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## **Lessons Learned for Effective FMEAs**

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*2007 Alan O. Plait Award for Tutorial Excellence*

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# SUMMARY & PURPOSE

Many companies are faced with intense global competition and must shorten product development times and reduce costs. Failure Mode and Effects Analysis (FMEA) is one of the most effective techniques to achieve high reliability during shorter product development timelines and budget constraints. Using the four broad success factors for effective FMEAs (understanding the basics of FMEAs and Risk Assessment, applying key factors for effective FMEAs, providing excellent FMEA facilitation and implementing a “best practice” FMEA process) will help to assure success in FMEA applications.

## Carl S. Carlson

Carl Carlson is a consultant and instructor in the areas of FMEA, reliability program planning and other reliability engineering and management disciplines. He has 25 years experience in reliability engineering and management positions, most recently conducting reliability consulting with dozens of commercial companies and military organizations, and previously as Senior Manager for the Advanced Reliability Group of General Motors. Previous to General Motors, he worked as a Research and Development Engineer for Litton Systems, Inertial Navigation Division.

Mr. Carlson co-chaired the cross-industry team to develop the Society of Automotive Engineers (SAE) J1739 for Design/Process/Machinery FMEA and participated in the development of the SAE JA 1000/1 *Reliability Program Standard Implementation Guide*. He has also chaired technical sessions for the Reliability Track of the Annual SAE Reliability, Maintainability, Supportability and Logistics (RMSL) Symposium, was a four-year member of the Reliability and Maintainability Symposium (RAMS) Advisory Board and served for five years as Vice Chair for the SAE's G-11 Reliability Division.

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## 1. INTRODUCTION

Few reliability tools elicit stronger responses from quality and reliability professionals than Failure Mode and Effects Analysis. Reactions range from “waste of time, lack of support” and “don’t want anything to do with it” all the way to “powerful tool, effective way to prevent problems” and “needs to be done across the board.”

Why is there so much variation in the application of a tool that has been around for many decades? What can be done to help achieve more uniformly successful results?

Today’s corporations are facing unprecedented worldwide competition as a result of three ongoing challenges: the mandate to reduce costs, faster development times and high customer expectations for the reliability of products and processes. The necessity for Reliability Assurance will continue to be important; however, there is increasing emphasis on Design for Reliability as a corporate strategy.

One of the tools that show up on most every “short list” of Design for Reliability tools is Failure Mode & Effects Analysis. Most corporate and military applications require some form of FMEA or FMECA (Failure Mode Effects and Criticality Analysis).

Yet questions remain on the overall effectiveness of FMEA as applied in many companies and organizations today. Frankly, there are mixed results with FMEA applications.

Four broad success factors are critical to uniformity of success in the application of FMEA in any company or organization. They are:

1. Understanding the basics of FMEAs and Risk Assessment
2. Applying key factors for effective FMEAs
3. Providing excellent FMEA facilitation
4. Implementing a “best practice” FMEA process

### 2. UNDERSTANDING THE BASICS OF FMEAS AND RISK ASSESSMENT

The prerequisite for effective FMEAs is a sound knowledge of the basics of FMEA. There is no substitute for learning these fundamentals. Once these basics have been well learned, it is possible to understand and apply certain lessons learned that make FMEAs highly effective.

Risk assessment is helpful to identify which FMEAs will be done as part of product and process development. Risk assessment is also an integral part of the FMEA procedure. FMEA costs money to perform and should be used where the highest risk is anticipated.

In order to identify the highest risk areas that are candidates for FMEA, the following criteria can be examined. It is suggested that FMEAs be done when risk is associated with one or more of the following areas:

- New technology
- New designs where risk is a concern
- New applications of existing technology
- Potential for safety issues
- History of significant field problems
- Potential for important regulation issues
- Mission Critical applications

#### ▪ Supplier Capability

Avoid excessive time on lower risk systems.

Every part of the FMEA procedure can have too much or too little detail. It is up to the FMEA Team and Facilitator to navigate the challenges of detail. Too little detail can result in not identifying root causes, ineffective actions, and other problems. Too much detail bogs down the FMEA team and can result in “missing the forest for the trees.”

The Key is to be “Risk Conscious” and to consistently keep the team focused on risk; the higher the risk, the higher the level of detail that is needed throughout the analysis.

### 3. APPLYING KEY FACTORS FOR EFFECTIVE FMEAS

The following FMEA lessons learned are the result of personally supervising or participating in over a thousand FMEA projects and collaboration with many corporations and organizations on the FMEA process and its shortcomings.

There is a maxim that says, “Good judgment comes from experience and experience comes from poor judgment.” The following lessons learned are based on considerable experience. Each of these lessons is from direct experience of how FMEAs were done wrong and how to improve their overall effectiveness.

What are the primary ways that FMEAs can be done wrong (Mistakes) and the key factors that make for effective FMEAs (Quality Objectives)?

#### 3.1 Mistake # 1

Based on empirical review of many FMEAs, some FMEAs do not drive any action at all; some FMEAs drive mostly testing; others drive ineffective action. The mistake is:

Failure of the FMEA to drive design or process improvements

##### 3.1.1 Quality Objective # 1

The FMEA drives product design or process improvements as the primary objective

Note: Reliability Engineering has a multitude of tools to choose from in driving design or process improvements. The key is to use the FMEA “Recommended Actions” field to identify and execute best practice tools that can optimize designs. This is one of the reasons that Reliability Engineers need to participate in FMEAs.

#### 3.2 Mistake # 2

There are various methods that the FMEA team can use to identify which failure modes (and their causes) require follow-up action. Some companies set pre-determined risk thresholds; others review RPNs or criticality using Pareto or other techniques. Whatever method is used, failure to address all high risk failure modes (including high severity) can result in potentially catastrophic problems or lower customer satisfaction. The mistake is:

Failure of the FMEA to address all high risk failure modes

##### 3.2.1 Quality Objective # 2

The FMEA addresses all high risk failure modes, as

identified by the FMEA Team, with effective and executable Action Plans

Note: The emphasis on this Quality Objective is to ensure that all of the high risk failure mode/causes are adequately addressed with effective actions. The key is effective action that reduces or eliminates the risk.

