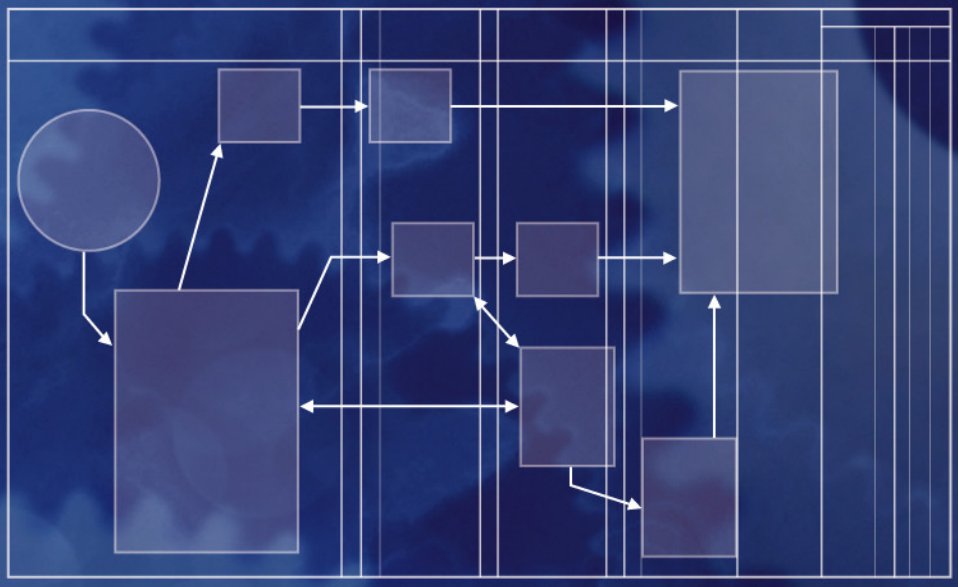
Failure Mode and Effects Analysis

FMEA Handbook (with Robustness Linkages)



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FMEA Handbook Version 4.1

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February 2004

Any italicized text quotes the SAE J1739 (August, 2002) standard.

Table of Contents

Title	Page Number
Table of Contents	TOC-1
Section 1 - Foreword	1-1
Section 2 - FMEA General Information	2-1
Section 3 - Design FMEA (DFMEA)	3-1
Section 4 - Process FMEA (PFMEA)	4-1
Section 5 - Concept FMEA (CFMEA)	5-1
Section 6 - Special Characteristics	6-1
Appendix A - FMEA Forms	A-1
Appendix B - Helpful Tools for FMEA	B-1
Appendix C - FMEA Checklist	C-1
Appendix D - Ford Automotive Procedures (FAPs)	D-1
Appendix E - FMEA Applications	E-1
Glossary	Glossary-1
Index	Index-1

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FMEA HANDBOOK VERSION 4.1 — COPYRIGHT © 2004

Section 1 – Foreword
Contents

In This Section

Description	See Page
FMEA Handbook Organization	1-2
Common Questions	
What Is the Purpose of this FMEA Handbook?	1-3
Can this FMEA Handbook be Given to Suppliers?	1-3
What Does this FMEA Handbook Contain?	1-3
Can the Guidelines Given in this FMEA Handbook be Supplemented?	1-4
FMEA Handbook Provenance	1-4
What Can I Read to Obtain More Background on FMEAs?	1-4
Where Can I Find More Information on Special Characteristics?	1-5
Why Does the Handbook Need a Revision?	1-5
What's New in the 2004 Update?	1-5
About this FMEA Handbook	
In this FMEA Handbook	1-7

FMEA Handbook Organization

FMEA Handbook Organization

The 2004 version of the FMEA Handbook is divided into six sections with five appendices and a glossary:

Section	Title	Contents
1	Foreword	Provides general information about the FMEA Handbook.
2	FMEA General Information	Provides general information about the FMEA process.
3	Design FMEA (DFMEA)	Explains the Design FMEA process.
4	Process FMEA (PFMEA)	Explains the Process FMEA process.
5	Concept FMEA (CFMEA)	Explains the Design Concept or Process Concept FMEA process.
6	Special Characteristics	Shows how FMEAs are used to identify Special Characteristics.
	Appendix A: FMEA Forms Appendix B: Helpful Tools for FMEA Appendix C: FMEA Checklist Appendix D: Ford Automotive Procedures (FAPs) Appendix E: FMEA Applications	
	Glossary	

Foreword

Common Questions

What is the Purpose of this FMEA Handbook?

This FMEA Handbook introduces Failure Mode and Effects Analysis (FMEA) as defined by the Society of Automotive Engineers (SAE) and gives specific requirements for FMEAs at Ford Motor Company.

Any *italicized text* quotes the SAE J1739 (Revised August 2002) standard.

You can use this FMEA Handbook:

- To learn the basics of FMEA
- As a reference tool, after training
- To assist in the writing, preparation, review, and editing of FMEAs

This FMEA Handbook is also intended to be used as a guide in deploying the Special Characteristics Operating System: i.e., to assist Ford engineering teams worldwide to identify product/process characteristics important to product safety, regulatory conformance, and customer quality. Specifically, the FMEA Handbook is intended to help deploy the policy and principles embodied in Ford Automotive Procedure – FAP 03-111.

Can this FMEA Handbook be Given to Suppliers?

This FMEA Handbook is available through FSN/FSP. Suppliers are encouraged to use it as a reference when they create FMEAs for Ford systems, sub-systems, and components.

Excerpts from this FMEA Handbook are also available on the Ford Intranet at:

http://www.quality.ford.com/cpar/fmea/

What Does this FMEA Handbook Contain?

This FMEA Handbook contains instructions for preparing an FMEA, and answers the What, Why, When, Who and How regarding FMEA methodologies. This FMEA Handbook shows how to conduct three types of FMEAs:

- Design FMEA
- Process FMEA
- Concept FMEA

Additionally, special applications of the three FMEA types are presented as examples. These special applications are machinery, environment, and software.

Continued on next page

Common Questions, Continued

What Does this FMEA Handbook Contain? (Continued)

This FMEA Handbook provides additional Ford-specific information for the creation of FMEAs. The most notable areas to reference are:

- Concept FMEA
- Designations for the Classification column
- Reduced emphasis on RPN, emphasis on Severity, the Severity times Occurrence (Criticality), then RPN (Severity x Occurrence x Detection)
- The inclusion of Robustness Tools in the FMEA process

Can the Guidelines Given in this FMEA Handbook be Supplemented?

This FMEA Handbook introduces the topic of potential FMEA and gives general guidance in applying the technique. FMEA techniques are continually being improved. Additional actions to improve the FMEA techniques may be implemented by the people preparing the FMEA. However, these actions should not undermine FMEA objectives.

FMEA Handbook Provenance

This FMEA Handbook is consistent with the SAE Recommended Practice, SAE J1739 – "Potential Failure Mode and Effects Analysis in Design (Design FMEA) and Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA), and Potential Failure Mode and Effects Analysis for Machinery (Machinery FMEA)" revision.

DaimlerChrysler, Ford Motor Company, and General Motors jointly developed the first release of this practice under the sponsorship of the United States Council for Automotive Research (USCAR). SAE J1739 gives general guidance in the application of the technique. DaimlerChrysler, Ford Motor Company, and General Motors representatives to the SAE have worked together to complete the latest revision of the SAE standards dated August 2002.

For more information or for a copy of J1739, visit:

http://www.sae.org/

Continued on next page

Common Questions, Continued

What Can I Read to Obtain More Background on FMEAs?

Ford/GM/DaimlerChrysler	Advance Product Quality Planning and Control Plan Reference (APQP)
Ford/GM/DaimlerChrysler	Quality System-9000 (QS-9000)
AIAG	http://www.aiag.org/
SAE	http://www.sae.org/
FMEA website:	http://www.quality.ford.com/cpar/fmea/

Where Can I Find More Information on Special Characteristics?

FAP 03 –111 – Selection and Identification of Significant and Critical Characteristics. Throughout Sections 2 through 5 of this handbook, the term Special Characteristics is used to denote those designated characteristics like YC and YS in DFMEA and ∇ (sometimes referred to as CC) and SC in PFMEA. Refer to Section 6 for detailed discussion of these and other types of Special Characteristics.

Why does the Handbook Need a Revision?

- Keep the handbook consistent with the industrial standard - new SAE J1739 was published in August, 2002, and a 2-column design control FMEA form is recommended.
- Improve the quality of the handbook - many recommendation, suggestions, and corrections have been received from experts, engineers, and suppliers since the publication of the previous version. The revision focused on achieving:
  - better flow of the contents;
  - better and clearer examples, definitions, and procedures; and
  - elimination of the inconsistencies and errors.

What's New in the 2004 Update?

The Version 4.1 minor update includes cosmetic updates and addition of an index. The Version 4.0 update included the following changes:

The FMEA flow chart has been updated according to FAP 07-005 - Vehicle Program Quality/Reliability/Robustness Planning. The new chart not only illustrated the information flow in the process of FMEA development, but also defines the role of FMEA in the failure modes avoidance. FMEA focuses on preventing mistakes, while as the Robustness Engineering Design Product Enhancement Process (REDPEPR) focuses on improving product robustness.

Continued on next page

Common Questions, Continued

What's New in the 2004 Update? (Continued)

SAE J1739 August 2002	The new SAE J1739 FMEA forms are introduced, and all the examples have been modified using the new form.
Simplified FMEA Checklist	This version of the handbook consolidated the "FMEA Checklist", the "Design FMEA Checklist", the "Process FMEA Checklist", and the "FMEA Quick Reference" of the previous version into a simplified FMEA Checklist given in Appendix C.
Revised Examples	Revised examples are included in the Design FMEA sections.
FAP Reference	The documents of FAP 07-005, and FAP 03-111 have been removed from the handbook. Instead, only the web addresses of the FAPs are given for the references.
Concept FMEA	The "Concept FMEA" section has been moved from Section 3 in the previous version to Section 5 in this version after the "Design FMEA" and "Process FMEA" sections.
Updated Glossary	The Glossary has been updated.
System Interface Analyzer (SIA)	A tool for analyzing the system interfaces, developing the system Boundary Diagram and Interface Matrix has been briefly introduced. For more information, please visit: http://www.quality.ford.com/cpar/sia/
New FMEA Website	For more information, please visit: http://www.quality.ford.com/cpar/fmea/

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Foreword

About this FMEA Handbook

In this FMEA Handbook

All *italic type* used in the body of this guide is text copied from the SAE J1739 standards.

