Proceedings of IMAPS Brazil 2003, the International Technical Symposium on Packaging, Assembling and Testing & Exhibition, Campinas - SP, Brazil, August 6-8, 2003.

RELIABILITY CAPABILITY ASSESSMENT METHODOLOGY

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ABSTRACT

The rapid pace of technological developments and the globalization of supply chains have made electronics manufacturers dependent upon worldwide suppliers who provide them with parts or subassemblies. Currently, many manufacturers have to wait until they get the products to assess if they are reliable. This can be an expensive iterative process. As an alternative, it is necessary to evolve a methodology that can help manufacturers to assess their potential suppliers and/or suppliers to assess themselves with respect to their ability for developing and supplying reliable products.

This paper presents a set of key practices that can be used as benchmarks to assess whether an organization has the ability to design, develop and manufacture reliable electronic products. It defines this ability as the reliability capability of an organization and discusses the different capability maturity levels. The auditing process for reliability capability assessment is provided and the possible causes for capability limitation are identified.

1. Introduction

The electronics market environment is characterized presently by high volatility, over or under capacity supply cycles, rapid obsolescence of parts and technologies, and instant globalisation of information. Institutional and individual customers have better and broader knowledge of products and services. They are more aware of safety and environmental issues, and want minimum life cycle cost for products. Quality is regarded as a basic requisite, and reliability is the expected norm. Consolidation and outsourcing of businesses is occurring at the same time.

The globalization of electronics manufacturing has created new encumbrances for the industry. The profit margins are slimming due to competition, and the consumers are seeking extended warranty periods. In some cases, no product returns are expected, leaving no room for error for the manufacturers.

For ensuring reliability and preventing failure, electronics manufacturers have to provide after sales services, and have to increase design and manufacturing efforts. This amounts to added costs due to increased investment on testing and risk informed technology insertion of new technologies, shorter lead times and push for performance improvement.

To be competitive, manufacturers need to know how things fail, in addition to knowing how things work. Reliability of products in field is a primary concern for most industries after the quality systems have been optimised to control in-house variabilities. However, the presence of a scheme to validate the ability of any manufacture to produce reliable product or service is still a nebulous area. Although a lot of work has been done, and a number of failure prediction methodologies (FPMs) and Physics-of-Failure based failure models are available for the reliability prediction of systems [9], there are none in place for measuring the robustness, or the flexibility of an organization to design in, manufacture in, or test in reliability, and to do so consistently.

Having a reliability capability assessment methodology for an organization provides a pre-facto assurance about goods and services before they are delivered for use. Creating a benchmarking methodology for reliability will also set standards for opportunity and competition.

2. Reliability capability

A manufacturer's capability firstly to "design for reliability" and secondly to implement a reliable design through manufacturing and testing is important to the customer. Measuring the performance of an electronics manufacturer yields important information about the likelihood that the company will provide a reliable product. For electronics manufacturers with worldwide suppliers, a metric is required so they can evaluate the ability of suppliers to provide reliable products. This ability is defined as reliability capability:

> " Reliability capability is the measure of an electronics manufacturer's ability to identify and understand its reliability - related objectives and the effectiveness of the processes and practices used by the organization to meet those objectives."

The assessment of reliability capability involves the identification of a set of key practices that should be

adopted in an organization involved with development of a reliable electronic product. These key practices should encompass all aspects of operation in the manufacturer's organization from a product reliability perspective.

3. Key practices

The IEEE Reliability Program Standard 1332 was developed to ensure that every reliability program activity adds value to the final product [3]. The standard identifies three reliability objectives:

1. The supplier, working with the customer, should determine and understand the customer's requirements and product needs so that a comprehensive design specification can be generated.
2. The supplier should structure and follow a series of engineering activities so that the resulting product satisfies the customer's requirements and product needs with regard to product reliability.
3. The supplier should include activities that assure the customer that reliability requirements and product needs have been satisfied.