### 3.3 Mistake # 3

Some companies miss the opportunity to improve the Design Verification Plan & Report (DVP&R) or Process Control Plans (PCP) based on the failure modes/causes from the FMEA. Some FMEA teams do not include knowledgeable representatives from the test or analysis department. The result is inadequate product testing or process control plans. The mistake is:

Failure of the FMEA to improve Test/Control Plans

#### 3.3.1 Quality Objective # 3

The Design Verification Plan & Report (DVP&R) or the Process Control Plan (PCP) considers the failure modes from the FMEA

Note: The FMEA team will often discover failure modes/causes that were not part of the Design Controls or Test Procedures. The key is to ensure that the test plan (DVP&R) or Control Plan is impacted by the results of the FMEA. This can be done by including test/control membership on the FMEA team or through well written actions.

### 3.4 Mistake # 4

Empirical data shows that at least 50% of field problems can occur at interfaces or integration with the system. Some companies focus on part or subsystem failures and miss the interfaces. The mistake is:

Not including system and subsystem interfaces or subsystem integration in the FMEA

#### 3.4.1 Quality Objective # 4

The FMEA scope includes integration and interface failure modes in both block diagram and analysis

Note: Interfaces can be included as part of the item by item analysis or as a separate analysis. It is recommended that the FMEA Block Diagram clearly show the interfaces that are part of the FMEA scope.

### 3.5 Mistake # 5

Some companies provide no linkage between FMEAs and field data. It takes concerted effort to integrate problem resolution databases with FMEA. Otherwise serious problems can be repeated. The mistake is:

Disconnect between FMEA and field lessons learned

#### 3.5.1 Quality Objective # 5

The FMEA considers all major "lessons learned" (such as high warranty, campaigns, etc.) as input for failure mode identification

Note: Field failure data can be brought into generic FMEAs on a regular basis. Then, when new program-specific FMEAs

are started, they benefit from field lessons learned. If generic FMEAs are not used, new FMEAs should be seeded with potential field problems and required to show how they will not be repeated in the new design/process. The key is to hold the FMEA team responsible to ensure that major field problems are not repeated.

### 3.6 Mistake # 6

A Key Characteristic is a feature of a material, process or part (including assemblies) whose variation within the specified tolerance has a significant influence on product fit, performance, service life or manufacture. Many companies have a Key Characteristics policy. The Design FMEA can identify Key Product Characteristics and the Process FMEA can identify Key Process Characteristics for special controls in manufacturing. Some companies miss this opportunity. The mistake is:

FMEA omits Key Characteristics

#### 3.6.1 Quality Objective # 6

The FMEA identifies appropriate Key Characteristics candidates, if applicable according to company policy

Note: This is an underutilized element of FMEAs. SAE J1739 and the AIAG FMEA standard use the "Classification" column to identify key product and process characteristics.

### 3.7 Mistake # 7

Many companies do FMEAs late, and this reduces their effectiveness. FMEAs should be done concurrently with the design process and completed by design or process freeze dates. This is a very common problem and greatly reduces the effectiveness of FMEAs. The mistake is:

Doing FMEAs late

#### 3.7.1 Quality Objective # 7

The FMEA is completed during the "window of opportunity" where it can most effectively impact the product or process design

Note: The key to getting FMEAs done on time is to start the FMEAs on time. FMEAs should be started as soon as the design or process concept is determined, with the exception of FMEAs done during trade-off studies, which should, of course, be started earlier.

### 3.8 Mistake # 8

Some FMEA teams do not have the right experts on the core team and some do not have good attendance. Some FMEA team members just sit in their chairs and don't contribute to team synergy. The mistake is:

FMEAs with inadequate team composition

#### 3.8.1 Quality Objective # 8

The right people participate on the FMEA team throughout the analysis and are adequately trained in the procedure

Note: An actual survey of Reliability Engineering internal customers on FMEAs showed that they thought FMEAs are too important not to do, but too time consuming to participate

in. The FMEA facilitator must value the time of team members and not waste time. Additionally, people have blind spots (scotomas) and a diverse team will mitigate this issue. The key is to get the people who are knowledgeable and experienced about potential failures and their resolutions to actually show up at the meetings. Attendance often takes management support. Team size is best kept between 4 and 8 people. If the team gets too large, consider breaking up the FMEA into additional limited scope FMEAs.

### 3.9 Mistake # 9

There are hundreds of ways to do FMEAs wrong. Some companies do not encourage or control proper FMEA methodology. Training, coaching, and reviews are all necessary to success. The mistake is:

#### FMEAs with improper procedure

#### 3.9.1 Quality Objective # 9

The FMEA document is completely filled out “by the book,” including “Action Taken” and final risk assessment

Note: One common problem is the failure to get to the root causes of a failure. Expert input is necessary. Follow-up actions based on poorly defined causes will not work and the FMEA will not be successful. Another common problem is a lack of follow-up to ensure that the FMEA Recommended Actions are executed and the resulting risk is reduced to an acceptable level.

### 3.10 Mistake # 10

Some companies mandate FMEAs and then do not ensure the time is well spent. Preliminary work must be completed, meetings must be well run and efficient follow-up of high risk issues is essential. Ask the FMEA team if their time is well spent and take action to address shortcomings. The mistake is:

#### Lack of Efficient Use of Time

#### 3.10.1 Quality Objective # 10

The time spent by the FMEA team is an effective and efficient use of time with a value-added result

Note: If this Quality Objective is met, future FMEAs will be well attended and supported by subject matter experts and management.

Reference the following Figures 1 and 2, which are taken from SAE J1739 Revised JUN2000, Appendix A and B.

**1. DESIGN IMPROVEMENTS:** The FMEA drives Design Improvements as the primary objective.

**2. HIGH RISK FAILURE MODES:** The FMEA addresses all high risk failure modes as identified by the FMEA team, with executable Action Plans. All other failure modes are considered.

**3. DVP&R PLANS:** The Design Verification Plan and Report (DVP&R) considers the failure modes from the Design FMEA.

**4. INTERFACES:** The FMEA scope includes integration and interface failure modes in both block diagram and analysis.

**5. LESSONS LEARNED:** The FMEA considers all major “lessons learned” (such as high warranty, campaigns, etc.) as input for failure mode identification.

**6. SPECIAL OR KEY CHARACTERISTICS:** The FMEA identifies appropriate Key Characteristics candidates, as input for the Key Characteristics selection process, if applicable due to company policy.

**7. TIMING:** The FMEA is completed during the “window of opportunity” where it could most efficiently impact the product design.

**8. TEAM:** The right people participate as part of the FMEA team throughout the analysis and are adequately trained in the procedure. A facilitator should be utilized, as appropriate.

