

Environmental Stress Testing

H. Anthony Chan
Paul J. Englert
Michael A. Olen
S. (Raja) Rajaram

Environmental stress testing (EST) is a means of systematically improving the reliability of electronic systems. In this paper, we discuss:

- The background and rationale for EST;
- The utility of accelerated testing to achieve robust design margins, high component quality, and well-controlled manufacturing processes;
- Various issues that must be addressed to make EST a safe and effective process, including the principal modes of implementation, the application of various kinds of stress stimuli and the associated faults that are precipitated, and the classification of failure types;
- Implementation issues, including methodology issues related to the stimulation and detection of failures, and the use of baseline experiments to determine the operational and destruct limits of a product, so as to arrive at a safe and effective EST regimen; and
- Economic issues, including the importance of failure mode analysis and corrective action to achieve a cost-effective EST methodology.

Introduction

Environmental stress testing (EST) is an effective method for improving product reliability. Products may often have hidden defects or weaknesses, which can cause failures during normal operation in the field. EST is a process in which environmental stress stimuli are applied to a product to turn such latent defects into observable failures. The EST process thus prevents defective product from being shipped to the field, and offers an opportunity to discover and correct weaknesses early in product life. The stress levels applied must be severe enough to precipitate the defects without causing damage to a good product or nucleating defects, which might cause early wearout and reduced life in the field. The application of EST accelerates the process of precipitation and detection of latent defects.

Environmental stress testing has its origins in the space program of the 1960's, which required 100% defect-free systems. While quality control was the ultimate objective, not much attention was paid to the cost of doing EST. Subsequently, in the 1970's, EST

was adopted by the defense electronics industries, which did much of the pioneering work to quantitatively establish the benefits of EST for quality control. Defense contractors are contractually obligated to perform EST on 100% of their final shipped products, which can be a costly process.

More recently, EST has been routinely applied in the commercial electronics industries, as well, and the number of commercial users is increasing at a rapid rate. While defense electronics industries apply EST as a contractual obligation, commercial industries have effectively applied EST as a tool for improving quality, while also making it more cost effective. IBM, Hewlett Packard, and Sun Microsystems routinely use EST during the qualification of new designs and the early manufacture of new products.¹⁻⁴ Within AT&T, effective EST-based, product-reliability improvement programs are being applied to a number of products.⁵⁻⁸

This paper provides a broad overview of the concept of EST as applicable to electronic systems. It also reviews various aspects of implementing EST that must be addressed

Panel 1. Acronyms Used in This Paper

EMI — Electromagnetic interference
ESD — Electrostatic discharge
ESS — Environmental stress screening
EST — Environmental stress testing
FMA — Failure mode analysis

to ensure it is a safe and effective process to achieve high quality. The "Background" section discusses the rationale for EST, and the concept of accelerated testing. "Technical Aspects of EST" describes various modes of implementing EST, and discusses the application of a number of stress stimuli and the faults such stresses precipitate, types of failures, and methodology issues related to the stimulation and detection of failures. "EST Implementation Issues" covers the need for robust design margins, establishing baseline operational and destruct limits of equipment to arrive at a safe and effective EST regimen, and the importance of failure analysis. The last section, "EST Economic Issues," discusses the sources of benefits, and some of the cost issues, related to EST.

Background

We will begin by first discussing the background and rationale for EST, and then reviewing the concept of accelerated testing.

Rationale for Stress Testing. Reliability problems are generally caused by poor design margins or excessive product variations. As illustrated in Figure 1, product failures may occur when the statistical distribution for a product's strength, or its capability of withstanding a stress, overlaps with the distribution of the operating-environment stresses.

To prevent product failures, reliability may be achieved through a combination of robust design and tight control of variations in component quality and manufacturing processes. Design enhancements increase a product's ability to withstand stresses, and stricter quality control in component and manufacturing processes tightens the product's capability distribution. Thus, when the product undergoes sufficient improvements, there will no longer be an overlap between the stresses encountered and product strength distributions, as is illustrated in Figure 2. As a result of this modification, field failures should be greatly reduced.

