Effective Implementation of an Enterprise Reliability Program with Suppliers

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SUMMARY & CONCLUSIONS

Design for Reliability (DFR) programs do not work in an organizational vacuum. To be successful the program should be integrated into what is called an Advance Product Quality Process (APQP) or a Design for Six Sigma (DFSS) process. Advanced product quality planning (or APQP) is a framework of procedures and techniques used to develop products in industry, particularly the automotive industry. It is quite similar to the concept of Design for Six Sigma.

When the DFSS and DFR approaches are integrated in your product development processes, the results are an enterprise Quality and Reliability centered culture with great productivity benefits. This paper focuses on the required steps to develop a Design for Reliability Program from the ground zero in an APQP or DFSS design environment and it benefits in terms of warranty cost and time to market.

1.0 INTRODUCTION

Reliability is the probability that an item will perform its intended function for a specified mission profile. High reliability means design it right and build it right. To achieve high reliability one must:

- Establish a reliability requirement.
- Use qualitative and quantitative analysis methods and tools to verify that the requirement is met.
- Analyze the manufacturing, assembly and test procedures concurrent with the design process.
- Use concurrent engineering to get everybody involved up front.

The key to any reliability program is the identification of risk. A credible reliability program must focus on the high-risk issues in the project. There will be risk issues at every stage of the product life cycle. Early in the concept phase, decisions are made relating to the features and specifications needed to capture the target market. Marketing uses extensive Voice Of the Customer (VOC) to identify the next high-growth opportunities. These growth opportunities usually involve new technologies [1]. For businesses that compete on the cutting edge of technology, new technologies represent a significant portion of the risk to the program and long-term reliability.

To develop the new platform product, a list of challenges must be devised. Each of these challenges represents risk to the program. To manage the risk, each item should be ranked on the severity of the risk and those items representing the highest risk should be tracked through the program. The role of reliability engineering in the concept phase is to ensure that the risk issues are properly identified. The risks should be ranked by severity with corrective actions listed so that when completed the risk is mitigated. The risk plan needs to include all the functions that are affected in the life cycle of the product. Risk issues that relate to maintenance, manufacturability, design, safety and environment should be included. Unfortunately, these activities are reactive and thus add to the program development time. However, it will be shown later that the net result of these activities is a reduction in the product development cost.

2.0 ENTERPRISE INTEGRATION BETWEEN DFSS AND DESIGN FOR RELIABILITY

DFSS and APQP have the objective of determining the needs of customers and the business, and driving those needs into the product solution to be created.

DFSS seeks to avoid manufacturing/service process problems by using advanced Voice of the Customer techniques and proper systems engineering techniques to avoid process problems at the outset.

DFSS is largely a design activity requiring specialized tools including: quality function deployment (QFD), axiomatic design, Theory of inventive problem solving (TRIZ), Design for X, design of experiments (DOE), Taguchi methods, tolerance design, robust design and Response Surface Methodology for a single or multiple response optimizations. The tools are uniquely used by DFSS to analyze new and unprecedented changes to systems/products (see Figure 1).

![Figure 1 – DFSS and DFR](image-url)
activities focus in demonstrating the achievement of the product performance time over time for the operational life of the component.

3.0 RELIABILITY PROGRAM ELEMENTS
(People, Process, Tools)

3.1 PEOPLE

To start with, one person must lead the activity. This person must have either the qualifications from other experiences or be willing to transfer current career ambitions toward reliability engineering.

The reliability engineer must have a firm understanding of the processes and concepts needed to develop and enhance product reliability. This person must have the drive and initiative to install processes in a company where there will be a natural resistance to a methodology new to everyone. This person must know that they have the backing of management all the way to the top. And finally, the reliability engineer must be a teacher. The smaller company can only afford one reliability engineer but needs all the processes. One engineer cannot do all the tasks. This engineer must be able to impart the reliability knowledge to everyone. This process may take several years but when done correctly, it will have trained other employees in the reliability process.

Companies that try to install reliability on their own without outside help or by hiring a reliability leader without an industry diversified experience or not hired at the directive level will probably fail [2].

3.2 PROCESS

The reliability process can be applied at any stage of the product development cycle. Ideally, the process should begin at phase one of the product development cycle. Don’t wait for the next new design cycle to begin the process. There is no better time than the present to start a reliability program. The reliability process can be initiated at any stage of the product life cycle. The greatest return on investment will always be with a reliability program that is implemented at the concept phase. The goal should be to identify and fix all reliability issues as early as possible, because the cost to fix a reliability problem increases an order of magnitude in each subsequent phase. Taking a proactive approach to identify the reliability issues, early in product development, will result in a better product, with lower development costs, a shorter development time, and a greater return on investment. Often, the reliability improvements made in the development phase result in a reduction in the number of product design escapes later.

