## The Case for Reliability Growth Projections

Complex Army systems are assumed to contain a large set of failure modes with varying failure rates from mode to mode. This basic concept is critical for properly planning and projecting system-level reliability growth. Recent insights into Army Reliability Programs have shown that this concept is often misunderstood, resulting in reliability projections that yield overly-optimistic results. This paper presents the recommended approach to reliability projections.

In a complex Army system with a large number of failure modes, the initial system failure rate is comprised of the individual failure rates for all failure modes. As shown in Figure 1, there is significant variability in the failure rates for each of the modes, with a few modes occurring every few hundred hours, and many modes occurring every few thousand hours. This variability, which is consistent with a Pareto relationship, is typical for complex Army systems.

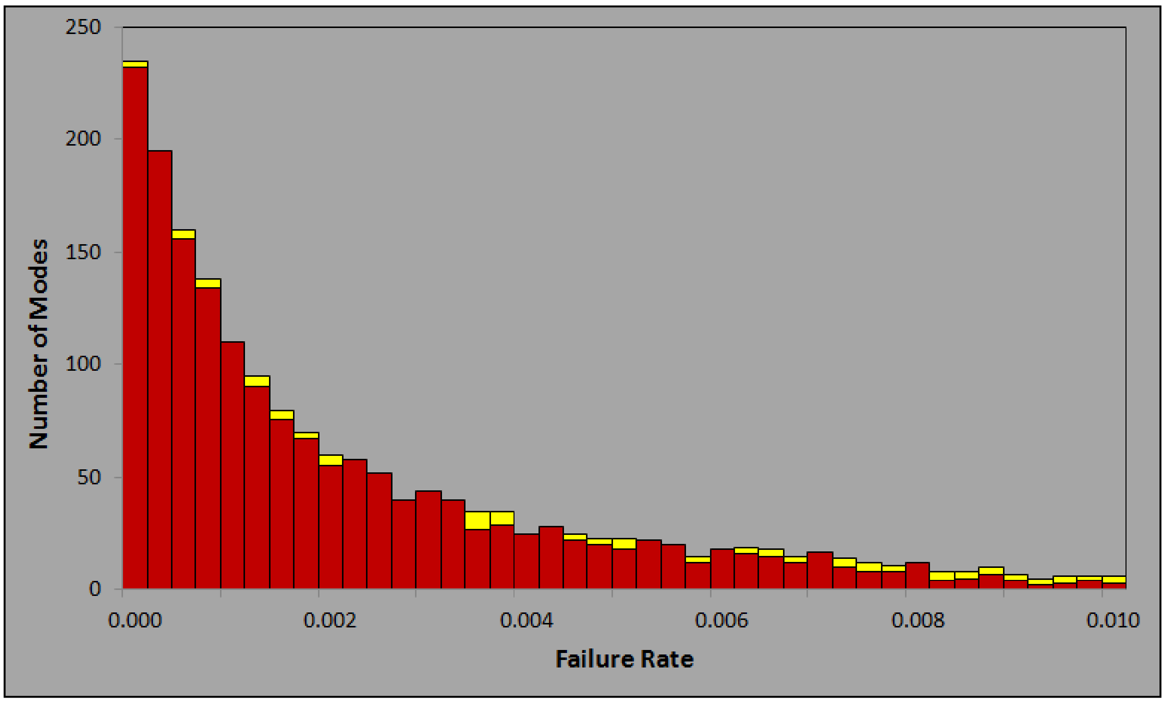


**Figure 1. Mode-to-Mode Variability**

System-level Reliability Growth Testing (RGT) aims to achieve reliability growth by surfacing a portion of the system's failure modes and reducing their rates of recurrence through effective corrective action implementation. In order to project the expected reliability resulting from these corrective actions, programs often make reliability projections. When made correctly, these projections should always be less than the Reliability Growth Potential ($R_{GP}$). $R_{GP}$ is the theoretical reliability upper limit that could be achieved if all of the correctable failure modes in the system were surfaced and corrected with their associated Fix Effectiveness Factors (FEFs). Since complex Army systems contain a large number of failure modes and test resources are limited, it is highly unlikely that the full set of correctable failure modes will be surfaced and corrected in RGT.