In general, it is desirable to improve product reliability by using environmental stress testing to reveal product deficiencies early in a product's life. Root-cause analysis can then be pursued to determine the causes of the deficiencies, and corrective actions can be quickly taken to eliminate any reliability problems. This product-improvement orientation is what differentiates EST from simply screening a product for defects—a process usually referred to as environmental stress screening (ESS).

EST and Accelerated Testing. Environmental stress testing generally involves applying an amplified or accelerated stress, usually in excess of the product's specified limits, to a potentially unreliable product to stimulate any latent defects to the point of detection. The stress conditions applied are not meant to replicate the stress conditions in a normal operating environment. Rather, they are designed to stimulate the failures that might be caused by stresses in that environment.

To this end, the use of accelerated test conditions offers several advantages. As illustrated in Figure 3, product variations are better revealed at heightened stress levels because a larger section of the failure distribution "tail" is exposed. Thus, for example, design margins may be quickly established using a small sample size. Another advantage of accelerated testing is that the time to achieve a given level of stressing may be dramatically reduced.

However, the stress levels used in EST must be selected so that they neither damage an otherwise good product nor significantly reduce the product's life. As shown in Figure 4, the intent of EST is to screen out defects that could lead to *infant mortality* without significantly wearing out the product. By determining the root cause of these early failures, and taking action to eliminate them, infant mortality in the field can be greatly reduced. It is important to understand that infant mortality often represents a weak sub-population of a product. This sub-population is normally well separated from the main, robust population. EST is intended to cause this weak sub-population to fail and, when properly applied, does not affect the main population.

Technical Aspects of EST

Environmental stress testing may be viewed from many perspectives. There are several issues of importance to the effective application of EST.

Modes of EST. There are several modes of doing

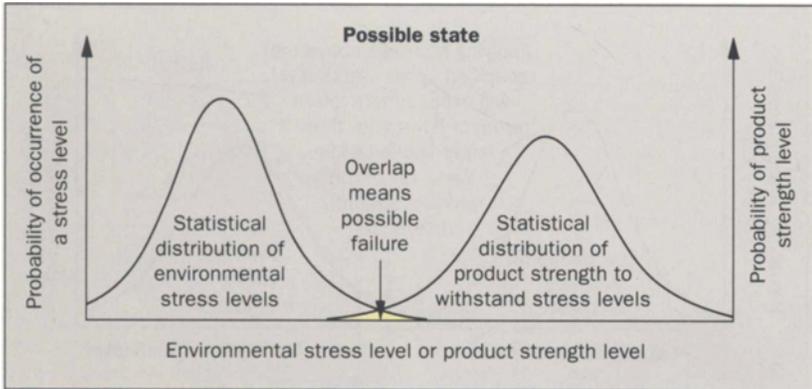


Figure 1. Typical probability distributions are shown for the operating environmental stress levels, and the product's strength or capability to withstand an environmental stress. This illustrates that product failures may occur when the statistical distribution for a product's strength overlaps with the distribution of the operating environment stresses.

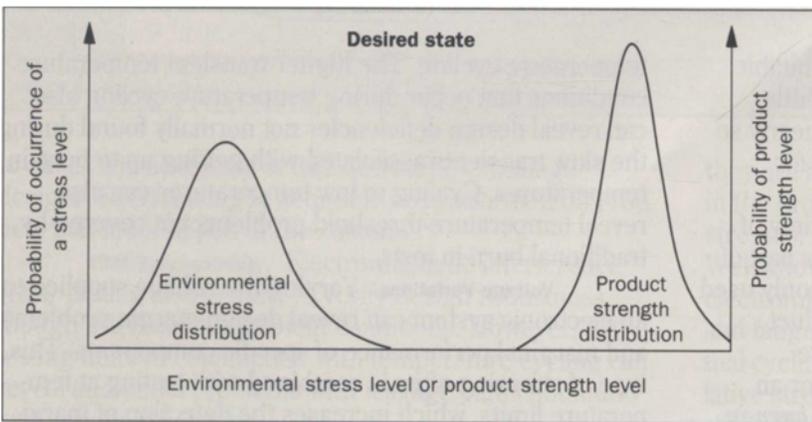


Figure 2. Desired distributions for environmental stress and product strength illustrate that when a product undergoes sufficient improvements, there will no longer be an overlap between the stresses encountered and the product's capability to withstand those stresses. Thus, field failures will be eliminated.