In this paper, the key practices defining the reliability capability of organizations have been developed under an analogous structure to maintain conformity with established standards. Eleven key practices have been identified and defined that form the basis of a strategy for reliability and risk management, and are important to electronics manufacturers that aspire to achieve high capability in producing reliable products.

3.1 Reliability requirements (set and allocate)

The customer's needs, expectations, constraints, and operational concepts for all phases of the product life cycle regarding reliability must be analyzed, harmonized, refined, and elaborated upon in order to arrive at a set of customer reliability requirements. The various inputs from the customer must be consolidated, missing information must be obtained, and conflicts must be resolved before documenting a recognized set of requirements.

When product reliability requirements will depend on two or more product components, the requirements must be allocated to each product component as a derived requirement and should be relatable to a higher-level requirement. Both the bottom-up and top-down approaches help determine that all source requirements have been completely addressed and that all lower - level requirements can be referred to a valid source. This association is particularly needed in conducting the impact assessment of specifications changes on reliability requirements and activities.

3.2 Reliability planning and project risk management (plan and execute)

Reliability planning and project risk management is a continuous process, from preliminary design to product maturity, that is needed to establish and maintain plans that define reliability activities and manage the defined activities. The purpose of reliability planning is to identify and tie together all program management tasks required to accomplish program requirements.

A documented plan that addresses all relevant planning items is necessary to achieve the mutual understanding, commitment, and performance of individuals, groups, and organizations that must execute or support the plans. Reliability planning parameters constitute typical indicators of progress and performance, and include attributes of activities, cost, effort, and schedule.

3.3 Organizational learning and training (document and disseminate knowledge)

The purpose of organizational learning and training is to develop the technical, business, specialized, and strategic skills and knowledge of people so that they can perform their roles in the development and manufacture of a reliable product effectively and efficiently. This includes training to support the organization's strategic business objectives and to meet some tactical training needs. The areas where a manufacturer can learn include the design process, the manufacturing scheme, attitudes at the workplace, and even mundane management and accounting practices.

Training and education of employees for career advancement and job proficiency is an important element of any organization's growth plan. Relearning and staying abreast of the prevalent technologies and ideas helps employees to develop professionally and gives the manufacturer the benefits of their enhanced abilities, which eventually transform into profits for the company. Education and training in the reliability - related technological areas enhance the possibility of obtaining a better, more reliable product.

3.4 Research and development (innovate)

The purpose of research and development is to select innovative technologies and processes that measurably improve the manufacturer's ability to produce reliable products in terms of less variability in manufacturing process, material handling, and storage. Innovative improvements are typically identified by reviewing process and technology improvement proposals or by actively investigating and monitoring innovations in use in other organizations or documented in research literature.

An emphasis on research as incorporated into the manufacturer's mission statement and realized in its practices has several impacts. It indicates the company's vision of itself in the future. It shows its desire and willingness for growth through technological innovations aimed at better products, rather than through market expansion. It also shows that the manufacturer expects to retain and maintain its standards of quality and reliability through sustained efforts or development of its technological and management practices.

3.5 Reliability analysis (assess risk)

Reliability analysis is used to understand, define, and select components or parts according to reliability requirements at all levels, distinguishing them from competing alternatives based on the relative merits and risks involved. Selection criteria are influenced by costs incurred by people, in the development process, procurement, support, and life cycle of product. Other selection criteria include technical performance, effectiveness, and limitations, complexity of the product due to related life-cycle processes, use conditions and operating modes, product expansion and growth. Risks associated with cost, schedule, technology, and final disposal, and capabilities and limitations of end users also affect the selection among competing alternatives.

The ability of an electronics manufacturer to analyze a product in terms of identifying reliability - critical components and to determine the risk elements and dominant failure modes indicates the maturity of the reliability analysis program.

3.6 Reliability assurance through testing (demonstrate)

Convincing an end user that he is getting a reliable product at a reasonable price requires demonstration of reliability assurance. An electronics manufacturer must specify the essential analyses that have been conducted for measurement specification, data collection, and data interpretation for such a demonstration. Reliability can be demonstrated by showing conformance to standards, by using virtual qualification techniques, or through real-time testing.

