Reliability Growth – Guidance

Summary

The majority of life cycle costs for DoD systems reside in the Operations and Sustainment (O&S) phase, where O&S costs are often driven by unreliability. The more reliable the system, the less it costs to operate and sustain in the field. With today's highly complex systems, a small decrease in reliability can mean additional, substantial cost, but a small investment in reliability growth can significantly decrease O&S costs.

A comprehensive reliability program, focusing on reliability growth is essential for developing and acquiring reliable systems. From the start, a program should formulate and document a comprehensive reliability, availability, and maintainability (RAM) program. The program should employ an appropriate reliability growth strategy to improve RAM performance until RAM requirements are satisfied. The reliability program should be documented in detail in the system engineering plan (SEP). In addition, key systems engineering and design activities needed for the test strategy should be included in the Test and Evaluation Master Plan (TEMP).

Elements of Reliability Program for the TEMP

The TEMP must provide an overview of the reliability program and testing needed to assess and monitor reliability growth, including design for reliability test and evaluation (T&E) activities. DOT&E is looking for a concise description of the following elements when reviewing the reliability portion of TEMPs:

- Key engineering activities supporting the reliability growth program including[1]:
  - reliability allocations to components and subsystems,
  - reliability block diagrams (or system architectures for software intensive systems) and predictions,
  - failure definitions and scoring criteria (FDSC),
  - failure mode, effects and criticality analysis (FMECA),
  - system environmental loads and expected use profiles,
  - dedicated test events for reliability such as accelerated life testing, and maintainability and built-in test demonstrations,
  - reliability growth testing at the system and subsystem level, and
  - a failure reporting analysis and corrective action system (FRACAS) maintained through design, development, production, and sustainment.
- The system's reliability growth program, including:

[1] The key engineering activities should be discussed in more detail in the appropriate supporting references. References to supporting information, such as the System Engineering Plan or the Reliability Program Plan, should be provided in the TEMP.

  - initial estimates of system reliability and a description of how this estimates were arrived at,
  - reliability growth planning curves (RGPC) illustrating the reliability growth strategy, and including justification for assumed model parameters (e.g. fix effectiveness factors, management strategy),
  - estimates with justification for the amount of testing required to surface failure modes and grow reliability,
  - sources of sufficient funding and planned periods of time to implement corrective actions and test events to confirm effectiveness of those actions,
  - methods for tracking failure data (by failure mode) on a reliability growth tracking curve (RGTC) throughout the test program to support analysis of trends and changes to reliability metrics,
  - confirmation that the FDSC on which the RGPC is based is the same FDSC that will be used to generate the RGTC
  - entrance and exit criteria for each phase of testing, and
  - operating characteristic (OC) curves that illustrate allowable test risks (consumer's and producer's risks) for assessing the progress against the reliability requirement. The risks should be related to the reliability growth goal. See the Reliability Test Planning Guidance for more information on OC curves.

- DOT&E has no default criteria for acceptable test risks. The rationale for the selection of test risks should derive from the specifics of each program.
- Resource requirements (including test articles and expendables) that reflect the best estimate for conducting all reliability T&E activities and are reflective of the allowable test risks

Reliability should be measured, monitored, and reported throughout the acquisition process. Reliability measurements and estimates should be recorded on the RGTC and compared to the RGPC. Systems not meeting entrance and exit criteria should revise the reliability growth strategy to reflect current system reliability. When necessary, reliability growth should continue after the full-rate production decision (FRP) and fielding until RAM requirements are met. Provisions should be made to monitor reliability even after requirements are met.

Figure 1 below shows a notional reliability growth curve. Key features include the idealized curve, important acquisition events, and corrective action periods (CAP). These CAPs are the projected periods during which the system will undergo changes to correct identified failure modes. Between the CAPs are test periods that should correspond to the test phases and acquisition decision milestones in the TEMP.

