Reliability Discipline: Overview of Methods

Reliability is:

- In a formal manner, *the probability (likelihood) an item (e.g., system, sub-system, component, part) will perform its intended function with no failures for a given time period (mission time) under a given set of operating conditions (environment)*.
- In brief, the likelihood of failure-free performance (i.e., up time only) for stated conditions (i.e., function, mission time, and environment).
- An inherent design characteristic (defined in the next paragraph) for non-repairable items.
- Note: When the life and performance are characterized for a repairable item, an item having both up and down times during its useful operating life, the precise term is availability and not reliability. Availability is a function of reliability and maintainability. **Maintainability** *is the probability that a failed item will be restored or repaired to a specified condition within a period of time*. **Availability** *is the probability that a repairable system will perform its intended function at a given point in time or over a stated time interval when operated and maintained in a prescribed manner—in brief, mission readiness*.

The use of the word "probability" in the above definitions does not mean the disciplines of Reliability, Maintainability, and Availability (**RMA**) are limited to the statistical treatment of failure, repair, maintenance data, or some combination. It is Design Engineering where most of the true RMA work is done. That is, an item's true reliability is built into the design and is called **inherent reliability**—and an item's inherent reliability is generally viewed as the item's highest reliability. Attempts to improve inherent reliability after design through manufacturing, testing, and preventive maintenance are usually expensive and not effective. Thus, assurance engineers make their greatest impact during the early phases of an item's life cycle.

Reliability Methods for the Design Phase:

Since reliability is a prime "design for" operational outcome, the reliability requirement is an integral part of engineering specifications. As contained in the formal definition of reliability, the **reliability requirement** or specification in complete form addresses four elements, namely, the:

a. Intended function (mission) to be performed.
b. Mission time.
c. Operating environment.
d. Probability of success (or no failure) the item will perform its intended function.

Strategies in order of precedence the designer uses to prevent failures:

a. Improve the design to eliminate the failure mode.
b. Design for fault tolerance (redundancy).
c. Design for fail-safety (i.e., failure affects function but no injury or additional damage will occur).
d. Provide early warnings of failure through fault diagnosis.

If these strategies are not viable, the designer may choose to issue special maintenance instructions to the user.

Reliability improvement *strategies* used during the Design Phase:

a. **Zero Failure Design** – Critical failures are entirely eliminated by design.
b. **Fault Tolerance** – Redundant elements are used to switch over to a backup or alternative mode.
c. **Derating** – A component is used much below its capability rating.
d. **Durability** – A component is designed a have a longer "useful life" or is designed for damage tolerance.
e. **Safety Margins** – Design for all applicable worst-case stresses and margins.

Analytical *techniques* used verify to reliability during the Design Phase:

a. **Design Reviews** challenge the design from different viewpoints and assess risk (technical, schedule, cost).
b. **Reliability Allocation, Modeling, and Prediction** provides a hierarchy of design requirements along with the distributed reliability goal, a model for system configuration, and estimated reliability of the configuration.
c. **Design Failure Mode, Effects, and Criticality Analysis** is an inductive (bottom up), qualitative analysis method.

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d. **Fault Tree Analysis** is a deductive (top down) analysis method; uses symbolic logic; qualitative or quantitative.
e. **Sneak Circuit Analysis** identifies failures not caused by part failures but are caused by logic flaws.
f. **Worst-Case Analysis** for circuits evaluates performance when components are at their high and low values.
g. **Statistical Analysis** of failure and repair distributions and stress-strength distributions.
h. **Quality Function Deployment** is a method for converting customer needs into engineering requirements.
i. **Robust Design** methodology using Design of Experiments.

Reliability *tests* used during the Design Phase:

a. **Reliability Growth Tests** –Essentially, "test, analyze, and fix" in a closed-loop corrective action manner.
b. **Durability Tests** – Typically, **accelerated tests** that determine the failure rate for the entire expected life. Duplicates field failures by providing a harsher but representative environment. Performed instead of testing under normal conditions in order to eliminate testing that would otherwise take months or years.
c. **Qualification Tests** – Consist of stressing the product for all expected failure mechanisms. Performed to measure the achievement of the reliability requirement. **Demonstration Tests** or **Design Approval Tests** are similar and usually require stressing during only a portion of the useful life. See note below.

Reliability Methods for the Manufacturing (Build) Phase:

Reliability *strategies* used during the Manufacturing Phase:

a. **Process Failure Mode, Effects, and Criticality Analysis** on the manufacturing process before it is installed.
b. **Statistical Process Control** – Often considered a test for determining the control of quality instead of reliability. Designed to ensure that the manufacturing process continues to produce products with no more than expected variation in the critical parameters.

Reliability *tests* used during the Manufacturing Phase:

a. **Environmental Stress Screening Tests** – Also, known as Burn-in and Screening Tests. Typically, use a profile of operating environments such as temperature cycling, burn in (subject to a constant high temperature), run in, vibration, and humidity. Note: These tests are also performed in the Design Phase such that early failures do not mask the true reliability. Unfortunately, these tests are sometimes used as the "final word." As a result, the screening may not be long enough and weak products may be provided to the customer.
b. **Production Reliability Acceptance Tests** – Also, known as Failure Rate (MTBF) Tests. Used to detect any degradation in the inherent reliability of a product over the course of production. Acceptance tests are also used to assure that products being delivered meet the customer's reliability requirements and/or expectations. These products, from a production lot, are then accepted on the basis of a sampling plan.

Reliability Methods for the Operation (User's) Phase:

Reliability *strategies* used in the User's Phase:

a. **Failure Reporting, Analysis, And Corrective Action System** – Provides the data needed to identify deficiencies for correction to ensure that inherent reliability is not degraded. This system is typically used to record data for product failures that occurred during all phases of testing as well as in the field. Also, the data from this system is typically used to detect trends and to respond accordingly in a timely and preventive manner.
b. **Warranties** – An attribute where reliability easily affects the manufacturer's current and future revenues. One of the biggest challenges facing manufacturers is competition due to longer warranties.

References:

- NASA KSC Reliability web page: http://kscsma.ksc.nasa.gov/Reliability/Default.html
- Assurance Technologies, Principles and Practices, 2nd Edition, Dev G. Raheja and Michael Allocco, John Wiley & Sons, Hoboken, NJ, 2006.
- Blueprints for Product Reliability, Reliability Analysis Center, Rome, NY, 1996.

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