EST. We will discuss them in the order of descending desirability.

Design Qualification EST. A product is tested near the end of the design stage to see if it is robust with respect to stress levels in excess of those likely to be encountered in the operating environment. If deficiencies are found, the root cause is determined and corrective actions are taken to fix the underlying causes of the problem. This is the most productive mode of doing EST, because the benefits are realized over the whole life of the product.

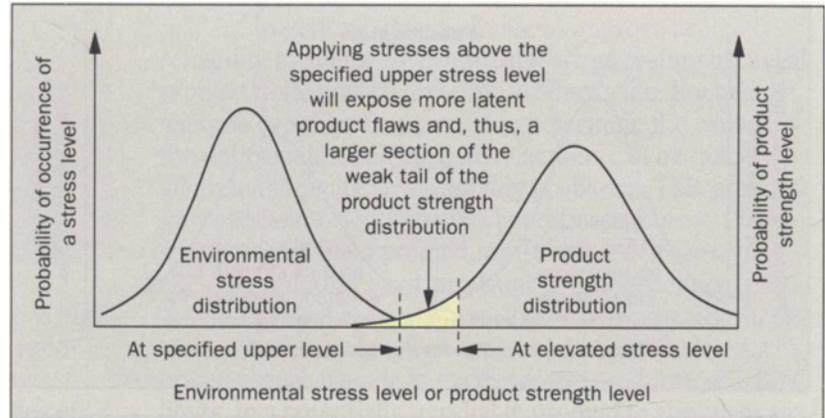
Manufacturing Qualification EST. A representative sample of a product is subjected to EST, during the manufacturing ramp-up, to identify any deficiencies in component quality or manufacturing processes. In addition, design-margin deficiencies that did not show up in design qualification EST may be found. The emphasis again is on failure mode analysis (FMA) and corrective action, so that deficiencies in the product can be quickly eliminated before production volumes become large.

Production Sampling EST. For products requiring high reliability, it is useful to continue to perform EST on a sampling basis, to monitor production for process or component quality variations, even after the products have satisfactorily passed the design-qualification testing. The emphasis continues to be on determining the root cause of any problems found, and taking corrective action to correct them.

Ongoing EST. Sometimes EST is performed with the intention of doing good FMA, and quickly correcting any problems found, but quality problems continue to persist. For a high-reliability product, it may still be economically feasible to continue to do EST on an ongoing basis, with some degree of FMA and corrective action, but this mode is certainly less desirable than the approaches mentioned above.

Ongoing ESS. Traditionally called environmental stress screening (ESS), this approach is directed mostly at sorting the good product from the bad, which is then repaired. But little emphasis is put on FMA and taking

Figure 3. A comparison of testing at specified and accelerated stress levels illustrates that product variations are better revealed at heightened stress levels, because a larger section of the failure distribution "tail" is exposed.



corrective action. Although this mode may be suitable for limited production volumes, where there is little opportunity for product improvement, it is not nearly so productive as the approaches mentioned above for higher-volume products.

Stress Stimuli and Flaws. There are a variety of stress stimuli that can be applied to a product as part of an EST regimen. We will review the most commonly used stimuli here, and note some of the types of product deficiencies they are likely to stimulate to failure.

Elevated Temperature. Testing a product for an extended period at an elevated temperature, or *burn-in*, is probably the most common form of stress testing. Marginal product designs often exhibit a temperature threshold above which the product will not function satisfactorily. Failure modes that involve chemical or diffusion processes can often be effectively accelerated at elevated temperatures. However, for many electronic products, there is a tendency to test the product only to the nominally specified upper temperature limit. Testing beyond the nominal temperature limit is productive, however, since one can better assess the robustness of the product.