The following icons are used in the FMEA Handbook:

Icon	Meaning
	Definitions
	Examples
	Mechanics
	Cautionary Notes
	Ford Specific
	Suggestion/Tip

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Section 2 – FMEA General Information Contents

In This Section

Description	See Page
FMEA Definition	2-3
FMEA Implementation	2-4
FMEA Purposes	2-5
General Benefits	
General Benefits	2-6
Best Practice FMEA	2-6
Types of FMEAs	
Types of FMEAs	2-7
Machinery Note	2-7
FMEA Flow and its Role in Failure Mode Avoidance (Robustness Linkages)	2-8
FMEA Flow (Robustness Linkages)	2-8
Useful Information Sources for Input to FMEA	2-10
FMEA Provides Input to	2-10
Change Point Approach	
FMEA Change Point Approach	2-11
Benefits of FMEA Types	
Concept FMEA Benefits and Uses	2-12
Concept FMEA Outputs	2-12
Design FMEA Benefits and Uses	2-13
Design FMEA Outputs	2-14
Process FMEA Benefits and Uses	2-15
Process FMEA Outputs	2-16

Continued on next page

Section 2 Contents, Continued

In This Section (Continued)

Description	See Page
Generating FMEAs	
Who Initiates an FMEA?	2-17
Who Prepares an FMEA?	2-17
Who Updates an FMEA?	2-18
How do I Start or Update an FMEA?	2-18
When is an FMEA Started or Updated?	2-19
FPDS Timings	2-20
Who is the FMEA Customer?	2-20
When is an FMEA Completed?	2-21
How are FMEA Results Documented?	2-21
When Can FMEA Documents be Discarded?	2-21
Systems Engineering Relationships	
FMEAs Related to Systems Engineering	2-22
Systems Engineering Fundamentals	2-22
APQP Relationship	2-22

FMEA Definition

FMEA Definition

An FMEA can be described as a systemized group of activities intended to:

(a) recognize and evaluate the potential failure of a product/process and its effects,

(b) identify actions which could eliminate or reduce the chance of the potential failure occurring, and

(c) document the process. It is complementary to the process of defining what a design or process must do to satisfy the customer.

FMEAs identify potential and confirm Critical and Significant Characteristics to be addressed by design changes, process changes, or inclusion in Process Control Plans.

FMEAs evaluate the adequacy of proposed controls and the need to mitigate risk by changes to the Design Verification Plan or the Manufacturing Control Plan. The intent of the evaluation and the proposed actions is to prevent failures from reaching the customers, improving customer satisfaction.

For more information on Control Plans, refer to Appendix page B-31.

FMEA Implementation

FMEA Implementation

Because of the general industry trend to continually improve products and processes whenever possible, using the FMEA as a disciplined technique to identify and help minimize potential concern is as important as ever. Studies of vehicle campaigns have shown that fully implemented FMEA programs could have prevented many of the campaigns.

One of the most important factors for the successful implementation of an FMEA program is timeliness. It is meant to be a "before-the-event" action, not an "after-the-fact" exercise. To achieve the greatest value, the FMEA must be done before a product or process Failure Mode has been incorporated into a product or process. Up front time spent properly completing an FMEA, when product/process changes can be most easily and inexpensively implemented, will minimize late change crises. An FMEA can reduce or eliminate the chance of implementing a preventive/corrective change, which would create an even larger concern. Communication and coordination should occur between all types of FMEAs.

Studies performed within Ford have shown that significant savings in engineering time and other costs could have been realized if FMEAs were completed according to the FMEA "Best Practices."

FMEA Purposes

FMEA Purposes

General/overall purposes of an FMEA:

- Improves the quality, reliability and safety of the evaluated products/processes.
- Reduces product redevelopment timing and cost.
- Documents and tracks actions taken to reduce risk.
- Aids in the development of robust control plans.
- Aids in the development of robust design verification plans.
- Helps engineers prioritize and focus on eliminating/reducing product and process concerns and/or helps prevent problems from occurring.
- Improves customer/consumer satisfaction.

FMEA purposes specific to Ford:

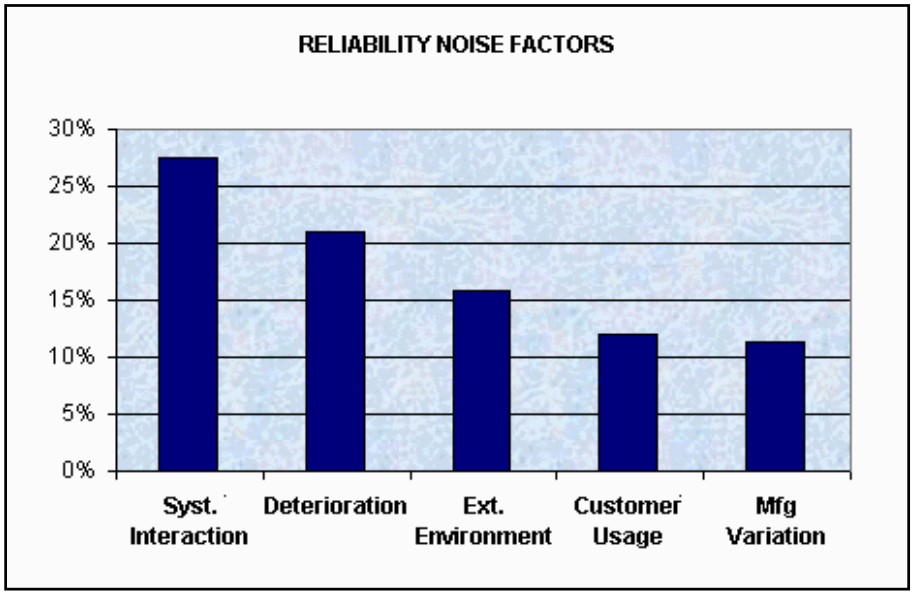
- Identifies Special Characteristics (Critical Characteristics and Significant Characteristics).
- Acts as a “lessons learned” input to System Design Specifications (SDS), Design Verification Plans (DVP), control plans, design guides, and other documents and procedures.
- Includes Robustness Tools in the FMEA process.

General Benefits

General Benefits

Because of Ford's commitment to continually improving its products/processes whenever possible, the need for using the FMEA as a disciplined technique to identify and help eliminate/reduce potential concerns is as important as ever. Studies of vehicle campaigns have shown that a fully implemented FMEA program could have prevented many of the campaigns.

Best Practice FMEA



A series of FMEAs completed according to the best practice could act on the noise factors shown in this illustration. A best practice FMEA series might be described as:

- Doing FMEAs at the right time
- Considering all interfaces and "noise factors" (shown on a P-Diagram and Interface matrix)
- Starting FMEAs at the system level and cascading information and requirements down to Component and Process FMEAs
- Using appropriate Recommended Actions to mitigate risk
- Completing all Recommended Actions in a timely manner

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Types of FMEAs

Types of FMEAs

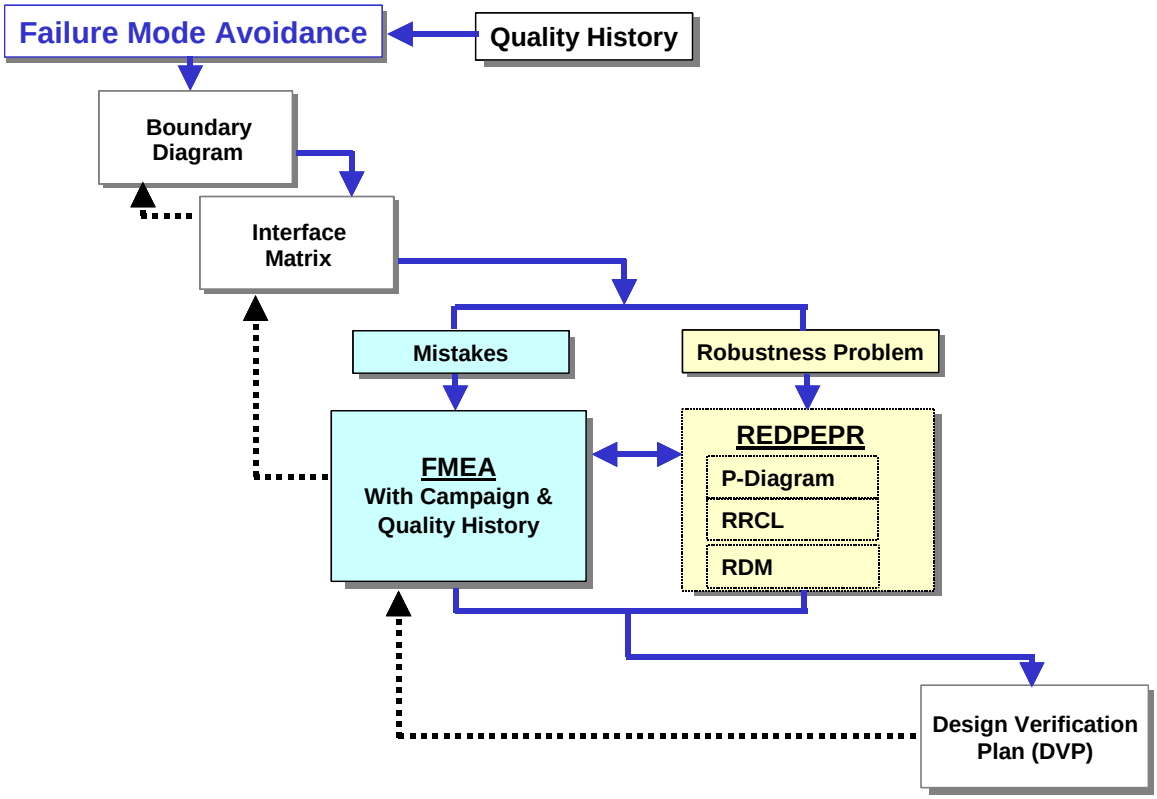
Ford recognizes the following types of FMEAs:

- Concept FMEA (CFMEA): Specific to Ford only, performed on designs and processes
  - System CFMEA
  - Sub-system CFMEA
  - Component CFMEA
- Design FMEA (DFMEA): Standardized industry-wide
  - System DFMEA
  - Sub-system DFMEA
  - Component DFMEA
- Process FMEA (PFMEA - Assembly, Manufacturing): Standardized industry-wide
  - System PFMEA
  - Sub-system PFMEA
  - Component PFMEA
- Machinery: As a Design FMEA application

Machinery FMEA Note

The Machinery FMEA (MFMEA) information has been provided due to the importance of Plant Machinery, Tooling, and Equipment functioning as intended in manufacturing and assembly plants. The use of the MFMEA, on Plant machinery, Tooling, and Equipment, will assist with the identification of potential Failure Modes, so that design and processing alternatives can be considered, prior to finalizing the Plant Machinery, Tooling, and Equipment Designs.