**9. DOCUMENTATION:** The FMEA document is completely filled out “by the book,” including “Action Taken” and new RPN values.

**10. TIME USAGE:** Time spent by the FMEA team is an effective and efficient use of time, with a value-added result. This assumes Recommended Actions are identified as required and the actions are implemented.

(NOTE: SPECIFIC PROGRAM REQUIREMENTS TAKE PRECEDENCE)

*Figure 1. Design FMEA Quality Objectives  
(from SAE J1739 Revised JUN2000, Appendix A)*

**1. PROCESS IMPROVEMENTS:** The FMEA drives Process Improvements as the primary objective, with an emphasis on Error/Mistake Proofing solutions.

**2. HIGH RISK FAILURE MODES:** The FMEA addresses all high risk failure modes, as identified by the FMEA team, with executable Action Plans. All other failure modes are considered.

**3. Process Control PLANS:** The Process Control Plan considers the failure modes from the Process FMEA.

**4. INTEGRATION:** The Process FMEA is integrated and consistent with the Process Flow Diagram and the Process Control Plan. The Process FMEA considers the Design FMEA as part of its analysis.

**5. LESSONS LEARNED:** The FMEA considers all major “lessons learned” (such as high warranty, campaigns, etc.) as input for failure mode identification.

**6. SPECIAL OR KEY CHARACTERISTICS:** The FMEA identifies appropriate Key Characteristics candidates, as input for the Key Characteristics selection process.

**7. TIMING:** The FMEA is completed during the “window of opportunity” where it could most efficiently impact the product design.

**8. TEAM:** The right people participate as part of the FMEA team throughout the analysis and are adequately trained in the procedure.

**9. DOCUMENTATION:** The FMEA document is completely filled out “by the book,” including “Action Taken” and new RPN values.

**10. TIME USAGE:** Time spent by the FMEA team is an effective and efficient use of time, with a value-added result. This assumes Recommended Actions are identified as required and the actions are implemented.

(NOTE: SPECIFIC PROGRAM REQUIREMENTS TAKE PRECEDENCE)

*Figure 2. Process FMEA Quality Objectives  
(from SAE J1739 Revised JUN2000, Appendix B).*

#### 4. FMEA CASE STUDIES

##### 4.1 FMEA Case Study # 1

A vehicle system integrator performs a System FMEA to address safety and field concerns. The FMEA was started on time, but progress was very slow due to inadequate FMEA software (not user friendly, not supporting best practice, etc.). The FMEA document grew to hundreds of pages. However, due to the resulting lateness of the FMEA the Test Plans, Control Plans, Design Reviews and Design modifications were not driven by a completed FMEA.

Analysis of this case study shows that the majority of FMEA Quality Objectives were not achieved: the FMEA did not drive Design Improvements, or Test/ Control Plans; it was too late to be effective; and the risk rankings were assigned by one person instead of the team.

Lessons learned include the following: FMEA software should be easy to use and support FMEA best practices; FMEAs need to be completed early; program teams need to focus on the highest risk items; and FMEAs that are too long may become ineffective.

##### 4.2 FMEA Case Study # 2

A product development team performed a Design FMEA in order to reduce the reliability risk of an optical system featuring new technology. In general, there were good results from the FMEA. However, there was one major failure mode that was not adequately addressed because it had “no solution.” The team did not know what to do, so the issue was not resolved.

Analysis of this case study shows that there was at least one FMEA Quality Objective that was not achieved: the FMEA did not address all high risk failure modes.

The lesson learned from this case study is that an FMEA team must ensure that all high risk failure modes have effective actions regardless of whether or not a solution is envisioned by the team. Further studies can be commissioned, outside help can be solicited or management support can be brought in. The FMEA facilitator should be on the alert for failure modes that have “no solution.”

##### 4.3 FMEA Case Study # 3

A medical company routinely performs Process FMEAs in order to meet ISO compliance.

Analysis of the quality of the Process FMEAs shows that overall, they were not value-added. Process FMEAs were performed regardless of whether or not a preliminary risk assessment revealed any risk in the process at all. RPNs used to assess the risk were uniformly low. No follow-up actions were identified; no process improvements were sought or driven. In effect, the FMEA team was only focused on meeting compliance instead of improving the design of either the product or the process. As a result, the majority of the FMEA Quality Objectives were not achieved: there were no recommended actions; the resultant RPNs indicated mostly high severity, low occurrence failure modes; and the FMEA document was very long and of little value.

The lesson learned from this case study is that the overall objective of an FMEA should be design or process improvement, and this objective needs to be identified and supported by both the FMEA team and management. Compliance with standards will follow if the FMEA meets Quality Objectives.

#### 5. PROVIDING EXCELLENT FMEA FACILITATION

A facilitator is “one who contributes structure and process to interactions so groups are able to function effectively and make high quality decisions.” Another definition is “a helper and enabler whose goal is to support others as they achieve exceptional performance.” Basically, a facilitator’s job is to support team members to do their best thinking.

An FMEA facilitator is a person who is trained in both FMEA procedures and facilitation techniques. The facilitator leads an FMEA team to successful completion of an FMEA project, with associated risk reduced to an acceptable level.

The primary FMEA facilitation skills are:

- Brainstorming and Probing Questions
- Encouraging Participation
- Active Listening
- Controlling Discussion
- Making Decisions
- Conflict Management
- Managing Level of Detail
- Managing Time

The importance of expert facilitation to effective results of FMEAs cannot be overstated.

Good FMEA facilitators drive the team through the process, saving valuable time and ensuring effective results. They help sort the insignificant input from those inputs that affect product and process reliability and safety.

#### 6. IMPLEMENTING A “BEST PRACTICE” FMEA PROCESS

Without an effective FMEA process, actual FMEA results will depend on individual personalities and the whims of varying company priorities. If participants happen to be knowledgeable in the application of FMEA and have the time to invest in FMEA team meetings, then it may be successful. If not, it may not be as successful.

Ten tasks are outlined that need to be established and operational within any company that aspires to achieving uniformly positive results in their application of FMEA. The entire process is presented graphically in Figure 3.

