

## MTBF and Prognostics – Comparison

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The major objective for engineers is to design reliable systems that meet the stated requirements. No engineer or project team sets out to design a system that fails, but with growing complexity in electronic systems, the impact of component or module failure becomes more likely. The first question is how long a system will survive in its targeted environment. In the past, engineers have utilized mean time between failures (MTBF) calculations. This first-level estimate is not adequate for critical systems. Fortunately, there are tools and solutions available to mitigate these effects.

### Mean Time Between Failures (MTBF)

MTBF, or mean time between failures, has been an accepted method of estimating the lifetime of a system. A specification may state the MTBF objective as, for example, 5,000 hours at 25 °C. For many years, reliability tables from Rome Air Development Center (RADC) or Bellcore provided data that was used to form the foundation for these estimates. These estimates are largely derived from the parts population, so the more parts in a system, the shorter the MTBF. Or to look at it another way, the fewer the parts, the longer the MTBF. Temperature acceleration could be accommodated, but omitted are other environmental aging effects such as radiation, vibration, shock and other factors that reflect the targeted use environment.

A typical bell-shaped curve is shown in Figure 1.

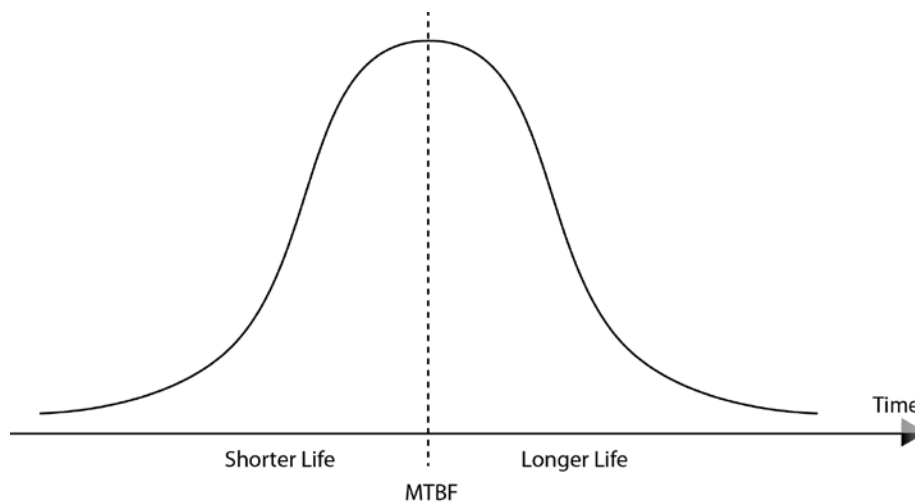


Figure 1: Statistical distribution of lifetimes, with MTBF indicated

In observing the curve, there are several limitations to note:

- 1) The distribution is a nicely formed bell-shaped curve, yet real-life component selection methods will make that assumption invalid. For example, selected components within 1% or 5% of their rated value, that are removed from distributions, create bifurcated distortions in the distribution of non-selected components from the production lot.
- 2) No accounting of actual use after the MTBF estimate is made, since the MTBF is largely drawn from parts populations, and not design rules. Thus, a system used in a harsh environment in Afghanistan will carry the same MTBF estimate as a system in a benign U.S. or European environment.
- 3) The distribution curve also has long asymptotic tails on both sides of the bell. So there is a non-zero probability of failure well before the MTBF milestone. Although good design

centering methods may have been employed, producing a long MTBF for the system, there is still a likelihood of a fault or failure that will affect system performance. If the unit is placed into a critical system, a catastrophic failure can occur. A production run may have 8 million units, yet 16 to 20 units fail due to being “outliers”. The role of prognostics is to help detect the onset of degradation before the fault becomes catastrophic.

## Prognostics

Prognostics, or predictive diagnostics, is the capability to detect the onset of failure before it occurs. Ridgetop Group has pioneered the development of advanced methods of detecting physics-of-failure-based indications of impending failure. Ridgetop’s approach deals with the extraction of unique “signatures” that are correlated to the impending failure condition.

There are five levels within electronic systems where degradation or faults can occur (Figure 2). The key items that should be monitored for degradation are determined using a Pareto ranking approach. This approach ranks expected failure rates with frequency of occurrence.