FMEA Flow and its Role In Failure Mode Avoidance (Robustness Linkages)



FMEA Flow (Robustness Linkages)

Preventing mistakes and improving robustness are two distinct, but complementary efforts in failure mode avoidance. Each of them has its own focus and strength.

The above flow chart illustrates the information flow when an engineering team performs a FMEA. The downward arrows represent the main flow and the upward arrows represent lessons learned and feedback. The two way arrow represents interfaces between a FMEA and REDPEPR (Robustness Engineering Design and Product Enhancement Process). The key tasks are:

Boundary Diagram – Defines the system boundary/scope and clarifies the relationship between the focused system and its interfacing systems.

Interface Matrix – Identifies system interfaces and both the effects of interfaces to the focused system and the interfacing systems. It documents system interface details.

Continued on next page

FMEA Flow and its Role In Failure Mode Avoidance (Robustness Linkages), Continued

FMEA Flow (Robustness Linkages) (Continued)

The **Quality History** is always an important input. Past quality issues need close attention to prevent reoccurrence.

DFMEA is a thorough and detail analysis of the potential failure modes (soft and hard failures) related to the system primary functions and interface functions. DFMEA is the primary document for capturing tests that are required to demonstrate we have avoided mistakes. It analyzes and prioritizes the effects and causes of failure mode actions. DFMEA identifies current controls and additional actions to reduce associated risks.

As a complementary effort Robustness Engineering (REDPEPR) includes:

1. **P-Diagram** – identifies and documents the input signal(s), noise factors, control factors, and error states as associated with the ideal function(s).
2. **Robustness Check List (RCL)** is an in-depth analysis of noise factor impact to the ideal function(s) and error states. It is a methodical assessment of the effectiveness of available DVMs (Design Verification Methods) in terms of noise factor coverage. It generates noise factor management strategies.
3. **Robustness Demonstration Matrix (RDM)** is a data driven approach to ensure the tests the noise factors, and test metrics are measured/quantified to prove out the robustness. RDM is a part of **Design Verification Plan (DVP)**.

DFMEA and **Robustness Engineering** are complementary. For example, noise factors assist failure cause identification and error states provide input to failure mode and effect identification. More importantly, the outcomes from REDPEPR become knowledge and need to be institutionalized for future mistake prevention. Conversely, high risk failure modes identified in the FMEA may need to be analyzed in-depth using REDPEPR.

Design Verification Plan (DVP) – is a comprehensive design verification plan that incorporates inputs from both DFMEA and REDPEPR. It ensures that the noise factors are included in tests and it addresses the critical measurables for evaluation of ideal functions and potential/anticipated failure modes during and after the tests.

Continued on next page

FMEA Flow and its Role In Failure Mode Avoidance (Robustness Linkages), Continued

Useful Information Sources for Input to FMEA

The following process elements/tools may provide input to the DFMEA:

- Requirements (WCR, Corporate, Regulatory, etc.)
- SDS
- QFDs
- Historical performance information
- Benchmarking data
- Pre-PD targets
- P-Diagram
  - Ideal Functions as Functions
  - Error States as Failure Modes or Effects of Failure
  - Control Factors may help in identifying Design Controls or Recommended Actions
- Boundary Diagram and Interface Matrix
  - Intended outputs as Functions
  - System interactions may help in identifying Cause(s) of Failure

FMEA Provides Input to:

- DVP
- Robustness Checklist
- Critical/Significant Characteristics
- System/Subsystem/Component design specifications
- Validation criteria
- Safety sign-off
- Control plans

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Change Point Approach

FMEA Change Point Approach

There are three basic cases for which FMEAs are generated, each with a different scope or focus:

Case 1: New designs, new technology, or new process. The scope of the FMEA is the complete design, technology or process.

Case 2: Modifications to existing design or process (assumes there is a FMEA for the existing design or process). The scope of the FMEA should focus on the modification to design or process, possible interactions due to the modification, and field history.

Case 3: Use of existing design or process in a new environment, location or application (assumes there is an FMEA for the existing design or process). The scope of the FMEA is the impact of the new environment or location on the existing design or process.

Ford refers to Change Point Philosophy as Change Point Approach.

In Cases 2 and 3 mentioned above, it is assumed that there is a completed, comprehensive FMEA. The "parent" design or process can be reviewed for the impact of the proposed change. If this is not true, then the scope should be the complete design or process, similar to Case 1.

Benefits of FMEA Types

Concept FMEA Benefits and Uses

The benefits of doing a Concept FMEA include:

- Helps select the optimum concept alternatives, or determine changes to System Design Specifications (SDS).
- Identifies potential Failure Modes and Causes due to interactions within the concept.
- Increases the likelihood all potential effects of a proposed concept's Failure Modes are considered.
- Helps generate Cause Occurrence ratings that can be used to estimate a particular concept alternative's target.
- Identifies system and subsystem level testing requirements.
- Helps determine if hardware system redundancy may be required within a design proposal.
- Focuses on potential Failure Modes associated with the proposed functions of a concept proposal caused by design decisions that introduce deficiencies (these include "design" decisions about the process layout).
- Include the interaction of multiple systems and the interaction between the elements of a system at concept stages (this may be operation interaction in the process).

Concept FMEA Outputs

The outputs of a Concept FMEA include:

- A list of potential concept Failure Modes and Causes.
- A list of design actions to eliminate the causes of Failure Modes, or reduce their rate of occurrence.
- Recommended changes to SDSs.
- Specific operating parameters as key specifications in the design.
- Changes to global manufacturing standards or procedures.
- New test methods or recommendations for new generic testing.
- Decision on which concept to pursue.

Continued on next page

Benefits of FMEA Types, Continued

Design FMEA Benefits and Uses

The Design FMEA supports the design process in reducing the risk of failures (including unintended outcomes) by:

- *Aiding in the objective evaluation of design, including functional requirements and design alternatives.*
- *Evaluating the initial design for manufacturing, assembly, service, and recycling requirements.*
- *Increasing the probability that potential Failure Modes and their effects on system and vehicle operation have been considered in the design/development process.*
- *Providing additional information to aid in the planning of thorough and efficient design, development, and validation programs.*
- *Developing a ranked list of potential Failure Modes according to their effect on the "customer," thus establishing a priority system for design improvements, development and validation testing/analysis.*
- *Providing an open issue format for recommending and tracking risk reducing actions.*
- *Providing future reference, e.g., lessons learned, to aid in analyzing field concerns, evaluating design changes and developing advanced designs.*
- Helping identify potential Critical Characteristics and potential Significant Characteristics.
- Helping validate the Design Verification Plan (DVP) and the System Design Specifications (SDSs).
- Focusing on potential Failure Modes of products caused by design deficiencies.
- Identifying potential designated characteristics, called Special Characteristics.

Continued on next page

Benefits of FMEA Types, Continued

Design FMEA Outputs

The outputs of a Design FMEA include:

- A list of potential product Failure Modes and Causes.
- A list of potential Critical Characteristics and/or Significant Characteristics.
- A list of recommended actions for reducing severity, eliminating the causes of product Failure Modes or reducing their rate of Occurrence, or improving Detection.
- For system-level Design FMEAs, confirmation of the SDSs or updates required for SDSs.
- Confirmation of the Design Verification Plan (DVP).
- Feedback of design changes to the design committee.

Continued on next page

Benefits of FMEA Types, Continued

Process FMEA Benefits and Uses

The benefits of doing a Process FMEA include:

- *Identifies the process functions and requirements*
- *Identifies potential product and process related Failure Modes.*
- *Assesses the effects of the potential failures on the customer,*
- *Identifies the potential manufacturing or assembly process causes and identifies process variables on which to focus controls for occurrence reduction or detection of the failure conditions.*
- *Identifies process variables on which to focus process controls*
- *Develops a ranked list of potential Failure Modes, thus establishing a priority system for preventative/ corrective action considerations, and*
- *Documents the results of the manufacturing or assembly process.*
- Identifies process deficiencies to enable engineers to focus on controls for reducing the occurrence of producing unacceptable products, or on methods to increase the detection of unacceptable products.
- Identifies confirmed Critical Characteristics and/or Significant Characteristics.
- Aiding in development of thorough manufacturing or assembly control plans.
- Identifies operator safety concerns.
- Feeds information on design changes required and manufacturing feasibility back to the design community.
- Focusing on potential product Failure Modes caused by manufacturing or assembly process deficiencies.
- Confirming the need for Special Controls in manufacturing, and confirming the designated potential "Special Characteristics" from the Design FMEA (DFMEA).
- Identifying process Failure Modes that could violate government regulations or compromise employee safety.
- Identifying other Special Characteristics – Operator Safety (OS) and High Impact (HI).

Continued on next page

Benefits of FMEA Types, Continued

Process FMEA Outputs

The outputs of a Process FMEA include:

- A list of potential process Failure Modes.
- A list of confirmed Critical Characteristics and/or Significant Characteristics.
- A list of Operator Safety and High Impact Characteristics.
- A list of recommended Special Controls for designated product Special Characteristics to be entered on a control plan.
- A list of processes or process actions to reduce Severity, eliminate the Causes of product Failure Modes or reduce their rate of Occurrence, and to improve product defect Detection if process capability cannot be improved.
- Recommended changes to process sheets and assembly aid drawings.

Generating FMEAs

Who Initiates an FMEA?

- During development of a Concept FMEA, the responsible activity may be Research & Advanced Engineering, Advanced Manufacturing, or the program team.
- Design FMEAs are initiated by an engineer from the responsible design function or activity. For a proprietary design, this may be the supplier.
- *Process FMEAs are initiated by an engineer from the responsible process engineering department, which may be the supplier.*

Who Prepares an FMEA?

