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Reliability Program Standard Implementation Guide

RATIONALE

Users who are currently using JA1000_201205, "Reliability Program Standard," are advised to consider GEIASTD0009A, "Reliability Program Standard for Systems Design, Development, and Manufacturing," revised May 27, 2020, for future projects needing a technical standard for Reliability Programs.

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Foreword—This Implementation Guide was developed as a companion, supporting document for SAE Reliability Program Standard JA1000 to provide guidance and assistance for planning and managing reliability programs.

This Guide was developed recognizing the need for customer satisfaction (high reliability, affordability, and speed to market) and increased profitability for suppliers. In addition, its development was influenced by Department of Defense (DoD) Acquisition Reform, and the wide diversity of potential users.

Stressing the importance of the supplier-customer dialogue, the Guide supports the belief that reliability programs are most efficient and effective when developed jointly by the supplier and customer. Rather than following a strictly prescribed approach, the supplier should design (tailor) the reliability program, with customer input to include only value added activities.

Section 1—*Introduction* explains the purpose, scope, and typical uses of the Guide. Section 2—*References*. Section 3—*Glossary, Terms and Definitions*. Section 4—*The Reliability Program* outlines how to develop a cost effective and value-added reliability program. Benefits and criteria for method selection are also included. Section 5—*Reliability Method Descriptions* includes reliability practices, many of which are recognized as best practices throughout industry. Also included in this Guide is a glossary of commonly used reliability terms, followed by an acknowledgement of contributors.

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1. **Scope—Introduction**

1.1 Introduction—The importance of reliability in design engineering has significantly grown since the early 1960's. Competition has been a primary driver in this growth. The three realities of competition today are: world class quality and reliability, cost-effectiveness, and fast time-to-market. Formerly, companies could effectively compete if they could achieve at least two of these features in their products and product development processes, often at the expense of the third. However, customers today, whether military, aerospace, or commercial, have been sensitized to a higher level of expectation and demand products that are highly reliable, yet affordable.

Product development practices are shifting in response to this higher level of expectation. Today, there is seldom time, or necessary resources to extensively test, analyze, and fix to achieve high quality and reliability. It is also true that the rapid growth in technology prevents the accumulation of historical data on the field performance of their products. Unfortunately, some reliability methods have depended upon the availability of historical data, other experiential information, or learning through extensive and time consuming tests. The new realities require innovation and creativity in the selection and use of reliability methods, and teamwork and collaboration in the management of product development programs. There must be a shift from seeking to eliminate complaints in products, to eliciting praise for them.

To enable this transition, reliability efforts must be directed toward anticipating problems and designing-in features that assure the achievement of quality and reliability, concurrent with the development process, instead of trying to assess quality and reliability downstream. The gains in time-to-market and cost savings from such an approach can be significant. More recent reliability programs tend not to prescribe reliability tasks or methods to be performed by suppliers. Rather, suppliers are considered equal partners in the effort to produce a reliable product and work with the companies in deciding which reliability methods provide most value in achieving objectives.

Nevertheless, developing reliable products and achieving reliability goals often requires different approaches for various product sectors. For example, in the defense/aerospace sector, the number of customers is relatively small. The product development cycle may span several years, while the product life cycle may last from mere minutes to as long as decades. Furthermore, it is not unusual for several design iterations of technologically different hardware and software to be developed before the final version is incorporated into the production product. Production volumes may range from rates of less than ten to hundreds per year. Also, the reliability discipline in this sector is generally a separate activity from the design discipline.

The commercial sector, in contrast to the defense/aerospace sector, usually has a higher number of different customers. Development cycles could range from months to a few years while life cycles are often measured in years. Production volumes may run up to thousands per day. The reliability discipline is treated usually as an integral part of the up-front design process rather than a separate activity.

Thus, developing a reliability implementation guide to meet the needs of all industry sectors is a formidable challenge. It recognized that this Guide will not strictly apply to all situations or industries. The suggestions made in this Guide must be interpreted in the context of the industry, its accepted practices, and unique company policies. The following statement will be repeated several times in this document to emphasize its importance: *"The selection of methods is a highly individualized process. This point cannot be overemphasized and this document does not attempt to prescribe any given method or set of methods. There is no right answer that will apply across the board to every organization or every product development. Suppliers and customers need to determine which methods are most applicable to their specific product developments."*

1.2 What is Reliability?—ISO 8402: *Quality Vocabulary* defines *Reliability* as: "The *ability* of an item to perform a *stated function* under *stated conditions*, for a *stated period of time*."

Assuming the *item* in the definition is a particular *product*, we see three interesting elements to this definition. First, the product must perform a *stated function*. Second, the product must perform under *stated conditions*, and third, the product must perform for a *stated period of time*. The important question is: "*Who* states the function, conditions, and period of time for the product?"

Considering why a product is purchased, it is obvious that the customer has certain expectations in terms of the product function, environmental conditions it should work in, and how long it should continue to work. If the product satisfies or exceeds these expectations, it is perceived to be reliable. If not, then it is perceived as unreliable. So, the ultimate indicator of product reliability is customer satisfaction! Therefore, it is a supplier's interest to build a product that satisfies (or delights) its customers. In fact, a product is said to have failed when it did not do what was required of it, i.e., it did not satisfy its customer (1).¹

The definition of reliability also has another interesting aspect - the word "ability." How this "ability" is measured becomes the means for quantifying reliability. Some measure the 'ability' in terms of a probabilistic statement, such as the percentage of products likely to survive (or failure-free life) after the required period of time (e.g., warranty) is over. In this approach, it is recognized that a certain number of failures will occur. Here, the emphasis is to minimize the number of failures to an acceptable level. This would allow a supplier to warrant a product to be "failure-free" for a certain period of time.

Others emphasize methods that help achieve reliability. In this approach, a product that meets all its customer needs, over a lifetime, is deemed reliable. They expect to achieve a failure-free period of time for all products. In other words, there is no such thing as an acceptable level of avoidable failure (2). Such methodologies approach reliability from a more physics-based viewpoint wherein the goal is to determine how the product could fail, understand what would make it fail in that manner, and design it so that the failure cannot happen under the usage conditions for the period of time required.

Both approaches are widely used throughout industry, and each have strong proponents.

1. References are listed in 2.1, Applicable Publications.

1.3 A Framework for Reliable Product Development—Companies need to face the future with quality and reliability programs that fit the new business era, rather than continue those that may have worked in the past (3). It is clear from our discussion previously that prior to building a product, it must be understood what the customer desires from the product in order to be satisfied. Without proper information about customer needs, quality improvement activities tend to lack both market focus and the proper use of business resources to enhance business results (4). Therefore, *to ascertain the needs of the customer* becomes an important objective towards the goal of customer satisfaction. Once the needs have been ascertained, a product that satisfies the customer's desires can be built. Therefore, the second objective of reliable product development is *to meet the customer needs*. Once the product is built, however, the customer may not buy it unless assured of its reliability. Therefore, the third objective is *to assure the customer that the needs are met*. These three objectives form the basis for a Framework for Reliable Product Development that underlies the SAE JA1000 *Reliability Program Standard*.

The Framework for Reliable Product Development is based on the concepts of reliability discussed previously and represents today's prevalent thinking of how to develop reliable products (5,6). The standard emphasizes the *supplier-customer* relationship among companies and their suppliers as well as among end-consumers and companies. The three objectives listed previously are set in SAE JA1000 as *Program Requirements* and are worded as follows:

- a. *The supplier shall ascertain customer requirements*
- b. *The supplier shall meet customer requirements*
- c. *The supplier shall assure that customer requirements have been met*

Each Program Requirement further consists of a number of activities. These activities are accomplished by a number of possible Reliability Methods. It is essential to understand that reliability transcends several disciplines across many industries. Therefore, it is important not to be prescriptive about the specific reliability methods used in product development. Consequently, SAE JA1000 does not specify the reliability methods to be used. Rather, the customer and supplier(s) must work together to develop a reliability program that completes each activity through the use of mutually acceptable reliability methods (7).

It should be recognized that SAE JA1000 uses the term "customer" to mean the *end-user* or a *company*. For example, the user of a lawn tractor is a customer of the dealer and manufacturer. A *company* may also be a customer. For example, an auto manufacturer is the "customer" of its instrument panel supplier. Also, there could be multiple or intermediate customers to a supplier. Therefore, when interpreting the Program Requirements and the activities therein, one needs to keep in mind the applicable context and the parties being discussed.

