SYSTEM RELIABILITY

Concepts and Applications

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Preface

The mind-boggling rate of industrial expansion of the past few decades has produced innumerable technical devices and systems on which we rely in our daily life for modern convenience, safety, and sometimes even preservation of human lives. These modern artifacts cover a broad spectrum ranging from a relatively simple electronic watch to very complex transportation systems such as airplanes or spacecraft. Often, one is not even aware of the use of particular systems (part of our electrical energy is generated by nuclear reactors) until one is most unpleasantly reminded (Chernobyl disaster).

It is a proven fact that all these technical systems are *producible*, in other words: One can at least make them work at the time of first use. A higher order requirement, however, is that they remain serviceable throughout their expected useful life; i.e. that they are *reliable*. The consequences of an unreliable functioning of these systems may vary from inconvenience, extra costs, environmental damage, to even death. Such inability to perform reliably may not only arise from the product itself (usually manifested in hardware or software failures), but also from human errors. Take for instance the (pilot) error where an aircraft is put down on the runway extremely hard. As the cover picture shows, this can result in a cracked fusilage and the dragging of the entire tail section over the runway until the aircraft comes to a complete stop (Eastern Airlines, Florida, Dec. 28, 1987).

Only recently has the reliability aspect of our industrial activity been increasingly emphasised. The U.S. automobile industry, after having lost out almost completely to the Japanese and their more reliable cars, has only lately improved the reliability of its products drastically. Of course, producibility, yield, and quality are of eminent importance for an industrial product, but a healthy reliability over the entire planned life span of the product is at least of equal importance. The hesitation of many manufacturers in accepting a high reliability as one of the product design goals can be explained by the extra cost associated with the reliability program and by the intangible nature of product reliability to the customer. The customer (at least initially) does not know that one system is more reliable than another, and also does not know that the price difference between the two is more than warranted if one takes into account the later savings on "inconveniences" such as repair costs, aggravation, loss of production, accidents, environmental damage, etc.. Judging from the large number of unreliable systems around today, not everybody recognizes the principle underlying reliability engineering: "*Invest now, save later*".

A secondary cause for the hesitation to regard reliability as an important product specification is the lack of training product design engineers receive in this field. To fill this gap for graduating engineers, Dr. K.B. Klaassen started a lecture series on Reliability Engineering at the Electrical Engineering Department of the Delft University of Technology in the Netherlands. Due to the great student interest in this topic (judging from the large enrollment figures), good lecture notes became a necessity. These notes found such a receptive audience outside the University that it was decided to publish them in the

form of a book, first in the Dutch language and later, when the authors had joined IBM's Almaden Research Center in San Jose, California, also in English.

This book is composed of nine chapters. At the end of each chapter the reader finds a number of problems designed to rehearse the subject matter of that specific chapter. To aid in solving the problem, the end of the book provides not only answers to these exercises, but also a detailed explanation of the solutions. Throughout the text of the book, practical examples are provided, taken from the various applications of reliability engineering such as: electronics, control engineering, avionics, power engineering etc.

Chapter 1 discusses the definition of reliability and the various associated aspects. It reviews the reasons for reliability improvement, dwells briefly on the probabilistic versus deterministic approach to reliability engineering, and gives the most important ways in which the reliability of a system may be increased.

Chapter 2 is devoted to the deterministic approach to reliability engineering, which is often indicated as the "physics of failure" approach. It deals with several degradation models, gives examples of important physical failure mechanisms, and explains the use of screening techniques for removing the potentially weak components.

From Chapter 3 on, the book focuses on probabilistic reliability engineering. *Chapter 3* covers the nomenclature, definitions and, mathematical relationships of all essential probabilistic reliability, availability, and maintainability parameters.

Chapter 4 deals with all frequently encountered failure probability distributions. It also covers reliability testing, confidence levels, and accelerated testing.

Chapter 5 is dedicated to probabilistic reliability models, in particular the catastrophic failure model, the stress-strength model, and the Markov model.

Chapter 6 discusses the effect of system structure on the reliability of non-maintained systems. It deals with series, parallel, *m*-out-of-*n*, and majority voting systems. This chapter also acquaints the reader with various techniques for reliability analysis and reliability optimization.

Chapter 7 deals with maintained systems. It introduces various forms of maintenance and their effect on the system's availability. The effect of redundancy combined with maintenance is also discussed. The chapter closes with a look at the problem of spare-parts provisioning.

Chapter 8 deals with system evaluation techniques such as Fault Tree Analysis (FTA) ans Failure Mode Effect and Criticality Analysis (FMECA). It also introduces the concepts of risk and safety.

Finally, *Chapter 9* is dedicated to software reliability. It discusses how to write reliable programs, how to test software for reliability, and gives an effective software failure model.

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