Power Cycling. Turning a product on and off is another common form of stress testing, and it is commonly done in conjunction with other types of stress testing. The temperature transients that occur during *power-up* can often stimulate thermo-mechanical defects. For electronic systems involving possible variable conditions resulting from an abrupt shut-down, on/off powering also may reveal design deficiencies.

Temperature Cycling. A number of interconnection and packaging failure modes may best be stimulated by

temperature cycling. The higher transient temperature conditions that occur during temperature cycling also can reveal design deficiencies not normally found during the slow transients associated with getting up to burn-in temperatures. Cycling to low temperatures can also reveal temperature-threshold problems not covered by traditional burn-in tests.

Voltage Variations. Varying the voltage supplied to an electronic system can reveal design-margin problems and marginal performance of specific components. This type of stressing often is combined with testing at temperature limits, which increases the detection of marginal conditions.

Clock Variations. Varying the clock rate can reveal timing-margin problems. This type of stressing is often difficult to achieve, however, because of the high degree of integration of clocks in the product circuitry. Often, special design provisions must be made for such tests to be feasible.

Vibration and Mechanical Shock. Vibration or mechanical shock stressing has traditionally been used to reveal structural-support problems; problems in securing specific, often large or heavy, components; and connectorization and cabling problems. In addition, problems with surface-mount solder joints are also increasingly being addressed using vibration testing.

Elevated Humidity. Elevated-humidity testing is usually done in conjunction with high-temperature testing to reveal problems with corrosion or high-voltage isolation breakdown. Extended testing is often required to get results.

ESD and Power Surge. Specialized testing is often done for electrostatic discharge (ESD) and power surges

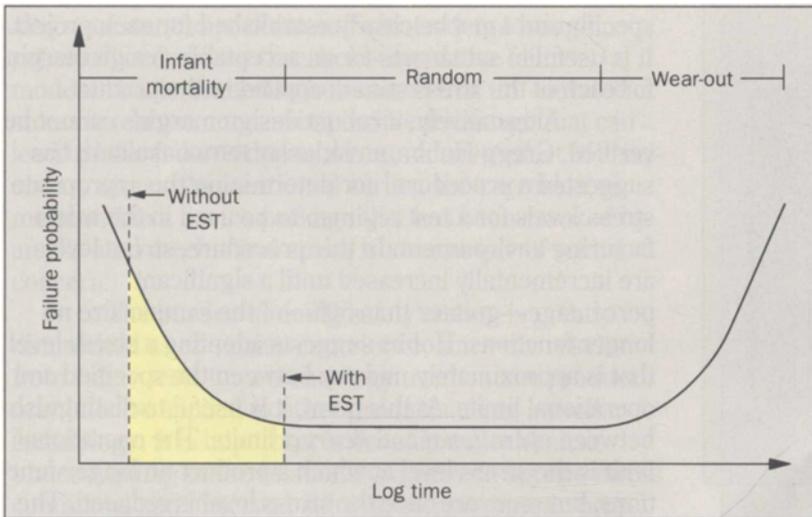


Figure 4. The classical product lifetime, or bathtub failure curve, illustrates that the intent of EST is to detect and screen out defects that could lead to infant mortality—without significantly contributing to the wearout of the product.

to check the adequacy of isolation and grounding designs. Such testing is generally not performed on products that are shipped to the customer.

EMI Susceptibility. Electromagnetic interference (EMI) testing also is done to verify design robustness, though often only at ambient conditions. However, EMI testing done in conjunction with temperature cycling can reveal additional problems with leakage paths not found under static conditions.

Types of Stress Failures. Products that are under stress may fail in different ways. The most appropriate way to perform EST on a product will depend on the nature of the failure modes. We will now consider three principal types of stress failures.

Threshold Stress Failure. A product typically exhibits a statistically distributed strength to withstand a given stress, as is illustrated in Figure 1. In the simplest case, a failure occurs in a specific product sample when the stress level exceeds the threshold strength of the sample. Examples of the threshold strengths are the mechanical strength of a brittle material, or the temperature level at which an electronic component begins to malfunction. A screening process at a certain stress level may sort out the weak products without damaging or wearing out the good products, which possess a threshold strength higher than the screening stress level.