1.3.1 THE SUPPLIER SHALL ASCERTAIN CUSTOMER REQUIREMENTS—Suppliers must understand customer needs to determine product functions, the conditions it has to perform under, and the expected performance duration. The input from customers may not be in a form that allows direct interpretation in terms of technical design or process parameters. Furthermore, inputs may come from multiple customers. Therefore, supplier engineers need to translate the input into the desired technical parameters to be able to achieve the required product functionality. Thus, the activities defining this SAE JA1000 Program Requirement include:

- a. *Establish Supplier-Customer Dialogue*
- b. *Identify Conditions of Use*
- c. *Define Maintenance and Service*
- d. *Establish Metrics*
- e. *Define Product Specification*

1.3.2 THE SUPPLIER SHALL MEET CUSTOMER REQUIREMENTS—Once customer requirements are known, the supplier must look at how to produce a satisfactory product. The resources available to build the product must be considered, including people, materials, tools, manufacturing and assembly processes, equipment, facilities, software, organizational learning, technology, money, and time. These resources must be characterized for their capabilities and limitations. With the knowledge of the product requirements, conditions of use, and resource capabilities and limitations, it must be determined whether or not the product will fulfill its requirements. This activity is an essential step that provides an assessment of the risk and determines the focus areas for managing it. Having identified risks, the supplier then needs to design the product (and process) by mitigating these risks, through design and process innovation, exploratory development, decision making on serviceability issues, as well as determination of manufacturing and assembly process control windows. Thus, the activities defining this SAE JA1000 program requirement include:

- a. *Characterize Resources*
- b. *Assess and Manage Risk*
- c. *Design to Achieve Reliability*

1.3.3 THE SUPPLIER SHALL ASSURE THAT CUSTOMER REQUIREMENTS HAVE BEEN MET—The supplier needs to demonstrate that given the capabilities of the resources, the product (and process) meets requirements, thus qualifying not just the product design, but also the design, manufacturing, and assembly processes that the supplier uses to build the product. Complete documentation must be maintained to show customers that the product can indeed satisfy their needs. The supplier must identify the specific process parameters that control critical product characteristics, and contain variation within required limits. In addition, suppliers must strive continually to reduce product variability to an acceptable level in their design, manufacturing, and assembly processes. The supplier must also develop a closed-loop feedback system that channels information about the product during the development process, as well as after it has been sold, to various groups within the supplier's organization. Thus, the activities defining this SAE JA1000 Program Requirement include:

- a. *Qualify the Product and Process*
- b. *Establish Process Controls*
- c. *Pursue Continuous Improvement*
- d. *Establish Data Collection & Reporting*

1.4 Using this Implementation Guide

1.4.1 PURPOSE—The SAE JA1000-1 Reliability Program Standard Implementation Guide (the Guide) is designed to assist suppliers in determining how to satisfy the Program Requirements of SAE JA1000 *Reliability Program Standard* (the Standard). Although this Guide has been designed for use with the Standard, it is not required by the Standard. The Guide may be used for programs in any Government or commercial application. It applies to all activities for achieving reliability throughout the product or service life cycle.

1.4.2 APPLICATION—This Guide primarily provides assistance for developing reliability programs according to the requirements of SAE Standard JA1000. Suppliers and customers frequently need answers to questions such as:

- a. *Who is responsible for reliability goals, planning, etc.?*
- b. *What reliability methods are most effective, and how are they applied?*
- c. *When are reliability methods used most effectively in the product development cycle?*
- d. *Where can we get more detailed information and instructions on how to use the reliability methods?*

This Guide may also be used as a general reference for reliability methods and reliability program management. Suppliers and customers may also find the Guide useful for other purposes such as those listed as follows:

- a. Resource for design and manufacturing engineers to select available reliability methods
- b. Provide an understanding of various reliability program activities
- c. Provide assistance to suppliers who need knowledge of various reliability methods and techniques, or assistance establishing a formal reliability program. (e.g., A supplier may have an excellent quality program, but lack a formal reliability program).
- d. Assistance in planning, scheduling, and structuring their reliability programs
- e. Knowledge of available reliability methods, a description of what they accomplish, and when they are best applied
- f. Evaluating potential benefits and limitations of reliability methods
- g. Practical method selection criteria
- h. Provide guidance for subcontractor (second tier) reliability programs, including product assessments (e.g., Commercial Off The Shelf (COTS))

1.5 Managerial Issues in Reliable Product Development—Table 1 depicts the Framework for Reliable Product Development. In order for companies to succeed in applying the Framework, certain managerial and organizational issues must be addressed. The most significant among these is the nature of the supplier-customer dialogue, the creation of self-managed, cross-functional product development teams, and the management of supply chains.

TABLE 1—A FRAMEWORK FOR RELIABLE PRODUCT DEVELOPMENT

The Supplier Shall Ascertain Customer Requirements
a. Establish Supplier-Customer Dialogue
b. Identify Conditions of Use
c. Define Maintenance and Service
d. Establish Metrics
e. Define Product Specification
The Supplier Shall Meet Customer Requirements
a. Characterize Resources
b. Assess and Manage Risk
c. Design to Achieve Reliability
The Supplier Shall Assure Customer Requirements Have Been Met
a. Qualify the Product and Process
b. Establish Process Controls
c. Pursue Continuous Improvement
d. Establish Data Collection and Reporting

1.5.1 SUPPLIER-CUSTOMER DIALOGUE—The key to successful reliability programs (product development in general), is the quality of the supplier-customer dialogue. Often, weak reliability programs result when customers leave little flexibility for the supplier. Customers often have invoked a standard that included reliability methods (or tasks) the supplier was expected to perform. This was often done with little customizing or "tailoring" to the specific product needs. Consequently, many of the reliability methods added little value to the reliability of the product.

According to SAE JA1000 Reliability Program Standard, the supplier-customer dialogue is the foundation for a reliability program. The Standard shifts the focus from a fixed "document" approach to a performance based, supplier-customer dialogue approach. With rapid technological advances (methods, materials, processes, etc.), documents quickly become obsolete. This Guide supports the belief that the supplier and customer can best determine the most efficient and effective program, and eliminate non-value added activities.

To be successful, an ideal supplier-customer dialogue should be initiated by the supplier as early as possible in the product development cycle, and continue throughout the entire product life cycle. The output from the dialogue will vary in complexity based on product and organizational requirements. As applicable, typical outputs would include the following:

- a. Details of the supplier-customer dialogue itself (roles, responsibilities, participants, authorization, frequency, duration, and modes of communication)
- b. Documentation of requirements
- c. Contractual issues (program costs, repair costs, metrics, liability, warranty, delivery, approved sources, applicable standards)
- d. Full and adequate definition of all product requirements (conditions of use, operating environment, maintenance and service, product specification, and the customer definition of product failure)
- e. Conflict resolution/trade offs procedure
- f. Subcontractor requirements/issues

The details and complexity of the dialogue and requirements will of course vary. The supplier-customer dialogue is the first step in developing the reliability program. However, it continues throughout the length of the product development.

- 1.5.2 **PRODUCT DEVELOPMENT TEAMS**—Up until the mid-1980s, a sequential product development model was standard practice throughout industry. Each step in the new product development process was handled by a single functional specialty. Unfortunately, such a leisurely approach is less and less viable in the emerging faster-paced high-tech arena. The new approach is to establish a product development team, with representatives from all the relevant functions working together from the start. Some industries carry this concept even further by giving these cross-functional teams much higher responsibility and authority in making decisions. Such “highly trained group of employees, ...fully responsible for turning out a well defined segment of finished work” are called self-managed teams (8).

The product development team is entrusted to guide new products through development. By placing decision making in the hands of the team, companies better coordinate product development, improve product quality, and speed time to market (9). The combination of several disciplines into one group expands the overall skill set of the team. Not only do the group members actively take advantage of group dynamics and collective thinking, but the diversity of skills present makes it possible to view issues from different perspectives, evaluate them, and assign and follow up on tasks within the team. The long association builds camaraderie between team members, gives each person a better appreciation for the others' jobs, and helps members clearly see the value of their work to the project.