3.2.2 ROLLING OUT THE RELIABILITY PROCESS

There are many reliability activities that can be performed to improve product reliability. Some will produce more benefit than others. A list of references that will provide greater insight about these activities can be found in Figure 2, which describes the Design for Reliability (DFR) process.

The best thing about a reliability program is that it can be applied successfully at any stage of the product life cycle. The reliability process can be applied to a product revision, derivative product, new platform product or a leapfrog technology. The timing of the process does impact the level of risk taken, the level of effort required, the resources required and the time frame necessary to ensure product reliability.

The reliability process is a comprehensive cradle-to-grave approach to improve product reliability. The process should be part of a continuous improvement program that applies lessons learned from past products to continuously improve next-generation products. The product life cycle consists of five phases:

1. Product concept phase
2. Design phase
3. Product Development phase
4. Manufacturing phase
5. Support phase.

Figure 2 graphically shows these phases. Because each company may define the product life cycle phases differently, we briefly describe each phase so you can align them to your unique product development structure.

Figure 2 – The Design for Reliability Process [7]

Your present level of reliability involvement is one of the factors that will determine how best to implement the process. Other factors (i.e., staffing constraints, organizational size, capital constraints, level of top down management support, product life cycle phase and time-to-market constraints) are important to consider when developing your implementation plan. The most important factor in the implementation of the reliability process is early success. There will be glitches along the way with the implementation process, especially if this is new to the organization. The reliability process is a cradle-to-grave approach. It uses continuous improvement to fine-tune the process for the organizational culture and business environment.

In order to ensure success, roll out the reliability process strategically. It is more important to achieve early, recognized successes from rolling out only parts of the process than to push the organization through the entire process.

Doing too many new things at one time is an almost impossible task. In other words, it is more important to do the right things well, even if it means doing less, than it is to do all
the right things to a lesser degree. Of the list of reliability steps, pick one or two and work hard to install them properly.

3.3 TOOLS

An essential part of any Design for Reliability program is to have access to the right set of reliability tools. Important tools for accomplishing DFR tasks include Life Data Analysis, Design of Experiments, Failure Report and Correction Action System (FRACAS), Reliability Growth Analysis (RGA), System Reliability modeling, Failure Mode, Effects and Criticality Analysis (FMECA), Reliability Centered Maintenance (RCM), and Accelerated Life Testing (ALT) (see Figure 2 and Figure 3).

4.0 SOFTWARE RELIABILITY

There are three distinct areas that make up the subject of achieving high software reliability:
1. Measurement and analysis of software.
2. Development techniques for reliable software.
3. Continuous improvement of the software development process.

4.1 SOFTWARE MEASUREMENT AND ANALYSIS

For the most part, software reliability models model the failures occurring because of the software. Software analyses enable development personnel to find errors in the software while the software is still in the laboratory environment.

There are many types of software metrics and reliability models. Some of these metrics, such as faults or thousands of software/ source line of code (KSLOC), have been shown over time to have low predictive power. The Institute for Electrical and Electronic Engineers (IEEE) has published standards and guidelines that describe product metrics that are measures of errors, failure rate, reliability growth, remaining faults, completeness, complexity and so on [5].

4.2 DEVELOPMENT TECHNIQUES FOR RELIABLE SOFTWARE

These are techniques used in every phase of the life cycle from concept to maintenance. The techniques are for the design, code, unit test, acceptance test, maintenance test and maintenance phases. These techniques include [5]:
1. Requirements tracing and translation to design and code.
2. Design methodologies that support high SW reliability.
3. Code methodologies that support high SW reliability.
4. Unit testing methodologies.
5. System testing methodologies.
6. Inspection and walkthroughs.
7. Error prevention and fault tolerance.

It has been shown in many studies that modular, structured design and code are less prone to errors than code that is not modular or structured.

4.3 CONTINUOUS IMPROVEMENT OF THE SOFTWARE DEVELOPMENT PROCESS

In order to drive continuous improvement, the reliability organization should focus on implementing the following tasks: Defining and documenting the reliability process; implementing a reliability process into the organization; setting requirements early in the software development process; developing reliability software design guidelines and checklists; implementing a FRACAS and implementing a Supplier Reliability Program.

5.0 DEVELOPING A RELIABILITY CULTURE

Product reliability must be everyone’s job. To achieve this work philosophy, you will need to transform the organization’s culture into one where everyone talks about product reliability issues. Getting an organization to this point will take time. If you are just beginning to implement a reliability program, the following three processes, we recommend, need to be in place before the program rolls out:
1. Formalize the reliability process in a document.
2. Implement top down training for the new reliability process.
3. Prepare a reliability process implementation plan.