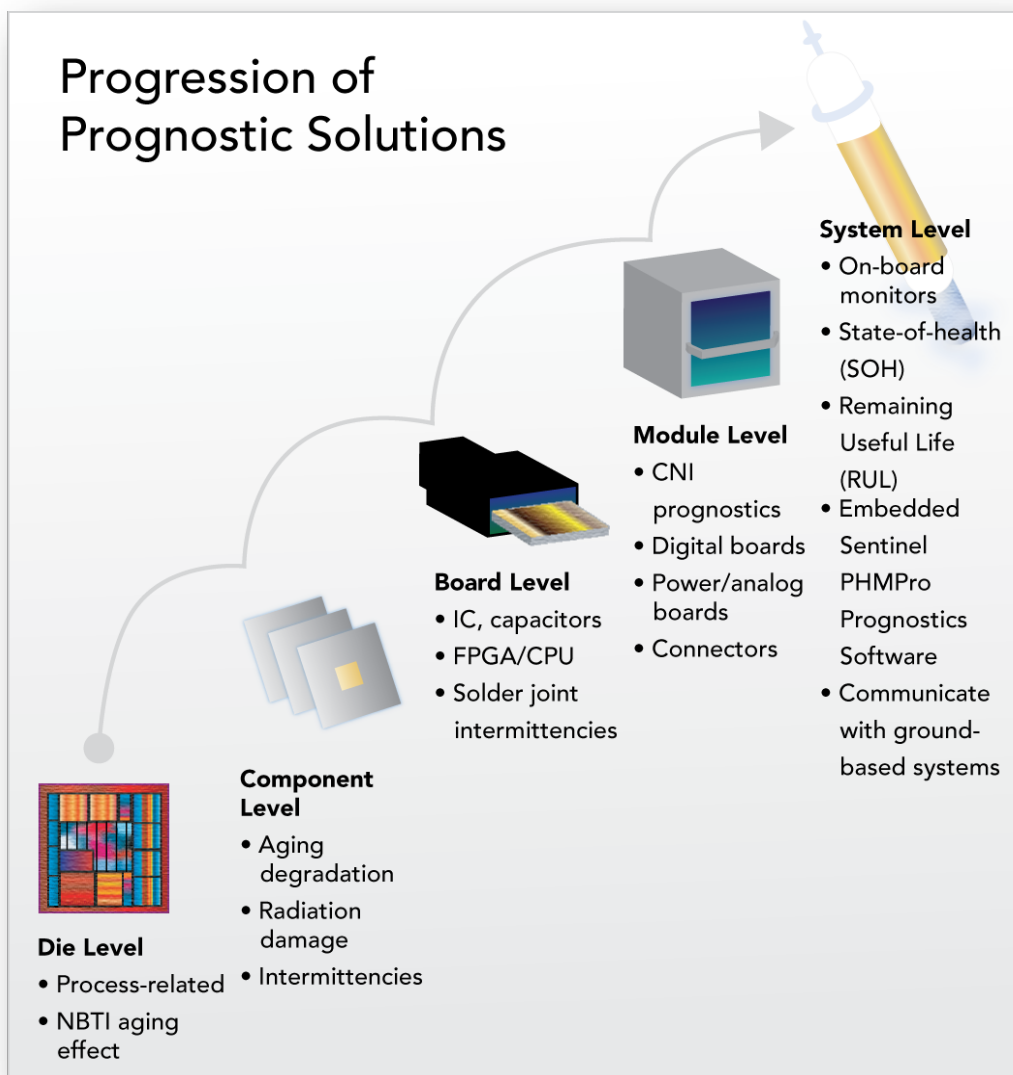


Figure 2: Electronic components can be ranked in a hierarchal manner, leading to their position within a system; all components are subject to degradation or faults

Unlike MTBF, which is largely statistical in nature, prognostics relies upon measured “signatures” that show physical evidence of degradation, and lead to catastrophic failure (unless otherwise mitigated), as shown in Figure 3.

The general concept is to determine where a particular system fits on the state-of-health degradation curve. This curve “maps” the extracted degradation information to a specific position on this curve, as shown in Figure 3.

