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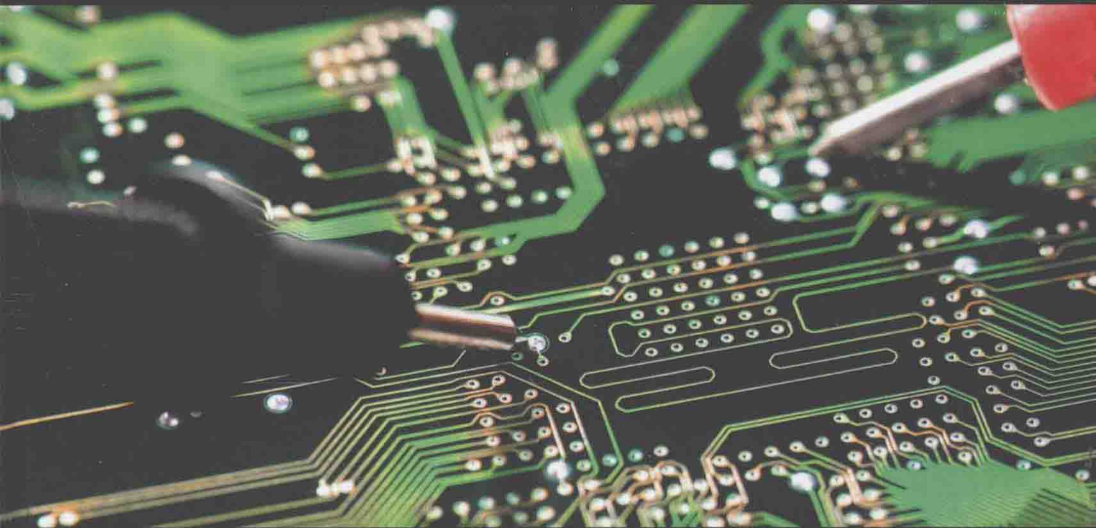

KIRK A. GRAY • JOHN J. PASCHKEWITZ

NEXT GENERATION HALT AND HASS

ROBUST DESIGN OF ELECTRONICS AND SYSTEMS

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Next Generation HALT and HASS

Robust Design of Electronics and Systems

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Series Editor's Foreword

The Wiley Series in Quality & Reliability Engineering aims to provide a solid educational foundation for researchers and practitioners in the field of quality and reliability engineering and to expand their knowledge base by including the latest developments in these disciplines.

The importance of quality and reliability to a system can hardly be disputed. Product failures in the field inevitably lead to losses in the form of repair costs, warranty claims, customer dissatisfaction, product recalls, loss of sales and, in extreme cases, loss of life.

Engineering systems are becoming increasingly complex, with added functions and capabilities; however, the reliability requirements remain the same or are even growing more stringent. Also the rapid development of functional safety standards increases pressure to achieve ever higher reliability as it applies to system safety. These challenges are being met with design and manufacturing improvements and, to no lesser extent, by advancements in testing and validation methods.

Since its introduction in the early 1980s the concept and practice of highly accelerated life testing has undergone significant evolution. This book *Next Generation HALT and HASS* written by Kirk Gray and John Paschkewitz, both of whom I have the privilege to know personally, takes the concept of rapid product development to a new level. Both authors have lifelong experience in product testing, validation and applications of HALT to product development processes. HALT and HASS have quickly become mainstream product development tools, and this book is the next step in cementing their place as an integral part of the design process; it offers an excellent mix of theory, practice, useful applications and common sense engineering, making it a perfect addition to the Wiley series in Quality and Reliability Engineering.

The purpose of this Wiley book series is not only to capture the latest trends and advancements in quality and reliability engineering but also to influence future developments in these disciplines. As quality and reliability science evolves, it reflects the trends and transformations of the technologies it supports. A device utilizing a new technology, whether it be a solar panel, a stealth aircraft or a state-of-the-art medical device, needs to function properly and without failures throughout its mission life. New technologies bring about new failure mechanisms, new failure sites and new failure modes, and HALT has proven to be an excellent tool in discovering those weaknesses, especially where new technologies are concerned. It also promotes the advanced study of the physics of failure, which improves our ability to address those technological and engineering challenges.

In addition to the transformations associated with changes in technology the field of quality and reliability engineering has been going through its own evolution by developing new techniques and methodologies aimed at process improvement and reduction of the number of design and manufacturing related failures. And again, HALT and HASS form an integral part of that transformation.

Among the current reliability engineering trends, life cycle engineering concepts have also been steadily gaining momentum by finding wider applications to life cycle risk reduction and minimization of the combined cost of design, manufacturing, warranty and service. Life cycle engineering promotes a holistic approach to the product design in general and quality and reliability in particular.

Despite its obvious importance, quality and reliability education is paradoxically lacking in today's engineering curriculum. Very few engineering schools offer degree programs, or even a sufficient variety of courses, in quality or reliability methods; and the topic of HALT and HASS receives almost no coverage in today's engineering student curriculum. Therefore, the majority of the quality and reliability practitioners receive their professional training from colleagues, professional seminars, publications and technical books. The lack of opportunities

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for formal education in this field emphasizes too well the importance of technical publications for professional development.

We are confident that this book, as well as this entire book series, will continue Wiley's tradition of excellence in technical publishing and provide a lasting and positive contribution to the teaching, and practice of reliability and quality engineering.

