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| Reliability Quantification |                      |                    |

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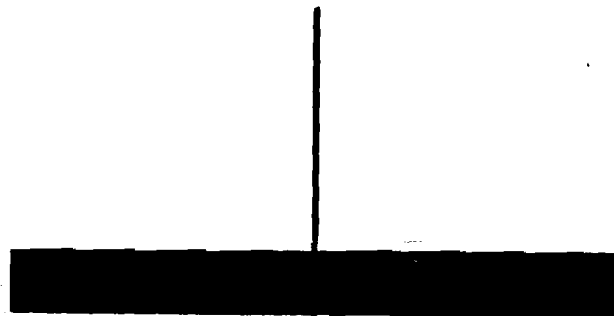
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**RELIABILITY BULLETIN No. 4-A**

# **Reliability Quantification**



**MAY 1969**



**PREPARED BY THE**

**G-41 COMMITTEE ON RELIABILITY**

***Engineering Department***

**ELECTRONIC INDUSTRIES ASSOCIATION**

2001 EYE STREET, N. W.  
WASHINGTON, D. C. 20006

RELIABILITY QUANTIFICATION BULLETIN

A GUIDE FOR THE USE BY COMPANIES CONTRACTING FOR  
DESIGN OF ELECTRONIC PRODUCTS WITH THE DEPARTMENT  
OF DEFENSE (DOD) AND OTHER GOVERNMENT AGENCIES

Prepared by the  
Reliability Quantification  
Task Group  
G-41 Committee on Reliability

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## F O R E W O R D

This Bulletin presents concepts and techniques for quantifying electronic equipment reliability. The techniques are responsive to the requirements of various branches of the Department of Defense and are also useful with regard to other Government agencies (e.g., NASA).

This Bulletin has been published by the Electronic Industries Association, in the belief that the approach, as defined, will interest and benefit those responsible for reliability quantification programs.

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## SECTION I

### INTRODUCTION

This reliability Bulletin is provided as a guide for engineering and management personnel concerned with the quantification of reliability and/or effectiveness. It covers the specification and apportionment of reliability, the essential elements or analytical activities of a quantification program, prediction, measurement, and demonstration.

For the purpose of this Bulletin prediction is based upon data from sources such as MIL-HDBK-217<sup>(1)</sup>, Department of Defense Publication PB-181080<sup>(2)</sup>, and RADC Reliability Notebook Volume 2<sup>(3)</sup>. Measurement uses actual test data from component (black box as opposed to piece part, e.g., resistor, capacitor) and higher levels of assembly to estimate system reliability. Measurement is described in NAVWEPS OD 29304<sup>(4)</sup> and NAVORD OD 29304/Addendum<sup>(5)</sup>. Demonstration may use the same information as measurement or may be predicted on specific tests (e.g., MIL STD 781<sup>(6)</sup>). Demonstration implies a penalty for failure to meet acceptance requirements. There may be various states of prediction and measurement and these can be combined into current dynamic assessments of reliability, using all information, by the Bayesian Measurement Techniques presented in the Appendix of this Bulletin.

Reliability and availability are two significant inputs to a system effectiveness calculation. The techniques described in this Bulletin are intended primarily for use in quantifying reliability in those instances where failure-free operation is required for a defined mission. The techniques are also applicable for determining the reliability inputs required for availability calculations. (Availability is a function of reliability and maintainability<sup>(7)</sup>).

Although it is recognized that the human element can be and frequently is a major factor in the reliable functioning of a system, this aspect is not specifically treated in this Bulletin. Another problem of system reliability which is not specifically treated in this Bulletin is the effect of degradation, in dormant storage, on reliability and the surveillance programs required to monitor and control aging.

Two techniques for measurement/demonstration are covered in the Appendix. They are not included in the main body of the report since there is too little experience with them to recommend them as standard methods at this point in time. They are not omitted altogether since they both offer considerable potential for the future.

## SECTION II

### ANALYTICAL ACTIVITIES

Quantification of reliability and assurance that design requirements will be met is dependent upon the successful completion of a number of tasks. To varying degrees each of these must be accomplished whether the desired output is a prediction, measurement, or demonstration. The tasks which should be performed are discussed in A through F: -

#### A. MISSION DEFINITION AND ANALYSIS

Reliability is the probability of successfully completing some specified mission. Without a stated mission, reliability is an indeterminate quantity.

The reliability requirement(s) provided by the customer include the mission(s) against which system reliability is measured. The apportionment provides the reliability allocated to lower level assemblies and the specific mission of each of these assemblies is defined in mission analysis.

Mission parameters such as functional requirements, success criteria, phases of the mission, sequence of events, operating modes, mission environments, and the required mission times are clearly identified. This information is required to determine the testing necessary to simulate the mission and to establish the manner in which test information will be used to measure/demonstrate reliability; it also provides a basis for assuring that design information required for total mission definition is considered in test planning. In summary, it is important to compare both the design requirements and the test requirements with the mission requirements to assure compatibility.