- 1.5.3 **SUPPLY CHAIN PARTNERING**—Over the last decade, US manufacturers have cut their production and component costs dramatically by overhauling their supplier bases. Suppliers now take responsibility for just-in-time (JIT) delivery of parts, part quality and reliability, reduction of inventory costs, mitigation of defects, and efficiency improvement of their manufacturing and assembly lines (10). However, many companies are now taking “supplier partnering” and “supplier alliances” into an even more advanced form of supply chain management called “supplier integration.” These companies focus on aligning with all the critical suppliers in their supply chain to achieve higher quality and reliability, faster new product development, improved use of technology, reduced time-to-market, minimized investment in resources, and reduction in product development costs (11). The traditional adversarial relationships resulting out of constant demands for price reduction, only served to create a competitive advantage in the short term. Since competitive advantage is increasingly a function of the efficiency and effectiveness of the supply chain, it is apparent that the greater the collaboration between supplier and the customer, the greater the likelihood of realizing a competitive advantage (12,13,14,15).

Suppliers increasingly indicate that they prefer involvement early in the development process, which develops mutual trust. Suppliers get involved in product design, support quality initiatives, are profitable, provide schedule sharing opportunities, respond to cost reduction ideas, maintain consistent communication and feedback, have a well organized crisis management/response system, and are, in general, totally committed to the partnership (16).

The supplier association must not only create an environment of mutual trust between the customer and the supplier, but also among suppliers. In the initial stages of the association, most of time goes into creating a group, exchanging market information, evaluating individual areas of poor performance, and establishing the credentials of other suppliers.

1.6 Augmenting the Role of Reliability Engineering—Looking closely at the Framework for Reliable Product Development (see Table 1), it is apparent that everyone in an organization does something that affects the reliability of the product. Thus, in a manner of speaking, everyone is responsible for product reliability! This begs the question, “What, then, is the responsibility of a Reliability Engineer?”

In a very loose manner, it can be said that a typical engineer knows “how things work.” However, a Reliability engineer is trained in “how things fail” (17). This is an essential discipline that requires a knowledge of the ways in which products can fail, the effects of failure, and aspects of design, manufacture, maintenance, and use which affect the likelihood of failure. Engineering education, unlike reliability education, is generally deterministic and does not pay sufficient attention to variability in engineering processes, materials, and applications (18). The Reliability engineer, thus, plays a key support role on the product development team in driving attention towards managing and controlling variation.

Concurrent product development teams rely on input from each function being provided by specialist team members, and managed by a team leader. Traditionally, this “specialist support” role has been the hallmark of a Reliability Engineering group. However, many companies are now beginning to consider certain Reliability Engineers equally capable of the leadership role on these teams. Although, many of the activities of the product development team may be quite removed from the traditional Reliability Engineering tasks, there are specific benefits that the team gains by having a Reliability person responsible for coordination of activities. These benefits arise from the very nature of the Reliability Engineering job.

Reliability engineers, in their day-to-day tasks, must interact with Engineering, Manufacturing, Marketing, Suppliers, Planning, Testing, Sales, Customers, and Management, among others, on a fairly regular basis. Therefore, these individuals must be knowledgeable about several disciplines, as well as of how they interface. In addition, a Reliability engineer needs a sound understanding of the product life cycle from “cradle to grave” as well as a top-level understanding of the role played by different disciplines. To be effective in this role, the Reliability engineer must also be an exemplary facilitator and be able to work with a variety of individuals. However, this multidisciplinary knowledge-base, thorough understanding of the product life cycle, and the ability to work with, a get work from, a diverse group of specialists are the very qualities that are desired of the leader of a product development team. With the added background in Reliability, this individual can also help fulfill two roles that organizations find essential for reliable product development: *coordination among the various specialities* and a *strategic understanding of variation as it relates to the potential for failure*.

In light of the previous discussion, it is in the interest of an organization to use the Reliability Engineering function as one of the breeding places for future product team leaders. Individuals demonstrating high potential should be encouraged to spend time in Reliability before moving into product development team leadership assignments. To effectively participate in this role, the Reliability group itself should, perhaps, include a mix of highly experienced and respected individuals in the various Engineering specialties mentoring younger engineers rotating within the Reliability discipline as part of their career path. The Reliability specialists should continue to play the traditional support function of the Reliability Engineering group along with the additional responsibility of coaching younger engineers on Reliability principles and methods, creating in them an awareness of the effects of variation, and training them in the use of Reliability methods to manage variation. This would satisfy the need for good product development team leaders as well as provide a foundation for future Reliability specialists.

In expanding their role, Reliability Engineering groups must also learn to accept a larger set of Engineering Methods than has been traditionally considered a part of a Reliability Engineer's toolkit. It is estimated that 70% of all problems in the automotive industry are design related (10). And by our definition, any problem is a Quality and Reliability problem. However, solutions to these problems lie not in Quality and Reliability, but in other disciplines such as Management, Engineering, and Science (18). Therefore, Reliability engineers must keep abreast of advancements in engineering methods and tools, management techniques, and technological accomplishments that may assist in the product development process. Many projects require the use of engineering tools such as Finite Element Analysis, Design of Experiments, and Statistical Engineering. These and other CAE tools should be part of every Reliability engineer's toolkit or, at the very least, the Reliability engineer should have a good understanding of them and their capabilities and limitations, in addition to traditional Reliability Engineering methods such as *Development Testing*, *Failure Reporting and Corrective Action*, and *Reliability Testing*. Management skills that a Reliability Engineer must possess to effectively perform the leadership role on a product development team, include *Project Management Techniques*, *Conflict Management and Resolution Skills*, *Presentation Skills*, and *Leadership Skills*.

Thus, with changes in organizational priorities and the demands for *Faster, Better, Cheaper* products increasing everyday, organizational skillsets must be adapted to the needs of the times, and Reliability Engineering must play a larger role in this effort than has traditionally been the case. The management of risk in product development necessitates that Reliability Engineering develop as a discipline to control these risks through interdisciplinary liaison and control. The challenge is not to let the need to "control" risks, stifle the creative process that drives innovation.

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14. Christopher, M., "Logistics and Supply Chain Management: Strategies for Reducing Costs and Improving Services." Pitman, London, England (1992)

15. Kanter, R.M., *"When Giants Learn to Dance: Mastering the Challenge of Strategy, Management and Careers in the 1990s."* Simon & Schuster, New York, NY (1989)
16. Moody, P.E., *"Customer Supplier Integration: Why Being an Excellent Customer Counts."* Business Horizons, Vol. 35, No. 4 (Jul-Aug 1992)
17. Evans, R.A., *"Negative Thinking."* IEEE Transactions on Reliability, Vol. 42, No. 3 (Sep 1993)
18. O'Connor, P.D.T., *"Practical Reliability Engineering 3rd. Edition (Revised)."* John Wiley & Sons, Chichester, England (1994).
19. Evans, R.A., *"Hope Springs Eternal ..."*. IEEE Transactions on Reliability, Vol. 42, No. 3 (Sep 1993)

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

- a. SAE J1000, "Reliability Program Standard," 1998-6
- b. "Reliability, Availability, and Maintainability (RAM) Dictionary," Edited by Tracy Philip Omdahl, copyright 1988 by ASQC Quality Press
- c. ISO 8402, "Quality Vocabulary"
- d. "Reliability Toolkit: Commercial Practices Edition," A practical Guide for Commercial Products and Military Systems Under Acquisition Reform," Joint Effort Document of Rom Laboratory and Reliability Analysis Center (RAC), P.O. Box 4700, Rome, NY 13442-4700
- e. *"Assurance Technologies, Principles and Practices,"* Dev. G. Raheja, McGraw-Hill, 1981
- f. MIL-STD-785B, *"Reliability Program for Systems and Equipment Development and Production,"* 15 Sept 1980
- g. *"Reliability Engineering Handbook,"* Dimitri Kececioglu, PTR Prentice Hall, 1991
- h. SAE AIR 4896, *"Recommended RMS Terms and Parameters,"* 1995-12

3. Definitions—The terms and definitions have been included to enhance the understanding of this document. See Appendix B. Many additional reliability terms and definitions can be found in the related publications listed in 2.2.

4. The Reliability Program—This section provides guidance for developing and implementing a reliability program. This implementation guide's intent is not to prescribe any specific reliability methods but rather to provide guidance to assist in structuring a reliability program. A reliability program includes reliability activities and methods selected to assure the reliability of a product in a cost effective manner. A properly planned and executed reliability program benefits both the customer and the supplier as illustrated in Table 2.