The first step is to define the reliability process that will be followed.

The second step is to develop training to educate the organization on the new reliability process and it should be rolled out in a top-down approach.

Senior and middle level managers need to buy into the process before it is disseminated to all other levels of the organization. If there are issues raised by senior and middle management that are not resolved before rolling out the training to the masses, you are unlikely to get the buy-in needed for success.

The final step involves developing a credible implementation plan that transforms the organization into a culture that is focused on reliability issues and is able to achieve the reliability goals. The implementation plan will be different for different-sized companies.

It is recommended using the seven-infrastructure approach to transform the organization into a culture that relies on the new reliability process to ensure product reliability. The organizational infrastructure approach identifies seven activities that need to take place: Goal setting, Organizational setting, Training and education, Promotion, Diffusion of success stories, Incentives and awards and Diagnosis and monitoring.
5.1 PROACTIVE AND REACTIVE RELIABILITY ACTIVITIES

The proactive region of the reliability program identifies all potential reliability issues before the products are shipped to customers. The proactive phase identifies potential risk and safety issues and resolves all potential reliability problems which are likely to occur. The proactive reliability activities are as follows:

1. Failure Modes and Effects Analysis (FMEA) before the design is complete.
2. Applying lessons learned.
3. Applying design guidelines:
   (a) Design for Reliability (DFR)
   (b) Design for Manufacturing (DFM)
   (c) Design for Tests (DFT)
   (d) Design for Serviceability and maintainability guidelines (DFS).
4. Design simulation and modeling.
5. Technology Risk Mitigation
6. Design specs and requirements before the design phase.
7. System and subsystem reliability budgets and estimates.
8. Highly Accelerated Life Tests (HALT) and Accelerated life Testing (ALT).
9. Four corners testing, testing at design margins.

These reliability activities will provide the greatest benefit early in the development program. By applying these activities early in the concept and design phase, you reduce development time, Non-Recurring Engineering (NRE) costs and the number of design spins. By performing these steps early in the development cycle, the design is likely to be error free the first time. The above described activities can be categorized as Risk Activities and Risk Management activities. There is one more element to be included and that is the Risk Communication (see Figure 4 and Figure 5). Risk communication has to do with the understanding and quantification of the risk as well as the business decision in how to proceed. These decisions should be reviewed by management during a gate review as part of the new product development process.

6.0 IMPLEMENTING THE PROGRAM – SETTING RELIABILITY GOALS

It is time to set reliability goals. There are two types of goal settings that take place in a reliability program. First, there are the high-level non-program specific goals. The highest-level goals are the mission and vision statements for the organization and address the business need for improved product reliability. Before you create the mission and vision engineering analysis and component or system testing (see Figure 6).
are product liability lawsuits a problem? Knowing the there been a problem with highly publicized product recalls? Are product liability lawsuits a problem? Knowing the answers to these questions can prevent the implementation of a very costly and misdirected reliability program. There are costs associated with improving product reliability and these costs affect the bottom line. When implemented effectively, they will bring significant long-term gains. However, a reliable product that is not cost competitive can have an adverse effect on market share [4].

If you are implementing a reliability program for the first time, there should be a high-level goal setting focused on the implementation of the reliability program. These goals focus on the following:

- Forming the reliability organization
- Installing the reliability lab
- Defining and documenting the reliability process
- Implementing a reliability process into the organization
- Developing reliability design guidelines and checklists
- Implementing FMEAs
- Implementing ALT, HALT, (Environmental Stress Screening (ESS), HASS and Highly Accelerated Stress Audit (HASA)
- Implementing a FRACAS
- Implementing a Supplier Reliability Program

The second sets of goals are the low-level goals. The low-level goals are program- or product-specific and are measurable, result oriented, customer focused, time-specific and support the high-level goals [3]. They can be different for different products. Examples of program goals would include the following:

- Will perform without failure for a specified time and under defined environmental use conditions
- Will reduce repair time
- Will reduce product development time through fewer design spins
- Will reduce product development costs through fewer design changes
- Will improve manufacturing first-pass yield (through improved design margins).

The goals that you define should be measurable and supportable in the business environment. As an example for a midsize corporation with a $1B of revenue you may have a potential $5M to $7M warranty reduction for an investment of $1M in Reliability Engineering, salaries and training.