Cumulative Stress Failure. Some failures occur under the cumulative effects of repeated low-level stressing. Although these stresses may be well below the level that would cause immediate product failure, each time

they are applied they produce some irreversible changes in the product. Thus, after repeated exposure to these stresses, the cumulative change grows to a failure level. Well-known examples of cumulative-stress failure are electromigration in a device under high-current density, and fatigue failure of solder joints due to extended thermal cycling. Screening weak products by applying cumulative stress is appropriate only when the product strength of the main population is much higher than that of the weak sub-population..

Combined Threshold-Cumulative Failure. Besides threshold stress and cumulative stresses, a combination of these may also stimulate certain failure modes. Thus, a high peak stress might initiate an incipient failure that later results in a hard failure due to cumulative stresses. For example, a device with a cracked package may be able to operate for a time, but may be vulnerable to future failure due to subsequent corrosion. Thus, the use of high stress to screen out weak products must be done with caution. If the incipient failure, such as the cracked housing induced by exceeding the threshold strength, is not driven to an observable failure, a later field failure may occur.

EST Implementation Issues

The following section discusses the selection of an appropriate stress testing regimen, how one demonstrates that the selected regimen is safe for a good product, and alternate schemes for detecting faults stimulated by the applied stress regimen.

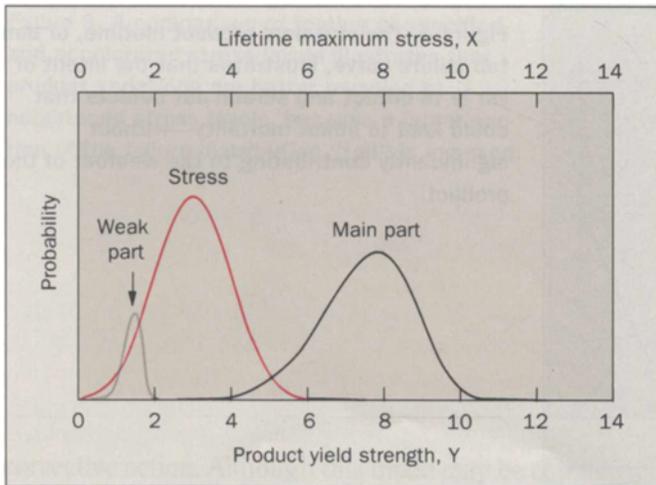


Figure 5. This illustration shows a bimodal product strength distribution, shown as a solid line, having a weak sub-population. This population is significantly lower in strength than the main part of the product population's strength distribution. This population also is weak relative to the distribution of the maximum lifetime stresses, shown by the red line, that the product may encounter during its life.

Stress Stimuli Selection. In planning an EST program, one of the first tasks is to decide what stress stimuli should be employed in examining the reliability of a given product. During design qualification EST, it is advisable to use a fairly wide spectrum of stress stimuli. However, in a production environment, where the cost of performing EST can be quite large, it is advisable to focus on those areas found to be of significance in design qualification testing, or which address the types of failure modes being found in the field for similar products.

Stress Level Determination. Once the relevant stimuli have been selected, appropriate stress application levels must be determined for a test regimen. During design qualification EST, one of the primary objectives is to verify that satisfactory design margins have been realized. For example, let's consider a printed circuit board that is designed to operate as part of a highly reliable system in a 0°C to 50°C environment. Guidelines established for how the system performs above, or below, these specified temperature limits regard 10°C beyond the specified limit as "marginally robust," 20°C beyond as "acceptable" or "robust," and 30°C beyond as "excellent" or "very robust." Margins should be product-

specific and must be clearly established for each project. It is useful to set targets for an acceptable design margin for each of the stress stimuli applied to the product.

Alternatively, if robust design margins cannot be verified, Gregg Hobbs, an industry EST consultant, has suggested a procedure¹ for determining the appropriate stress levels for a test regimen to be used in the manufacturing environment. In this procedure, stress levels are incrementally increased until a significant percentage—greater than 50%—of the sample size no longer functions. Hobbs suggests adopting a stress level that is approximately midway between the specified and operational limits. At this point, it is useful to distinguish between *operational* and *destruct* limits. The operational limit is the stress level at which a product no longer functions, but recovers once the stress level is reduced. The destruct limit is the stress level at which a product fails, but does not recover even when the stress level is reduced.