- Although an individual is usually responsible for the preparation of an FMEA, input should be a team effort. A team of knowledgeable individuals should be assembled (e.g., engineers with expertise in Design, Analysis/Testing, Manufacturing, Assembly, Service, Recycling, Quality, and Reliability).
- The FMEA is initiated by the engineer from the responsible activity, which can be the Original Equipment Manufacturer (i.e., produces the final product), supplier, or a subcontractor.
- Team members may also include Purchasing, Testing, the supplier and other subject matter experts as appropriate. Team members will vary as the concept, product, and process designs mature.
- For proprietary designs (black/gray box), suppliers are responsible. The responsible Ford design activity approves the accuracy and thoroughness of suppliers' FMEAs, including subsequent FMEA updates, whether Design or Process FMEAs.
- *During the initial Design FMEA process, the responsible engineer is expected to directly and actively involve representatives from all affected areas. These areas of expertise and responsibility should include, but are not limited to: assembly, manufacturing, design, analysis/test, reliability, materials, quality, service, and suppliers, as well as the design area responsible for the next higher or lower assembly or system, sub-assembly or component. The FMEA should be a catalyst to stimulate the interchange of ideas between the functions affected and thus promote a team approach. Unless the responsible engineer is experienced with FMEA and team facilitation, it is helpful to have an experienced FMEA facilitator assist the team in its activities.*

Continued on next page

Generating FMEAs, Continued

Who Updates an FMEA?

- The need for taking specific, preventive/corrective actions with quantifiable benefits, recommending actions to other activities and following-up all recommendations cannot be overemphasized. A thoroughly thought out and well developed FMEA will be of limited value without positive and effective preventive/corrective actions. The responsible engineer is in charge of assuring that all recommended actions have been implemented or adequately addressed. The FMEA is a living document and should always reflect the latest level, as well as the latest relevant actions, including those occurring after the start of production.
- Suppliers keep their own FMEAs up to date. These FMEAs need to be reviewed and approved by the responsible Ford design activity.

How do I Start or Update an FMEA?

- To assist in developing the FMEA, the team leader may choose to start the FMEA to provide initial discussion framing for the team.
- When a new item is being developed from the start (not being created from a modification of existing technologies) sometimes a previously created FMEA is utilized as a starting point. This can be a “generic” FMEA, which usually lists all potential Failure Modes as a guideline for starting at the beginning – the blank FMEA. “Generic” FMEAs serve as a repository of history but are not the natural starting point during the update of existing products or the use of carryover design. For those, the FMEA for that previous product can be used.

Continued on next page

Generating FMEAs, Continued

When is an FMEA Started or Updated?

The Concept FMEA is a recommended process to validate/verify customer functional requirements and provides System Design Specifications for the Design FMEA process. Concept FMEA may be used on a process to test the proposal for the manufacturing process design. The Concept FMEA should be initiated as early in the program as possible, but must be initiated at program definition. It is updated and changed as changes occur or additional information is obtained throughout the phase of program development.

The Design FMEA is a living document and should:

- *Be initiated before or at finalization of design concept*
- *Be continually updated as changes occur or additional information is obtained throughout the phases of product development, and*
- *Be fundamentally completed before the production drawings are released for tooling*

When fully implemented, the FMEA discipline requires a Process FMEA for all new parts/processes, changed parts/processes, and carryover parts/processes in new applications or environments.

The Process FMEA is a living document and should be initiated:

- *Before or at the feasibility state*
- *Prior to tooling for production, and*
- *And take into account all manufacturing operations, for individual components to assemblies*

Early review and analysis of new or revised processes is promoted to anticipate, resolve, or monitor potential process concerns during the manufacturing planning stages of a new model or component program.

Note: Although an FMEA is required, it is not necessary to begin an FMEA from a clean sheet of paper. Previous FMEAs or "generic" FMEAs may be employed as a starting point.

Continued on next page

Generating FMEAs, Continued

FPDS Timings

For new product programs, the recommended FMEA timing is shown within the Ford Product Development System (FPDS):

Type	Start	Complete "First Pass" Finish
Concept FMEA	Pre <SI>	<SI>
Design FMEA	<SI>	<PA>
Process FMEA	<SC>	<PR>

- This FPDS timing is generic and directional. Actual timing is determined by program direction and degree of change and can vary depending on the commodity. In addition, FPDS requires program-specific design and process FMEAs to be updated periodically as testing progresses.
- Generally, Concept FMEAs should be completed during the process of readying technology for implementation, and should be done as an early step by the group developing the technology.

Who is the FMEA Customer?

- Concept FMEA - The definition of "CUSTOMER" for a Concept FMEA is not only the "END USER" of the concept, but the design responsible activities and teams for the vehicle systems or next level assemblies where the concept will be utilized as well as the manufacturing process activities such as assembly and service.
- *Design FMEA - The definition of "CUSTOMER" for a Design potential FMEA is not only the "END USER," but also the design responsible engineers/teams of the vehicle or higher-level assemblies, and/or the manufacturing process responsible engineers in activities such as manufacturing, assembly, and service.*
- *Process FMEA - The definition of "CUSTOMER" for a Process potential FMEA should normally be seen as the "END USER." However, the customer can also be a subsequent or downstream manufacturing or assembly operation, as well as a service operation.*

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Generating FMEAs, Continued

When is an FMEA Completed?

An FMEA is a living document, and in that sense, must be updated whenever significant changes occur in the design or manufacturing/assembly process. The FMEA is “complete” when matched with a released/signed-off product or process. Remember that subsequent updates may be required. At any point the FMEA should reflect the actual present design or process. A periodic FMEA review and update schedule should be developed and followed.

- A Concept FMEA is considered “complete” when the System Design Specifications are frozen and the design functions are defined.
- A Design FMEA is considered “complete” when the product design is released for production or program has reached sign-off.
- A Process FMEA is considered “complete” when all operations have been considered, when all Special Characteristics have been addressed, and when the Control Plan has been completed.

How are FMEA Results Documented?

- Refer to the Industry Standard (SAE J1739) Form (Appendix A).
  - Printed output from the FMEA software conforms to industry standards for FMEA reports.
  - To archive FMEAs on EKB II, please visit: http://www.quality.ford.com/cpar/fmea/

When Can FMEA Documents be Discarded?

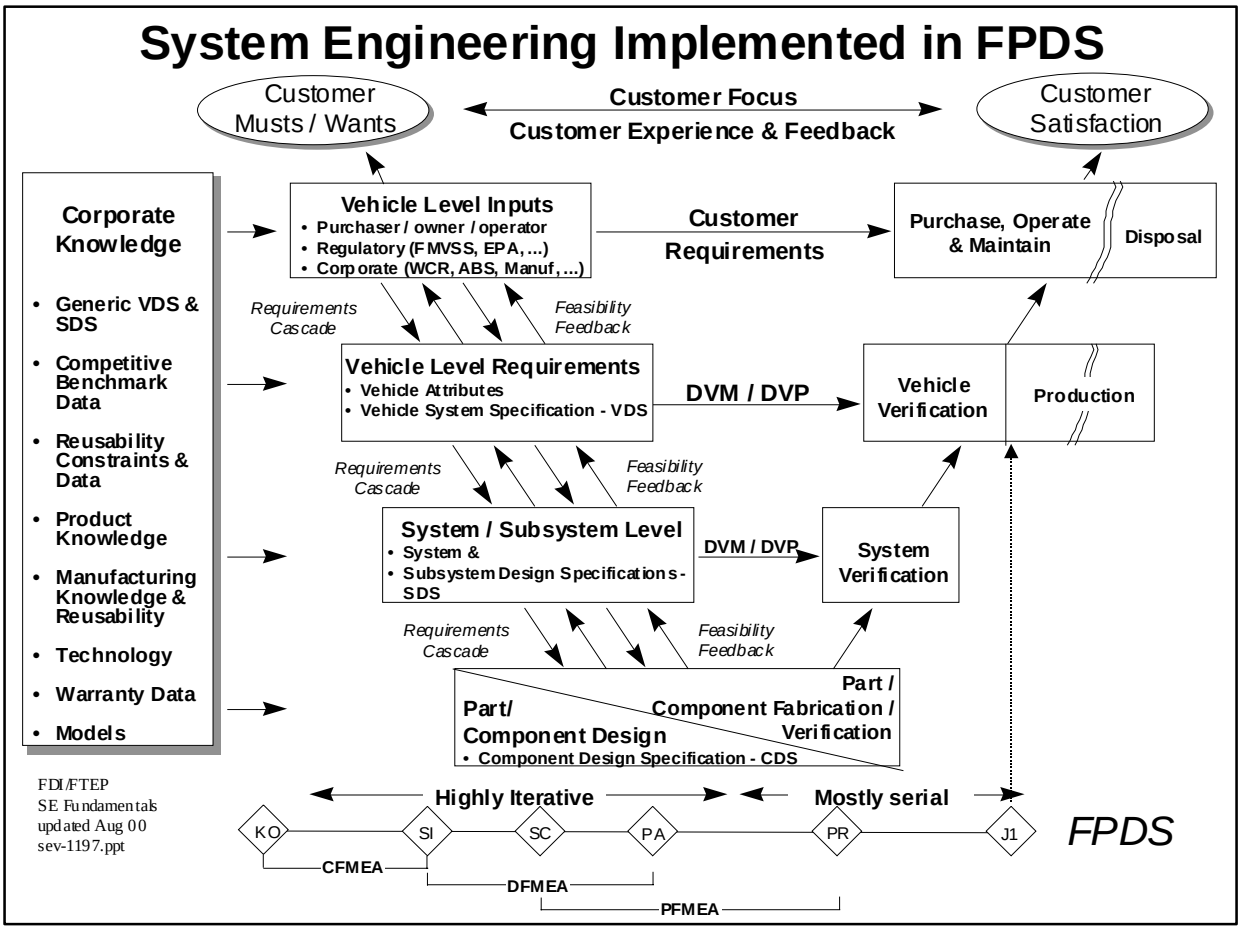
The record retention requirements for FMEAs developed by Ford engineers are specified on the Global Information Standards Record Retention Schedule index web page at:

http://www.dearborn4.ford.com/gim/gis/index.cgi?p=gis1/attachment

Systems Engineering Relationships

FMEAs Related to Systems Engineering

These three types follow the Systems Engineering "V" model as implemented in FPDS shown below:



Systems Engineering Fundamentals

Note: For further information on this model, refer to the Ford Technical Engineering Program (FTEP) course in Systems Engineering Fundamentals (SEF).