#### B. SYSTEM ANALYSIS

This analysis includes configuration definition, failure modes and effects, preparation of the reliability block diagram(s), development of reliability equation(s), and reliability allocation. This analysis defines the hardware on which data collection is required. In the case of redundant devices, it is necessary to state whether data are required on each redundant channel or whether system performance is sufficient. Success-failure criteria are established for each hardware element at this state of the analysis.

## C. INTEGRATED TEST PLAN

On programs where statements such as "No special testing shall be accomplished for reliability/demonstration" appear in contractual documents such as the Statement of Work, it is necessary to analyze the integrated test plan to determine which of the tests being accomplished for other purposes provides data relevant to reliability measurement. In those cases where demonstration is required and the integrated test plan is not structured to provide sufficient test data for this demonstration, a special reliability test to provide the additional information required must be undertaken. Among the advantages of analysis of the integrated test plan is the visibility that it provides. If one component (black box as opposed to piece part) is receiving several thousand equivalent missions of test and another component only ten this fact is dramatically highlighted and reallocation of test resources can be considered without increasing total cost.

On programs where special reliability tests are required for demonstration (e.g., MIL-STD-781<sup>(6)</sup>) it is still advantageous to analyze the integrated test plan and to perform the mission and system analyses. The mission and system analyses enable the contractor to determine the relationship between MIL-STD-781 tests and the actual mission environments. This permits realistic recommendations of the proper test level (i.e., A, A-1, B, C, D, E, F, G, H, or J) and a realistic appraisal of the relationship of the test to the mission. Employing the techniques for reliability measurement which are recommended in Section VI of this Standard would provide a timely assessment of the risks of entering the reliability demonstration test.

If the contractor is assigned to develop the reliability demonstration test, a guide manual such as reference 8 should be used in conjunction with the analyses described herein.

## D. FAILURE ANALYSIS AND CLASSIFICATION

The primary purpose for a failure evaluation and reporting activity is the analysis of failures and elimination of failure causes. However, this activity also provides an important input to a reliability measurement/demonstration program. It is essential to clearly define failure prior to instituting test, particularly in the case of demonstration programs with incentive aspects.

Classification is based upon many factors among which the more significant are: The success criteria developed during mission analysis, the

type and level of the test, the degree and cause of the failure, and the severity of the test relative to the mission. It is important that the ground rules for elimination of failure be clearly established prior to test. Several ground rules are generally applicable:

- (1) In any testing, the test time and associated failures are treated collectively. Either both time and failures collected from a test are applicable or neither time nor failures collected from the test are applicable. (This does not mean a failure cannot be excluded for valid reasons or that test data is not used when failure-free tests are accomplished.)
- (2) Failures and test time in the non-mission environment are not counted. (Testing under ambient conditions is normally considered relevant.)
- (3) Failures occurring as a result of mishandling, test error or test equipment error are not normally counted, but the link between reliability and human factors should not be overlooked.

#### E. STATISTICAL MODEL

Reliability measurement/demonstration requires a statistical model which permits estimation of system reliability based upon data obtained from independent test of lower assembly levels, as well as system level test. Many techniques have been developed for this purpose<sup>(9)</sup>. The standard recommended here is that shown in NAVWEPS OD 29304<sup>(4)</sup>, and NAVORD OD 29304/Addendum<sup>(5)</sup>. This method is well documented, flexible, and easily understood. The techniques described in NAVWEPS OD 29304 have been applied successfully on Air Force Programs such as Thor, Atlas, Titan, Minuteman, and various Recoverable Satellite Programs. The Navy's contractors have applied NAVWEPS OD 29304 on Navy Programs (e.g., the Strategic System Program Office Polaris and Poseidon and Ship Systems Command Sonar). It has also been applied on programs under the direction of other governmental agencies.

In addition to the rather wide and successful use it has enjoyed, on R&D Programs it has been subjected to considerable review. The OD lists fourteen companies that contributed to its development in conjunction with various Navy activities under the direction of the Strategic Systems Project Office (then Special Projects Office).

Some of the documents which review the technique are listed (references 25, 26, and 27). While no method of system reliability estimation is

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being used as a standard in industry, NAVWEPS OD 29304 is the method in widest use today. The first step in incentive contracting for reliability is development of a measurement yardstick such as that provided in OD 29304.\*

#### F. RELIABILITY REPORTING

There are three basic reports associated with reliability quantification which are considered essential for transmittal from the contractor to customer. These are:

##### (1) Reliability Measurement/Demonstration Plan

This report is submitted to the customer for approval. It contains the results of Mission Analysis, System Analysis, Analysis of the Integrated Test Plan, Failure Analysis and Classification, and Statistical Analysis. It also provides information on the reliability reports to be prepared by the contractor for in-house use and those to be transmitted to the customer.

Basically this plan contains the complete ground rules which are to be used for reliability measurement/demonstration. Both the contractor and the customer have a clear picture of the entire measurement/demonstration program when this document is approved. This report would typically be submitted early in the program and updated as program requirements dictate.