Regardless of which method is used, determining the stress level for robust design must be viewed as an *iterative* process. Hence, it may be necessary to repeat the process through the following loop several times:

- Stress and test product,
- Analyze failures,
- Take corrective action to eliminate the failures, then
- Re-test the improved design.

Safety Testing. EST should precipitate flaws in a marginal product before it is shipped from the factory, but it should not induce flaws or failure modes that normally would not be present in a good product. In addition, the useful life of a product should not be diminished by EST. To prevent this from happening, safety testing should be applied to the candidate regimen.

The preferred safety test method for a manufacturing stress test is to repeatedly apply a candidate stress testing regimen "X" to a product until failure can be shown to occur beyond some level, "Y," where "Y" is much larger than "X." For example, suppose a candidate regimen of 10 thermal cycles is proposed. Then, if experiments are conducted showing that more than 1000 thermal cycles are needed to eventually "break" the product, one may reasonably conclude that the proposed regimen of 10 cycles will not significantly reduce the useful life of any good product.

In using highly accelerated stress testing, it is

also necessary to perform sufficient safety testing on potentially combined threshold-cumulative failure modes. This is needed to be assured that the elevated stress levels are not causing incipient damage that can lead to later failures due to the cumulative effect of a secondary stress. As mentioned earlier, the corrosion of metal within a device package that has been cracked by an elevated mechanical stress is an example of such a concern.

The burden of doing safety testing is greatly diminished as one gains experience, since the results from safety tests for a technology used on one product may later be applied to other products using a similar technology. It is important to develop a mechanistic understanding of the relationship between applied stress conditions and observed failures, so that one can properly judge when it is appropriate to extrapolate previous safety testing, and when additional testing is required.

Stimulation/Detection Schemes. In performing EST, fault stimulation and fault detection may be concurrent or sequential. The three stimulation and detection schemes are as follows:

- *Passive* - Unpowered stressing, with later fault detection.
- *Static* - Powered, but electrically non-functioning while stressing, with later fault detection.
- *Dynamic* - Powered and electrically functioning during stressing, with concurrent fault detection.

Intermittent failures tend to comprise a significant percentage of overall failures. Therefore, one should strive to do dynamic testing, if possible.⁴⁻⁸ It may be quite productive, however, to "precondition" a product with a low-cost, passive- or static-stress regimen to help precipitate failures, followed by an abbreviated dynamic-stress test aimed principally at detection. Preconditioning may be done selectively to only those elements of a system for which it is most productive. However, the detection phase of EST generally is most effective if it is applied to the smallest, fully testable part of a system.

EST Economic Issues

The next section reviews some of the principal factors that impact on the economic benefits and costs associated with an effective EST program.

Benefits. A principal direct benefit of an EST program is a reduction in warranty repair costs. For high-

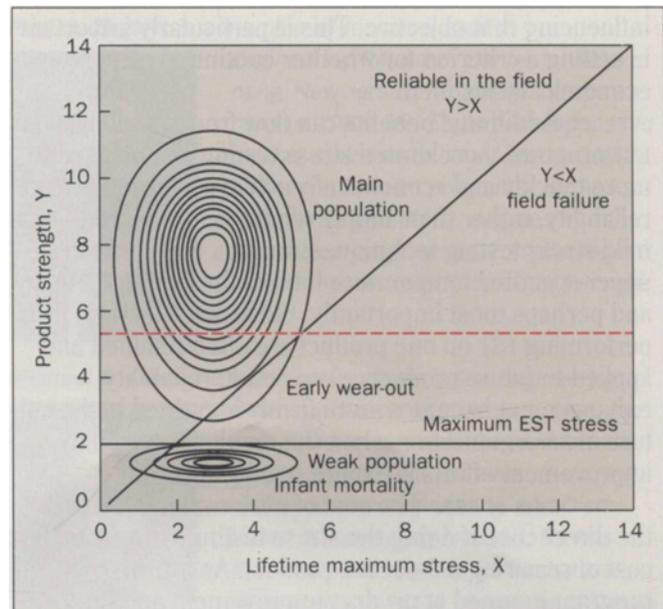


Figure 6. This contour plot shows the joint probability that a specific product having strength "Y," characterized by a product strength distribution, will experience a lifetime maximum stress, "X." The plot shows the part of the product population that is subject to field failure (including infant mortality of the weak sub-population and early wear-out of the weak tail of the main population), and how the application of EST reduces potential field failures by finding weak product before it is shipped.