APQP Relationship

FMEA is a "focus point" in APQP. For more information on APQP, refer to the AIAG website at:

http://www.aiag.org/

Section 3 – Design FMEA
Contents

In This Section

Description	See Page
Introduction to Design FMEA (DFMEA)	
Introduction	3-4
Design FMEA Information Flow	3-5
FMEA Team	3-6
FMEA Scope	3-7
Inputs to Design FMEA	
Introduction to Robustness Tools (Robustness Linkages)	3-8
Boundary Diagram	3-8
Interface Matrix	3-10
P-Diagram	3-14
FMEA Form Header	
Filling In Header Information	3-17
Design FMEA Form	3-19
FMEA Model	3-20
Ford FMEA Working Model	3-20
Working Model Step 1	
Ford FMEA Working Model Step 1	3-21
Item/Function	
Item/Function	3-22
Determine Function	3-22
How to Identify Item/Functions	3-23
Examples of Item/Functions	3-23
Item/Function Worksheet	3-24
Potential Failure Modes	
Potential Failure Modes	3-25
How to Identify Failure Mode Types	3-25
Sample Functions and Failures	3-27
How to Identify Potential Failure Modes	3-29
Functional Approach	3-29

Continued on next page

Section 3 Contents, Continued

In This Section (Continued)

Description	See Page
Potential Effect(s) of Failure	
Potential Effect(s) of Failure	3-30
How to Identify Potential Effect(s) of Failure	3-30
Examples of Potential Effect(s) of Failure	3-31
Severity	
Severity	3-32
How to Identify Severity	3-32
Design Severity Rating Table	3-33
Classification	
Classification	3-34
YC Classification Rating	3-34
Recommended Actions	
Consider Recommended Actions	3-35
Working Model Step 2	
Ford FMEA Working Model Step 2	3-36
Potential Cause(s)/Mechanism(s) of Failure	
Potential Cause(s)/Mechanism(s) of Failure	3-37
How to Identify Potential Cause(s) of Failure	3-37
Assumption 1	3-39
Examples of Assumption 1	3-40
Assumption 2	3-40
Examples of Assumption 2	3-41
Occurrence	
Occurrence	3-42
How to Identify Occurrence	3-42
Occurrence Rating Table	3-44
Classification	
YS Classification Rating	3-45
Design Classification Possibilities	3-46

Continued on next page

Section 3 Contents, Continued

In This Section (Continued)

Description	See Page
Working Model Step 3	
Ford FMEA Working Model Step 3	3-47
Current Design Controls	
Current Design Controls	3-48
Types of Design Controls	3-48
How to Identify Design Controls	3-49
Examples of Design Controls	3-50
Detection	
Detection	3-51
How to Identify Detection Rating	3-51
Effectiveness Factors	3-52
Design Detection Rating Table	3-53
Risk Priority Number (RPN)	3-54
Recommended Actions	
Recommended Actions	3-55
How to Identify Recommended Actions	3-56
Examples of Recommended Actions	3-56
Actions Taken	
Actions Taken	3-57
How to Identify Actions Taken	3-57
Responsibility and Target Date Completion	3-58
Resulting RPN	
Revised Severity, Revised Occurrence, Revised Detection, and Revised RPN	3-59
Outputs from Design FMEA	3-60
Robustness Checklist	
Robustness Checklist	3-61
Robustness Checklist Example	3-62
Sample Design FMEA	3-63

Introduction to Design FMEA (DFMEA)

Introduction

A Design potential FMEA is an analytical technique utilized primarily by a design responsible engineer/team as a means to assure that, to the extent possible, potential Failure Modes and their associated Causes/Mechanisms have been considered and addressed. End items, along with every related system, subassembly and component, should be evaluated. In its most rigorous form, an FMEA is a summary of the team's thoughts (including an analysis of items that could go wrong based on experience) as a component, subsystem, or system is designed. This systematic approach parallels, formalizes, and documents the mental disciplines that an engineer normally goes through in any design process.

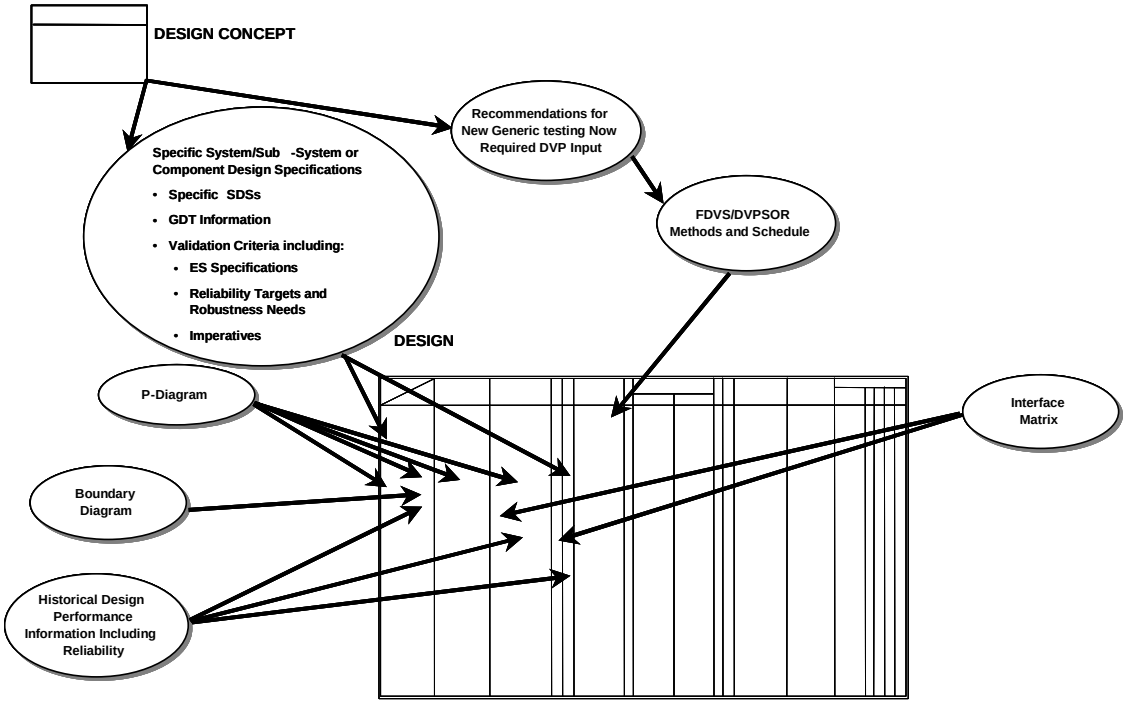
The responsible design engineer has at his/her disposal a number of documents that will be useful in preparing the Design FMEA. The process begins by developing a listing of what the design is expected to do, and what it is expected not to do (i.e., the design intent). Customer wants and needs should be incorporated, which may be determined from sources such as Quality Function Deployment (QFD), Vehicle Requirements Documents, known product requirements, and/or manufacturing/assembly/service/ recycling requirements. The better the definition of the desired characteristics, the easier it is to identify potential Failure Modes for preventive/corrective action.

Continued on next page

Introduction to Design FMEA (DFMEA), Continued

Design FMEA Information Flow

The graphic below depicts some typical inputs to a Design FMEA (DFMEA). When available, many of these input items are fed from the Concept FMEA, or from the results of the Recommended Actions of the Concept FMEA. The full DFMEA form is shown on page 3-19.



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Introduction to Design FMEA (DFMEA), Continued

FMEA Team

During the initial Design potential FMEA process, the responsible engineer is expected to directly and actively involve representatives from all affected areas. These areas of expertise and responsibility should include, but are not limited to: assembly, manufacturing, design, analysis/test, reliability, materials, quality, service, and suppliers, as well as the design area responsible for the next higher or lower assembly or system, sub-assembly or component. The FMEA should be a catalyst to stimulate the interchange of ideas between the functions affected and thus promote a team approach.

At Ford, the team is often separated into two distinct groups — the "core" team members and the "support" team members. Core members are typically involved in all phases of the FMEA, are stakeholders and decision-makers and are responsible for carrying out actions. Support team members are generally utilized on an “as needed” basis to provide specific insight and input.

- Early management support is crucial for getting the team started, generating motivation, and maintaining momentum.
- Support must be visible and active; for example, chief program engineer reviews of the FMEAs for Priority Systems or components.

Introduction to Design FMEA (DFMEA), Continued

FMEA Scope

Scope is the boundary or extent of the analysis and defines what is included and excluded.

FMEA scope is set by a Boundary Diagram. To set the scope of the analysis, obtain team consensus by determining from the Boundary Diagram:

- What is included?
- What is excluded?

Setting the correct boundaries prior to doing an FMEA analysis will focus the FMEA and avoid expanding the FMEA analysis into areas not being revised or created. This will prevent lengthening or missing the analysis and establishing the wrong team membership.

To determine the extent of the FMEA, the following decisions are made by the team or responsible engineering activity:

- Determine the stability of the design or process development. Is the design or process approaching or just past a checkpoint?
- How many attributes or features are still under discussion or still need to be determined?
- How close is the design or process to completion? Can changes still be made?

As many open issues as possible should be addressed prior to starting the FMEA. The design of the product or process must be stable, or it will be necessary to re-visit the FMEA after every change. Design stability does not mean the final release level has been reached or that the process is finalized. Changes must be able to occur as the FMEA is developed so that Recommended Actions can be implemented where possible.

Inputs to Design FMEA

Robustness Tools (Robustness Linkages)

Robustness Tools (Robustness Linkages) have been added to the FMEA process to significantly reduce vehicle campaigns, enhance the corporate image, reduce warranty claims, and increase customer satisfaction. These Robustness Tools primarily emanate from the P-Diagram, which identifies the five noise factors. These factors need to be addressed early to make the design insensitive to the noise factors. This is the essence of Robustness. It is the engineer's responsibility to ensure that the Robustness Tools are captured in the engineering documentation.