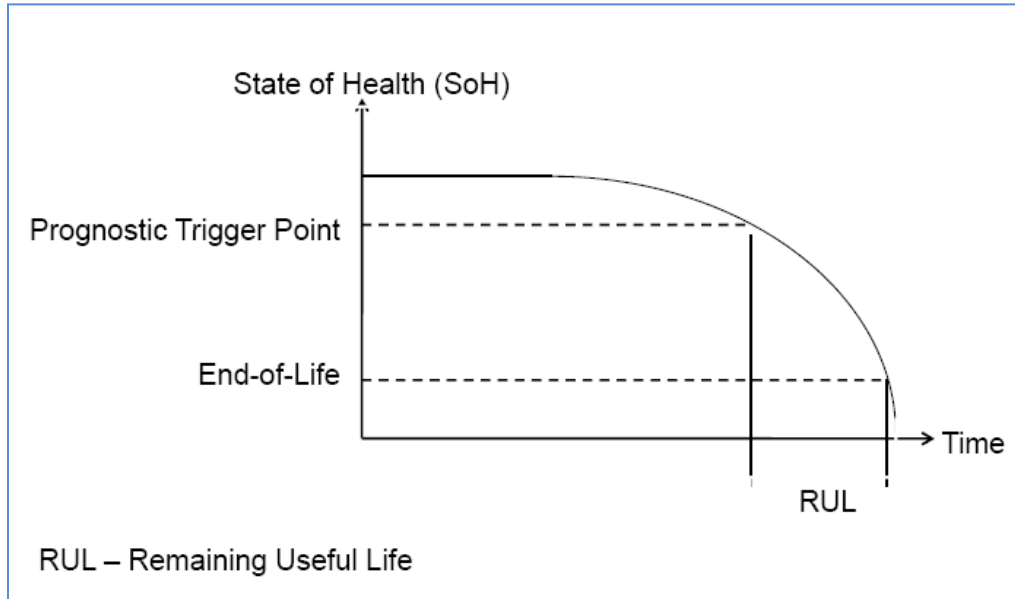


Figure 3: State-of-health curve for electronic systems

Ridgetop has developed unique extraction methods and processing algorithms to position particular points on the degradation curve. This is separated into a three-step process, with sensing and data collection, processing with algorithms, and presentation of state-of-health (SoH) and remaining useful life (RUL). This left-to-right flow is shown in Figure 4.

<b>Extract signature of degradation:</b>	<b>Collect data and process using algorithms:</b>	<b>Prognostic results:</b>
<b>RingDown™</b> <b>SJ BIST™</b> <b>DigIO™</b> <b>Sentinel Silicon™</b> <b>(Canaries)</b> <b>Direct measurements</b>	<b>ARULE™</b> <b>ATTF™</b>	<b>State of health (SoH)</b> <b>Remaining useful life (RUL)</b>

Figure 4: Prognostics foundation is built upon a solid foundation of physical evidence of degradation

The display of results utilizes Sentinel Network™, as shown in Figure 5.