7.0 RELIABILITY ELEMENTS CRITICAL TO PRODUCTION

PART APPROVAL PROCESS FOR SUPPLIERS

The Production Part Approval Process (PPAP) is used in the automotive supply chain to establish confidence in component suppliers and their production processes, by demonstrating that all customer engineering design record and specification requirements are properly understood by the supplier and that the process has the potential to produce product consistently meeting these requirements during an actual production run at the quoted production rate [6].

Although individual manufacturers have their own particular requirements, the Automotive Industry Action Group (AIAG) has developed a common PPAP standard as part of the advanced product quality planning process (APQP) – and encouraging the use of common terminology and standard forms to document project status.

The PPAP process is designed to demonstrate that the component supplier has developed their design and production process to meet the client's requirements, minimizing the risk of failure by effective use of APQP.

Using the PPAP process to drive supplier Reliability combined with a supplier assessment has proven to be effective in driving supplier reliability.

The critical elements of the process approach are: Process owner exists, Process is defined, Process is documented, Linkages of process established, Process is monitored, analyzed and improved and Records are maintained.

7.1 PPAP Approval

The PPAP package is a series of documents which need a formal approval by the supplier and customer. The form that summarizes this package is called a PSW (part submission warrant). The approval of the PSW indicates that the supplier responsible person (usually the Quality Engineer) has reviewed this package and that the customer has not identified any issues that would prevent its approbation.

The documentation on the PPAP package is closely related to the advanced product quality planning process used during the design and development of new vehicles and component systems to reduce the risk of unexpected failure due to errors in design and manufacture.

PPAP may be required for all components and materials incorporated in the finished product, and may also be required if components are processed by external sub-contractors.

7.2 PPAP ELEMENTS

Following are the elements of a PPAP process: Design Records, Authorized Engineering Change (note) Documents, Engineering Approval, Design Failure Mode and Effect Analysis (DFMEA), Process Flow Diagram, Process Failure Mode and Effect Analysis (PFMEA), Control Plan, Dimensional Results, Records of Material / Performance Tests, Initial Process Studies, Qualified Laboratory Documentation, Appearance Approval Report, Sample Production Parts, Master Sample, Checking Aids, Customer-Specific Requirements

Make sure that a copy of the DFMEA is reviewed and signed-off by the supplier. However, the list of all critical or high impact product characteristics should be shared with the supplier, so they can be addressed on the PFMEA and Control Plan. A summary of every test performed on the part is required. This summary is usually on a form like a Design Verification Plan and Report (DVP&R) or Test Plan, which
lists each individual test, when it was performed, the specification, results and the assessment pass/fail. The DVP&R shall be reviewed and signed off by both the customer and the supplier engineering groups. The quality engineer will look for a customer signature on this document. In addition, this section lists all material certifications (steel, plastics, plating, etc.), as specified on the print.

Statistical Process Control charts affecting the most critical characteristics should be identified and followed up with the process control document. The intent is to demonstrate that critical processes have stable variability and that it is running near the intended nominal value. Each customer may have specific requirements to be included on the PPAP package. It is a good practice to ask the customer for PPAP expectations before even quoting for a job.

8.0 REDUCING RISK AND ASSURING TIME TO MARKET

Revealing problems that need attention is just part of the program function. If not addressed, all these problems can lead to low reliability. Each issue must be carefully studied for the root cause and recommendations with sound engineering basis must be made to mitigate these problems. Each recommended corrective action must be tracked to final closure and audited by reliability engineering to verify completeness. Here, often is where the reliability effort fails.

In the rush to ship the product, the time it takes to correct a problem and make design or process changes can seriously delay delivery of the product to the customer. These delays are very visible to the bottom line and no one wants to be blamed for causing delays in shipments. Many times, the needed corrective measures are skipped, just to make shipments. This can be a reliability disaster.

Less visible are the unaddressed reliability problems that can lead to early failures in the field. The drive to ship as soon as possible, to beat competition and capture early market entry dollars can be wiped out by low reliability, safety and poor customer satisfaction. The money gained by early market delivery can be lost due to excessive warranty claims. If the failures are serious enough to require design changes, the cost to do the design changes are considerably higher now since there are many units in the field. Fixing the problem(s) early in the development stage is the least expensive and the fastest way to make corrections. All the reliability efforts in the world will be completely wasted if the issues that need to be fixed are not addressed. That is why design assurance programs with Design for Reliability elements and an organizational reliability oriented culture are a cost effective way of creating a great experience for your customer while assuring faster time to market and minimizing warranty costs.

9.0 REFERENCES

3. H. McLean, Harry, HALT, HASS and HASA Explained, ASQ, 2009
5. A. Neufelder, Ensuring Software Reliability, Dekker Inc., 1993

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