HANDBOOKS AND STANDARDS

Reliability specifications, standards, and handbooks have been widely used in the electronics industry for over forty years. As the US government drove this industry for much of that time, the US government produced many of these 'specs.' However, as market shares changed and commercial industry began to drive the electronics market, military 'specs' and their restrictive 'how-to' approaches, no longer applied to the dynamic commercial electronics market. As a result the Department of Defense began canceling its military 'specs.'

Performance based 'specs,' rather than regimented 'how-to' 'specs,' are being used to provide suppliers with the flexibility to design, manufacture, and test products according to technological developments and market demands. This article explores the history and current status of reliability 'specs,' and presents a methodology useful for developing performance-based reliability 'specs.'

DEFINITIONS

A specification, standard, or handbook controls almost every aspect of electronics and electronic equipment design, manufacture, and test. However, these 'specs' also have various other effects associated with global competitiveness, policy decisions, and life cycle costs (1). This section explores the intended function of specifications, standards, and handbooks and the differences among them.

A specification is a document prepared specifically to support acquisition, which describes essential technical requirements (i.e., design details) for purchasing materials, physical commodities, data products, and technical manuals. Procedures necessary for determining that the specification requirements have been met are often included.

Standards are documents issued in accordance with some basic policy of a standardization body, such as the Institute of Electrical and Electronic Engineers (IEEE), the American Society of Mechanical Engineers (ASME), and the Joint Electronic Devices Engineering Council (JEDEC). Standards are used for the comprehensive presentation of engineering practices, test methods, procedures, processes, codes, safety requirements, symbols, abbreviations, nomenclature, and equipment type designations. Standards also address characteristics of electronic component families. These characteristics include, as applicable, envelope dimensions, performance ratings, primary structural features, and required data for component interchangeability.

Handbooks are documents that can supplement design, engineering, production, acquisition, and supply management operations. Handbooks contain general information, procedural data, technical use data, and design information related to commodities, processes, practices, and services. Handbooks are guidance documents not intended for incorporation into contracts. However, because contracts often refer to a handbook, handbooks sometimes indirectly and incorrectly become a contract item.

RELIABILITY SPECIFICATIONS

Reliability specification (specs) generally can be divided into three basic categories: design and analysis, test (design verification), and management. Each of these specs plays a specific role in ensuring the reliability of the end item.

Reliability design and analysis specs provide engineering and other technical information about reliability and maintainability theory, lessons learned, options for resolving technical issues, and interpretive direction techniques, for example. Reliability design and analysis specs are intended to aid the user in identifying failures. These specs suggest reliability assessment techniques for use during system concept definition and design phases. Often these techniques are used to compare the predicted system reliability, availability, maintainability, and necessary safety precautions with the specified requirements.

Reliability test specs are used to verify the reliability, maintainability, and availability of a product design. These specs provide an outline of the kinds of information that must be defined and answered when specifying reliability compliance testing. This information includes test item sample quantity, statistical test plans, test conditions, test observations, field test considerations, and test reports.

Reliability management specs outline the development of reliability, maintainability, and availability (RM&A) program plans and emphasize constant review and assessment throughout the development process. Like most management documents, reliability management documents are written for the program managers who are responsible for planning and overseeing RM&A functions within product development. Reliability management 'specs' present features essential for planning, organizing, directing, and controlling resources. These 'specs' address the details of product development from concept to final delivery.

HISTORY OF RELIABILITY SPECIFICATIONS

The development of reliability specs was initially due to the military's desire to explicitly define the reliability design, test, and management methodologies used on products made according to military contracts. Despite their technological limitations and overly restrictive approaches, military-generated reliability specs continued to receive support within the military long after their usefulness ended. Possible explanations for continued reliance on military specs include perceived difficulties in evaluating diverse products against any other type of spec (i.e., a performance-based spec); a preference for known government procedures and a belief that only these procedures minimize risk; a lack of expertise by government acquisition personnel; a lack of adequate guidelines for preparing performance specifications and; a fear by government employees that eliminating military specs would eliminate jobs.

The origin of reliability specs can be traced to the publication in November 1956, of the RCA release TR-1100, "Reliability Stress Analysis for Electronic Equipment," which presented models for computing rates of component failures. The "RADC Reliability Notebook" in October 1959, various compendiums of failure rate models, and the publication of MIL-HDBK-217, "Reliability Prediction of Electronic Equipment," followed.

MIL-HDBK-217A, published in December 1965, listed a single-point failure rate of 0.4 failures per million hours for all monolithic integrated circuits. This number lacked technical merit as it did not account for the integrated circuit environment, application, architecture, power requirements, manufacturing processes, or manufacturer. In view of these omissions, the single-point failure rate approach further indicated that accuracy was less a concern than having "some number" for the logistics community or a general.