Boundary Diagram

A boundary diagram is a graphical illustration of the relationships between the subsystems, assemblies, subassemblies, and components within the object as well as the interfaces with the neighboring systems and environments.

Boundary diagrams are a mandatory element of a Design FMEA. It breaks the FMEA into manageable levels. When correctly constructed it provides detailed information to the Interface Matrix, P-Diagram, and the FMEA. It is important to note that when completed or revised, the boundary diagram shall be attached to the FMEA.

Although boundary diagrams can be constructed to any level of detail, it is important to identify the major elements, understand how they interact with each other, and how they may interact with outside systems.

Furthermore, early in the design program, a boundary diagram may be no more than a few blocks representing major functions and their interrelationships at the system level. Then, as the design matures, boundary diagrams may be revised, or additional ones developed to illustrate lower levels of detail, all the way down to the component level.

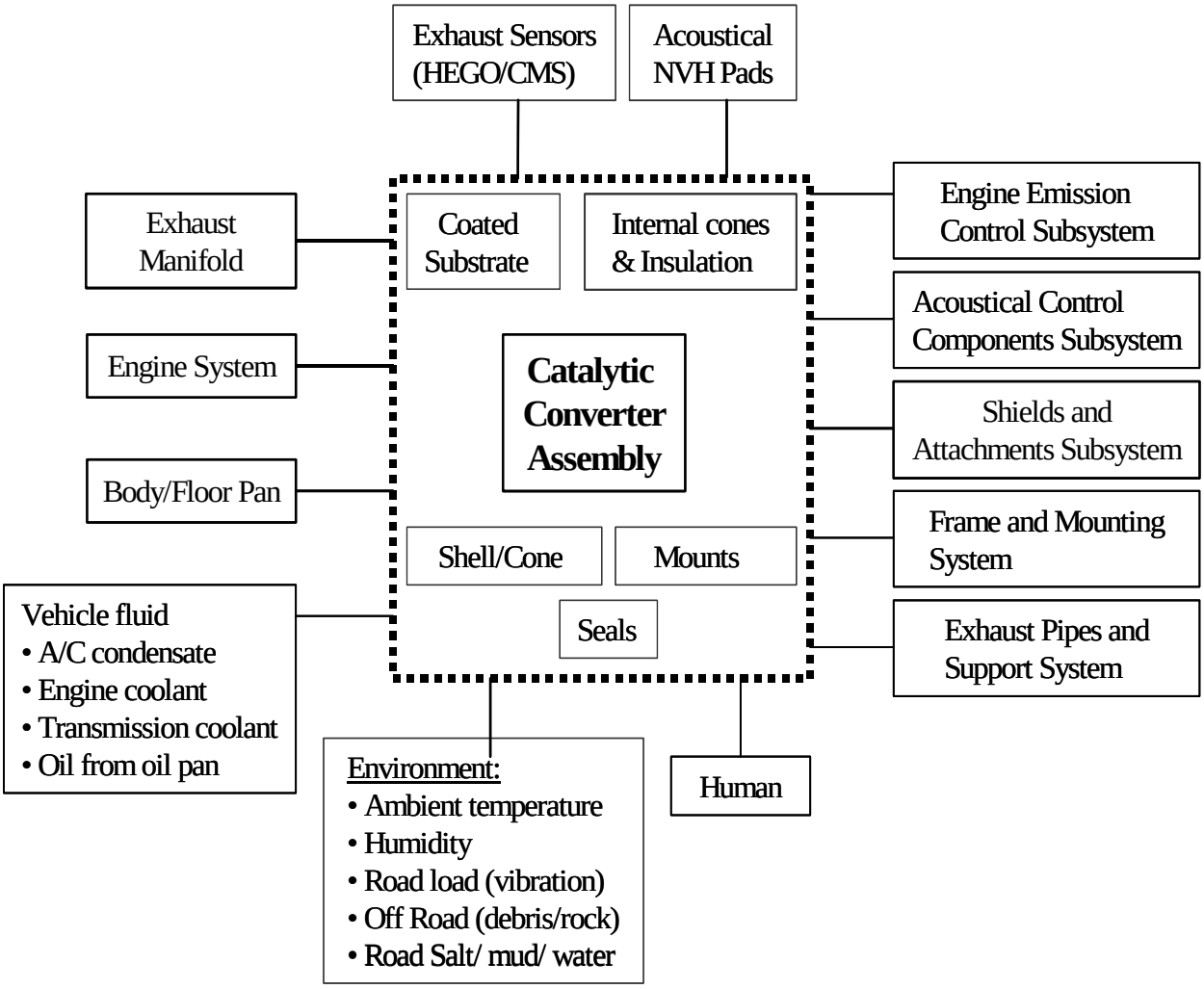
For example, a completed system FMEA boundary diagram has blocks representing the subsystems within its scope and its interfacing systems. Then, moving into the subsystem, another boundary diagram is developed showing components of the subsystem as the block elements. In addition, on large systems a third or fourth level boundary diagram may be necessary to fully identify smaller subsystems, components and their relationships to the lowest level.

Continued on next page

Inputs to Design FMEA, Continued

Boundary Diagram (Continued)

The following graphic is an example of a boundary diagram.



Generic Catalytic Converter Assembly Boundary Diagram

Continued on next page

Inputs to Design FMEA, Continued

Interface Matrix

A system interface matrix illustrates relationships between the subsystems, assemblies, subassemblies, and components within the object as well as the interfaces with the neighboring systems and environments. A system interface matrix documents the details, such as types of interfaces, strength/importance of interface, potential effect of interface, and etc. It is a recommended robustness tool that acts as an input to Design FMEA. It is important to note that not addressing interactions at this point can lead to potential warranty and recall issues. Therefore, the interface matrix should always be used, especially on new designs.

The information in a system interface matrix provides valuable input to Design FMEA, such as primary functions or interface functions for system function identification, and/or the effects from neighboring systems, environments or human for Potential Causes/Mechanisms Failure identification. Also, it provides input to P-Diagram in the section of input/output and noise factors. In addition, every interface with positive or negative impact should be verified. Then, negative impacts are analyzed for corrective and/or preventive actions. When completed or revised, attach the interface matrix to the FMEA.

Two types of system interface matrix are introduced in this section.

- Type A – It was introduced in the previous edition of this handbook. Data are entered and organized symmetrically in an MS Excel spreadsheet. Therefore, the data do not indicate the direction of the interfaces. Refer to the example on the following page.
- Type B – It was introduced recently. It is generated from the software called System Interface Analyzer (SIA). Data are entered and organized in an MS Access Database. A system interface matrix can be generated automatically from SIA.

The example on the following page shows a Type A interface matrix which identifies and quantifies the strength of system interactions by:

- Showing whether the relationship is necessary or adverse
- Identifying the type of relationship (spatial relationship, energy transfer, information exchange, and material exchange.)

It is strongly recommended to document the details, which are the evidence for the interface ratings, and it helps in communication.

Visit the following web site for more information on creating an interface matrix from using the MS-Excel template:

http://www.quality.ford.com/cpar/fmea/

Continued on next page

Inputs to Design FMEA, Continued

Interface Matrix (Continued)

The illustration below is a Catalytic Converter Assembly Interface Matrix, partially completed to illustrate technique.

	Shell/Cone - Catalytic Converter	Seals - Catalytic Converter	Coated Substrate - Catalytic Converter	Mounts - Catalytic Converter	Internal Cones & Insulation - Catalytic Converter	Environment	Exhaust Manifold	Engine Emission Control Subsystem	Acoustical NVH Pads
Shell/Cone - Catalytic Converter		2		-1 -1	2	-1	2		-2 -2
Seals - Catalytic Converter	2		2 -1	2 -1	2	-1	-1		-1 -1
Coated Substrate - Catalytic Converter		2 -1		2 -1		-1	2	2 2	
Mounts - Catalytic Converter	-1 -1	2 -1	2 -1			-1			-2 -2
Internal Cones & Insulation - Catalytic Converter	2	2				-1			-1 -1
Environment	-1	-1	-1	-1	-1				
Exhaust Manifold	2	-1	2						
Engine Emission Control Subsystem			2 2						
Acoustical NVH Pads	-2 -2	-1 -1		-2 -2	-1 -1				

P	E
I	M

P: Physically touching — E: Energy transfer
I: Information exchange — M: Material exchange

Numbers in each corner represent the above interface types, with values denoting the following:

- +2 Interaction is necessary for function
- +1 Interaction is beneficial, but not absolutely necessary for functionality
- 0 Interaction does not affect functionality
- -1 Interaction causes negative effects but does not prevent functionality
- -2 Interaction must be prevented to achieve functionality

Continued on next page

Inputs to Design FMEA, Continued

Interface Matrix (Continued)

The interface matrix showing on the following page is an output from SIA. System Interface Analyzer (SIA) is recommended for the development of system interface matrix, especially for a complex system or those systems have complex interfaces. SIA offers the following main functions:

- Define project contents (vehicle level or system level). The contents are organized by a hierarchical system breakdown structure.
- Define program team structure and cascade program contents and responsibilities from higher-level program teams to sub-teams.
- Build system interfaces into SIA database, including add, edit or delete system interfaces.
- Analyze and report system interfaces. When the system interfaces are identified and recorded in SIA, system/subsystem boundary diagrams, interface matrices can be automatically generated.