quality products, however, a more important benefit may be in meeting—or exceeding—customer expectations for a highly reliable product, leading to increased sales and market share. For certain products, such as computers or telecommunications systems that may be critical to a customer's revenue stream, a product failure may result in substantial losses. The cost to the customer for redundant capacity, or maintenance capabilities to avoid such losses, can be substantial. For such situations, high reliability can be a significant factor for a customer in making a decision to buy a product. In other markets, such as consumer products, a customer may buy a product based principally on cost or features, provided the reliability is acceptable.

In order to plan an appropriate EST program, it is important to have a clearly defined reliability objective for a product, and to understand the economic factors

influencing that objective. This is particularly important in setting a criterion for whether continued screening is economically justified.

Additional benefits can flow from a well-planned EST program. Accelerated stress testing can be used to more quickly and economically achieve a target level of reliability, rather than simply relying on more traditional mild-stress testing techniques, such as burn-in at the upper-specified temperature limit of the product. Finally, and perhaps most importantly, the lessons learned from performing EST on one product are often retained and applied to future products. As a result, reliability enhancement becomes more firmly ingrained in the culture of an organization when the results of reliability improvement efforts are more readily apparent.

Cost of EST. The cost of performing EST involves the direct cost of doing the stress testing, as well as the cost of repairing a defective product. An effective EST program is aimed at product improvement and the associated costs of performing failure-mode analysis, however, and taking corrective action to fix problems should also be factored into the total EST program cost. For design qualification and manufacturing qualification EST programs, these latter costs for FMA and corrective action may far exceed the more direct costs of performing stress testing and repair. Nonetheless, improving the reliability of a product early in its life is the best way to achieve highly leveraged economic benefits.

Optimizing the Application of EST. It is often difficult to judge the most appropriate extent of an EST program, since it is difficult to project the relationship between failures found through EST and the probability that these failures would have occurred in the field. To illustrate this difficulty, we return to a discussion of the statistical distributions of a product's strength and the stress encountered in the field. Figure 5 shows a bi-modal product-strength distribution which, for illustrative purposes, has a significantly weak population that is distinct from the main population. We will consider that the early failures showing up in the bathtub curve in Figure 4 are principally associated with this weak population.

Now consider Figure 6. This is a contour plot showing the joint probability that a specific product of a given strength will experience a maximum stress of a given level during its product life (called lifetime maximum stress). The population lying to the lower-right of the diagonal line is subject to failure in the field because

the lifetime maximum stress level, "X," exceeds the strength, "Y." The population to the upper-left of the diagonal will not fail in the field because the strength exceeds the lifetime maximum stress to which it is exposed. Thus, even a weak product may survive a relatively benign stress environment.

An object of EST is to precipitate failures in the weak population. The appropriate stress level to achieve this is shown as the solid horizontal line in Figure 6. As seen in this figure, however, this stress level does not catch the lower-right part of the main population that will fail in the field because it happens to experience an abnormally high-stress level. If we raise the EST stress level to the level shown by the dashed line, in an attempt to eliminate this part of the population, we then fail a significant portion of the main population that, though relatively weak, would nonetheless survive in a typical stress environment. Thus, we see that the main population must be very robust with regard to the stress levels required to screen out weak and predominantly unreliable product. Otherwise, a stress screen may fail substantially more product than would fail in the field.

We can thus conclude that, to economically achieve high reliability, a product must be robust with regard to the stress levels encountered in an operational environment. If it isn't, stress screening may be a costly way of trying to achieve high reliability. EST is principally of value in helping to achieve a robust product through product improvement and, if very high reliability is required, in screening out a small, weak population that is well separated from a robust main population.

