No Evidence of Correlation Between Field Failures and Traditional Reliability Prediction Methods

Kirk A. Gray
©2026 Accelerated Reliability Solutions, L.L.C.

Revised 5/15/2026

Abstract

For decades, electronic reliability engineering has relied heavily on predictive methodologies intended to estimate product failure rates and operational life expectancy using statistical and probabilistic models. Many of these approaches originate from methodologies developed during the early years of electronic system development, including MIL-HDBK-217 and related derivative tools. However, despite widespread historical adoption, there remains limited publicly available empirical evidence demonstrating a consistent correlation between predicted reliability metrics and verified field-return behavior in modern electronic systems. This paper examines the limitations of traditional reliability prediction methodologies and argues that manufacturing variation, latent defects, insufficient design margins, unforeseen system interactions, and process-related weaknesses instead dominate many real-world electronic failures. The paper further discusses the growing importance of stress- and margin-based methodologies, such as Highly Accelerated Life Testing (HALT) and Highly Accelerated Stress Screening (HASS), which focus on identifying and eliminating weak links rather than statistically predicting failures.

Keywords— reliability engineering, MIL-HDBK-217, HALT, HASS, accelerated stress testing, field failures, electronics reliability, design margin

I. INTRODUCTION

Traditional electronic reliability engineering has historically been founded on two central assumptions:

1. The operational life or probability of failure of complex electronic systems can be estimated or mathematically predicted.
2. Product reliability can be improved through probabilistic calculations based on component failure-rate models.

These assumptions have shaped reliability engineering practices for decades and continue to influence portions of the aerospace, defense, telecommunications, and commercial electronics industries. However, despite extensive use of predictive reliability methodologies, there remains little publicly available field-failure data demonstrating a strong correlation between calculated reliability predictions and actual field-return performance.

This paper examines the historical foundations and limitations of traditional reliability prediction methodologies. It discusses the growing importance of empirical, stress-based approaches for identifying latent weaknesses and insufficient design margins.

II. HISTORICAL DEVELOPMENT OF RELIABILITY PREDICTION

The modern framework for electronic reliability prediction emerged during the 1950s. One of the earliest publications was RCA TR-1100, *Reliability Stress Analysis for Electronic Equipment*, released in November 1956, which introduced methods for estimating component failure rates. This work was followed by the *RADC Reliability Notebook* in 1959 and later by MIL-HDBK-217, which became the dominant reliability prediction framework for electronic systems.

Many modern reliability prediction software tools remain direct descendants of the MIL-HDBK-217 methodology. These approaches generally assume that electronic unreliability is primarily driven by intrinsic component failure mechanisms influenced by environmental stress factors, particularly temperature.

Most prediction methodologies incorporate Arrhenius-based acceleration assumptions, which suggest that failure rates increase exponentially with temperature and are frequently approximated by the rule that failure rates double for every 10 °C increase in operating temperature.

However, MIL-HDBK-217 was officially removed as an active military handbook in 1996 and has not undergone substantial modernization to keep pace with current semiconductor technologies, manufacturing processes, or modern high-speed digital architectures.

III. LIMITATIONS OF TRADITIONAL PREDICTION MODELS

A significant challenge in validating reliability prediction methodologies is the lack of publicly available field-failure data. Verified failure analysis results and root cause investigations are among the most confidential information maintained by manufacturers. Except in rare legal, regulatory, or public-safety circumstances, these data are seldom released publicly.

As a result, the broader reliability engineering community rarely gains access to sufficiently large empirical datasets to validate or refute long-standing predictive assumptions.

Engineers involved in field-return investigations frequently observe that many failures occurring before technological obsolescence are associated with factors such as:

- manufacturing process defects,
- assembly variation,
- insufficient design margins,

- unforeseen system interactions,
- latent weaknesses,
- marginal signal integrity,
- and accidental overstress or misuse.

These failures are often driven by interacting variables and process deviations that were unknown during design qualification and cannot be adequately represented by component failure-rate summation models.

In practice, many organizations have observed a weak correlation between predicted reliability values and actual field-return behavior. This observation raises an important question: if dominant failure mechanisms are associated with latent defects, manufacturing variation, and margin deficiencies, can system reliability truly be predicted using traditional probabilistic models alone?

IV. TRANSITION TO STRESS- AND MARGIN-BASED RELIABILITY METHODS

An alternative reliability engineering philosophy has emerged through methodologies such as Highly Accelerated Life Testing (HALT) and Highly Accelerated Stress Screening (HASS). Unlike traditional prediction approaches, these methodologies focus on discovering and eliminating weak links through controlled stress-to-failure testing.

The primary objective of HALT and HASS is not to estimate statistical life expectancy, but rather to determine the operational and destructive limits of a product and improve those margins before production release.

This represents a fundamental shift in engineering perspective:

- from time-based reliability metrics,
- to stress- and margin-based robustness metrics.

Organizations implementing HALT and HASS methodologies frequently identify latent weaknesses much earlier in the development cycle. These methods can accelerate product maturity, reduce field failures, and improve manufacturing robustness by exposing defects and insufficient margins before volume production.

Additionally, production-level stress screening methods can help reduce variability introduced by manufacturing processes and supply chain inconsistencies.

V. DISCUSSION

The continued use of legacy prediction methodologies may partly reflect institutional inertia and the lack of accessible, large-scale empirical field-failure databases. In many industries, reliability prediction remains a contractual or procedural requirement even when correlation with actual field performance is uncertain.

By contrast, empirical stress-based methodologies focus directly on discovering failure mechanisms rather than mathematically estimating them. This distinction becomes increasingly important in modern electronic systems characterized by:

- extremely high integration densities,
- high-speed digital signaling,
- complex software-hardware interactions,
- advanced semiconductor packaging,
- and globally distributed manufacturing processes.

Under these conditions, system failures are often dominated by complex interactions and process variability rather than simple intrinsic component wear-out mechanisms.

VI. CONCLUSION

Traditional electronic reliability prediction methodologies were developed during an earlier technological era and were based on assumptions that may not adequately represent modern electronic systems. Despite decades of use, little publicly available evidence demonstrates a consistent correlation between predicted reliability metrics and actual field-return behavior.

Many real-world electronic failures appear to be driven primarily by latent defects, manufacturing variation, insufficient design margin, and unforeseen system interactions rather than by statistically predictable intrinsic component failure rates.

Stress- and margin-based methodologies such as HALT and HASS provide an alternative approach focused on identifying and eliminating weak links before field deployment. In modern electronics, reliability may be determined less by the ability to predict failures statistically and more by the ability to expose and eliminate latent weaknesses before products reach customers rapidly.

References

[1] RCA, *Reliability Stress Analysis for Electronic Equipment*, TR-1100, Nov. 1956.

[2] Rome Air Development Center, *RADC Reliability Notebook*, 1959.

[3] U.S. Department of Defense, *MIL-HDBK-217: Reliability Prediction of Electronic Equipment*, various revisions.

[4] G. K. Hobbs, *Accelerated Reliability Engineering: HALT and HASS*, Hobbs Engineering, 2000.

[5] C. M. Creveling, J. L. Slutsky, and D. Antis Jr., *Design for Six Sigma in Technology and Product Development*. Upper Saddle River, NJ, USA: Prentice Hall, 2002.