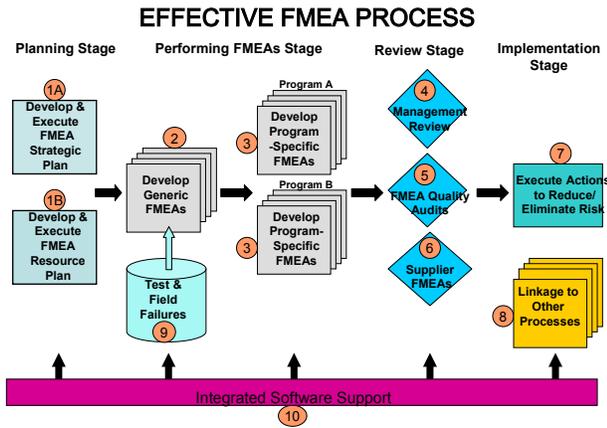


Figure 3. Effective FMEA Process.

### 6.1A FMEA Strategic Plan

As with any significant project, it is important to develop and follow a strategic plan that will guide the organization’s efforts. Some of the key decisions that management must make regarding FMEA policy include the type of FMEAs to be performed (e.g. Design, Process, Equipment, etc.), the timing of FMEAs (e.g. prior to design freeze) and the selection criteria (e.g. new technology, new applications, etc.).

Additional strategic management decisions that relate to other aspects of an effective FMEA process will be described in the following sections.

### 6.1B FMEA Resource Plan

Together with the development of the FMEA Strategic Plan, management must also make decisions to ensure that the required resources will be available to all FMEA teams. Along with decisions about FMEA software and meeting facilities, key questions include the use and staffing of FMEA facilitators, ownership of FMEA documents and the FMEA process and FMEA training.

Strong support of management is vital to both short- and long-term success of FMEAs in any company. I would go so far as to say that without solid management support, FMEAs will fall far short of their potential as effective problem prevention tools.

Such support is often led by an FMEA champion at the executive level, who helps to generate support at the staff level, advocates for an FMEA budget and process and sees to the staffing, training, business process, standards, management reviews and quality audits.

### 6.2 Generic FMEAs (optional)

The development of generic FMEAs may be part of the organization’s Strategic Plan. They contain both *historic* (empirical) and *potential* failure modes, effects, causes and controls, and are done at the generic level of the system,

subsystem or component. It is important to keep them updated with test and field data and for new technology.

Once accomplished, generic FMEAs can save considerable time in the performance of program-specific FMEAs. They are also useful in support of concept trade-off studies.

To perform each generic FMEA, it will be necessary to complete steps 1 through 4 of the “Basic FMEA Steps” outlined in Figure 4. (Note: Step 4 of Figure 4 is only completed up to design or process controls.)

### 6.3 Program-Specific FMEAs

This is where the bulk of the FMEA work is performed. Program-specific FMEAs focus on specific applications and can either be done from the beginning or tailored from a generic FMEA. They should be performed by a team made up of the right experts to examine the design or process and follow the directions from FMEA strategic planning.

To be successful, FMEA teams should be well staffed (between 4 to 8 members are recommended, depending on FMEA scope and complexity) and trained. Their work should be well facilitated and executed during the “window of opportunity” that maximizes the impact of the analysis to improve the design or process.

To perform each program-specific FMEA it will be necessary to complete steps 1 through 10 of the “Basic FMEA Steps” outlined in Figure 4.

**For each Generic FMEA (complete 4 steps -- the 4<sup>th</sup> step up to design or process controls)**

**For each Program-Specific FMEA (complete 10 steps)**

1. Assign FMEA facilitator and team
2. Establish FMEA timing and scope
3. Gather relevant documentation (Generic FMEAs if available, past FMEAs from Archive and all other needed preliminary work)
4. Perform FMEA analysis (according to FMEA standard) up through Recommended Actions
5. Provide input to DVP&R or Process Control Plan
6. Review risk and Recommended Actions with management (per FMEA Strategic Planning)
7. Update FMEA project tracking (per FMEA Strategic Planning)
8. Execute Recommended Actions and do new risk assessment
9. Review and approve all critical Supplier FMEAs (per FMEA Quality Objectives)
10. Ensure risk reduced to acceptable level and FMEA is completed “by the book.”

Figure 4. Basic FMEA Steps.

### 6.4 Management Reviews (sometimes called Failure Review Board)

Many organizations have a Failure Review Board established to review and address high risk issues discovered during test or field phases. High risk issues identified from FMEAs should also be included in the review format. This

ensures management understanding, buy-in, support and adequacy. In addition, FMEA reports and charts can be generated to provide valuable status per the FMEA Strategic Plan.

It is useful to have the design owner present the FMEA high risk item to the Failure Review Board in order to bring proper context and ownership to the issue.

### *6.5 Quality Audits*

Effective process models inevitably include a feedback loop to “improve the process” by incorporating both positive and negative feedback. An effective FMEA process includes both FMEA quality surveys (of the internal customer of the FMEA) and FMEA quality audits (in-person audits of completed or nearly completed FMEAs done by the FMEA manager).

FMEA quality surveys and audits are based on the FMEA Quality Objectives outlined in Figures 1 and 2. They provide valuable information to strengthen what works and address shortcomings.

Having personally done hundreds of FMEA Quality Audits, I believe this is one of the most important steps to achieving a uniformly successful FMEA application. Audits take about one hour each and provide valuable ways to improve the FMEA process.

### *6.6 Supplier FMEAs*

Potential high risk system or subsystem level failures can have their root causes in Supplier components. FMEA Strategic Planning should determine how to address Supplier FMEAs, and how to identify which suppliers require formal FMEA review. For suppliers of parts that are identified as high risk (critical parts), it is recommended that the supplier be required to perform and submit an FMEA for review and approval by a qualified company representative.

Reviewing Supplier FMEAs should be based on the FMEA Quality Objectives. I suggest returning inadequate FMEAs to be redone by the supplier until they meet the Quality Objectives.

### *6.7 Execution of Recommended Actions*

FMEAs have little value unless the recommended actions are fully executed. Each recommended action must be followed up to ensure completion to the satisfaction of the FMEA team and the risk eliminated or mitigated to an acceptable level. The Failure Review Board must ensure that all high risk actions are successfully executed.

It is my experience that the FMEA team should stay intact during the execution stage. Many companies want to disband the team once the FMEA is completed up through the Recommended Actions step (step # 4 of the “Basic FMEA Steps” in Figure 4). The FMEA team needs to be responsible for and empowered to reduce the risk to an acceptable level. The execution stage is fraught with variables that can derail the important work of reducing risk. New failure modes

introduced by changes in the design to mitigate one risk may also need to be reviewed by the team.