Dr. Andre Kleyner,
Editor of the Wiley Series in
Quality & Reliability Engineering

Preface

This book is written for practicing engineers and managers working in new product development, product testing or sustaining engineering to improve existing products. It can also be used as a textbook in courses in reliability engineering or product testing. It is focused on incorporating empirical limit determination with accelerated stress testing into a physics of failure approach for new product and process development. It overcomes the limitations, weaknesses and assumptions prevalent in prediction based reliability methods that have prevailed in many industries for decades.

We are especially grateful to the late Dr Gregg Hobbs for being the creator of HALT and HASS and a teacher and mentor.

We especially appreciate Dr Michael Pecht, the founder of CALCE at the University of Maryland, for his encouragement for writing this book and sharing CALCE material.

We would like to indicate our gratitude to our colleagues who provided support, input, review and feedback that helped us create this book. We thank Andrew Roland for permission to use his article *MTBF – What Is It Good For?* We would also like to thank Charlie Felkins for the pictures and drawings he provided and Andrew Riddle of Allied Telesis Labs for use of their case history. We are also grateful for the assistance of Fred Schenkelberg in providing support, contributions and promotion of this book.

We would like to thank Mark Morelli for material used in the book, as well as working with him early on implementing HALT and HASS at Otis Elevator, and Michael Beck for his support on implementing HALT and HASS, and access to information on DRBFM. We are grateful to Bill Haughey for introducing us to GD^3, DRBFM and DRBTR, as well as to James McLeish for his support and work on Robust Design, Failure Analysis and GD^3 source information.

We want to acknowledge Watlow and in particular Chris Lanham for providing opportunity to expand and apply our reliability knowledge, as well as Mark Wagner for his case history contribution to the Appendix.

Reliasoft granted us permission to use material in this book and we appreciate the support and encouragement from Lisa Hacker. We thank Linda Ofshe for her technical editing of early chapters, Richard Savage for his support and encouragement and Monica Nogueira at SAE International for her review of manuscript sections and resolving questions on copyrighted material.

Ella Mitchell, Liz Wingett and Pascal Raj Francois, who are our contacts at John Wiley & Sons, have guided us through the process of writing a technical book and all the details of manuscript development and preparation for publication.

List of Acronyms

ALT	Accelerated Life Testing
AMSAA	Army Material Systems Analysis Activity
AST	Accelerated Stress Tests
CALT	Calibrated Accelerated Life Test
CDF	Cumulative Distribution Function
CHC	Channel Hot Carrier
CND	Can Not Duplicate
CRE	Certified Reliability Engineer
DoD	Department of Defense
DFX	Design for X (Test, Cost, Manufacture & Assembly, etc.)
DFR	Design for Reliability
DFSS	Design for Six Sigma
DOE	Design of Experiments
DRBFM	Design Review Based on Failure Modes
DRBTR	Design Review Based on Test Results
DVT	Design Verification Test
ED	Electrodynamic (Shaker)
EM	Electromigration
ESS	Environmental Stress Screening
FEA	Finite Element Analysis
FIT	Failure in Time
FLT	Fundamental Limit of Technology
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects & Criticality Analysis

FRACAS	Failure Reporting, Analysis, & Corrective Action System
GD^3	Good Design, Good Discussion, Good Dissection
HALT	Highly Accelerated Life Test
HASS	Highly Accelerated Stress Screening
HASA	Highly Accelerated Stress Audit (Sampling)
HTOL	High Temperature Operating Life
HCI	Hot Carrier Injection
ICs	Integrated Circuits
LCD	Liquid Crystal Display
LCEP	Life Cycle Environmental Profile
MSM	Matrix Stressing Method
MTBF	Mean Time between Failures
MTTF	Mean Time To Failure
MWD	Measurement While Drilling
NBTI	Negative Bias Temperature Instability
NDI	Non Developmental Item
NFF	No Fault Found
NPF	No Problem Found
OEM	Original Equipment Manufacturer
ORT	Ongoing Reliability Test
PoF	Physics of Failure
PRAT	Production Reliability Acceptance Test
PTH	Plated Through Holes
PWBA	Printed Wiring Board Assembly
QFD	Quality Function Deployment
RoHS	Restriction of Hazardous Substances
RMA	Returned Material Authorization
RMS	Reliability, Maintainability, Supportability
RDT	Reliability Demonstration Test
SINCGARS	Single Channel Ground Air Radio Set
SPC	Statistical Process Control
TDDB	Time Dependent Dielectric Breakdown
VOC	Voice of the Customer
WCA	Worst Case Analysis

Contents

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Introduction

This book presents a new paradigm for reliability practitioners. It is focused on incorporating empirical limit determination with accelerated stress testing into a physics of failure approach for new product and process development. This extends the basics of highly accelerated life test (HALT) and highly accelerated stress screens (HASS) presented in earlier books and contrasts this new approach with the limitations, weaknesses, and assumptions in prediction based reliability methods that have prevailed in many industries for decades. It addresses the lack of understanding of why most systems fail, which has led to reliance on reliability predictions.

Chapters 1, 2 and 3 examine the basis and limitations of statistical reliability prediction methods and shows why they fail to provide useful estimates of reliability in new products even if they are derivatives of previous products. It also addresses the prevailing focus on estimating life or reliability with metrics such as MTBF (mean time before failures) and MTTF (mean time to failure) and the misleading aspects of using these metrics in reliability programs. This includes difficulties and limitations in using field return data on previous products or results of reliability demonstration tests to derive an MTBF or MTTF estimate on new products. The section concludes with an assessment of practices in many reliability programs and shows how they can be inadequate, resulting in warranty claims, customer dissatisfaction and increased

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