Summary

The use of EST is increasing rapidly among commercial electronics companies. The concept of EST is the application of accelerated stresses—usually beyond product specifications—to stimulate potentially weak products to detectable failures. This is followed by root-cause analysis and corrective action to eliminate the cause of failures, thereby ensuring a robust product.

Acknowledgments

This paper has drawn on contributions from many AT&T design and manufacturing engineers who have been active in the implementation of EST programs, as well as engineers in other companies practicing EST, and industry consultants on stress testing.

References

1. G. K. Hobbs, "Development of Stress Screens," *Proceedings of the Annual IEEE Reliability and Maintainability Symposium*, Philadelphia, Pa., January 1987, pp. 115-118.
2. C. J. Suesy, "Achieving Phenomenal Reliability Growth," *Proceedings of the American Society of Metals (ASM) Reliability Conference*, Los Angeles, Calif., March 1987, pp. 79-88.
3. C. Shinner, "The Board Electronic STRIFE Test (B.E.S.T.) Program," *American Society of Quality Control Reliability Review*, June, 1988, pp. 3-6.
4. D. Pachucki, "Environmental Stress Screening Experiment Using the Taguchi Method," *Institute of Environmental Sciences Proceedings*, May, 1993.
5. T. P. Parker, "ESS Case Study of a High Density Surface Mount Circuit Card," *1991 Proceedings of the Institute of Environmental Sciences*, pp. 393-402.
6. T. P. Parker, "A Study of Failures Identified During Board Level Environmental Stress Testing," *IEEE Transactions on Components, Hybrids, and Manufacturing Technology*, Vol. 15, No. 6, pp. 1086-1092, December, 1992.
7. F. LoVasco and K. Lo, "Relative Effectiveness of Thermal Cycling vs. Burn-in," *Proceedings of the 42nd Electronic Components and Technology Conference*, San Diego, Calif., May, 1992.
8. B. P. Beaton, "Thermal Accelerated Reliability Go-No-Go Environmental Testing Dynamic Board Thermal Shock Using A Single Fluid And Bath," *Proceedings of the IEEE Components, Hybrids, and Manufacturing Technology (CHMT) and the International Electronics Manufacturing Technology (IEMT) Symposium*, San Francisco, Calif., Sept. 1991.

(Manuscript approved December 1993)

H. Anthony Chan is a member of technical staff in the Engineering Research Center in Whippany, New Jersey. He joined the company in 1986. Mr. Chan is responsible for performing research on product-reliability improvements using environmental-stress testing (EST). He has a B.S. degree in physics from the University of Hong Kong, an M.S.E.E. degree from the Chinese University of Hong Kong, and a Ph.D. in physics from the University of Maryland in College Park.



Paul. J. Englert is a member of technical staff in the Engineering Research Center in Whippany, New Jersey. He joined the company in 1988. Mr. Englert is responsible for the implementation of product reliability improvement programs. He has B.S., M.S., and Ph. D. degrees in mechanical engineering from Carnegie Mellon University in Pittsburgh, Pennsylvania.



Michael A. Oien is a technical manager in the Engineering Research Center in Whippany, New Jersey. He is responsible for product reliability improvement, systems packaging, and assembly engineering. Mr. Oien joined the company in 1967. He has B.S. and M.S. degrees in mechanical engineering from the University of Cincinnati in Ohio, and Brown University in Providence, Rhode Island, respectively, and a Ph. D. in engineering mechanics from Cornell University in Ithaca, New York.



S. (Raja) Rajaram is a distinguished member of technical staff in the Engineering Research Center in Whippany. He joined the company in 1982. He is responsible for the implementation of product reliability improvement programs and consults on the thermal and electrical performance of electronic systems packaging. He has a B.S. degree in mechanical engineering from Bangalore University in Bangalore, India, an M.S. degree in mechanical engineering from the University of Waterloo, in Waterloo, Canada, and a Ph.D. in engineering science from the State University of New York at Buffalo, New York.