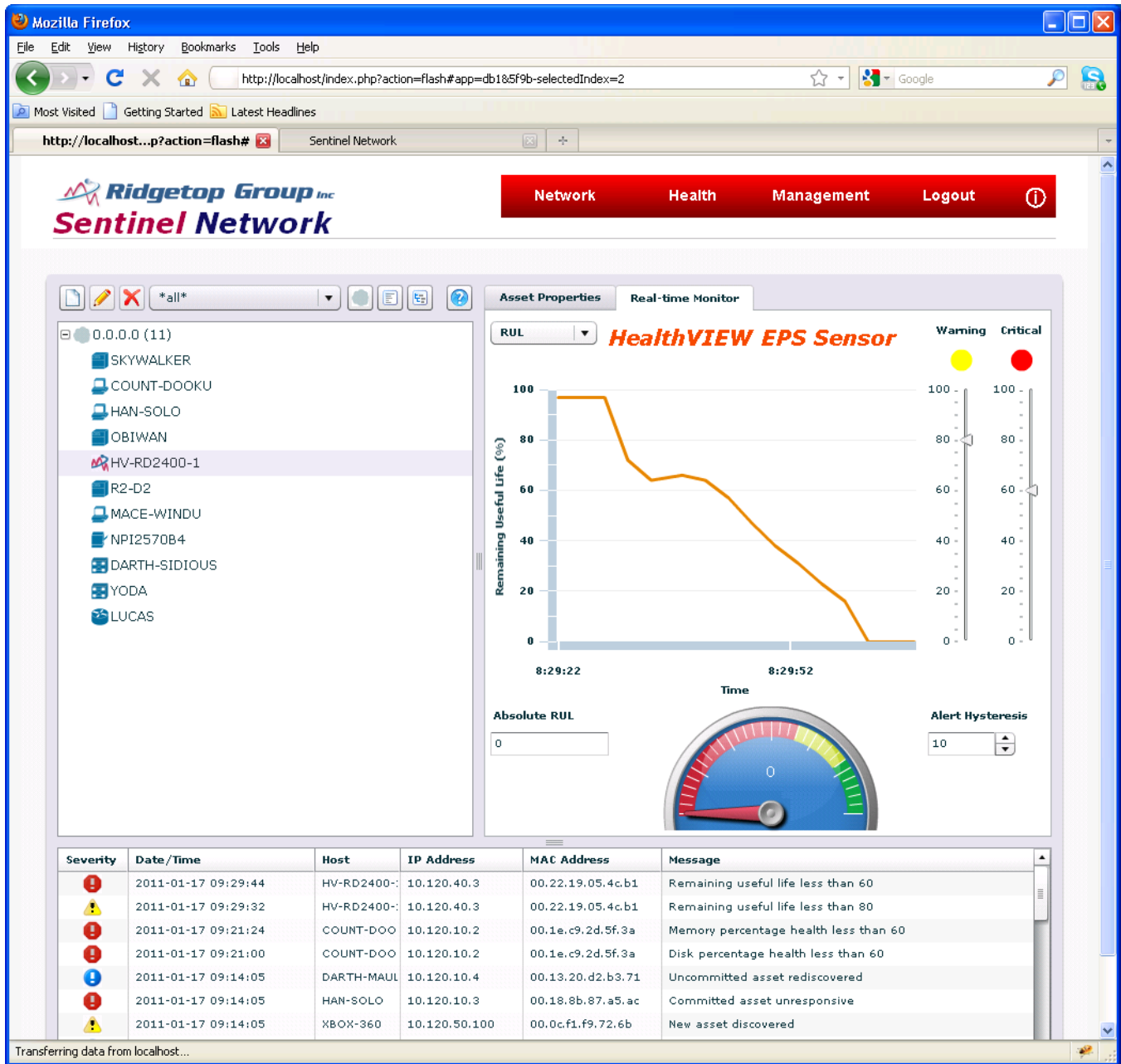


Figure 5: Sentinel Network interface, showing degradation curve

As shown in Figure 6, prognostics focuses on the region of concern on the left side of the curve.

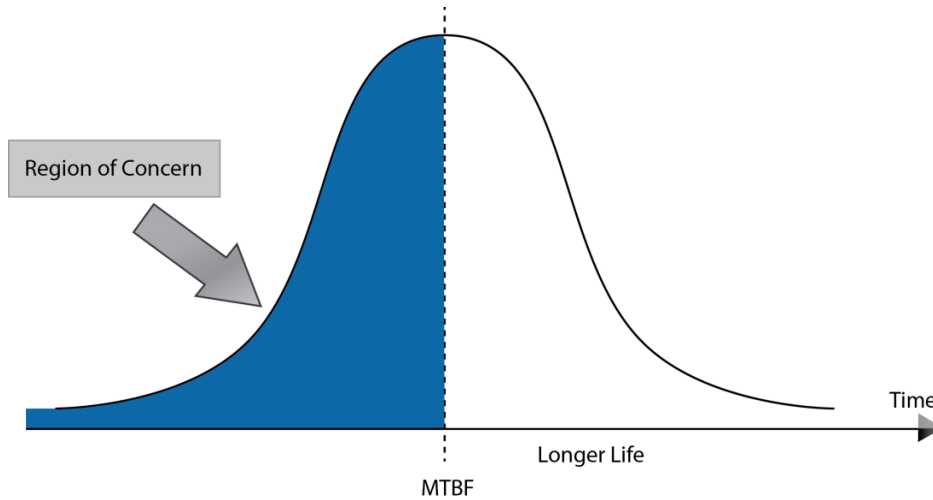


Figure 6: Prognostics focuses on identifying impending failures on the left side of the curve

### Points of Electronic System Vulnerability

With prognostics, an analysis of the system or LRU (line replaceable unit) is required. Usually the high failure rate items tend to be power supplies and power drivers. These stages are subjected to heat and repetitive stresses that prematurely age the circuit. In addition, the constituent components of power systems include electrolytic capacitors and power switching components, such as MOSFETs and IGBTs. These devices have historically populated the high side of Pareto charts when analyzing root cause failure information.