### *6.8 Linkage to Other Processes*

FMEAs can and should be linked to other important processes to leverage their effectiveness. FMEA software that is based on a relational database can integrate requirements from Advanced Product Quality Planning (APQP) guidelines and has the potential to generate the beginning of new Process FMEAs based on existing Design FMEAs. Such software also has the potential to create integrated Design Verification Plan and Reports (DVP&Rs), Process Control Plans (PCPs) and Process Flow Diagrams (PFDs).

FMEAs can provide important input for other processes, such as Design Reviews, Design Trade Studies, Reliability Growth Analyses, etc. The FMEA Process should be integrated with the overall Product Development Process.

Linking FMEA with other key processes improves quality and saves both time and money.

### *6.9 Test and Field Failures*

One of the common mistakes when implementing an FMEA process is to omit subsequent test and field failures. If generic FMEAs are used, they can be updated with information from FRACAS. This is invaluable when FMEA documents become input for future design programs. When feedback from subsequent test and field failures is omitted from the FMEA process, future designs are at risk for repeating past failure modes.

### *6.10 Integrated Software Support*

To be most effective, the FMEA process should utilize software that provides database functionality. The best software to integrate the steps of the FMEA process is based on a relational database. Such software can do an excellent job of managing multiple FMEA projects and databases and also provide the plots/reports and linkages to other processes that are essential to successful FMEA outcomes.

One of the most important factors for the success of FMEAs in any organization is an effective FMEA process. It takes a focused strategy to bring about the infrastructure necessary to support effective FMEAs, but it is well worth the time and effort.

## *7. CONCLUSION*

It is not enough to learn and perform FMEAs by “filling out the form”. In order to ensure FMEAs are fully effective in supporting high product and process reliability there are four broad success factors: understanding the basics of FMEAs and Risk Assessment, applying key factors for effective FMEAs, providing excellent FMEA facilitation and implementing a “best practice” FMEA process. Individual practitioners and management will succeed in FMEA strategies by learning and applying these four factors.

# LESSONS LEARNED FOR EFFECTIVE FMEAS

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## Agenda

1. Introduction
2. Risk Assessment
3. Key Factors for FMEAs
4. FMEA Case Studies
5. FMEA Facilitation
6. Best Practices for a Successful FMEA Process



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## Prerequisites

- This tutorial is “Intermediate” level
- It is not an introduction to FMEA/FMECA
- It presupposes familiarity with FMEA/FMECA



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## Purpose

The purpose of this tutorial is to share the key factors for achieving success in FMEAs and to highlight an FMEA process that is helpful for consistently good results.



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## Review

Failure Mode and Effects Analysis (FMEA) is a methodology designed to:

- Identify and fully understand potential failure modes for a product or process
- Assess the risk associated with those failure modes and prioritize issues for corrective action
- Identify and carry out corrective actions to address the most serious concerns



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## Introduction



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## Failure Mode and Effects Analysis

- You either love it ...



- ...or hate it.



*Everyone has an opinion!*



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## So, What's the Truth About FMEA?

- Is it a giant waste of time and resources?
- Or is it a powerful tool that is essential to the goal of designing in reliability?



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# It depends!



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## Heard at the “Virtual” Water Cooler

- “Waste of time,” “lack of support,” “don’t want anything to do with it”
- “Powerful tool,” “effective way to prevent problems” and “needs to be done across the board”



---

## Drum Roll!

And the answer is...



*OK. So what does the success of this potentially powerful tool depend on?*



## Stay Focused on Risk

- Perform preliminary risk analysis
- Use FMEA method on higher risk areas, such as:
  - New technology
  - New designs where risk is a concern
  - New applications of existing technology
  - Potential for safety issues
  - History of significant field problems



## FMEA Success Factors

*Four broad success factors are critical to uniformity of success in the application of FMEA in any company:*

- Understanding the basics of FMEAs and Risk Assessment
- Applying key factors for effective FMEAs
- Providing excellent FMEA facilitation
- Implementing a “best practice” FMEA process



## Understanding the Basics of FMEAs and Risk Assessment



## Basics of FMEAs

- There are many existing courses and tutorials covering the basics of FMEAs
- It is essential to the success of FMEA applications that the FMEA facilitator and team thoroughly understand and can apply these basics
- Basics include FMEA terminology and how to perform FMEAs



## Risk Assessment and FMEAs

- Risk assessment is used to identify which FMEAs will be done as part of product and process development
- Risk assessment is also an integral part of the FMEA procedure
- FMEAs cost money to perform and should be used where the highest risk is anticipated



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## Stay Focused on Risk

- Potential for important regulation issues
- Mission Critical applications
- Supplier Capability
- Avoid excessive time on low risk systems



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“The art of being wise is the art of knowing what to overlook.”

*--William James, American Philosopher*



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## Level of Detail

- Every part of the FMEA procedure can have too much or too little detail
- It is up to the FMEA Team and Facilitator to navigate the treacherous waters of detail
- FMEAs with hundreds of pages (small font) come from:
  - Boiler plates
  - Brainstorming gone amuck
  - Poor facilitation



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## Key Factors for Effective FMEAs



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## Common Error

### Too Little Detail

- FMEAs that are too generalized or miss the high risk areas are all too common
- Not getting to **Root Cause**
- Not developing the analysis fully for the high risk areas
- Not developing “executable” actions
- FMEA gets a bad name



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## Stay Focused on Risk

*The Key is to be “Risk Conscious”  
and to consistently keep the team  
focused on risk*



- 
- Learning the FMEA procedure is not enough to be a successful FMEA practitioner
  - Performing successful FMEAs requires understanding and implementing the Key Factors for Effective FMEAs



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## Maxim

*“Good judgment comes from  
experience and experience comes  
from poor judgment.”*



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## Mistake #1

### *Failure to Drive Design or Process Improvements*

- Some FMEAs do not drive any action at all
- Some FMEAs drive mostly testing
- Some FMEAs drive ineffective action



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## A Note on Quality Objective #1

- Reliability Engineering has a multitude of tools to choose from in driving design or process improvements
- The key is to use the FMEA “Recommended Actions” field to identify and execute best practice tools that can optimize designs
- This is one of the reasons that Reliability Engineers need to participate in FMEAs



- 
- What are the primary ways that FMEAs can be done wrong? (Mistakes)
  - What are the Key Factors that make for effective FMEAs? (Quality Objectives)



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## Quality Objective #1

*The FMEA drives Product or Process Design Improvements as the primary objective*



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## Mistake #2

### *Failure to Address All High Risk Failure Modes*

- Risk thresholds can be defined by FMEA Team or set as company policy
- In addition to high RPN or criticality, high severity must be addressed
- Some companies fail to take effective action on all high risk failure modes