Visit the following web site for more information on creating an interface matrix from SIA:

http://www.quality.ford.com/cpar/sia/

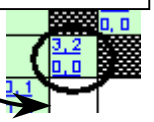
Continued on next page

Inputs to Design FMEA, Continued

S: Spatial
E: Energy
I: Information
M: Material

	Catalytic Converter Assembly (Ceramic) (Single Node)	Shell/Cone - Catalytic Converter	Seals - Catalytic Converter	Coated Substrate - Catalytic Converter	Mounts - Catalytic Converter	Internal Cones & Insulation - Catalytic Converter	Human	Environment	Exhaust Manifold	Engine Emission Control Subsystem	Acoustical NVH Pads
Catalytic Converter Assembly (Ceramic) (Single Node)							0, 0 0, 1				
Shell/Cone - Catalytic Converter			1, 1 0, 0		1, 1 0, 0	2, 0 0, 0			1, 0 0, 0		
Seals - Catalytic Converter		0, 1 0, 0		1, 2 0, 0	1, 1 0, 0	1, 0 0, 0					
Coated Substrate - Catalytic Converter					0, 2 0, 0						
Mounts - Catalytic Converter				3, 2 0, 0							
Internal Cones & Insulation - Catalytic Converter			0, 1 0, 0								
Human											
Environment	1, 1 0, 2										
Exhaust Manifold	0, 2 0, 4		0, 1 0, 0	0, 1 0, 0							
Engine Emission Control Subsystem											
Acoustical NVH Pads											

(3) Spatial interfaces
(2) Energy interfaces
(0) Information interface



Interface Description	Type	Remarks
FROM: Catalytic Converter Assembly (Ceramic) --> To: Human		
Odor/Smoke FROM Catalytic Converter Assembly (Ceramic) TO End Customer	M	H2S produced during the chemical reaction
FROM: Shell/Cone - Catalytic Converter --> To: Seals - Catalytic Converter		
Touching/Contacting BETWEEN Shell/Cone - Catalytic Converter AND Seals - Catalytic Converter	S	Dimentional Specification to maintain gas seal (V seal) to prevent exhaust bypass or mat errosion protection (Z seal) during customer operation

Continued on next page

Inputs to Design FMEA, Continued

P-Diagram

A P-Diagram is a structured tool recommended to identify intended inputs (Signals) and outputs (Functions) for the subject under investigation. Once these inputs and outputs are identified for a specific Function, error states are identified. Noise factors, outside of the control of Design Engineers, that could lead to the error states are then listed (according to the five basic sources of noise defined by Ford):

- Piece to Piece Variation
- Changes Over Time/Mileage (e.g. wear)
- Customer Usage
- External Environment (e.g. road type, weather)
- System Interactions

Finally, control factors are identified and means for Noise Factor Management settled to compensate for the identified noise factors.

Depending on the level of detail contained in the P-Diagram, this information will input to various FMEA columns. When completed or revised, it is recommended to attach the P-Diagram to the FMEA.

The P-Diagram:

- Describes noise factors, control factors, ideal function, and error states
- Assists in the identification of:
  - Potential Causes for failure
  - Failure Modes
  - Potential Effects of failure
  - Current Controls
  - Recommended Actions

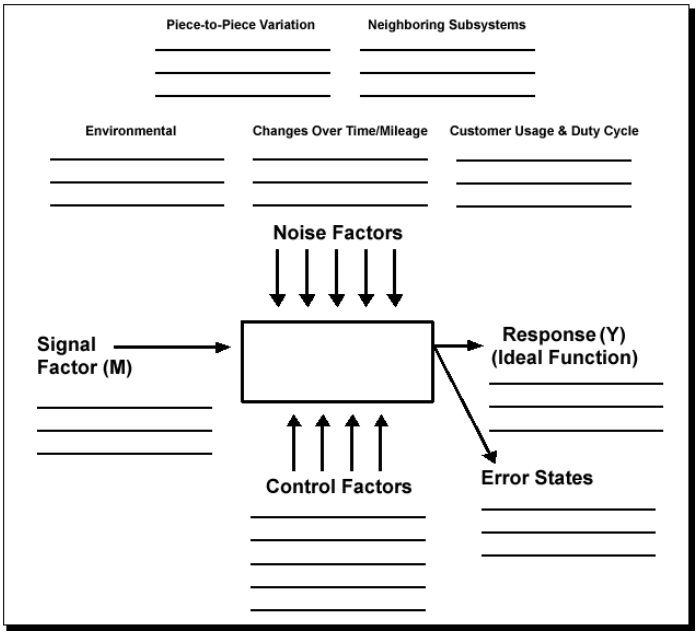
An example of a blank P-Diagram template is found on the following page. The subsequent page contains an example of a completed P-Diagram.

Continued on next page

Inputs to Design FMEA, Continued

P-Diagram
(Continued)

Blank
P-Diagram



Control Factors are the means to make the items´ function more robust.

An **Error State** can be classified into two categories:

1. Deviation of intended Function - Deviation of intended Function is equal to Potential Failure Modes in the FMEA. Potential Failure Modes are:
   - No Function
   - Partial Function (including Degraded Function over time)
   - Intermittent Function
   - Over Function
2. Unintended system output (e.g. engine vibrations)

Noise Factors are unintended interfaces, or conditions and interactions that may lead to failure of the function (i.e. vibration-induced part wear).

Responses are ideal, intended functional output (i.e. low beam activation for a headlamp).

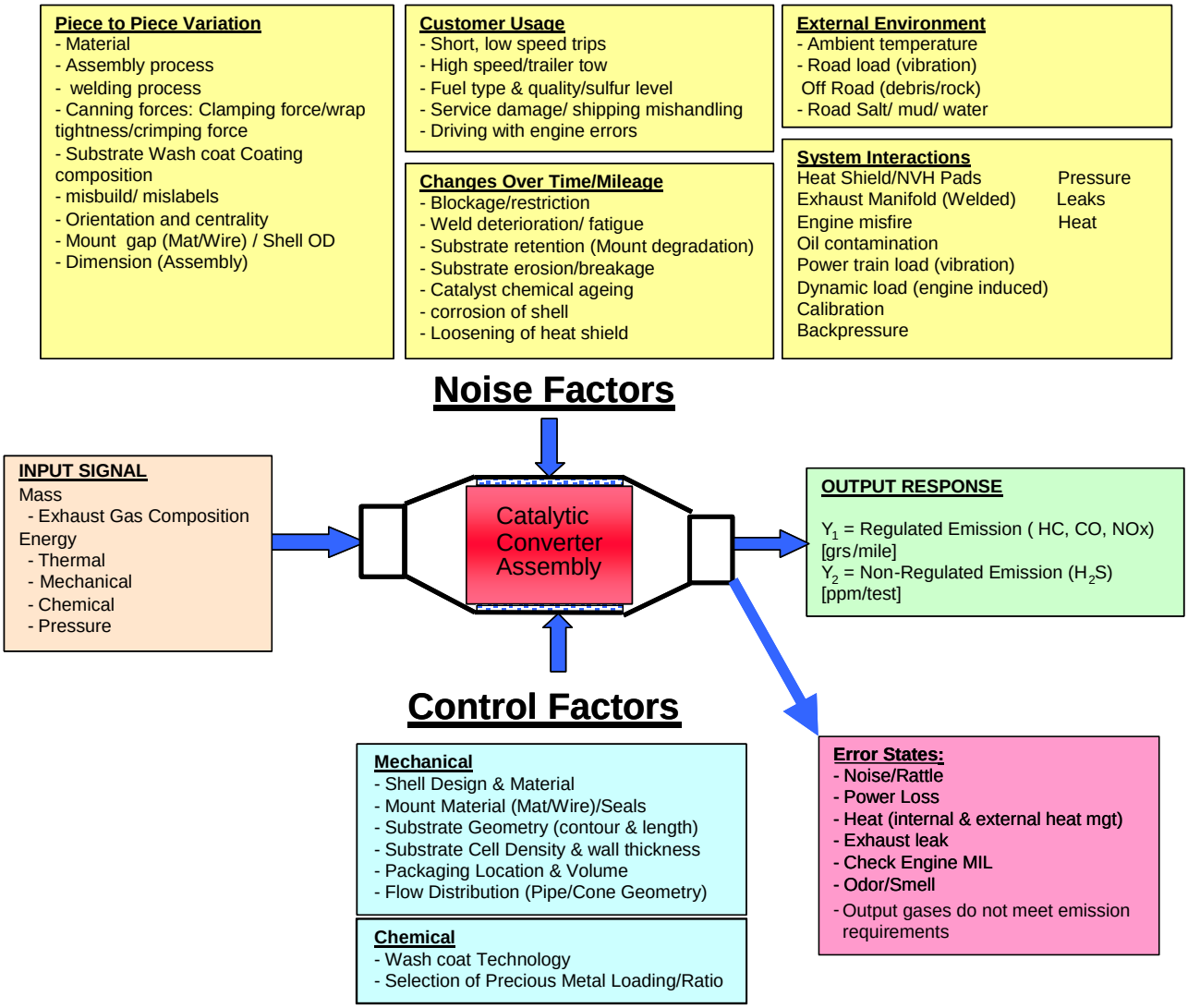
Signal Factors are what the input, which triggers the function being analysed, is (i.e. when user activates a switch).

Continued on next page

Inputs to Design FMEA, Continued

P-Diagram (Continued)

The following graphic is an example of a completed P-Diagram for a generic ceramic catalytic converter assembly.

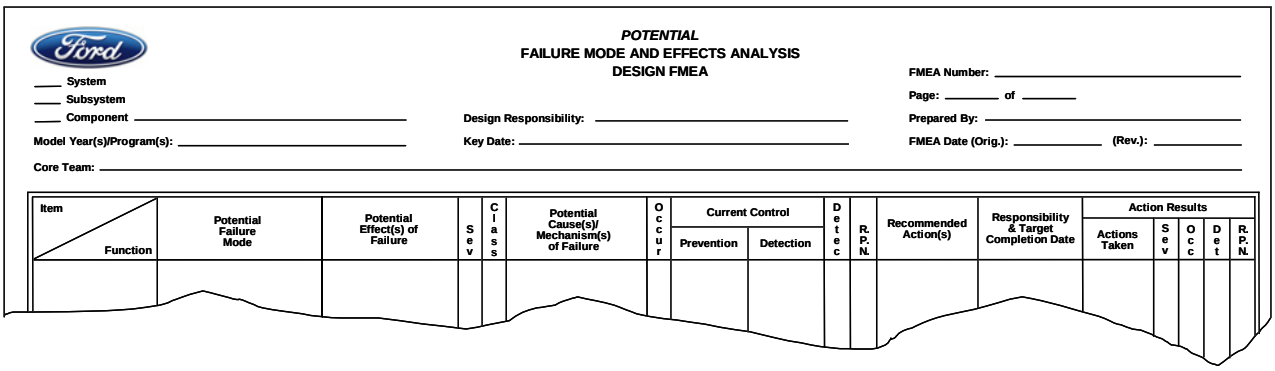


Generic Ceramic Catalytic Converter Assembly P-Diagram

FMEA Form Header

Filling In Header Information

The FMEA form, slightly different for each FMEA type, is a repository for FMEA data. Items defined on the following pages comprise the typical Design FMEA header.