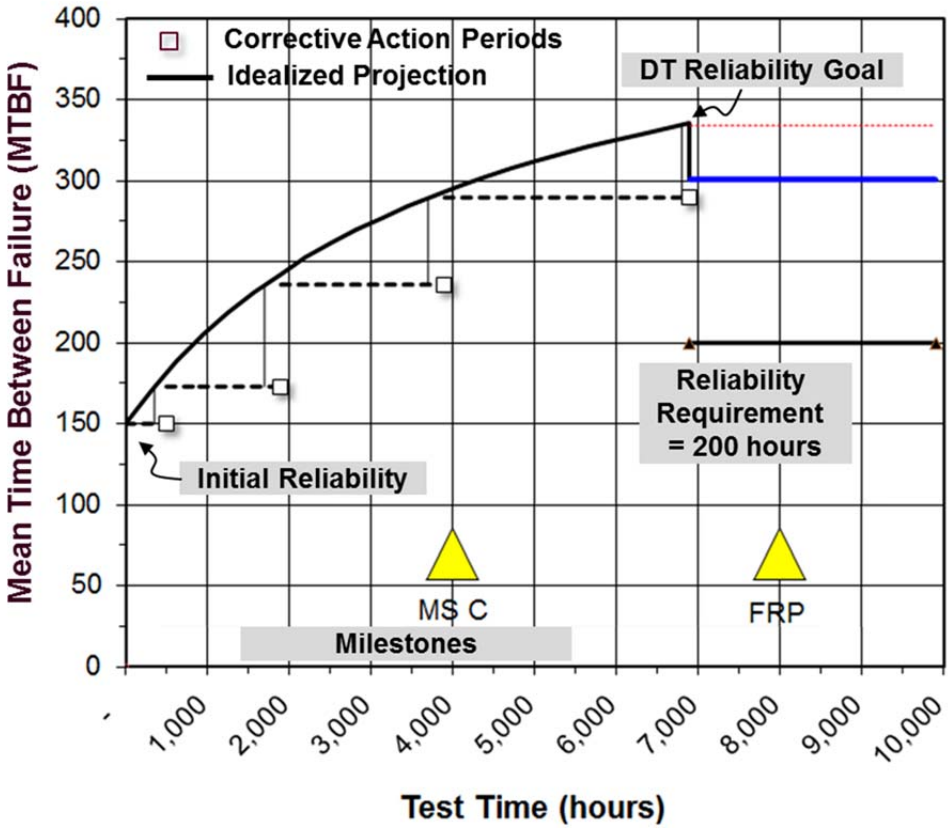

Figure 1: Notional Reliability Growth Curve

Note that the curve includes an adjustment from the DT reliability growth goal to the OT reliability growth goal, which is itself higher than the requirement. Design margins should be included to ensure that the requirement is met. Larger design margins increase the likelihood that the requirement can be demonstrated with statistical confidence during the program's IOT&E.

Guidance for documentation of reliability growth in TEMPs is discussed below by grouping DoD systems into three general categories:

- Hardware only systems, which contain no software (bullets, personal protective equipment);
- Hybrid systems containing a combination of software, hardware, and human interfaces. Critical functionality is a combination of hardware and software sub systems (complicated ground combat vehicles, aircraft, and ships);
- Software-intensive systems characterized by built-in redundancies that result in high reliability for the hardware (or hardware is not a component of the system), leaving the software reliability as the limiting factor (safety critical systems, automated information systems, and some space systems).

Hardware Only and Hybrid Systems

System level reliability growth for hardware and hybrid systems can be planned for using the AMSAA Planning Model based on Projection Methodology (PM2) or the Crow-Extended Planning Model. Using these models, program management is able to establish a realistic reliability growth curve in relation to time (or distance, use cycles, etc.) that provides interim reliability goals and serves as a baseline against which reliability assessments can be compared.