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## Quality Objective #2

*The FMEA addresses all high risk failure modes as identified by the FMEA Team, with executable Action Plans*



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## Mistake #3

### *Failure to Improve Test/Control Plans*

- Some companies miss the opportunity to improve DVP&R (Design Review Plan and Report) or Process Control Plans based on failure modes from FMEA
- Some FMEA teams do not include knowledgeable reps from test department
- Result is inadequate testing or control plans



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## A Note on Quality Objective #3

- The FMEA team will often discover failure modes/causes that were not part of the Design Controls or Test Procedures
- The key is to ensure that the Test Plan (DVP&R) or Control Plan is impacted by the results of the FMEA
- This can be done by including test/control membership on FMEA team or through well written actions



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## A Note on Quality Objective #2

- The emphasis on this Quality Objective is to ensure that all of the high risk failure mode/causes are adequately addressed with effective actions.
- Company policy or the FMEA team will define which RPNs or Criticality will rise to the level of high risk
- The key is effective action that reduces or eliminates the risk



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## Quality Objective #4

***The FMEA scope includes integration and interface failure modes in both block diagram and analysis***



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## Quality Objective #3

***The Design Verification Plan & Report (DVP&R) or the Process Control Plan (PCP) considers the failure modes from the FMEA***



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## Mistake #5

***Disconnect from Field Lessons Learned***

- Some companies provide no linkages between FMEAs and field data
- It takes concerted effort to integrate problem resolution databases with FMEA
- Otherwise serious problems are repeated



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## Mistake #4

***Not Including Interfaces in the FMEA***

- Empirical data shows that at least 50% of field problems can occur at interfaces
- Some companies focus on part or subsystem failures and miss the interfaces



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## A Note on Quality Objective #5

- Field failure data can be brought into generic FMEAs on a regular basis
- Then, when new program-specific FMEAs are started, they benefit from field lessons learned
- If generic FMEAs are not used, new FMEAs should be seeded with potential field problems and show how they will not be repeated in the new design/process
- The key is to hold the FMEA team responsible to ensure that major field problems are not repeated



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## A Note on Quality Objective #4

- Interfaces can be included as part of the item by item analysis or as a separate analysis
- It is recommended that the preliminary FMEA Block Diagram clearly show the interfaces that are part of FMEA scope



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## Quality Objective #5

*The FMEA considers all major “lessons learned” (such as high warranty, campaigns, etc.) as input for failure mode identification*



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## Mistake #6

### ***FMEA Omits Key Characteristics***

- Many companies have a Key Characteristics policy
- FMEA can identify Key Characteristics for special controls in manufacturing
- Some companies miss this opportunity



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## Quality Objective #6

*The FMEA identifies appropriate Key Characteristics candidates, if applicable according to company policy*



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## Mistake #7

### ***Doing FMEAs Late***

- Many companies do FMEAs late and this reduces their effectiveness
- FMEAs should be done concurrently with the design process and completed by design or process freeze dates



## A Note on Quality Objective #7

*FMEAs need to be done during the “window of opportunity” to best impact design of product or process.*

- For Design FMEAs:
  - Too early: before design concept is established
  - Too late: after design freeze
  - Ideal: while design of product is being developed
- For Process FMEAs:
  - Too early: before manufacturing or assembly concept is established
  - Too late: after manufacturing or assembly process is finalized
  - Ideal: while design of the manufacturing or assembly process is being developed



## Mistake #8

### *Inadequate Team Composition*

- Some FMEA teams do not have the right experts on the core team
- Some FMEA teams do not have good attendance
- Some FMEA team members just sit in their chairs and don't contribute to team synergy



## A Note on Quality Objective #6

- This is an underutilized element of FMEAs
- SAE J1739 or the AIAG FMEA standard uses the “Classification” column



## Quality Objective #8

*The right people participate on the FMEA team throughout the analysis and are adequately trained in the procedure*



## Quality Objective #7

*The FMEA is completed during the “window of opportunity” where it can most effectively impact the product or process design*



## Mistake #9

### *Improper Procedure*

- There are hundreds of ways to do FMEAs wrong
- Some companies do not encourage or control proper FMEA methodology
- Training, coaching and reviews are all necessary to success



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## A Note on Quality Objective #9

- One of the most common FMEA errors is to fail to get to root cause
- Expert input is necessary
- Follow-up actions based on poorly defined causes will not work and FMEA will not be successful



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## A Note on Quality Objective #8

- People have blind spots (scotomas)
- Key is to get the people who are knowledgeable and experienced about potential failures and their resolutions actually showing up at the meetings
- Attendance takes management support
- Team size is best between 4 and 8 people
- If team gets too large, consider breaking up the FMEA into additional limited scope FMEAs



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## Quality Objective #9

***The FMEA document is completely filled out “by the book,” including “Action Taken” and final risk assessment***



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## Mistake #10

### ***Lack of Efficient Use of Time***

- Some companies mandate FMEAs, then do not ensure the time is well spent
- Preliminary work must be completed, meetings well run and high risk issues efficiently followed up
- Ask FMEA team if their time is well spent and take action to address shortcomings



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## Quality Objective #10

***The time spent by the FMEA team is an effective and efficient use of time with a value-added result***



## FMEA Quality Objectives

1. **DESIGN IMPROVEMENTS** *FMEA primarily drives Design Improvements*
2. **HIGH RISK FAILURE MODES** *FMEA addresses all high risk failure modes*
3. **DVP&R/CONTROL PLAN** *Comprehends failure modes from the Design FMEA*
4. **INTERFACES** *FMEA scope includes integration and interface failure modes*
5. **LESSONS LEARNED** *Warranty, field issues and "hardy perennials" included*



## FMEA Quality Objectives

6. **KCDS CONNECTION** *The FMEA identifies appropriate KPC candidates [Note, KCDS is Key Characteristics Designation System and KPC is Key Product Characteristics]*
7. **TIMING** *The FMEA is completed during the "window of opportunity"*
8. **TEAM** *The right people participate as part of the FMEA team*
9. **DOCUMENTATION** *FMEA document is completely filled out "by the book"*
10. **TIME USAGE** *Effective and efficient use of time by FMEA Team*



## Meeting FMEA Quality Objectives

- Make FMEA Quality Objectives part of FMEA training
- Review them at each meeting
- Participate in FMEA Quality audits
- Keep FMEA open until Quality Objectives are met



## FMEA Preliminary Work Lesson Learned

- Time spent prior to the first FMEA team meeting can save valuable subject matter expert time in meetings
- Try to predict all of the documents that will be needed during team meetings and provide hard copies or on-line access



## A Note on Quality Objective #10

- If this Quality Objective is met, then future FMEAs will be well attended and supported by subject matter experts and management



## FMEA Scope Lesson Learned

### *A common problem with the scope of an FMEA project:*

- Starting the FMEA meetings before the exact scope is agreed upon
  - For example, need to agree on the exact configuration of subsystems and components, interfaces, indenture level, role of suppliers, etc.



