1/\lambda$ (pp. 6, 40, 392-93), $R(t_1, t_2)$ for *interval reliability* (not for reliability, pp. 40, 179, 397), and $\lambda(x)$ for *nonrepairable & repairable items* (as necessary for investigations on repairable systems, pp. 5, 390 - 91), as well as comments to $\lambda(x)$, *MTBF*, *MTTF* (pp. 390 - 94);
  - distinction between $MTTR_S$ and MDT_S (footnote on p. 121, pp. 123 - 24, 200, 217, 279, 394);
  - distinction between *MTBF*, *MTTF*, MUT_S (pp. 6, 199 - 200, 217, 279, 392 - 94, 515 - 16);
  - advantage of only one repair crew at system level (pp. 171 & 240, footnotes on pp. 386, 204, 121);
  - influence of a repair priority (footnote on p. 220), and of a series element (footnote on p. 221);
  - acceleration factor for assemblies, e. g. populated PCBs (p. 376);
  - approximate expressions for imperfect switching & incomplete coverage (pp. 245 - 58);
  - memoryless property (pp. 40, 179, 442 - 43; p. 220 for repair priority, p. 138 for minimal repair);
  - question catalogues for design reviews (pp. 79, 120, 423, 424);
  - comments to a skillful, allegorical story of reliability (p. 406);
- removal of some minor shortcomings.

Furthermore, considering that reliability, maintainability, safety, and software quality have to be built into complex equipment & systems, particular attention has been paid, since the first edition of this book, to the:

- selection of *design guidelines* for reliability, maintainability, and software quality (Chapter 5), as well as to practical aspects in a great number of examples, figures & tables, in Chapters 1, 3, 8 & Appendices A1 - A5, and in Chapters 2, 4, 6, 7 whenever dealing with const. failure & repair rates;
- investigation of *causes limiting redundancy efficacy* (like imperfect switching, incomplete coverage, common cause / mode failures, and multiple failure mechanisms);
- clear *formulation* and critical *validation of models used,* to identify their possibilities and limits, as well as elaboration of *analytical solutions* to allow *trade off studies*;
- specification of the *item's (system's) state at* $t=0$, often tacitly assumed new or as-good-as-new in practical applications, which has great influence on its reliability and availability if the involved failure and / or repair rates are time dependent (to satisfy this necessity, reliability figures at system level have in this book *indices* Si, where S stands for system (the highest integration level of the item considered) and i for the *state entered at* $t=0$, $i=0$ for system new or as-good-as-new);
- development of powerful and practically oriented tools for the investigation of large series-parallel structures with constant failure & repair rates (macro structures), and of complex structures (key item, totally independent elements, models based on Markov or semi-regenerative processes);
- generalization of repair time distributions, and as far as possible of failure-free time distributions, step by step up to the case in which the process involved remains regenerative with a *minimum number of regeneration states*, to show *capability and limits* of models involved, evaluate the influence of distribution function shapes on final results, and provide approximate expressions useful for practical applications;

- central role of *software quality assurance* for complex equipment & systems, by considering that software problems are *quality problems* which have to be solved with quality assurance tools;
- *prerequisites for accelerated tests*, in particular in transferring an acceleration factor A from the *MTTF* to the (random) failure-free time τ;
- consequent use of failure-free time for failure-free *operating* time, *MTBF for* $1/\lambda$ (at equipment & system level, as usual in practical applications), repair for *restoration* (by neglecting logistic & administrative delays), and *interarrival times* starting by $x=0$ at each occurrence of the event considered (*necessary* when investigating repairable systems; in this context, the assumption *as-good-as-new after repair* is critically discussed wherever necessary, and the historical distinction between non-repairable and repairable items (systems) is scaled down);
- use of the *memoryless property* wherever possible to simplify calculations and considerations; however, taking care that *it applies only with exponentially distributed random times,* in particular thus *only with constant failure and/or repair rates;*
- use of *independent* for mutually, statistically, stochastically independent (as generally occurs in practical reliability applications), *mean* for expected value, and *asymptotic & steady-state* for stationary (by assuming *irreducible embedded chains*, for availability considerations);
- careful definition and comment on terms used in RAMS engineering (Appendix A1), as well as distinction between basically different quantities (e. g. between $\lambda(t)$ and $f(t)$, $z(t)$, $h(t)$, $m(t)$).

The book were used for over 15 years at the ETH Zurich (for an introductory course at undergraduate level and for postgraduate courses), as well as for a large number of seminars in industry.

Reliability (RAMS) engineering is a key for future reliable, safe, sustainable & long life products. It is thus to be regretted that at the author retirement, some "Colleagues" found it correct to transfer the Reliability Laboratory of the ETH to the EMPA. The few practitioners which consider this book too theoretically oriented, overlook the strong practically oriented Chapters 1, 3, 5, 8 & Appendices A1 - A5, as well as that investigations in Chapter 6 are necessary to assess factors affecting redundancy efficacy (e. g. incomplete coverage) & influence of repair time distribution function shapes on final results, and that Appendices A6 - A8 are useful to make the book mathematically self contained. Modeling is important in engineering sciences to *investigate and predict item's behavior* (e. g. in relation to performance, reliability & safety); oversimplified models should be avoided, and validation of model assumptions (physical & statistical aspects) should precede any data analysis (of course, approach for lifeless or living entities/systems is quite different).

This final edition extends and replaces all previous editions. The agreeable cooperation with Springer-Verlag is gratefully acknowledged. Looking back to all editions (1 st German 1985 [6.5]), thanks are due, in particular, to K. P. LaSala for reviewing the 4 th & 6 th Editions [1.17], I. C. Bacivarov for reviewing the 6th Edition [1.0], book reviewers of German editions, P. Franken & I. Kovalenko for commenting Appendices A6 - A8 (1990 & 1996), W. Luithardt for commenting Section 5.3 (2016), A. Bobbio, F. Bonzanigo & M. Held for supporting numerical evaluations, J. Thalhammer for the final edition of all figures, and L. Lambert for reading final manuscripts.

On the front-page, four new sentences have been added to the three given since the 4 th Edition; these seven sentences, centered on generosity, modesty, ethics, responsibility, liberty, sustainability and people rights, should help, in particular young people, to make the world a better place (see also [1.2 (2010), 1.0 (2016)]).

Zurich and Florence, September 13, 2017 *Alessandro Birolini*

* For [...], see References at the end of the book.

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