Consider a complex Army system that is entering RGT consisting of two test phases – Phase 1 and Phase 2. At the beginning of Phase 1, the system is comprised of failure rates for the entire set of failure modes. Throughout Phase 1, a subset of the system's failure modes (depicted in yellow in Figure 1) will be surfaced via one or more failure occurrences. Assume the corrective actions for the failure modes in this subset will be implemented after Phase 1, but prior to Phase 2. Therefore, at the beginning of Phase 2, the system's reliability will be comprised of two equally important components:

(1) the decreased failure rates for the surfaced (yellow) failure modes, and

(2) the collective failure rate of the system's unsurfaced (red) failure modes.

Reliability growth projection models provide a means to estimate the reliability in Phase 2 while accounting for these two components. Rather than utilizing these widely-accepted projection models to estimate the Phase 2 reliability, many PMs and analysts within the Army have been using an assessment technique that only considers component (1) stated above. The technique attempts to obtain a reliability projection by "discounting" each observed failure by the associated FEF of the corrective action. In actuality, this reliability estimate is akin to a reliability growth potential since it lacks component (2), which represents the unsurfaced (red) failure modes. As a result, this widely-used assessment technique can generate an overly-optimistic and misleading reliability estimate for Phase 2.

Reliability growth assessments are critical for assessing a system's reliability and projecting reliability based on planned/proposed corrective actions. These projections can inform decision-makers and influence programmatic resources. There are several models that are available for Army programs to utilize, many of which are free of charge. These models and their methodology are well-documented in the DoD Handbook for Reliability Growth, MIL-HDBK-189C. These models are applicable at any point in the test and can also provide an estimate of the system's $R_{GP}$. It is recommended that all Army programs adopt these methods, which effectively represent the total set of failure modes in the system (some surfaced and corrected, and others not yet surfaced), and terminate use of the commonly-used, flawed "discounting" method.

## Example

**Values are shown below to illustrate the potential difference in the projection model reliability estimate and the "discounting" method reliability estimate. The total test time in Phase 1 was 475.3 hours.**

Table 1 contains Phase 1 failure data, FEFs, and the calculated discounted failures for each failure mode.

**Table 1. Phase 1 Sample Test Data and FEFs**

| Mode | Failure Occurrences of Mode | First Occurrence Time of Mode | Mode FEF | Discounted Failures of Mode |
|---|---|---|---|---|
| 1 | 1 | 23.5 | 0.70 | 0.3 |
| 2 | 1 | 27.2 | 0.70 | 0.3 |
| 3 | 2 | 68.7 | 0.70 | 0.6 |
| 4 | 1 | 96.6 | 0.70 | 0.3 |
| 5 | 1 | 108.1 | 0.70 | 0.3 |
| 6 | 1 | 126.6 | 0.70 | 0.3 |
| 7 | 1 | 187.7 | 0.70 | 0.3 |
| 8 | 1 | 219.7 | 0.70 | 0.3 |
| 9 | 1 | 221.1 | 0.70 | 0.3 |
| 10 | 1 | 234.6 | 0.70 | 0.3 |
| 11 | 2 | 275.7 | 0.70 | 0.6 |
| 12 | 1 | 331.9 | 0.70 | 0.3 |
| 13 | 1 | 334.9 | 0.70 | 0.3 |
| 14 | 2 | 360.4 | 0.70 | 0.6 |
| 15 | 1 | 362.2 | 0.70 | 0.3 |
| 16 | 1 | 376.5 | 0.70 | 0.3 |
| 17 | 1 | 395.9 | 0.70 | 0.3 |
| 18 | 1 | 472.9 | 0.70 | 0.3 |

**The Mean Time Between Failure (MTBF) projection for Phase 2 was generated using the AMSAA Maturity Projection Model (AMPM), assuming the fixes were applied at the end of Phase 1, but prior to Phase 2. The model also estimated the MTBF growth potential based on Phase 1 data. The MTBF estimate for the "discounting" method is the total test time divided by the sum of discounted failures.**

Table 2 compares the Phase 2 MTBF estimates for both methods.

**Table 2. MTBF Estimates for Phase 2**

| | AMPM Projection | AMPM Growth Potential | "Discounting" Method |
|---|---|---|---|
| MTBF (hrs) | 27.7 | 75.4 | 75.4 |

In this example, the AMPM projection provides a much lower estimate than the growth potential since it accounts for the failure rates of unsurfaced modes. The “discounting” method doesn’t account for unsurfaced modes, so its estimate is equal to the growth potential. This example illustrates the importance of using the appropriate assessment technique when analyzing reliability growth data.

**References**


1. MIL-HDBK-189C, “Reliability Growth Management,” June 14, 2011.