Virtual qualification techniques through simulations evaluate the damage to the product through its life cycle from manufacture to operation, including storage and transportation, and come up with the life expectancy of the product under the stresses encountered. The types of real-time tests that can be conducted for reliability assurance include initial reliability testing, qualification testing, and pre-production testing.

3.7 Supply chain management (identify and foster)

The purpose of supply chain management is to proactively identify sources of products that could be used to satisfy reliability requirements, to manage the selected suppliers, and simultaneously maintain a symbiotic customer-supplier relationship. It is not enough to know about component specifications and their particular reliability metrics unless the electronics manufacturer is able to find a supplier who can manufacture them reliably and consistently.

The products available in the market continually change, as does the information about the capabilities of products and their suppliers. Thus, new information that may be essential for deciding which potential sources are most effective continually becomes available. This key practice evaluates the ability of the electronics manufacturer to manage its supply chain as a positive input towards its reliability goal.

3.8 Verification and validation (prove)

Verification and validation demonstrate that planned reliability processes are implemented to ensure that the product properly reflects the specified reliability requirements and that it will fulfill its intended use. Products and practices are selected for validation on the basis of their relationship to user needs. All processes, models, and data associated with setting, allocating, demonstrating, and assuring reliability of a product must be verified and validated to establish whether there are any operational difficulties or conflicting processes that impede the development of a reliable product.

Up-front preparation is necessary to ensure that reliability verification provisions are embedded in product designs, developmental plans, and schedules. This incrementally promotes early detection of problems and can result in the early removal of defects.

3.9 Failure tracking (analyze and report)

A root cause is the source of a defect that, if removed, results in the defect being decreased or eliminated. The purpose of fault tracking and reporting is to identify and analyze root causes of defects; to take specific actions to remove the causes; and to prevent the occurrence of those types of defects in the future. This key practice evaluates the manufacturer's capability to track field failures, establish a closed loop failure reporting system, and document a corrective action.

Product tracking is essential to establish the failures in the field, particularly by identifying and isolating those involving potential sources of unreliability. Tracking failures requires encouraging reports back from customers and establishing a service apparatus within the organization to respond promptly whenever such a call is made. The results save considerable cost in fault isolation and rework associated with troubleshooting problems.

3.10 Management of change and life - cycle transitions (anticipate and adapt)

The requirements of the market are never static. As needs change and as work proceeds, additional requirements develop and changes may need to be made to existing reliability requirements. To effectively analyze the impact of such changes, the source of each requirement must be known and the rationale for any change must be documented.

The purpose of managing change and life-cycle transitions is to track appropriate measures of requirement volatility during the life of a product and to judge whether new or revised reliability specifications, processes, and controls are necessary to manage these additions and changes efficiently and effectively. This key practice determines the ability of an electronics manufacturer to affect product

design changes and to produce a redesigned or mildly altered product with the same reliability standards as for the earlier product.

3.11 Reliability improvements (reduce risk)

This key practice establishes the sensitivity of the practices and processes of a manufacturer to respond to cost, schedule, and reliability performance risks ascertained from reliability testing and field failures during all phases of the product life cycle. Its results allow initiation of risk reduction steps.

Risks are identified and analyzed to determine their relative importance and assigned values in accordance with the defined risk parameters, which may include likelihood, consequence (severity or impact), and acceptable thresholds. There may also be potential risks discovered that are outside the scope of the project's reliability requirements but are vital to customer interests.

4. Reliability capability maturity levels

The reliability capability maturity of an organization can have five levels of accomplishment. The learning process within the organization, the repeatability of the activities, and the organizational response to the failure of products characterize these levels. For any organization, there is a progression through these different levels. The five levels of maturity are defined below.