In July 1973, under contract to the Air Force Rome Air Development Center (RADC), RCA proposed a new set of reliability prediction models for microcircuits, based on previous work by the Boeing Aircraft Company. RCA researchers documented the concept that any reliability model should reflect differing device fabrication techniques, materials, and architecture. Unfortunately, this understanding was not used by the RADC, which simplified the models in-house by presenting characteristics of the devices as a pair of complexity factors and by assuming an exponential failure distribution during the device's operational life. Then this simplified model was published as MIL-HDBK-217B, under the preparing activity of the Air Force. The exponential failure distribution assumption remains in the handbook today in spite of overwhelming evidence suggesting that this assumption is not appropriate (2).

New versions of MIL-HDBK-217 appeared about every seven years to 'band-aid' the inaccuracies and damages caused by earlier versions. In 1987, the Air Force awarded two one-year contracts, requiring each team to provide guidelines to update sections of MIL-HDBK-217. The IIT Research Institute/Honeywell SSED team and the Westinghouse/University of Maryland team proposed reliability models for technologically advanced microelectronic devices. The teams determined that the constant failure rate model should not be used; that many of the failure mechanisms should be modeled by a nonexponential distribution; that the Arrhenius-type formulation of the failure rate should not be included in the package failure models; and that temperature cycling and humidity should be included as factors that affect part reliability. All of these suggestions were ignored by the Air Force's Rome Laboratory, even though the suggestions were supported by studies from the National Institute of Standards and Technology (NIST) (3), Bell Northern Research (4), and by the Army-Fort Monmouth (5). Again, the models used by the Air Force's Rome Laboratory in MIL-HDBK-217 led to high costs, weight and size restrictions, and decreased reliability (6,7,8,9). On February 15, 1996, Gilbert Decker, Assistant Secretary of the Army (Research, Development, and Acquisition), said that "In particular, MIL HDBK 217, *Reliability Prediction of Electronic Equipment,* is not to appear in an RFP [request for proposal] as it has been shown to be unreliable and its use can lead to erroneous and misleading reliability predictions." Nevertheless, the US military (except the Army) maintained MIL-HDBK-217 as an active guidance document.

Military generated specs reduced performance and quality and increased life cycle costs (1) in ways not directly related to faulty models. Generating and maintaining the documents became an industry in and of itself, as numerous offices and agencies sprung up to monitor, distribute, and modify the documents continuously. The dynamic electronics industry eventually outpaced the capabilities and technical expertise of the document writers, and the military generated "how-to" documents became outdated. As the commercial marketplace began to drive the electronics industry, the military-generated documents could no longer address the needs of industry. The military simply did not possess the technological expertise or necessary resources to produce and maintain military specs usefully.

On June 29, 1994, Secretary of Defense William Perry directed the Department of Defense (DoD) to abandon its reliance on military specs (10). Dr. Perry directed the DoD to give preference to performance based specs. Organizations including the IEEE and the SAE Reliability, Maintainability & Supportability (RMS) G-11 Committee developed documents to support this need (11).

RELIABILITY PROGRAM 'SPECS'

One way to compete successfully in the dynamic electronics industry is to use performance-based reliability specs from product concept to final delivery. A performance-based spec does not state the methods to be used to achieve the required results but rather states the objectives. A performance-based spec allows the user to define the specific methods used to achieve the required objectives.

There are three requirements for creating a successful and effective [reliability] program standard [SAE draft J2335-1] (11). These requirements are as follows: the supplier shall define customer requirements; the supplier shall meet customer requirements; and the supplier shall assure the customer that the requirements have been met. IEEE [draft Annex A] states similar reliability program requirements (12). It is important to note that the objectives presented here do not limit the spec user to a particular methodology for achieving these objectives. The user is responsible for selecting and implementing a methodology to achieve these objectives, as the user develops the product.

An effective performance based reliability program spec begins by prompting the user, working with information provided by the customer, to define the customer's requirements. The customer's requirements may include the product's functional, physical, maintainability, testability, safety, and service characteristics. The product definition effort continues with the supplier planning and analyzing the available capabilities and technology with respect to the customer's requirements and with the supplier analyzing the environmental conditions provided by the customer. Performing this preliminary planning and analysis generates clear understanding of the requirements and allows identifying solutions to potential roadblocks. Furthermore, reducing the requirements into basic subrequirements allows identifying conflicts and inconsistencies within the evolving requirements at the lowest functional level.