Reliability Growth Planning Curves (RGPC) should be included in the TEMP and reflect the reliability growth strategy. A RGPC must be included in the TEMP beginning at Milestone B, and updated at each subsequent milestone. The RGPC should be stated in a series of intermediate goals and tracked using a suitable Reliability Growth Tracking Curve (RGTC) through fully integrated, system-level test and evaluation events until the reliability threshold is achieved. If a single curve is not adequate to describe overall system reliability, multiple curves should be provided for critical subsystems with rationale for their selection. In many cases, multiple curves should be constructed to track both top-level reliability metrics (e.g., system aborts) as well as lower-level metrics (e.g., essential function failures). Tracking lower-level metrics allows for a more granular assessment of reliability and given their more frequent occurrence, can give a higher resolution view of reliability growth early on in system testing.

Programs using quantitative time-based measures of mean time between failure (MTBF) metrics (or life units such as miles, cycles, rounds, operations, etc.) should calculate the reliability growth potential (the maximum life unit that can be attained with the current management strategy) to ensure that reliability thresholds are achievable. PMs should continue to track reliability on the RGTC after FRP, regardless of whether reliability requirements have been met.

Operational test events should be noted on the growth curve, and intermediate reliability goals should be associated with each OT event. These events may also include Reliability, Availability, and Maintainability (RAM)-based entrance and criteria. This could include demonstrating that the point estimate for system reliability is at or above the growth curve prior to entering test or that the system must achieve a certain level of reliability prior to proceeding beyond an acquisition milestone.

At Milestone C, RGPCs should be updated based on the current status results of the RGTC and the reliability program plan should be updated with current information (including the current reliability estimate). The TEMP should characterize key failure modes and their disposition. Post-Milestone C TEMPs must be updated as needed to continue reliability monitoring and reliability growth after fielding until terminated by the receiving Service.

For hybrid systems, in addition to the RGPC, the TEMP (or supporting documentation references in the TEMP) should outline a plan for categorizing hardware failures verses software failures, provide a plan for tracking software failures on the RGTC, and a clear plan for regression testing software failure fixes.

Software-intensive Systems

Software-intensive systems must address reliability growth by providing either a reliability growth planning curve (RGPC) or reliability growth tracking curve (RGTC). If a RGPC is appropriate for the program, then the TEMP should provide a RGPC based on an appropriate methodology. The Crow-Extended and the AMSAA Projection Methodology (PM2) models are two recommended reliability growth planning models. If using a RGTC, programs should follow the guidance for hybrid systems. For software-intensive systems that are primarily software, the RGTC may be more appropriate. The selection of the appropriate curve for inclusion in the TEMP should be reflective of the program.

If a RGTC is appropriate for the program, then the TEMP should outline a plan for categorizing software failures; a reliability tracking curve for software failures (plot of system faults over test time) should be provided once available and should be updated over time. Additionally, a plan for regression testing of software failure fixes should be discussed.

All software intensive systems, starting at Milestone A should describe the plan to track software reliability across the acquisition development life cycle with defined entrance and exit criteria for system reliability at critical decision points. Software reliability growth curves provide one rigorous methodology for defining reliability projections based on past test data. IEEE 1633™ - 2008, Recommended Practice on Software Reliability, Annex F, provides a three-step approach for applying software reliability growth models to plan, track, and project software reliability growth for software-intensive systems from detailed design and through design, analysis, coding, and testing. For more information on this methodology please see the DOT&E working group page of software reliability growth.

Reliability Growth for Ships

Guidance

New Ship Example

Mature Ship Example

Examples

Reliability Growth Example

Software Reliability Tracking – Example

Reliability Test Planning Guidance

References

Independent Operational Test and Evaluation (OT&E) Suitability Assessments

DoD Instruction 5000.02

Recommended Practice on Software Reliability, Annex F, IEEE 1633™ ,

MIL HDBK 189 C – Reliability Growth Management

DOT&E Working Group Software Reliability Growth