## FMEA Assumptions and Limitations

### *A common problem with the assumptions and limitations of an FMEA project:*

- Starting the FMEA meetings before the all assumptions and limitations are agreed upon
  - For example, need to agree on assumptions relating to design and process, part quality/usage, analysis level of detail, etc.



## FMEA Case Studies



## FMEA Case Study #1

### *FMEA Project Description*

- Vehicle system integrator performs System FMEA to address safety and field concerns

### *FMEA Quality Analysis*

- Started on time, but progress very slow due to inadequate FMEA software (not user friendly, not supporting best practices, etc.)
- FMEA document grew to hundreds of pages
- Test Plans, Control Plans, Design Reviews, Design modifications not driven by completed FMEA



## FMEA Case Study #2

### *FMEA Project Description*

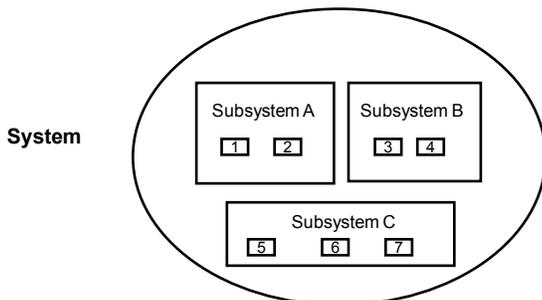
- Design FMEA performed to reduce reliability risk of an optical system featuring new technology

### *FMEA Quality Analysis*

- Generally good results on FMEA
- One major failure mode was not adequately addressed because it had “no solution”



## FMEA Scope



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## FMEA Case Study #3

### ***FMEA Project Description***

- Medical company routinely doing Process FMEAs in order to meet ISO compliance

### ***FMEA Quality Analysis***

- Few Recommended Actions
- Overall, FMEAs were not value-added
- FMEA team was focused on meeting compliance instead of improving design of product or process



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## Excellent FMEA Team Facilitation



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## The Subject of FMEA Facilitation

- FMEA facilitation is a different subject from FMEA methodology
- To be successful, FMEA leaders need to develop expert facilitation skills



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## What are Characteristics of Successful FMEA Facilitation?

- Facilitator must be well trained in effective meeting facilitation techniques
- Facilitator must know FMEA procedure and use of software
- FMEA team members need to be trained in overview of FMEA procedure
- Good facilitation is key to prevention of high risk problems without wasting time



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## Primary FMEA Facilitation Skills

- Brainstorming and Probing Questions
- Encouraging Participation
- Active Listening
- Controlling Discussion
- Making Decisions
- Conflict Management
- Managing Level of Detail
- Managing Time



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## Best Practices for a Successful FMEA Process



## What is an FMEA Process?

- The company-wide systems and tasks essential to support development of high reliability products and processes through timely accomplishment of well done FMEAs.



*An Effective FMEA Process addresses these issues and ensures successful FMEA application*



## 1A FMEA Strategic Planning

### Strategic decisions to be made by management:

1. What types of FMEAs will be done? (Design, Process, Equipment, Maintenance, etc.)
2. What selection criteria will be used to identify new FMEAs? (New designs, new processes, etc.)
3. What is appropriate FMEA timing? (e.g. prior to design freeze, while designs or processes are being developed)
4. What FMEA standard will be used? (J1739, MIL-STD-1629A, etc.)
5. What generic FMEAs will be developed? By whom?

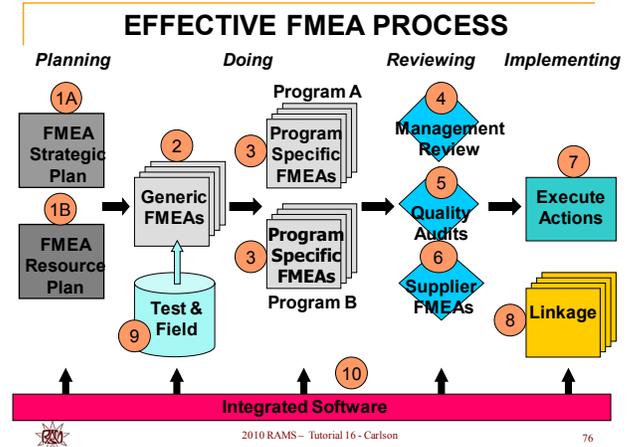


## Why Implement an FMEA Process?

*(Why not just start doing FMEAs?)*

### Primary reasons for ineffective FMEAs (based on practical experience):

1. Insufficient strategic or resource planning
2. Doing FMEAs improperly (“check off” item) or too late
3. Lack of management sponsorship and support
4. Failure to execute Recommended Actions for high risk issues
5. Not meeting FMEA Quality Objectives
6. Failure to address supplier issues
7. Failure to incorporate Lessons Learned from past FMEAs or test and field data
8. Failure to integrate FMEAs with other key processes



## 1A FMEA Strategic Planning (continued)

### Strategic decisions to be made by management:

6. What program-specific FMEAs will be developed? By whom?
7. What level of detail is needed for generic or program-specific FMEAs? (System, Subsystem, Component, etc.)
8. Will FMEA Quality Audits be used to gauge FMEA effectiveness and provide ongoing improvements to FMEA process? If so, how will this be done?
9. How will FMEA projects be archived and tracked?
10. How will FMEA Post-Analysis Lessons Learned be captured?



## 1A FMEA Strategic Planning (continued)

### **Strategic decisions to be made by management:**

11. What linkages are needed to other processes? (FRACAS, DVP&Rs, Design Reviews, Process Control Plans, etc.)
12. How will Supplier FMEAs be handled? Who will review and approve Supplier FMEAs for critical parts?