TABLE 2—BENEFITS OF A PROPERLY PLANNED RELIABILITY PROGRAM

Customer Benefits	Supplier Benefits
Reduce customer cost of ownership	Increase Probability to meet reliability targets
Improve the availability of the product	Reduce supplier risk
Reduce maintenance and logistics burdens	Reduce warranty costs
	Quantify risk in achieving program requirements
	Help allocate resources to the most value-added activities
	Improves supplier reputation

Section 4 is divided into three functional areas: 4.1 Reliability Program Development, 4.2 Reliability Program Integration and Implementation, and 4.3 Reliability Program Metrics.

4.1 Reliability Program Development

4.1.1 RELIABILITY PROGRAM REQUIREMENTS—In developing a reliability program, the three requirements identified in the parent SAE JA1000 document need to be met. Summarized, the three requirements are:

- a. Ascertain Customer Requirements (referred to as R1)
- b. Design/Develop to Meet Customer Requirements (referred to as R2)
- c. Assure That Customer Requirements Have Been Met (referred to as R3)

The term “customer” may refer either to the end user, an intermediate contracting agency (such as in the case of a DoD program office), or a primary supplier obtaining products from a secondary supplier (e.g., major product developer obtaining parts from a third party supplier). In a similar vein, a supplier may be the customer for sub-suppliers.

Considering these different perspectives, the guide was written for a broad audience. It treats the activities within each phase at a conceptual level of abstraction and identifies typical methods used by industry to satisfy each of the three generic requirements.

When viewing the three requirements, the user needs to take a holistic perspective by considering both the product and process for a particular product development program. For example:

- R1—Ascertaining requirements includes identifying customer requirements for the product and the program
- R2—Meeting customer requirements means building the product to meet customer requirements, and executing the required program to meet program requirements.
- R3—Assurance means conducting verification activities on the product as well as monitoring and controlling the program (assuring that the program used to develop the product is executed correctly).

Central to all activities throughout the reliability program is the supplier-customer dialogue. This dialogue is essential to fully understand required product characteristics and application and should continue throughout the program to ensure that all customer requirements and changes are known by the supplier.

4.1.2 GENERIC DEVELOPMENT CYCLE PHASES—All products progress through a number of development life cycle phases², the definition of which may vary between organizations³. While it is recognized that industry employs a variety of different defined development phases, this Guide will use three broad generic development phases to illustrate program implementation. These phases provide a basis for the topics discussed in this implementation guide and should be modified by each user of the guide to suit their specific practices and particular product development strategies. There may be more or fewer than three phases, and the nomenclature may be different than that shown here.

There are three generic development phases used in this Implementation Guide. To assist the reader of this implementation guide in understanding the boundary lines for these phases, a number of actions have been identified for each phase. The three development-cycle phases used are:

- a. The Concept Phase which typically involves such actions as determining customer needs, understanding the products intended operating environment, studying product feasibility, and considering alternate design solutions to meet customer needs.
- b. The Design and Development Phase which typically involves such actions as developing a detailed approach and solution for producing a product, and then designing the solution using the detailed approach.
- c. The Production and Use Phase which typically involves building, testing and deploying, and supporting operational units to users.

2. Since this document focuses on the development of new products, a complete set of life cycle phase definitions are not warranted.

3. Organizations may include commercial organizations at both the primary supplier and secondary supplier levels or contracting organizations and contractors.

- 4.1.3 **RELIABILITY PROGRAM ACTIVITIES**—A reliability program activity is a defined action that uses one or more methods to satisfy a reliability program requirement. The three requirements of SAE JA1000, i.e., R1, R2, and R3 each have their own set of reliability program activities. Table 3 illustrates the three requirements of SAE JA1000 along with the activities associated with each. The paragraph numbers from the standard are also shown. Table 4 provides a mapping of activities to R1, R2, and R3, cross referenced to the three generic product development cycle phases defined in 4.1.2. It should be noted that not all activities of SAE JA1000 may be applicable to every program. Activity selection should be part of the customer-supplier dialogue.

TABLE 3—SAE JA1000 REQUIREMENTS AND ASSOCIATED ACTIVITIES

Requirements		
R1	R2	R3
4.1 The Supplier Shall Ascertain Customer Requirements	4.2 The Supplier Shall Meet Customer Requirements	4.3 The Supplier Shall Assure That Customer Requirements Have Been Met
Activities		
4.1.1 Establish Supplier-Customer Dialogue	4.2.1 Characterize Resources	4.3.1 Qualify the Product and Process
4.1.2 Identify Conditions of Use	4.2.2 Assess and Manage Risk	4.3.2 Establish Process Controls
4.1.3 Define Maintenance and Service	4.2.3 Design to Achieve Reliability	4.3.3 Pursue Continuous Improvement
4.1.4 Establish Metrics		4.3.4 Establish Data Collection and Reporting
4.1.5 Develop Product Specification		

TABLE 4—RELIABILITY PROGRAM ACTIVITIES MAPPED TO REQUIREMENTS AND PHASES

	Concept Phase	Design and Development Phase	Product and Use Phase
R1	4.1.1 Establish Supplier-Customer Dialogue 4.1.2 Identify Conditions of Use 4.1.3 Define Maintenance and Service 4.1.4 Establish Metrics 4.1.5 Develop Product Specification	4.1.1 Establish Supplier-Customer Dialogue ⁽¹⁾ 4.1.2 Identify Conditions of Use ⁽¹⁾ 4.1.3 Define Maintenance and Service ⁽¹⁾ 4.1.4 Establish Metrics ⁽¹⁾ 4.1.5 Develop Product Specification ⁽¹⁾	4.1.1 Establish Supplier-Customer Dialogue ⁽¹⁾ 4.1.4 Establish Metrics ⁽¹⁾
R2	4.2.1 Characterize Resources 4.2.2 Assess and Manage Risk	4.2.1 Characterize Resources ⁽¹⁾ 4.2.2 Assess and Manage Risk ⁽¹⁾ 4.2.3 Design to Achieve Reliability	4.2.2 Assess and Manage Risk ⁽¹⁾ 4.2.3 Design to Achieve Reliability
R3	4.3.4 Establish Data Collection and Reporting	4.3.1 Qualify the Product and Process 4.3.2 Establish Process Controls 4.3.3 Pursue Continuous Improvement 4.3.4 Establish Data Collection and Reporting	4.3.1 Qualify the Product and Process ⁽¹⁾ 4.3.2 Establish Process Controls ⁽¹⁾ 4.3.3 Pursue Continuous Improvement ⁽¹⁾ 4.3.4 Establish Data Collection and Reporting ⁽¹⁾

1. Activity also appears in previous phase.

- 4.1.4 **APPLICABLE METHODS (METHODS APPLICABLE TO R1, R2, AND R3)**—Section 5 of this guide provides short descriptions for a number of reliability methods. Methods are used to accomplish activities. Tables 5A, 5B, and 5C list the methods in relation to their applicability to the requirements and activities of SAE JA1000 for the concept, design and development, and production phases respectively. The selection of methods is a highly individualized process. This point cannot be overemphasized and this document does not attempt to prescribe any given method or set of methods. There is no right answer that will apply across the board to every organization or every product development. Suppliers and customers need to determine which methods are most applicable to their specific product developments. No priority of importance should be inferred by their relative listing in the tables.

