Reliability Test Planning – Guidance

Summary

Operational mission reliability is the ability of a system to perform a required function under given environmental and operating conditions and for a stated period of time. Operational testing provides the ability to assess mission reliability because the testing is conducted to evaluate how systems improve mission accomplishment under realistic combat conditions. Ideally, adequate data on the mission reliability will be collected during operational testing, using representative users under a range of operationally realistic conditions. In these cases operating characteristic curves should be used to assess the test adequacy for the assessment of mission reliability. Operating characteristic curves can be constructed for mission based reliability requirements or duration based requirements. In cases where it makes sense testers should use duration based versions of the requirements to maximize information.

Unfortunately, it is often not possible or cost effective to collect all of the data on system reliability in operational testing. In these cases, using a range of additional sources of information may provide a better assessment of the operational mission reliability. If additional information will be used in the reliability assessment the TEMP should outline the source of the additional information, the required fidelity to include operational conditions and scoring criteria for failures, finally the methodology for combining information should be outlined. Data from different test events should not be combined into one pool of data and used to calculate and average reliability, rather advanced analysis methodologies (See Bayesian Statistics Guidance) should be used to combine information from multiple tests.

Reliability Requirements

The duration of reliability testing depends on the form of the reliability requirement. Reliability requirements can be pass/fail in nature or time/duration based. Pass/fail reliability requirements are common for single-use systems:

Probability of a fuse igniting without failure in a weapon system > 90%

For repairable systems, reliability requirements might be specified in terms of mission duration and probability of mission completion:

A howitzer must have a 75% probability of completing an 18-hour mission without failure.

Alternatively, requirements might specify a mean time between failures:

A howitzer mean time between failures must exceed 62.5 hours.

One can translate between probabilistic mission duration requirements and the mean time between failures using the exponential distribution. The cumulative distribution function for the exponential distribution (cumulative probability of failure in a reliability context) is:

$$F(t) = 1 - e^{\frac{-t}{\theta}}$$

Where θ is the mean time between failures (MTBF) and *t* is the mission length. Note that by plugging the mission duration and the MTBF from the example howitzer requirement we obtain the probability based requirement:

$$F(18) = 1 - e^{\frac{-18}{62.5}} = 0.25$$

A system with a MTBF of 62.5 hours has a 25 percent chance of mission failure in an 18 hour mission, or a 75 percent chance of completing the mission successfully.

The mission reliability equation provides a useful translation between system reliability and operational implications, as long as it is reasonable to assume that the failure rate is exponentially distributed. In some cases, this equation can illustrate that MTBF requirements exceed the expected use of the system and are unnecessarily high. For example, consider a bomb that is employed by a fighter aircraft. As Table 1 illustrates, we would need a large MTBF requirement if we require a high probability of completing a standard 2-hour mission without an in-flight failure. Since an individual weapon will never exceed 50 hours of flight time, 200-hour MTBF requirement is unreasonable.

Table 1: Mission Reliability and MTBF

Probability of Mission Completion / Mission Duration	Mean Time Between Failure (MTBF)
99% (2-hour mission)	199 Hours
95% (2-hour mission)	39 Hours
95% (4-hour mission)	78 Hours

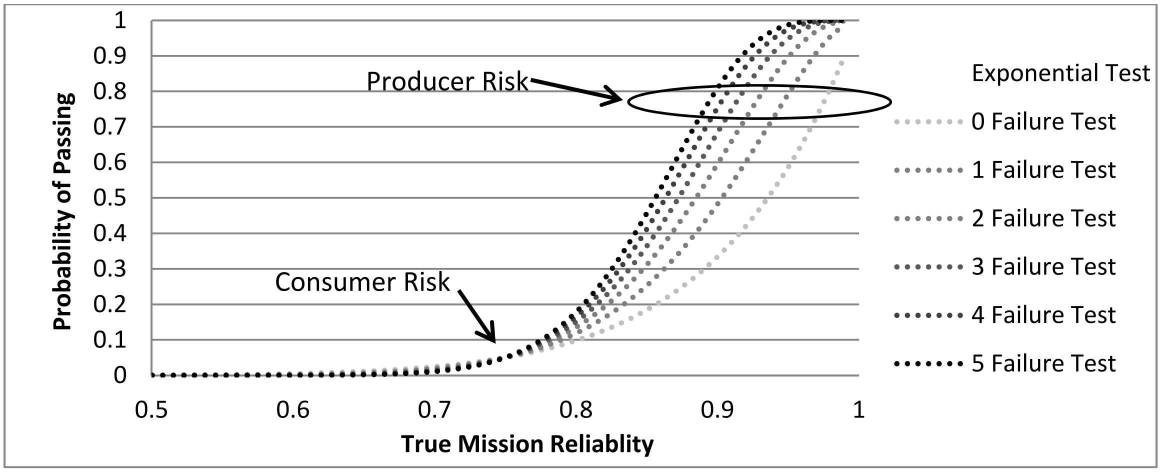
Operating Characteristic Curve – Planning an Adequate Test

Operating characteristic curves are useful statistical tools for planning the length of a reliability test. OC curves illustrate the probability of passing the test as a function of the true mission reliability. In practice, we never know exactly how reliable the system is so it is important to select a test that balances risk and achieved reliability. Central to the development of these curves is the balancing of Consumer Risk and Producer Risk. Consumer Risk is defined as the probability that a bad system (below threshold reliability) will be accepted, whereas Producer Risk is the probability that a good system (above threshold reliability) will be rejected. The risks should be related to the reliability growth goal. An example of a generic OC curves is provided in Figure 1.

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.

The following curve shows an OC curve for determining the test length for a howitzer requirement of 75 percent probability of completing an 18-hour mission without failure. OC curves should be provided for the selected test duration and corresponding risks highlighted in the TEMP.

Figure 1. Example Operating Characteristic Curve for Operational Test Planning



Incorporating Additional Information

Assessing the operational reliability of complex systems can often require the incorporation of multiple sources of data in order build a credible statistical analysis of system reliability. When additional sources of information are used in reliability assessments, all of the following should be specified in the TEMP:

- The conditions the data must be collected under to be acceptable for OT use.
- The methodology for scoring reliability data collected outside of an OT. If you plan to use developmental test data for operational evaluation, developmental test reliability failures must be scored by the same methods as the operational reliability data.
- The statistical models and methodologies for combining information. Data should not simply be pooled together and an average reliability calculated. The analysis should account for the conditions the reliability data were collected under to the extent possible. See Bayesian Methods for additional guidance on using various sources of information in analyses.
- The methodology for determining adequate operational test duration. Bayesian assurance testing can be used in place of traditional operating characteristic curves to determine adequate operational testing when prior information will be incorporated. Table 2 shows how Bayesian assurance testing can reduce required test time and control test risks.

Table 2: Bayesian versus OC Curve Reliability Test Planning

Failures Allowed	**Bayesian Assurance Test Miles** 10% Consumer Risk 5% Producer Risk	**Classical OC Curve Miles** 10% Consumer Risk Producer Risk Varies
1	2,940	7,780 – 58% Producer Risk
2	4,280	10,645 – 50% Producer Risk
3	5,680	13,362 – 43% Producer Risk
4	7,120	15,988 – 37% Producer Risk
5	8,580	18,550 – 32% Producer Risk