Chapter 1

INTRODUCTION

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1.1 SYNOPSIS OF RELIABILITY TRENDS AND AIM OF BOOK

This handbook describes a set of Best Practices for utilizing accelerated stress testing (AST) as part of the methodology for systematically improving the hardware reliability of manufactured products. A key feature of this methodology is to apply stress testing techniques to a product early in its life and then corrective action to fix the problems found as quickly as possible. A main goal of accelerated stress testing is to identify design deficiencies or problems with component quality or manufacturing processes in order to achieve a more reliable product as production volumes increase. The emphasis of this reliability improvement methodology is on identifying and eliminating reliability problems, not on screening out defects. However, since it may take some time to eliminate certain problems, the AST Best Practices also seek to optimize the application of ongoing stress testing (that is, burn-in and/or temperature cycling) where appropriate so as to minimize test costs and test intervals.

This book is oriented principally toward the authors' backgrounds, the electronics industry. The methods presented here may also be applied to other types of products. Before proceeding with our discussion of the accelerated stress testing methodology, it is useful first to consider the status of reliability within the electronics industry, thereby establishing the business context within which reliability enhancement programs must exist. The remainder of the Introduction outlines the contents of the handbook.

The electronics industry generally recognizes the desirability of "high" product reliability, but there are also strong business pressures that tend to compromise product reliability. Consequently, it is useful first to consider reliability from a realistic business perspective. Failure to provide adequate reliability can be costly to a business in several ways. Most immediately, there is the cost of reworking or scrapping goods within the manufacturing environment. In addition, poor product quality or lack of robustness can lead to excessive component and product inspection or test costs. After products are shipped, the cost of poor quality or reliability can mount rapidly. Warranty repairs may not only be expensive to the manufacturer but are often far more costly to the customer in terms of loss of service or increased maintenance costs. Finally, a lack of product reliability can have a significant impact on future sales.

On the other hand, a business may incur excessive expenses pursuing very high reliability standards with very little payback (though in our experience this rarely occurs). The cost of improving or maintaining product reliability must be weighed against the benefits derived, and it should be recognized that from a business perspective there is an adequate, though less than perfect, level of reliability appropriate for any product. Of course, the appropriate level of quality does depend on the nature of the product and how the customer uses it. On one end of the spectrum, very high reliability is required for high-end computing or communications systems that are important to a customer's revenue stream. On the other end, relatively simple but innovative products that have a high degree of customer appeal may be able to prosper for a time even if they are not very reliable. A business must understand the cost of reliability, both directly to its own operations and indirectly to its customers and their willingness to make future purchases, and must have a plan for achieving an appropriate level of reliability for its products. Unfortunately, however, this is often not the case.

Several ongoing trends in the electronics industry pose a challenge to those seeking to provide adequate product reliability consistently. The fast pace of increased silicon integration and increased device speed, coupled with an associated trend toward miniaturization, are leading to products with ever higher functional capability and complexity packaged in smaller volumes and often at increased power densities. This has been accompanied by a fairly rapid evolution in packaging techniques, materials, and manufacturing processes. The rapid improvement in the functionality of electronic system components, together with the sharp drop in the associated cost of functionality, has created consumer demand for products offering ever more features and capabilities. This in turn has led to a rapid pace of new product development and existing product obsolescence. This is particularly true for the ongoing convergence of communications, computing, and consumer products, which represents yet another major trend in the electronics industry.

This convergence, along with a strong move toward global markets, is leading to further widening of the environmental conditions under which a product is expected to operate. This picture of rapid-paced development of new products of ever increased complexity operating in diverse global environments, coupled with intense competitive pressures, has led to a strong emphasis in the electronics industry on bringing a continual stream of new products to market in a very short time while at the same time maintaining a low cost of goods to assure adequate profit margins.

In response to the time and cost pressures of the market, businesses frequently take a rather minimal approach to reliability, attempting to establish a minimum level of product testing or inspection that will provide a level of reliability they feel is just adequate for the market they serve. However, given the manner in which most companies organize their product and functional responsibilities, the total cost of reliability to the business is often underestimated or unrecognized, and local optimization in reducing costs tends to lead to less than desirable reliability results. While this book does not delve into the methods by which a business should optimize its overall approach to quality and reliability, the reliability improvement methodology advocated in this book does require a proactive management attitude toward reliability. Management must be willing to invest in the early detection and elimination of reliability problems with the expectation that they will be rewarded with lower "downstream" reliability costs and enhanced sales through improved customer satisfaction.