A major issue in fielded systems, such as automotive electronics, occurs when the vehicle is struck and a load-dump transient occurs. Transients of this type propagate throughout the vehicle as current seeks a path to ground. These can either cause an immediate failure, or age the modules within the vehicle in a manner to reduce their remaining useful life. Prognostics can be employed to identify the signatures associated with degraded life, and support condition-based maintenance (CBM) when the vehicle is repaired.

### The Return on Investment (ROI) from Prognostics

Another important point is that MTBF-driven maintenance schedules often conduct service too early or too late, with corresponding cost impacts. This relationship is depicted in Figure 7.

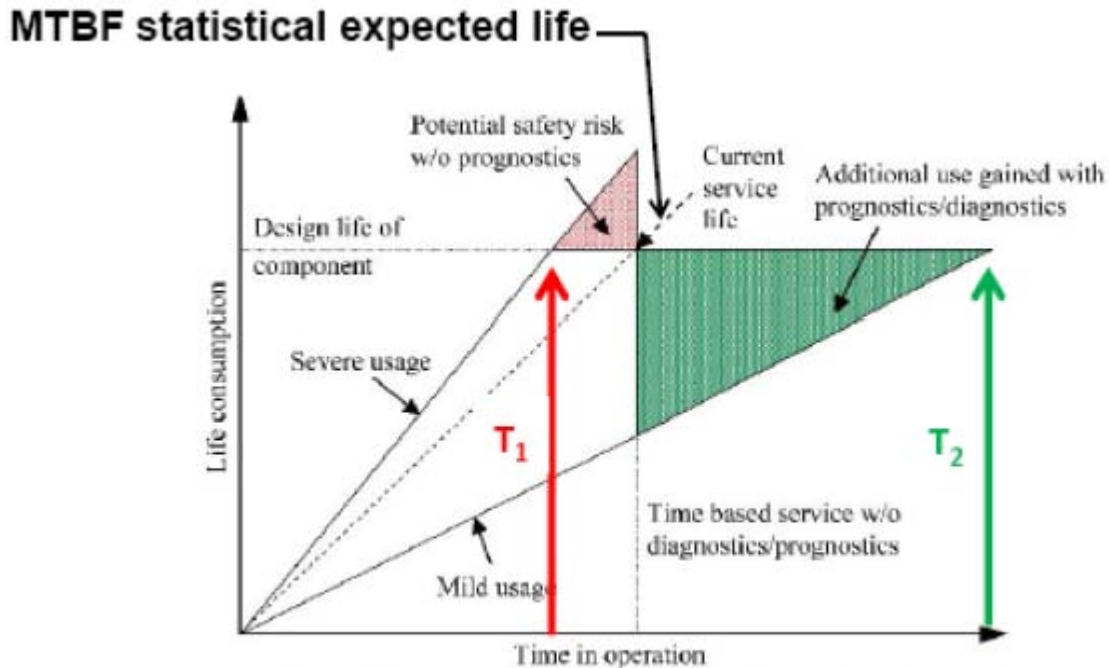


Figure 1: Economic and Safety Benefits of Dignostics & Prognostics (Romero et al. 1996).

Figure 7: MTBF and prognostic ROI relationships

### Prognostic-Enabling an LRU

The central concept of prognostics is that it should provide LRU state-of-health (SoH) and remaining useful life (RUL). For legacy designs, it is necessary to tease out the signatures to be monitored. Fortunately, Ridgetop has developed effective methods of extracting these signatures from analysis of power supply rails, data buses, and other indirect methods without compromising LRU performance. For new systems, the system design has more flexibility to add prognostic “observability” where it is needed. Ridgetop offers non-statistical, signature-based products including:

- RingDown™ for power supplies and power drive systems
- SJ BIST™ for interconnects, including ball grid array (BGA) packages
- DigIO™ for power rail extraction
- Sentinel Silicon™ Library of IC Prognostic test structures

### Summary

It has been shown that prognostics offers significant advantages in providing advance warnings of impending failures, and is far superior to MTBF-based statistical approaches.

For more information, please contact your local Ridgetop representative.