**TABLE 5A—MAPPING OF RELIABILITY METHODS TO SAE JA1000 REQUIREMENTS AND ACTIVITIES—
CONCEPT PHASE**

Requirement	Activities and Methods Concept Phase	Activities and Methods Concept Phase	Activities and Methods Concept Phase	Activities and Methods Concept Phase
R1 The Supplier Shall Ascertain Customer Requirements	Activity 4.1.1: Establish Supplier-Customer Dialogue a. Focus Groups b. Quality Function Deployment c. Reliability Benchmarking d. Risk Assessment e. Surveys/Market Analysis	Activity 4.1.2: Identify Conditions of Use a. Environmental Characterization b. Focus Groups c. Mission Profile Generation d. Quality Function Deployment e. Real World Usage Profiles f. Reliability Benchmarking g. Surveys/Market Analysis	Activity 4.1.3 Define Maintenance and Service a. Focus Groups b. Mission Profile Generation c. Quality Function Deployment d. Real World Usage Profiles e. Reliability Benchmarking f. Surveys/Market Analysis g. Reliability Allocation h. Reliability Centered Maintenance	Activity 4.1.4: Establish Metrics a. Environmental Characterization b. Pugh Selection c. Quality Function Deployment Activity 4.1.5 Develop Product Specification a. Environmental Characterization b. Mission Profile Generation c. Pugh Selection d. Quality Function Deployment e. Real World Usage Profiles f. Reliability Allocation g. Reliability Centered Maintenance
R2 The supplier Shall Meet Customer Requirements	Activity 4.2.1: Characterize Resources a. Regression Analysis/Correlation b. Production Process Capability Study	Activity 4.2.2 Assess and Manage Risk a. FMEA/FMECA b. Mission Profile Generation c. Probabilistic Design - Stress & Strength Interfer. Method d. Real World Usage Profiles e. Regression Analysis/Correlation f. Reliability Modeling and Prediction g. Risk Assessment h. FRACAS	i. Reliability Allocation j. Reliability Centered Maintenance k. Design Review l. Fault Tree Analysis	Activity 4.2.3: Design to Achieve Reliability a. Activity 4.2.3 is usually not applicable to the Concept Phase. However, the activities listed in the Design & Development Phase may begin in this phase.
R3 The Supplier Shall Assure That Customer Requirements Have Been Met	Activity 4.3.1: Qualify the Product and Process a. Activity 4.3.1 is usually not applicable to the Concept Phase. However, the activities listed in the Design & Development Phase may begin in this phase.	Activity 4.3.2 Establish Process Controls a. Activity 4.3.2 is usually not applicable to the Concept Phase. However, the activities listed in the Design & Development Phase may begin in this phase.	Activity 4.3.3 Pursue Continuous Improvement a. Activity 4.3.3 is usually not applicable to the Concept Phase. However, the activities listed in the Design & Development Phase may begin in this phase.	Activity 4.3.4: Establish Data Collection and Reporting a. Warranty Tracking/Info Collection b. FRACAS

**TABLE 5B—MAPPING OF RELIABILITY METHODS TO SAE JA1000 REQUIREMENTS AND ACTIVITIES—
DESIGN AND DEVELOPMENT PHASE**

Requirement	Activities and Methods Design and Development Phase	Activities and Methods Design and Development Phase	Activities and Methods Design and Development Phase	Activities and Methods Design and Development Phase
R1 The Supplier Shall Ascertain Customer Requirements	<u>Activity 4.1.1:</u> <u>Establish Supplier-Customer Dialogue</u> • Focus Groups • Quality Function Deployment • Reliability Benchmarking • Risk Assessment • Surveys/Market Analysis	<u>Activity 4.1.2:</u> <u>Identify Conditions of Use</u> • Environmental Characterization • Focus Groups • Mission Profile Generation • Quality Function Deployment • Real World Usage Profiles • Reliability Benchmarking • Surveys/Market Analysis	<u>Activity 4.1.3:</u> <u>Define Maintenance and Service</u> • Focus Groups • Mission Profile Generation • Quality Function Deployment • Real World Usage Profiles • Reliability Benchmarking • Surveys/Market Analysis • Reliability Allocation • Reliability Centered Maintenance	<u>Activity 4.1.4:</u> <u>Establish Metrics</u> • Environmental Characterization • Pugh Selection • Quality Function Deployment • Real World Usage Profiles • Reliability Allocation • Reliability Centered Maintenance <u>Activity 4.1.5:</u> <u>Develop Product Specification</u> • Environmental Characterization • Mission Profile Generation • Pugh Selection • Quality Function Deployment • Real World Usage Profiles • Reliability Allocation • Reliability Centered Maintenance
R2 The Supplier Shall Meet Customer Requirements	<u>Activity 4.2.1:</u> <u>Characterize Resources</u> • Regression Analysis/Correlation • Production Process Capability Study	<u>Activity 4.2.2:</u> <u>Assess and Manage Risk</u> • FMEA/FMECA • Mission Profile Generation • Probabilistic Design - Stress & Strength Interfer. Method • Real World Usage Profiles • Regression Analysis/Correlation • Reliability Modeling and Prediction • Risk Assessment • FRACAS	• Reliability Allocation • Reliability Centered Maintenance • Design Review • Fault Tree Analysis	<u>Activity 4.2.3:</u> <u>Design to Achieve Reliability</u> • Block Diagram Development • Environmental Characterization • FMEA/FMECA • Fault Tree Analysis • Mission Profile Generation • Probabilistic Design - Stress and Strength Interfer. Method • Pugh Selection • Quality Function Deployment • Real World Usage Profiles • Regression Analysis/Correlation • Reliability Modeling and Prediction • Accelerated Testing • Design for Mfg/Assembly • Design of Experiments • Error/Mistake Proofing • Fault Tolerance Analysis • Finite Element Analysis • FRACAS • Pareto Analysis • Part Derating • Reliability Allocation • Reliability Centered Maintenance • Robust Design • Root Cause Analysis • Sneak Circuit/Path Analysis • Variation Simulation Modeling • Weibull Analysis • Worst Case Analysis • Quality Loss Function • Design Review
R3 The Supplier Shall Assure That Customer Requirements Have Been Met	<u>Activity 4.3.1:</u> <u>Qualify the Product and Process</u> • Risk Assessment • Accelerated Testing • Error/Mistake Proofing • Pareto Analysis • Production Process Capability Study • Reliability Growth Testing • Environmental Stress Screening • Reliability Demo Testing • Sampling Procedures	<u>Activity 4.3.2:</u> <u>Establish Process Controls</u> • Design Review • Risk Assessment • Error/Mistake Proofing • Pareto Analysis • Parts, Materials, Process Review Control • Production Process Capability Study • Environmental Stress Screening • Sampling Procedures • Statistical Process Control	<u>Activity 4.3.3:</u> <u>Pursue Continuous Improvement</u> • Design Review • Warranty Tracking/Info. Collection • Error/Mistake Proofing • Pareto Analysis • Production Process Capability Study • Sneak Circuit/Path Analysis • Statistical Process Control	<u>Activity 4.3.4:</u> <u>Establish Data Collection and Reporting</u> • Warranty Tracking/Info. Collection • Accelerated Testing • FRACAS • Pareto Analysis • Reliability Growth Testing • Environmental Stress Screening • Reliability Demonstration Testing • Sampling Procedures • Statistical Process Control

**TABLE 5C—MAPPING OF RELIABILITY METHODS TO SAE JA1000 REQUIREMENTS AND ACTIVITIES—
PRODUCTION AND USE PHASE**

Requirement	Activities and Methods Production and Use Phase	Activities and Methods Production and Use Phase	Activities and Methods Production and Use Phase	Activities and Methods Production and Use Phase
R1 The Supplier Shall Ascertain Customer Requirements	<u>Activity 4.1.1: Establish Supplier-Customer Dialogue</u> • Focus Groups • Quality Function Deployment • Reliability Benchmarking • Risk Assessment • Surveys/Market Analysis	<u>Activity 4.1.2: Identify Conditions of Use</u> • Methods from the Design and development Phase may continue into this phase.	<u>Activity 4.1.3: Define Maintenance and Service</u> • Methods from the Design and Development Phase may continue into this phase.	<u>Activity 4.1.4: Establish Metrics</u> • Environmental Characterization • Pugh Selection • Quality Function Deployment <u>Activity 4.1.5: Develop Product Specification</u> • Methods from the Design and Development Phase may continue into this phase.
R2 The Supplier Shall Meet Customer Requirements	<u>Activity 4.2.1: Characterize Resources</u> • Methods from the Design and Development Phase may continue into this phase.	<u>Activity 4.2.2: Assess and Manage Risk</u> • FMEA/FMECA • Mission Profile Generation • Probabilistic Design - Stress & Strength Interfer. Method • Real World Usage Profiles • Regression Analysis/Correlation • Reliability Modeling and Prediction • Risk Assessment • Error/Mistake Proofing • Fault Tolerance Analysis • Finite Element Analysis • FRACAS	<u>Activity 4.2.3: Design to Achieve Reliability</u> • Pareto Analysis • Parts Derating • Parts, Materials, Process Review/Control • Reliability Allocation • Reliability Centered Maintenance • Root Cause Analysis • Sneak Circuit/Path Anal • Weibull Analysis • Worst Case Analysis • Quality Loss Function • Design Review • Reliability Growth Testing • Fault Tree Analysis	<u>Activity 4.2.3: Design to Achieve Reliability</u> • Methods from the Design and Development Phase may continue into this phase.
R3 The Supplier Shall Assure That Customer Requirements Have Been Met	<u>Activity 4.3.1: Qualify the Product and Process</u> • Design Review • Risk Assessment • Accelerated Testing • Error/Mistake Proofing • Pareto Analysis • Production Process Capability Study • Reliability Growth Testing • Environmental Stress Screening • Reliability Demo Testing • Sampling Procedures	<u>Activity 4.3.2: Establish Process Controls</u> • Design Review • Risk Assessment • Error/Mistake Proofing • Pareto Analysis • Parts, Materials, Process Review Control • Production Process Capability Study • Environmental Stress Screening • Statistical Process Control	<u>Activity 4.3.3: Pursue Continuous Improvement</u> • Design Review • Warranty Tracking/Info. Collection • Error/Mistake Proofing • Pareto Analysis • Production Process Capability Study • Sneak Circuit/Path Analysis • Statistical Process Control	<u>Activity 4.3.4: Establish Data Collection and Reporting</u> • Warranty Tracking/Info Collection • Accelerated Testing • FRACAS • Pareto Analysis • Reliability Growth Testing • Environmental Stress Screening • Reliability Demonstration Testing • Sampling Procedures • Statistical Process Control

- 4.1.5 METHOD SELECTION CRITERIA—Selecting methods for a given program is a highly individualized process. This point cannot be overemphasized and this document does not attempt to prescribe any given method or set of methods. There is no right answer that will apply across the board to every organization or every product development. Suppliers and customers need to determine which methods are most applicable to their specific product developments. Selecting methods should be based on product development strategies and individual needs procedures.