In this book, we assume that management has already established the traditional quality assurance programs for components and manufacturing processes and has instituted robust design methods to some degree. However, given the ever increasing complexity of new products, the faster schedules on which they are developed, and the need to be at or near the leading edge in new technologies or manufacturing processes, there is still a need for additional proactive processes to assure product reliability. The main purpose of this book then is to provide the means to quickly and economically assess the potential reliability of a product and afford the opportunity to fix reliability problems early before they lead to major losses. Doing accelerated stress testing is not cheap, and the cost of the associated failure mode analysis and corrective action may be even more expensive. Typically, these costs can only be justified by recognizing the full-stream cost of product reliability over the life of a product. However, in a number of well-organized business operations where the full-stream cost of reliability has been understood, the accelerated stress testing methodology discussed in this book has been found to be of great value.

1.2 BACKGROUND OF MILITARY AND INDUSTRIAL STRESS TESTING PRACTICES

In 1992, a technical committee on Environmental and Reliability Testing was formed under the Component, Packaging, and Manufacturing Technology Society (CPMT) of the Institute of Electrical and Electronics Engineers (IEEE). This committee promotes the free technical exchange of stress testing practices and experiences without releasing proprietary product information. This committee also initiated the annual IEEE Workshop on Accelerated Stress Testing in 1995 [1]. In 1997, the IEEE Reliability Society (RS) joined efforts with the IEEE CPMT Society to co-sponsor this workshop [2]. In addition, the Screening and Testing Committee of the IEEE RS has also expanded its activities, shifting its focus from conventional screening to accelerated stress testing.

The need to lower costs and to take advantage of various reliability efforts in the electronics industry has recently prompted the U.S. military to begin a series of efforts to phase out military standards and to purchase Components Off The Shelf (COTS). The elimination of military standards does not diminish the need to strive for reliability; rather, it leaves open the means to achieve reliability. Without utilizing military specifications and standards, alternatives are needed to ensure that products are reliable, while their costs are kept down. That part of the electronics industry that has been relying on military reliability standards is also affected in the same way. The scope of Environmental Stress Screening for the military and space applications has also moved towards AST as the U.S. government buys components from commercial vendors. The environmental stress screening for electronic hardware (ESSEH) guidelines issued by the Institute of Environmental Sciences and Technology (IEST) has also attempted to expand its scope to encompass more progressive forms of AST [3].

For the telecommunications industry, a set of guidelines on Environmental Stressing was issued by Telcordia Technologies (the former Bell Communications Research Company – Bellcore), which had been the research and development arm for the regional telephone companies in North America [4]. Starting in 1994, the National Center for Manufacturing Science (NCMS) has also been sponsoring a team of electronic equipment manufacturers to evaluate the effectiveness of certain AST methods [5].

1.3 OVERVIEW OF THE AST HANDBOOK

This handbook is divided into a number of chapters dealing with various aspects of accelerated stress testing (AST).

Chapter 2 provides background on the concept of accelerated stress testing and lays the foundation for later discussions of the more practical aspects of the implementation of AST programs. The chapter begins with a rationale for accelerated stress testing based on the observation that many reliability problems are caused by inadequate design margins or variations in manufacturing processes or component quality. To create a reliable product, one must achieve robust design margins and tighten control of product variations. We observe that AST programs are of value chiefly in identifying and eliminating product deficiencies early in a product's life. Stress testing must be coupled with root cause analysis (RCA) and corrective action to achieve product robustness. We also explain that there are limitations to what can be achieved with stress testing, depending on the types of failure modes present in a product. We then discuss a series of technical issues regarding the implementation of AST. These technical issues include identifying the principal modes of performing AST and how they relate to each other, as well as milder forms of stress testing. We review the variety of stress stimuli that can be used in stress testing, and we note the types of failure mechanisms that they are most effective at addressing. We then explain how to determine an appropriate level of stress to use in an AST program and how to ascertain that the applied stresses are safe and do not damage good products. We also discuss approaches for better detecting faults stimulated by stress testing and provide preferences on the form of product to be tested. The economic benefits of AST and qualitative guidelines for optimizing the cost effectiveness of an AST program are discussed at the end of the chapter.

Chapter 3 presents a set of Best Practices for performing accelerated stress testing. We recommend a strategy for implementing accelerated stress testing so as to achieve maximum benefit. We explain that a number of options are available and that the development of an optimal AST program for a given product will depend on the nature of the product itself (how robust or unreliable it is, and what the principal failure modes are) and on the reliability objectives set for the product. AST is really an iterative process in which reliability data gathered at one stage of stress testing should be used to determine what should be done in a subsequent stage. We define the principal implementation modes for AST as follows:

- Design AST
- Manufacturing Qualification AST
- Periodic Qualification AST
- Production Sampling AST
- Full-Production AST

Each of these implementation modes is described as a macro-process consisting of a series of generic subprocesses. The generic subprocesses, which may be common to more than one of the above macro-processes, are:

- Plan Program
- Baseline Product

- Take Corrective Action
- Develop Manufacturing AST Regimen
- Demonstrate Safety of AST Regimen
- Perform Manufacturing AST
- Optimize Manufacturing AST Regimen

In presenting this methodology, a principal recommendation and working assumption is that reliability improvement efforts can best be carried out within the framework of a formally defined reliability program conducted by a multidisciplinary team. Such a program should include activities ranging from planning the program and conducting the tests on through root cause analysis of failures and implementation of corrective actions to eliminate problems found. These diverse activities require the participation of a variety of team members with component, design, test, and manufacturing responsibilities. In Chapter 4 we describe these generic subprocesses as a detailed series of tasks to be performed by a multidisciplinary team conducting a formal reliability program. Most of these tasks need to be carried out to perform an effective program, even if the program is not as rigorously defined as in this chapter.

