RELIABILITY: Definition & Quantitative Illustration

PART I. What is reliability?

Reliability is defined as the probability that a given item will perform its intended function with no failures for a given period of time under a given set of conditions.

A. What are some concepts that support this definition?

1. This definition has four parts, namely, 1) probability, 2) item's intended function, 3) time, and 4) conditions. A reliability statement is complete when all four parts have been provided.

2. **Probability** is the likelihood that some given event will occur and as a measure is assigned a value between 0 and 1. In practice, this number has to be estimated. As a best guess, the probability is stated as a number (e.g., 0.949 or 94.9%) and is technically called a **point estimate**. The uncertainty encountered is stated as an interval (e.g., between 0.899 and 0.983 with 95% confidence) and is technically referred to as an **interval estimate** or as a **confidence interval**.

3. The **item** can be hardware (system, subsystem, and component), software, and/or human.

4. The **intended function** and **conditions** (i.e., the operating and environmental conditions) have to be defined by the customer and understood by the reliability engineer. What is success to one person may be defined as failure by another.

5. The "given period of time," commonly referred to as the **mission time**, can be clock hours or cycles. However, run (exposure) time is not always available or applicable. For example, a reliability measure can be determined when the data is in the form of demands (as in a car starter) or in the case of stress-strength (load-capacity) interference problems.

6. Another name for reliability (R) is the "**probability of success**" (p_s). Many times at NASA, we speak in failure space as in the "**probability of failure**" (p_f) instead of reliability, a concept and measure in success space. Other names for the probability of failure usually found in textbooks are the complement of reliability or unreliability (U).

7. A fundamental math rule on the above is: $p_s + p_f = 1$ or $R + U = 1$.

B. An example of a reliability statement: assume the reliability analysis has been completed.

The Collins TACAN has a reliability (or probability of success) of 0.9991 of operating as required in XXXX document for the next 10 hours in flight. Note: Or 0.0009 or a 9/10,000 chance of not operating in the next 10 hours.

Comment: In this example, reliability is stated only as a point estimate. To tell a more complete story, an interval estimate (confidence interval) should have been provided as well. Note: Even if an interval estimate was stated, this would only address the uncertainty in the math model's parameter(s) and not the others types of uncertainty.

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PART II: Which manufacturer has the most reliable product?

Suppose two manufacturers, A and B, manufacture similar products. Both manufacturers claim that the average or mean life (denoted θ) of their product is 100 hours. However, manufacturer A states that the distribution of times-to-failure for its product is *exponential*, and manufacturer B states that the distribution of times-to-failure for its product is *normal* with a standard deviation (denoted s) of 40 hours.

If your mission time requirement is 10 hours of operation, which manufacturer should you select from a reliability viewpoint? Assume the other product parameters such as technical performance, initial cost (not life cycle cost), availability, supportability, and training are the same.

Reliability of Manufacturer A:

Reliability for the exponential case is determined by $R(t) = e^{-\lambda t}$ where $\lambda = 1/\theta$.

Thus $R_A = e^{-(1/100)(10)} = e^{-0.1} = 0.905$

Reliability of Manufacturer B:

Reliability for the normal case is determined by $R(t) = 1 - \Phi(z)$ where $\Phi(z)$ is the cumulative failure distribution and $z = (t - \theta)/s$, thus, $R(t) = 1 - \Phi((t - \theta)/s)$.

Note: Because Φ(z) is difficult to determine, a table, commonly called the Standard Normal Table, is used to find the value for Φ(z) at a particular z. The area under the standard normal curve (or any probability density function) is 1. We are interested in finding the portion of area from $-\infty$ to z. This area of interest is the sum (actually the integration) of all probabilities from $-\infty$ to z and is identical to the cumulative failure distribution from 0 to t. The probabilities from $-\infty$ to 0 are assumed to be negligible.

Thus, $R_B = 1 - \Phi((10 - 100)/40) = 1 - \Phi(-2.25) = 1 - (0.0122) = 0.988$

Conclusion:

Manufacturer B has the best reliability when the mission time requirement is 10 hours. **Note:** When the mission time is increased, there is a point in time when $R_A = R_B$.

Key Point:

The above example illustrates that *knowing only the average life parameter is not sufficient information* to determine which manufacturer has the most reliable product. The math model (i.e., the graph and function used to describe the distribution of failures) along with the math model's parameters (mean life being one parameter) are required to make a correct determination of the probability portion of the reliability requirement.

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