After defining the customer's performance requirements, an effective performance-based reliability program spec prompts the supplier to define the operating and environmental conditions applicable to the system. This effort includes reviewing the duty cycles imposed on the system during its intended operation and determining the expected environmental conditions experienced throughout the system's life, including those experienced during maintenance, storage, and transportation. The 'spec' should prompt the supplier to review the environmental conditions regularly throughout the design process, ensuring that no part of the environmental requirements reduces product reliability or is overlooked. The effects of manufacturing, storage, shelf life, packaging, transportation, handling, and maintenance on reliability should also be determined through analysis and/or testing. Once the customer's performance and environmental requirements have been determined and understood by the supplier, an effective performance-based reliability spec prompts the supplier to solicit active involvement by management to ensure that supplier resources may be allocated as needed to provide a reliable product to the customer.

To ensure that the customer's requirements are met, an effective performance-based reliability 'spec' must address management responsibilities. Management responsibilities include performing periodic reviews with milestones, assuring that system elements meet the reliability requirements, performing design reviews and resource allocation, identifying critical activities, and using a data reporting, analysis, and corrective action system. The purpose of performing periodic reviews is to address the status of the reliability program and to keep the customer and supplier management informed of the program status and of any unresolved problems that could impact the program's milestones. Such active management involvement allows orienting program direction and resources as required, so that system elements meet the reliability requirements. An effective performance-based reliability program 'spec' prompts the user to include periodic formal design reviews, which facilitate communication between the customer and supplier. Critical activity identification helps reduce the risk that the final product falls short of customer requirements. Including a closed-loop system for reporting, collecting, recording, analyzing, categorizing, and investigating program elements allows timely, effective corrective action on discrepancies and failures relating to design, manufacture, and test processes.

Once the customer's requirements are defined and management is actively involved to ensure that the requirements will be met, the supplier proceeds to design and develop a product that meets or exceeds the customer's requirements. Applicable methods for meeting customer requirements include design for manufacture and design for assembly, fault tree analysis, reliability allocation, reliability modeling and prediction, physics of failure analysis, design of experiments, finite element analysis, robust design, and worst case analysis. The supplier is responsible for applying method selection criteria and engineering judgment to determine which methods are best for product development and should be prepared to defend the chosen methods to the customer. An effective performance-based reliability 'spec' will not dictate which methods should be applied to meet the customer's requirements. As the responsibility for reliable product development rests with the supplier, the supplier is free to use whatever means are available to meet the customer's requirements.

Finally, an effective reliability program standard prompts the user to assure the customer that the product requirements have been met. The performance-based 'spec' must prompt the user to define a means of measuring compliance with the requirements. For example, the accuracy of a measuring device must be defined in advance, so that a finite means exists by which the accuracy of the product can be evaluated. Applicable methods for assuring the performance of the product include sampling procedures, accelerated life testing, environmental stress screening, reliability demonstration testing, reliability improvement testing, Pareto analysis, a system for failure report, analysis, and corrective action, failure modes and effects analysis, and statistical process control. Qualification tests, such as first article inspection or conformance inspection, are useful and describe the procedures, sequence, conformance criteria, and sample size to ensure that the performance specification of the end item has been met. The objective of test and evaluation is to ensure the customer that the requirements have been met. Using a continuous evaluation approach for test and evaluation provides feedback to the customer and supplier, improving system design and performance. Whether for development, production, or maintenance, test, or evaluation, the method chosen to assure the customer that the requirements have been met should address all aspects of the technical requirements and should be designed to demonstrate that the system or product offered is suitable for its intended purpose. Ideally, the assurance approach should be developed in conjunction with product development. This methodology ensures that only verifiable parameters are included in the customer's requirements.

SUMMARY

Flexibility in electronic product development techniques is essential to competitive product development in this dynamic industry. Performance-based reliability specs allow suppliers the necessary flexibility for competitive product development in the rapidly moving electronics industry. An effective performance-based reliability spec prompts the user to meet three objectives: define the customer's requirements; meet the customer's requirements; and assure the customer that the requirements have been met. Although the supplier and the customer work together in defining the customer's requirements and the methods chosen by the supplier to meet the objectives and to ensure that the objectives have been met, an effective performance-based reliability 'spec' does not specify the methods used to accomplish the three objectives. The supplier enjoys flexibility in determining the best methods to meet the objectives, in view of supplier resources and customer requirements. The supplier is responsible for choosing the methods used to meet the customer's requirements, therefore the supplier is responsible for reliable product development.

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HAND-HELD CALCULATORS. See ELECTRONIC CALCULATORS.

HANDWRITING RECOGNITION, ONLINE. See ONLINE HANDWRITING RECOGNITION.

HARDWARE AND SOFTWARE INSTALLATION. See COMPUTER INSTALLATION.

HARDWARE PROTOTYPING. See EMULATORS.