Chapter 5 provides a set of Guidelines for Design and Manufacturing AST Qualification. Here we discuss in greater detail some of the more practical issues that are commonly encountered in planning and conducting an AST program, and we describe specific approaches and techniques that have been found to be particularly useful in testing electronic products or systems.

Chapter 6 describes some methods that provide a basis for optimizing accelerated stress testing programs. This chapter also presents some simple conceptual models that provide an improved understanding of various basic issues that are often raised in the electronics industry with regard to the effectiveness of accelerated stress testing.

Chapter 7 provides a theoretical basis for estimating the appropriate number of product samples that should be subject to AST in order to achieve a reliability goal.

Chapter 8 presents an overview for failure analysis for electrical components.

Chapters 9 through 13 present a practical overview of equipment and techniques that have been commonly utilized for accelerated stress testing. The types of stresses addressed in these chapters include air-based thermal, liquid-based thermal, vibration, and shock.

Chapter 14 describes the Guidelines for AST Safety Qualification. This chapter describes the sort of work that is performed to demonstrate that the stress levels used for a selected AST regimen are safe and do not damage good products. We discuss two principal approaches to safety qualification, namely, the direct safety qualification of a fully assembled product and the more generic qualification of the individual components that go into the product.

Chapters 15 and 16 describe helpful ways for AST practitioners to plan AST experiments and to analyze resultant failure data.

Chapters 17 through 21 provide some excellent case studies that illustrate the application of accelerated stress testing in the computer, communications, and consumer product industries. Because of the proprietary nature of much of the failure data obtained in reliability studies, much of the documented work on accelerated stress testing appears only in internal company publications and is not available for general presentation to the public.

TABLE 1.1 Type of AST and the Acronyms Used in Chapters 7, 11–13, and 15–21

Chapter	Author	Research—R or Safety—S	Design	Manufacturing Qualification	Periodic Qualification	Production Sampling	Full Production
7	Clifton Seusy		X	X	X	X	X
11	King Lo					X (EST)	X (EST)
12	Abhijt Dasgupta	R					
13	Paul Englert	S (LEST)	X (LEST)		X (LEST)		X (LESS)
15	Dennis Pachucki					X (ESS)	
16	Charles Schinner		X (ART)				X (ESS)
17	Donald Dalland		X (STRIFE)				X (ESS)
18	Edmond Kyser		X (HALT)		X (HASA)	X (HASA)	
19	Harry McLean					X (EST)	X (EST)
20	Paul Parker						X (HASS)
21	Kevin Granlund						

Chapter 22 illustrates how benchmarking techniques may be applied to AST.

Table 1.1 shows the type of AST demonstrated in each of each cases. This table also gives the different acronyms used by the individual authors when they refer to the different AST processes.

The cases in this book were selected for a variety of reasons. Some were chosen because they are frequently cited in the literature due to the seminal nature of the work, others because of the dramatic improvements realized by diligent usage of AST, and still others because of their unique or novel approach to stress testing.

A glossary of stress testing terminology is provided following Chapter 22. Some of the terms used in the field of stress testing may be confusing even to experienced reliability engineers because of the many variations in usage. We have attempted to delineate some of the most often used terminology in the glossary.

A bibliography of over 250 publications is presented at the end of the handbook. Prior to the 1990s, publications on stress testing were sparse, primarily because of the proprietary nature of much reliability work. And most of the prior published material was devoted to stress screening. In the early 1990s, publications in stress testing began to blossom with the wave of interest in improved quality and reliability. Today, papers on stress testing methods and results are appearing regularly in IEEE and IES publications and conference proceedings.

REFERENCES

[1] Proceedings of the 1996 Workshop on Accelerated Stress Testing, October 17–18, 1996, Ottawa, Ontario, Canada.

[2] Proceedings of the 1997 Workshop on Accelerated Stress Testing, October 15–17, 1997, Dallas, TX.

[3] Environmental Stress Screening Guidelines for Assemblies (1990), Prepared by the IEST ESSEH Technical Committee, 1990.

[4] Generic Requirements for Environmental Stressing Applied to Telecommunications Product, Document No. GR-2840, Telcordia Technologies, 1995.

[5] Environmental Stress Screening 2000 – Final Report, Report No. 0006RE 97, National Center for Manufacturing Sciences, April, 1997.