##### (2) Reliability Status Report

The purpose of the Reliability Status Report is to present a quantitative index of the reliability of each component, equipment, and subsystem derived from test data in accordance with the measurement plan; to indicate status against estimated growth; to pinpoint quantitative reliability problem areas; and to discuss problem areas indicating corrective action planned and anticipated reliability gained by incorporating corrective action.

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\*The Navy has distributed several thousand copies of OD 29304 and it is currently available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. , 20402.

The Reliability Status Report is normally issued periodically (volume of data being accumulated determines optimum frequency) and contains mission failure rate and reliability results at two confidence levels (usually, but not necessarily, maximum likelihood estimate and 80%) for each appropriate hardware level (e. g., component, equipment, subsystem). It could also report the confidence level at which the specified reliability has been demonstrated by each hardware element.

The reliability status report contains items such as:

- (a) A brief description of the subsystem and equipment operation and of the mission for which reliability is reported.
- (b) The subsystem block diagram and reliability equation.
- (c) A summary of the test data sources.
- (d) A table relating the currently measured reliability versus reliability requirements for the subsystem and equipments.
- (e) Growth curves for the subsystem and equipments showing measured reliability versus time with the required reliability a fixed reference line. The major changes affecting reliability should be indicated on these curves.
- (f) Discussion of reliability problem areas as to cause, proposed corrective action, date or serial number effectivity, and anticipated effectiveness. Subsequent reports should show the effectiveness by growth curves indicating the introduction of significant changes in design or manufacturing.
- (g) A tabulation showing the failure rates and reliability indices for the components, equipments and subsystem comprising the selected configuration.
- (h) The confidence level to which the apportioned reliability has been demonstrated.

### (3) Failure Summary Report

The purpose of the Failure Summary Report is to present a complete log of failures that have occurred on a particular contractual program. The report provides a tool for assuring that failures are identified and reported to the cognizant engineers and management; that significant and repetitive failures are analyzed in depth; that causes and modes of equipment failure are determined; and that the required corrective action is pinpointed.

The failure analysis program must provide for and monitor close-out of each reliability significant failure.

The Failure Summary Report is issued periodically. It contains the hardware identification, including nomenclature, drawing number, serial number, vendor, and program code; the test description including test type, environment, site or reporting activity, and date of test; the test results including failure report number, failure classification, and description of failure; the failure investigation analysis including an indication of whether formal failure board action is required, and the conclusions of the formal or informal analysis including the corrective action recommended or taken; and the responsible personnel.

In addition to these three basic reports, a number of related reports of considerable value in controlling the reliability of the product are discussed in Section 4.2 of reference 4. These reports are generated at little or no additional cost and have considerable value in areas directly related to reliability (e.g., critical and time sensitive component control, logistics planning, and experience retention).

## SECTION III

### REQUIREMENTS

Reliability, to many persons, associates with consistent successful performance of a task. However, practically anything attempted has, in practice, a finite, however small, probability of failure. One of the first decisions usually faced in specifying reliability is the extent to which the possibility of failure is tolerable. The converse of this, i. e., degree of assurance or probability that a system will perform its intended function, is the quantitative concept usually labeled "reliability".

Reaching a decision on a reliability objective to accomplish a specific function frequently involves realizing a compromise or balance between the following factors:

1. Consequences of failure
2. Past experience with similar hardware
3. Technology and complexity of anticipated system
4. Economics of different reliabilities
5. Maintenance concepts

For a system reliability objective to have meaning, it has to associate directly with mission conditions. These include both a time profile (duration of mission, etc.) and an environmental profile (environments in which the system is to operate). Of prime importance is the need to relate system operating characteristics, e. g., power, sensitivity, capacity, etc., to reliability objectives. In order for reliability objectives to be effective in guiding and influencing system development and equipment design, success criteria based on system operating states have to be established.

In the specification of reliability objectives and in the subsequent studies and efforts to achieve these objectives, reliability should be treated as a design parameter and analyzed in conjunction with other performance parameters.

Reliability requirements should contain at least:

1. Definition of the mission
2. Definition of success or failure

3. Reliability design objective (specified reliability)
4. Reliability to be demonstrated, and the associated confidence level (minimum acceptable reliability level)
5. Definition of the measurement technique which will be employed or a requirement to generate a measurement plan to be approved by the customer.

Reliability requirements are generally specified by the customer, based upon strategic or tactical considerations. In the absence of customer requirements or in cases where they are incomplete, the contractor can and should develop requirements and establish controls to assure product reliability.

The difference between the reliability design objective and the reliability to be demonstrated should be kept clearly in mind when specifying reliability. It is necessary that the reliability to be demonstrated be less than the true reliability and for practical purposes less than the reliability design objective. It should be recognized that it is not possible to demonstrate the true reliability by direct measurement. Consider a coin for example, if heads is defined as success and tails as failure, the reliability of a true coin is 50 percent. It would take an infinite number of tests to prove this (e.g., after 1001 tests we would be equally likely to observe 501 heads - 500 tails or 501 tails - 500 heads). In this example it would, however, be possible to demonstrate that the probability of a head (achieved reliability) is at least 40% at a desired confidence level.

It is important to specify reliability realistically. Asking for more than is actually required could greatly increase design and demonstration costs.