PRACTICAL RELIABILITY ENGINEERING and ANALYSIS for SYSTEM DESIGN and LIFE-CYCLE SUSTAINMENT

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To my O. A. O. and the love of my life, Tudor.

Preface

Product reliability is becoming a global competitive discriminator. It is a concept that people relate to even if they do not know what must be done to achieve it. Reliability engineering is a young discipline that evolved following World War II. It has its roots in military and commercial aviation use of electronics and digital components to control and monitor aviation systems. Defined as the probability that a system will perform its function without failure for the mission duration under stated conditions of use, "reliability" has been treated as a statistical analysis used to audit a design rather than as a design analysis that is part of system design. Time to failure (TTF) is the dominant parameter of reliability. Reliability failure models seek to characterize part failure rate, failures per hour, and mean time between failure (MTBF).

Few universities offer reliability degree programs. Reliability courses taught at universities introduce probability and statistical methods to characterize point estimates of failure rate and MTBF; they present methods to compute the reliability of serial and redundant design configurations. Reliability engineering books describe the same topics taught in universities with the same emphasis on probability and statistics. Reliability tutorials and seminars emphasize selected reliability topics without context to the whole system.

The bathtub curve is the common thread of these instructional programs. This curve assumes that a system goes through three phases in its life cycle: infant failure, useful life, and wear out. A system is assumed to experience constant, random failure during the useful-life phase. This approach to reliability analysis works well when the system is an electronics circuit board constructed of digital components and solder connections.

However, reliability analysis of mechanical design for structures and dynamic components demands a different approach. Mechanical design must mitigate failure mechanisms acting on components as well as achieve functional specifications. Mechanical structures and dynamic components experience wear out that does not manifest constant failure rates over the useful life. Reliability of mechanical design is based on the relationship between stress and strength over time.

This book departs from the mainstream approach to TTF-based reliability engineering and analysis. As a mechanical engineer, I enjoyed a career in mining before becoming a defense contractor. The most enlightened reliability specialists that I have known are maintenance technicians, foremen, and engineers. They deal daily with the demand to keep mobile machinery and process equipment operating. What I learned from them is first to understand why a part fails, then learn how to fix it, and finally learn how to

prevent it from failing. This reliability book seeks to blend those lessons with mechanical engineering design, systems integration, and sustainment in order to enable organizations to achieve world-class reliability in products.

I remain a student of the reliability engineering discipline and welcome comments, criticism, and case studies from everyone who works in reliability. I hope this book generates interest in expanding the body of reliability knowledge.

Best regards,

Bill Wessels
wesselsw3@mchsi.com

The Author

Bill Wessels has been a reliability engineer since 1970. He did not know that he was a reliability engineer until 1989, when he was first tagged with that label. Bill discovered that field engineering assignments were tasked to maintain mobile machinery and process equipment far more often than to design or build them. Maintenance employees in mining and process plant organizations provided Bill with several decades of education in system maintainability and insights into how design for reliability can influence system sustainability. Business managers taught him that cash flow is the lifeblood of every organization, that capital assets only earn revenue when performing their function, and that unscheduled downtime causes lost-opportunity costs that can never be recovered.

Bill wrote this book to convey what he has learned to fellow design and field engineers. His formal education has equipped him to learn from those who perform maintenance and engineering work. It began with a BS in engineering from the U.S. Military Academy at West Point (1970), followed shortly after with an MBA (1975), and culminating in a PhD in systems engineering in 1996. Along the way, Bill earned his professional engineer license in mechanical engineering from Pennsylvania (1982) and ASQ certification as a reliability engineer (CRE).

Bill is currently a reliability, maintainability, and sustainability researcher at the University of Alabama in Huntsville, where he also teaches in the College of Engineering. Bill and his wife, Tudor, live on a small farm with seven dogs; ever changing numbers of horses, donkeys, goats, geese, turkeys, and chickens; and who knows how many barn cats. The beasts ignore the findings of statistically rigorous algorithms, defy any statistical level of significance, behave in a random walk manner, and ridicule his attempted analytical methods when they are applied to them. Tudor finds his attempts to predict their behavior to be a lack of common sense and a waste of time. But he continues to try.

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