However, selecting methods can be made easier by using the criteria listed in 4.1.5.1, Examples 1 and 2 (4.1.5.2 and 4.1.5.3), and Section 5 of this guide (Section 5 provides short descriptions of various methods including their purpose, intended application, benefits, and limitations).

4.1.5.1 Sample Criteria for Selecting Reliability Methods

- a. Improves the total quality of the product
- b. Reduces the time to field the product
- c. Is cost effective
- d. Reduces safety and environmental risks
- e. Has the potential to achieve a "quantum improvement" in the product
- f. Can be used within current resource constraints
- g. Is proven
- h. Is efficient and easily executed
- i. Is directly focused on the product under development
- j. Has management buy-in for use
- k. Is perceived as "best-in-class"
- l. Is planned for use based on previous experience
- m. Is quantifiable
- n. Can be easily introduced to those who must apply
- o. Is simple to apply

The following examples illustrate two ways methods could be selected. Example 1 shows a *qualitative* approach, and Example 2 is *quantitative*.

- 4.1.5.2 *Example 1: Using Decision Matrixes To Tradeoff Between Criteria (Qualitative Approach)*—There are many factors to consider in selecting reliability method(s) for a product development program. It is desirable that a method would possess all or many of the criteria listed in 4.1.5.1. However, it is unlikely that any one method would have many, or all of them. Therefore, it is sometimes necessary to do a tradeoff evaluation. The following example (Figure 1A) shows Time Required to Implement versus Cost. The optimum condition would be a "short" time to implement at a "low" cost. However, in any given situation there may be a need to tradeoff cost to speed the implementation of a method. In another situation, it may be important to lower cost and extend the time necessary to implement.

The same principle is illustrated in the Figure 1B, matrix "Level of Skill" versus "Method Type." In fact, any of the criteria listed in 4.1.5.1 (or other criteria) may be evaluated to help determine the most effective method for a given situation.

Time to Implement	Long		Avoid
	Short	Target	
		Low	High
		Cost	

FIGURE 1A—METHOD SELECTION CRITERIA: TIME TO IMPLEMENT VERSUS COST

Level of Skill	High		Avoid
	Low	Target	
		Prevention	Resolution
		Method Type	

FIGURE 1B—METHOD SELECTION CRITERIA: LEVEL OF SKILL VERSUS METHOD TYPE

4.1.5.3 Example 2: Selecting Methods Using Group Prioritization and Relative Weighting (Quantitative Approach)—Company ABC needs to improve a product design. Based on a review of the method descriptions in Section 5, the product development team has determined that either "Method 1" or "Method 2" would be useful in this situation. The team has also determined that implementing both methods would be too costly and must therefore select one. The process used to select the better method is illustrated in Figure 2.

1	2	3	4	5	6
Applicable Criteria	Weighting	Method 1	Method 2	Method 1 Col 2 x Col 3	Method 2 Col 2 x Col 4
a.	3	0	1	0	3
c.	6	1	0	6	0
g.	2	1	0	2	0
h.	5	1	0	5	0
j.	1	0	1	0	1
l.	4	1	0	4	0
Scores:				17	4

FIGURE 2—SAMPLE CRITERIA USED TO SELECT BETWEEN METHODS

(Refer to Figure 2) Column 1 lists the applicable method criterion, identified a thru o in 4.1.5.1. These were selected through a brainstorming session. Attributes a, c, g, h, j, and l are considered important for the development of this product.

Column 2 ranks the criteria relative to their importance to the product development. The rankings were determined through use of a group prioritization exercise. The highest priority criteria was assigned a weight of 6, second highest a weight of 5, and so on. In this example, c ("Is very cost effective") is most highly weighted (6).

Columns 3 and 4 are either 1 or 0 depending on the group consensus as to which of the two methods best meets the intent of the criterion. In this example, h ("Is efficient and easily executed") is best met by Method 1.

Columns 5 and 6 are the scores for each method (the product of Weighting and Method). The column is then added. Since the Method 1 scored 17 and Method 2 scored only 4, the decision is to use Method 1.

4.2 Reliability Program Integration and Implementation—Historically, product reliability efforts were sometimes integrated without sufficient planning and integration into the overall product development program. Consequently, the reliability program was disjointed from the rest of the program and was therefore less beneficial to the product. Ideally, reliability methods and activities should be carefully chosen and integrated into the overall program.

4.2.1 RELIABILITY PROGRAM PLAN—A product development program normally has a documented plan. The plan for the reliability program could be a stand-alone reliability program plan or integrated in the broader overall program plan (e.g., product assurance plan). The plan should document the following program details:

- a. A description of how the reliability program will be conducted to meet customer requirements.
- b. A description of how each reliability activity and method will be performed.
- c. Identification of the relevant points of contact responsible for managing the reliability program and those responsible for implementing each activity and method.
- d. A description of critical activities.
- e. A description of how reliability elements will interface with other engineering disciplines and how reliability tasks and activities are disseminated to designers and other associated personnel.
- f. A schedule with estimated start and completion points for all activities and methods.
- g. A description of known reliability problems to be solved and an assessment on the impact of these problems on meeting customer requirements. Plans on how to solve these problems could also be included.
- h. Statements of sources of reliability guidance documentation.
 1. Identification of inputs required from other disciplines necessary to help implement reliability activities and methods.
 2. Resource allocation information.

A Plan may not always be required, but when required, the extent of the Plan should be mutually agreed upon by the supplier and customer.

4.2.2 RELIABILITY PROGRAM IMPLEMENTATION—As each reliability program will be implemented differently according to the particular product development strategy and unique program issues, Tables 4, 5A, 5B, and 5C show how all the elements described in this implementation guide may come together for the implementation of the reliability program. Keep in mind that every organization will have their own phase terminology which will most likely differ from that shown here.

4.3 Reliability Program Metrics—Metrics provide a mechanism for monitoring product and process characteristics to facilitate control over a product's development. In the context of this implementation guide, the metrics of concern are those that measure the reliability characteristics of a product and any process characteristics that may affect the reliability of that product. It is generally recognized that metrics may be applied in either the process or product domains. These two categories provide a mechanism for classifying the plethora of metrics into manageable groupings of either product metrics, which relate to the characteristic of the product (e.g., MTTF, MTBF, Failure Rate, Defect Rate/Defect Density), or process metrics, which relate to the characteristic of the processes used in the development of the product (e.g., Process Capability Level Indices (Cp)).

4.3.1 KEY ELEMENTS—The measurement process is a control process and as such can be effectively modeled by the four elements of the PDCA closed loop process (Figure 3): [1]

- a. Plan - deciding what product or process characteristics to measure, defining the process by which the characteristics will be measured and establishing quantifiable targets or trigger points.
- b. Do - monitoring and gathering data on the object of measurement (product or process).
- c. Check - evaluating data against defined target values and reporting results.
- d. Act - deciding whether to maintain the status quo or make a change to the object being measured.