1. ***Uncontrolled:*** This lowest level is defined by the absence of qualities linked to the higher levels. Organizations or projects at this level, which can usually be called learner organizations, are essentially ad hoc in their approach,.
2. ***Repeatable:*** At this level, organisations can repeat what they have done before, but not necessarily define exactly what they do or understand why they do it. They might, for example, repeat practices that satisfy quality standards or repeat practices that have become accepted industry practices.
3. ***Defined:*** At this level, organizations can define reliability requirements and key process goals but may not have fully implemented them or have limited feedback leading to reliability improvements. The management process is almost but not completely open loop. Organizations at this level understand what is required, but their practices do not influence the designed product.
4. ***Managed:*** At this level, organizations can control what they do in the way of design for reliability. They lay down requirements and through benchmarking ensure that these are met. The learning mode is single loop, in that only the product is changed, but all the important key practices are verified and acted upon in the feedback process. Reliability models and data are validated and the product reliability is validated.
5. ***Optimized:*** Organizations at this level are best in practice. They are capable of learning and adapting themselves as a result of complete and effective benchmarking and organizational feedback. They practice double-loop learning -- that is, they do not just use experience to correct problems, but also change the nature of the way they operate. They are proactive, anticipating and avoiding project risks and product failures, and are able to sustain this from project to project.

5. Auditing reliability capability

The auditor's task in reliability capability assessment of manufacturers is to highlight the supplier's blind spots beyond its public façade and to bring forth the areas of delinquencies with respect to its reliability practices. The audit is not only meant to assign a maturity level to an organization but also to point out the possible causes for a lower maturity level and make suggestions for improvements. The audit can be an internal exercise or an independent assessment by a business partner.

Auditing is a two-step process. The first step is to identify the presence or absence of practices; the second step is to assign scores based on some scoring pattern. For each key practice, the auditors should look for evidence and make judgments on the following:

- what has been done (tasks, activities);
- commitment to perform (leadership, resources);
- ability to perform (experience, training, tools);
- methodology used to perform (logic, framework) ;
- coverage scope and depth of activities; and
- organizational integration of process to achieve strategy.

On the basis of the information obtained above, each reliability key practice should be scored using defined scoring rules. A very broad scoring pattern can have a form such as presented in Table 1.

Table 1: Broad scoring pattern for auditors

Characteristic	Score
The processes and practices are present	1
Processes and practices are consistent and repeatable	2
Processes and practices are defined	3
The output of the processes influences products	4
The output of the processes influences other processes	5

6. Possible causes of capability limitation

Provided below is a representative list of some common possible causes of capability limitation.

1. There is insufficient reliability expertise -- e.g., the organization has no reliability engineers.
2. There is no education and training or research in reliability engineering.

3. There is inappropriate reliability specifications and poor communication to the supplier's organization and across the supply chain.
4. There are major differences in risk perception between the customer and the supplier.
5. Lack of leadership in driving reliability improvements results in reversion to old strategy defaults -- i.e., project risk takes priority over product reliability.
6. Suppliers may possess excellent management and data collection processes that focus on quality but they do not really influence product reliability.
7. There is inadequate front - loading of effort and poor planning of reliability activities.
8. Lack of designer / engineering knowledge results in poor models and inadequate data to inform design or to make good judgements.
9. There are conflicting heuristic decision rules, for example: " Any change to products decreases reliability," and " Products must change to improve reliability."
10. Critical changes to design, usage, or environment are not recognized or understood.
11. No reliability testing is conducted; only qualification testing to some standards is done.

7. Conclusions

Reliability capability is the measure of an electronics manufacturer's ability to identify and understand its reliability - related objectives and of the effectiveness of the processes and practices within the organization in meeting those objectives. Defining reliability capability and maturity involves the identification of a set of key practices that should be present in any organization involved with development of reliable electronic products. This paper has identified and defined eleven key practices that form the basis of a strategy for reliability and risk management, and that are important to electronics manufacturers that aspire to achieve high capability in producing reliable products. These key practices can help electronics manufacturers to assess their potential suppliers or the potential suppliers to assess themselves.

The auditor's task in the assessment of capability maturity has been discussed and the five maturity levels for final assignment through an audit process have been defined. The paper presents the auditing process suggesting a broad scoring pattern. A list of possible causes of capability limitation is also provided.

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