## 1B Some Notes on FMEA “Training”

- FMEA Facilitator training:
  - How to perform effective FMEAs
  - Overview of FMEA process from viewpoint of facilitator
  - How to facilitate effective meetings
- FMEA team member training:
  - Basics of FMEA procedure
- Management training:
  - Effective FMEA process from viewpoint of management
  - Roles and responsibilities needed to support effective FMEAs



## Heroes

“Heard at a seminar. One gets a good rating for fighting a fire. The result is visible; can be quantified. If you do it right the first time, you are invisible. You satisfied the requirements. That is your job. Mess it up, and correct it later, you become a hero.”

--W. Edwards Deming  
*Out of the Crisis*



## 1B FMEA Resource Planning

### **Resource decisions to be made by management:**

- What software is needed? (such as Xfmea or other relational database, FMEA project tracking, etc.)
- Where will the homeroom for FMEA expertise reside? (FMEA process, FMEA facilitators, etc.)
- Who will perform FMEA facilitation and administration?
- What is the FMEA training plan for facilitators, teams and management?
- What should be composition of core FMEA team?
- How will Management support be provided?



## 1B Some Notes on FMEA “Management Support”

### ***The importance of broad support from management in implementing an effective FMEA process cannot be overstated***

- Provides agreement on strategy and supports needed resources
- Assists in integrating FMEA with other business processes
- Provides effective reviews of high risk failure modes and recommended actions
- Mandates attendance of expert FMEA team members



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## 2 Generic FMEAs

### Definition:

- FMEAs that contain both *historical* (empirical) and *potential* failure modes, causes, controls, etc.
- Done at the generic level of the system, subsystem or component, not program-specific
- Done once, then updated (as needed) from Test and Field data and/or new technology

### Generic FMEAs can be used for:

- Design Trade Studies
- Input for program-specific FMEAs
- Most useful if the product line is relatively stable over time



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## 3 Program-Specific FMEAs

### Definition:

- FMEAs that focus on specific applications
- Either tailored from generic FMEAs or newly done
- Completed through entire FMEA worksheet



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## 5 FMEA Quality Surveys or Audits

### Quality Surveys (based on FMEA Quality Objectives)

- FMEA “customers” (such as managers and engineers) can be surveyed for FMEA effectiveness
- Surveys are in writing, one or two pages
- Provide valuable feedback to improve future FMEAs

### Quality Audits (based on FMEA Quality Objectives)

- In-person audits of FMEAs, done with FMEA facilitator and core team, performed by management in an interview format
- Done on random basis, one hour maximum per audit
- Provides valuable feedback to improve future FMEAs, with Action Items identified for follow-up



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## 6 Supplier FMEAs

- Potential high risk system or subsystem level failures can have their root cause in Supplier components
- FMEA Strategic Planning should determine how to address Supplier FMEAs and how to identify which Suppliers require FMEA review
- FMEA team can invite Suppliers to participate in FMEA



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## 4 Management Review

*(Sometimes Called Failure Review Board)*

- Management reviews FMEA high risk issues and recommended actions (*essential to ensure understanding, buy-in, support and adequacy*)
- FMEA reports/charts should be generated per FMEA Strategic Plan
- Feedback from management goes back to FMEA Teams for review and incorporation
- There may already be a process in place to review failure modes from field or test
- Most companies “piggy-back” the review of FMEA failure modes with the review of field or test failure modes



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## 5 Notes on FMEA Quality Surveys/Audits

- Focus on improving the FMEA process, not on the person/team doing the FMEA
- Don’t expect to instantly achieve all 10 objectives; work to maintain steady improvement
- Management audits demonstrate commitment; in the words of W. Edwards Deming: “Quality cannot be delegated”



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## 6 Supplier FMEAs (continued)

### *For Suppliers who are identified as high risk:*

- Require submission of completed FMEA for review and approval prior to part shipment
- Review conducted by FMEA team or qualified representative based on FMEA Quality Objectives
- Supplier continues FMEA until Quality Objectives met



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## 7 Execute Actions to Reduce or Eliminate Risk

### *FMEA has little value unless the recommended actions are fully executed*

- Follow up each recommended action to ensure:
  - Completion to satisfaction of FMEA Team
  - Risk eliminated or mitigated to acceptable level
- Bring problems with execution back to Management
- Update Action Status and Risk Reduction in FMEA database



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## 8 Linkages to Other Key Processes (cont'd)

- FMEAs can provide important input for other processes:
  - Design Reviews, Trade Studies, Reliability Growth Analyses, etc.
- FMEA must be fully integrated with the Product Development Process
- FMEA can be implemented as a stand-alone process and make significant design improvements
- However, linking to other processes results in efficiencies and can make the other processes more effective



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## 10 Integrated Software Support

- Relational Database for all FMEA Projects
- FMEA Standards: configurable to organization
- Maintains generic and program-specific FMEAs
- Import/Export and Attachment Features
- Linkages to Other Processes
- Tracks Execution of Risk Reduction Actions
- Generates Plots and Reports for Management Reviews
- Simultaneous FMEA users accessing database



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## 8 Linkages to Other Key Processes

### *Look for software that integrates requirements from Advanced Product Quality Planning (APQP) or other quality guidelines*

- Generate new Process FMEAs based on existing Design FMEAs
- Create integrated:
  - Design Verification Plan and Report (DVP&R )
  - Process Control Plan (PCP)
  - Process Flow Diagram (PFD)



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## 9 Test and Field Failures

*There needs to be a separate process and database to capture all test and field failure data*

- Often called “FRACAS”
- Provides updates to FMEAs, after initial FMEA analyses are completed (called “post analysis lessons learned)
- High risk failure modes from FMEA are passed on to FRACAS
- The best way to prevent recurring problems is to backfill the FMEA with lessons learned from field or test



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## 10 A Note on Integrated Software Support

- Some companies stay with Excel so they can tailor worksheets to specific formats
  - They miss out on features of a relational database



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## Summarizing the Key Factors for a Successful FMEA Process

1. Broad management support
2. Strategic and Resource Planning
3. FMEA process integrated with Business Process
4. Well trained FMEA Facilitators and Teams
5. Management reviews and support
6. Follow-up on all high risk issues
7. FMEA Quality Audits
8. Integrated FMEA software support
9. Supplier FMEAs for higher risk parts
10. FMEAs linked to other key processes



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## Remember!

*Four broad success factors are critical to uniformity of success in the application of FMEA in any company:*

- Understanding the basics of FMEAs and Risk Assessment
- Applying key factors for effective FMEAs
- Providing excellent FMEA facilitation
- Implementing a “best practice” FMEA process