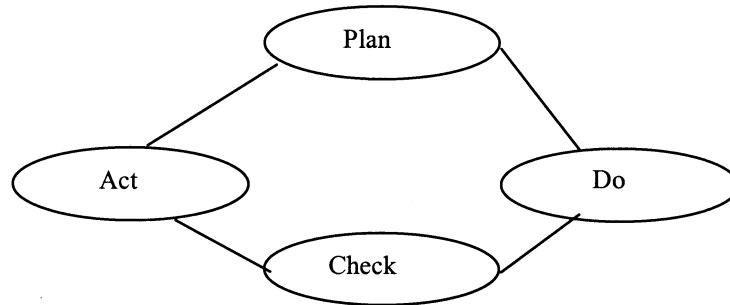


FIGURE 3—THE MEASUREMENT MODEL

4.3.2 PLANNING THE METRICS EFFORT—There are three key elements to planning the metrics effort:

- a. Define and Document the Object of Measurement—Define and document the object of measurement (product or process) in a concise and unambiguous manner. This information should be documented in the reliability program plan (or equivalent document).
- b. Define and Document Quantifiable Targets—This is essential, as without measurable targets or trigger levels there are no indicators to enable management to make informed decisions. This information should also be documented in the reliability program plan (or equivalent document).
- c. Define and Document the Measurement Method—Define the method by which the subject characteristics will be measured⁴. This includes selecting the metric(s) and defining the data collection process. In selecting a metric, care should be taken to ensure that the metric is: [2]
 1. Accurate and sufficient
 2. Efficient to collect (cost effective)
 3. Timely
 4. Understandable (simple)
 5. Useful (needed and meaningful) and
 6. Traceable to the organizations/customers objectives⁵

4. The only effective way to measure or predict reliability, to date, is through the use of defect data or operational failure data. In the area of project control, the main concern of metrics is related to faults and changes required to correct faults.

5. This last point is an important issue which is normally understated. If a metric is not easily related to the method by which a customer defines needs, or the way an organization defines its objectives in developing a product, then inappropriate metrics may be used to monitor a products development.

One mechanism that may be used to assess the quality of the metric selected is to use the SMART test as described in the Department of Energy PBM handbook [3]:

- a. S - Specific; clear and focused to avoid misinterpretation (should include measure assumptions and definitions).
- b. M - Measurable; can be quantified and compared to other data. It should allow for meaningful statistical analysis.
- c. A - Attainable; achievable, reasonable, and credible under conditions expected.
- d. R - Realistic fits into the organizations constraints and is cost-effective.
- e. T - Timely; doable within the time frame given.

The selected metrics and the process to be used should be documented in the reliability program plan (or equivalent document). In the case of metrics, the definitions should include not just the name but also description of Purpose, Data Inputs and Collection, and Use.

Data collection procedures should include Organizational Details, i.e., who's responsible for collecting, verifying, and analyzing the data, and should be documented in the reliability program plan (or equivalent document). To enable efficient collection of the data, some consideration should be given to:

- a. The means by which this possibly large volume of data is to be stored
- b. The degree of overhead to be placed on those responsible for monitoring or collecting the data
- c. The appropriateness of the storage mechanism for timely dissemination of information to management

Timely reporting of any results is essential to enable management to make a decision. Agencies responsible for reporting and the reporting chain should be explicitly defined and documented in the reliability program plan (or equivalent document).

- 4.3.3 GATHERING AND EVALUATING DATA AND REPORTING RESULTS—Throughout the product development, data on the defined metrics concerning the product and process characteristics are monitored and collected, and actions taken as necessary. Data may be collected continuously, at specific intervals, or based on some event. Management can be alerted to the need for possible actions, such as redesign, change in parts, etc., based on trending analysis or a triggering event (when a limit is exceeded). Trending is used to compare achieved results with some predefined goal. Triggering occurs when a predefined limit or trigger point is exceeded. Trending is preferred because it provides an early indication of potential problems, i.e., it is proactive. Depending on where the trigger point is set, when a limit exceeded, the problem has usually already occurred.

Timely reporting of any results, even before an unacceptable condition has occurred (e.g., observing unfavorable trends), is essential to enable management to make a decision. "The quicker the response from the standard, the more uniform the produced quality." [1]

- 4.3.4 ACTING ON THE RESULTS—Once a condition(s) has been reported, it is up to management to make a decision to maintain the status quo or change product/process. If there are any changes to the metrics or mechanism by which the metrics are collected, these changes should be documented in the reliability program plan (or equivalent document).

5. **Reliability Methods**—A product team⁶ typically uses a number of engineering, mathematical, and managerial techniques to achieve the objectives of reliable product development (i.e., *define customer needs, meet those needs through the design and manufacture of a product, and assure the customer that the needs have been met*). Collectively, these techniques are referred to as reliability methods. The purpose of this section is to provide the reader with concise descriptions of a number of reliability methods in the industrial, military, governmental, and academic world that are available to product teams.

The product team needs two kinds of information to properly apply reliability methods to the reliable product development. First, it needs to select the proper method from a number of available techniques, i.e., *do the right things*. Having selected a particular method, the team then needs to determine the right way to perform it, i.e., *do things right*. The descriptions in this Implementation Guide are designed to assist product teams with the former, i.e., *selection of proper reliability methods to use at various points in the making of a reliable product*. Rather than providing detailed descriptions of each method, an attempt has been made to focus only on the key aspects that determine the relevance of a method to a particular product situation. This information then enables the team to identify the activities that need to be performed at various points during product development to ensure a reliable product. The team may then compile a reliability program that is in consonance with the overall product development plan.

Having decided on a particular set of reliability methods for the reliability program, the team then needs information on how to use and apply them. Since, this information is readily available in the literature, as well as through various university courses, seminars, and lectures, the descriptions in this section do not describe how to perform the reliability methods. However, a bibliography of references is provided with each description and the reader is encouraged to refer to these sources for detailed information on the selected reliability methods.

- 5.1 **Format of the Method Descriptions**—The information in each method description is divided into eight sections. These are:

- a. Description (*The main features of the method*)
- b. Purpose (*What the method helps in achieving*)
- c. Application (*The types of situations where the method is usually used*)
- d. Key Elements (*A very brief summary of how the method is used, i.e., the main steps involved, typical inputs, and typical outputs*)
- e. Benefits (*The value that the method adds to the product development process*)
- f. Limitations (*Cautionary statements about the method, its cost or skill levels required*)
- g. References (*Bibliography of sources for more information on the method*)

The content of each section is similar across descriptions. This is done to ensure uniformity and to assist the product development team in selecting the reliability method that best suits their needs.

- 5.2 **Criteria for Inclusion of Reliability Methods in this Guide**—Reliability impacts such a large number of activities, that it is sometimes difficult to conclusively say whether or not a particular method is a reliability method. Thus, in order to define the scope of this section, the reliability methods included in this Guide were selected on the basis of the following criteria:

- a. Must be a generally recognized practice in at least one industry segment (i.e., not unique to a single company)
- b. All methods must have a similar level of hierarchy (i.e., neither too narrow nor too broad)
- c. Must be a technique, not a “process” or a “subject”
- d. Must be generally considered as a technique that impacts reliability
- e. Must not be proprietary to any individual or organization

6. A product development “team” commonly refers to multi-discipline organizations. However, a product development “team” could be any size, a few or even an individual.

- f. Must not be exclusive to software products only

With this brief overview, we now turn to the reliability methods.

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PREPARED BY THE SAE G-11 RELIABILITY PROGRAM STANDARD SUBCOMMITTEE

REAFFIRMED BY THE SAE G-11R, RELIABILITY COMMITTEE

APPENDIX A

A.1 Accelerated Testing

A.1.1 Description—In planning and executing a test, there will often be some need to shorten the test time to obtain information quickly and efficiently with cost, manpower, and facility constraints. This means testing has to be accelerated.

A.1.2 Purpose—Accelerated testing is used to:

- a. Remove Dormant Time (or Cycle, Mileage, Revolutions, etc.) and also remove non-damaging and/or less damaging occurrences (Expedited Testing)
- b. Determine the critical stressor(s) for acceleration
- c. Increase the level of stress, i.e., higher than normal stressor (or stress factor) magnitude (Single Factor Accelerated Test)
- d. Simultaneously increase more than one stressor/factor (Multiple Factors Accelerated Test)

A.1.3 Application—Accelerating test can be used in all product development phases in determining requirements through bench-marking, in robust design study and prototype testing, and in Key Life Tests and/or other Design Verification tests.

A.1.4 Key Elements

- a. Identify the objective and scope of the accelerated test. A typical test may have one or more of the following objectives:
 1. Compare the estimated life of two or more designs,
 2. Develop a relationship between stress and life,
 3. Estimate the life of a product at a given stress condition,
 4. Investigate failure modes at elevated stress,
 5. Verify known stress-life model limitation.
- b. Collect and understand the failure-related and usage-related information.
- c. Identify desired test duration.
- d. Determine test duration by removing dormant time/cycle and non/less damaging cycle. This step shortens test time by removing unimportant cycles or time without affecting stress(es). This is the least risky way of shortening time and it is strongly recommended to execute this first.
- e. Determine single stressor. After removing dormant time and non/less damaging cycles, test must now be accelerated by selecting a critical stressor. The selected stressor should have a significant impact on accelerating failure modes of interest and should not introduce new failure modes.
- f. Identify single factor stress-life model. Once the stress factor is determined, life as a function of this stress factor should be established. This relationship is generally referred to as the S-N curve.

A.1.5 Benefits

- a. Shortens product verification time which helps to reduce product design cycle
- b. Can reduce product development cost
- c. Reveals rapid product performance information for design evaluation
- d. Provides an estimation of life in relation to the stress(es) induced for decision making on design
- e. Provides a baseline for determination of Environmental Stress Screening parameters
- f. Enables early identification of potential failure modes

A.1.6 Limitations

- a. Excessive stresses may induce a physical change in the product and/or cause unrealistic damage
- b. Cumulative damage to the product may not correlate accurately to actual product usage and determination of the acceleration factor may be difficult
- c. Cannot be undertaken until product (or prototype) is available

A.1.7 References

- a. Hu, J.M., Barker, D., Dasgupta, A., and Arora, A. "*Role of Failure-Mechanism Identification in Accelerated Testing*," Journal of the IES, July/August, 1993, pp. 39-45
- b. Meeker, W. and Hahn, G. "*How To Plan An Accelerated Life Test --- Some Practical Guidelines*," The ASQC Basic Reference in Quality Control, Vol. 10, June 1985, pp. 1-36
- c. Nelson, Wayne. "*Accelerated Testing*," John Wiley & Sons, 1990
- d. Rabinowicz, E., McEntire, R.H., and Shiralkar, B. "*A Technique for Accelerated Life Testing*," Transactions of ASME, August, 1970, pp.706-710

A.2 Block Diagram Development

A.2.1 Description—There are three commonly used block diagrams:

- a. Hierarchy Block Diagram—Breaks a product into natural and logical elements and becomes more detailed at each level down, e.g., vehicle, chunk, system, subsystem, and component.
- b. Functional Block Diagram—Breaks the system into its smaller elements and shows the functional and physical relationships among the elements.
- c. Reliability Block Diagram—Breaks a system into smaller elements and shows the relationship from a reliability standpoint; that is, the sequence and relationships of elements that define operational failure or success of a system.

A.2.2 Purpose—The purpose of a block diagram is to divide a complex system into more manageable levels and to depict the relationships among various elements in a system.

A.2.3 Application—Block diagrams are among the first tasks completed during product definition. They should be constructed as part of the initial concept development. They should be started as soon as the program definition exists, completed as part of the requirements analysis, and continually expanded to a more detailed level as data become available in order to make decisions and trade-offs.

A.2.4 Key Elements—The following are the key elements of block diagrams

- a. Determine both the system boundaries and the levels of detail or complexity to be analyzed.
- b. Partition the system into logical subsystems or components
- c. Identify the physical and functional relationships of the various elements of a system
(Additional elements specific to reliability block diagrams)
 1. Define system reliability
 2. Translate to a mission success diagram, which is a Reliability Block Diagram (RBD) constructed using the basic configurations of series, parallel, and complex subsystems
 3. Conduct qualitative analysis, such as the success path from input to output
 4. Develop reliability model to quantify the reliability of the system at a specific time as depicted by the RBD
 5. Assign reliability for each block and calculate system reliability

A.2.5 Benefits

- a. Facilitates an understanding of the system by showing the relationships among its elements
- b. Can provide a visualization of the flow of information within a system
- c. Assists in identification of, or lack of, redundant features and paths
- d. Provides inputs to other reliability methods, e.g., Failure Modes and Effects Analysis/Failure Modes, Effects, and Criticality Analysis, Reliability, Prediction, and Fault Tree Analysis
- e. Provides input to facilitate design decisions and trade-offs

A.2.6 Limitations

- a. May provide an overly simplistic view of a complex system
- b. The level of detail of the block diagram may mask the functional interdependencies of its elements
- c. The diagram does not show the physical location of elements within the system. This may constitute a problem if the elements are affected by their relative locations.

A.2.7 References

- a. Denson, W. and Chandler, G. "*Nonelectronic Parts Reliability Data*," Reliability Analysis Center, Department of Defense Information Analysis Center.
- b. Kapur, K.C. and Lamberson, L.R. "*Reliability in Engineering Design*," Wiley, New York, 1977.
- c. Lewis, E.E. "*Introduction to Reliability Engineering*," Wiley, 1987.

A.3 Design for Manufacturing (DFM) and Design for Assembly (DFA)

A.3.1 Description—DFM and DFA are methods encompassing core design principles and several related design analysis methods focusing on production manufacturing and assembly. They seek to optimize the activities of product design, manufacturing, and ease of assembly into a single multifunctional, simultaneous engineering activity.

A.3.2 Purpose—The purpose of DFM and DFA is to optimize a product consistent with the intended manufacturing, assembly, and service strategy. Specific objectives include:

- a. Assures that manufacturing, assembly, and service of the design is well matched to the intended strategies
- b. Assures that every unit is produced correctly without adverse affect on function, appearance, or reliability
- c. Promotes concurrent engineering, cross-functional teamwork, and consensus decisions
- d. Balances design features to production methods resulting in minimum overall costs and maximum value
- e. Assures easy serviceability
- f. Enhances ergonomic conditions for production operators and service technicians

A.3.3 Application—DFM and DFA are applicable to any product that must be manufactured and/or assembled. They are especially valuable where the original design requires multiple fasteners, and steps in the manufacturing and assembly processes.

A.3.4 Key Elements—DFM and DFA core principles include teamwork, integration, and minimization of part count, easy error-proof assembly (Poke-Yoke), ergonomic driven operations, avoidance of adjustments and fasteners, obvious part identification, and easy part handling. The main points of DFM and DFA consider the following:

- a. Gravity is the assembly's best ally
- b. Sufficient room for hands and standard tools
- c. Visibility of operation
- d. Holding/resistance to insertion
- e. Insertion guidance
- f. Ease of alignment and positioning
- g. Fasteners versus snap together
- h. One person assembly
- i. One hand retrieval and positioning.

Handling issues include:

- a. Size and weight
- b. Two-handed insertion and assembly
- c. Fragile, flexible or won't hold its own shape
- d. Tangles and nesting problems
- e. Sticky, sharp, hot, slippery
- f. Handling or adjustment.

Examples of qualitative measures that have been marketed to assess effectiveness include the Lucas Design Efficiency (number of essential parts/total parts), Xerox Producibility Index (sum of each part's assembleability rating/total parts), the Boothroyd and Dewhurst Design Efficiency (3 x total essential parts/total assembly time), and the Westinghouse DFA Calculator (assembly time predictor). Numerous company assessment methods have also been developed with their approaches widely published.

A.3.5 Benefits

- a. Encourages design teams to consider the impact of design on how the product is manufactured and assembled
- b. Leads product development teams towards less complex designs
- c. Reduces manufacturing and/or assembly time
- d. May result in improved manufacturing and assembly processes
- e. Encourages Human Factors' and ergonomic considerations during design

A.3.6 Limitations

- a. Projected savings in time and cost may be overly optimistic
- b. Improvements may not be applicable to other similar products
- c. The method is labor intensive and requires a cross-functional team with a high level of technical and interpersonal skills
- d. Needs to be done in coordination with other method, such as FMEA, that ensure failure modes are not introduced
- e. Elements that help DFM/A may have an adverse effect upon reliability, maintainability and supportability.

A.3.7 References

- a. Ardayfio, D., Carlson, A., and Marcel, R., "*Application of DMFA in Automotive Vehicle Development*," Paper No. 92-DE-7, The American Society of Mechanical Engineers, 1992
- b. Adler, R. and Schwager, F., "*Software Makes DFMA Child's Play (Westinghouse DFA Calculator)*," Machine Design, April 9, 1992
- c. Boothroyd, G. and Dewhurst, P., "*Product Design for Assembly*," Boothroyd and Dewhurst, Inc., 1987
- d. Munro and Associates, Inc., "*Design for Manufacture*," Participant Training Manual (Lucas DFM Technique), 1994