- ***System, Subsystem or Component Name and Number*** — Indicate the appropriate level of analysis and enter the name and number of the system, subsystem, or component being analyzed. The FMEA team must decide on what constitutes a system, sub-system, or component for their specific activities. The actual boundaries that divide a System, Sub-System, and Component are arbitrary and must be set by the FMEA team. Some descriptions are provided below:
- *A system can be considered to be made up of various sub-systems. These sub-systems have often been designed by different teams. Some typical System FMEAs might cover the following systems: Chassis System, or Powertrain System, or Interior System, etc. Thus, the focus of the System FMEA is to ensure that all interfaces and interactions between the various sub-systems that make up the system as well as interfaces to other vehicle systems and the customer are covered.*
- *A sub-system FMEA is generally a sub-set of a larger system. For example, the front suspension sub-system is a sub-set of the chassis system. Thus, the focus of the Sub-System FMEA is to ensure that all interfaces and interactions between the various components that make up the sub-system are covered in the Sub-System FMEA.*
- *A component FMEA is generally an FMEA focused on the sub-set of a sub-system. For example, a strut is a component of the front suspension (which is a sub-system of the chassis system).*

  Enter the name and Corporate Product System Classification (CPSC) code of the system or subsystem being analyzed.

Continued on next page

Filling In Header Information (Continued)

- ***Model Years/Program(s)*** *— Enter the intended model year(s) and programs(s) that will utilize and/or be affected by the design being analyzed.* Enter Generic, if appropriate.
- ***Core Team*** — List the names of core team members. It is recommended that all team members' names, departments, telephone numbers, addresses, etc. be included on a separate distribution list and attached to the FMEA.
- ***Design Responsibility*** — Enter the organization, department, and group. Also, include the supplier name if known.
- ***Key Date*** — Enter the next milestone FMEA due date. The date should not exceed the scheduled design release date.
- ***FMEA Number*** *— Enter the FMEA document number, which may be used for tracking.* It is recommended that each vehicle line and/or model year develop and maintain a discrete numbering system.
- ***Prepared By*** *— Enter the name, telephone number, CDS ID, and company of the engineer responsible for preparing the FMEA (team leader).*
- ***FMEA Date —*** *Enter the date the original FMEA was compiled and the latest revision date.*

Design FMEA Form

Design FMEA Form

The following is the standard format called out in the SAE Recommended Practice J1739 for Design FMEAs.

- New Form: two columns for Current Control.

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
DESIGN FMEA

FMEA Number: _____

Page _____ of _____

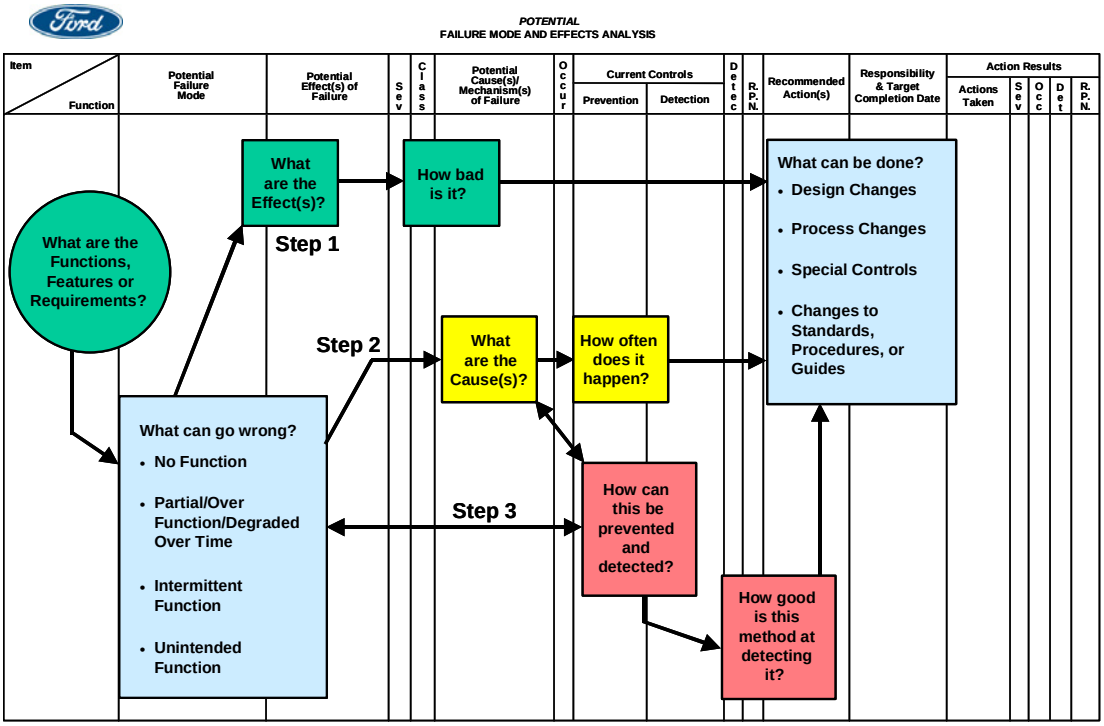
___ System
___ Subsystem
___ Component _____ Design Responsibility: _____ Prepared By: _____
Model Year(s)/Program(s): _____ Key Date: _____ FMEA Date: (Orig.) _____ (Rev.) _____
Core Team: _____

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control: Prevention	Current Control: Detection	Detect	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Action Results: Sev	Action Results: Occ	Action Results: Det	Action Results: R.P.N.

FMEA Model

Ford FMEA Working Model

The FMEA methodology is not “form driven” but model driven. Note how the Ford FMEA Model components relate to the column headings on this FMEA form.

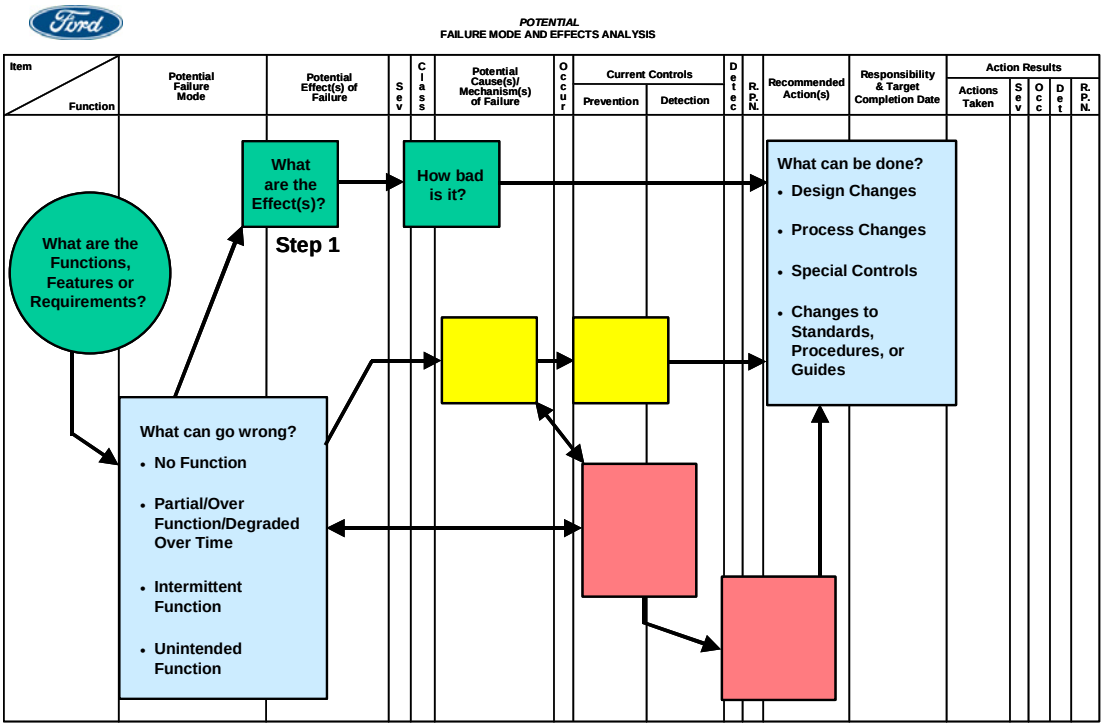


The Ford FMEA Model has three distinct steps that should be executed according to the directions on the following pages.

Working Model Step 1

Ford FMEA Working Model Step 1

The first step that should be followed is illustrated here:



Starting with Step 1:

- Identify all Functions within scope.
- Identify how each Function can fail (Failure Modes).
- Identify a group of associated Effects for each Failure Mode.
- Identify a Severity rating for each Effect group that prioritizes the Failure Mode(s).
- If possible, Recommend Actions to eliminate Failure Mode(s) without addressing "Causes".

  Note: This is a very rare event.

You will find that most often it is necessary to complete Steps 2 and 3, because rarely can a Failure Mode be completely eliminated.

Item/Function

Item/Function

Enter the name and other pertinent information (e.g., the number, the part class, etc.) of the item being analyzed. Use the nomenclature and show the design level as indicated on the engineering drawing. Prior to initial release (e.g., in the conceptual phases), experimental numbers should be used.

Enter, as concisely as possible, the function of the item being analyzed to meet the design intent. Include information (metrics/measurables) regarding the environment in which this system operates (e.g., define temperature, pressure, humidity ranges, design life). If the item has more than one function with different potential modes of failure, list all the functions separately.

Determine Function

Describe the Function in terms that can be measured. A description of the Function should answer the question: "What is this item supposed to do?" Functions are design intent or engineering requirements.

Functions are:

- Written in Verb/Noun/Measurable format.
- Measurable, which includes all relevant SDSs:
  - Can be verified/validated.
  - Includes additional constraints or design parameters such as reliability specs, serviceability specs, special conditions, weight, size, location, and accessibility.
  - Includes pertinent standards and requirements (i.e., FMVSS numbers).
- Design intent or engineering requirement.
- Representation of all wants, needs and requirements, both spoken and unspoken for all customers and systems.

Remember, Functions cannot be "failed" if they do not have measurables or specifications.

Continued on next page

Item/Function, Continued

How to Identify Item/Functions

The Functional approach is required for developing Ford system/subsystem FMEAs; this involves listing the measurable Functions and the Potential Failure Modes leading to the loss/reduction of each Function. The functional approach is also strongly recommended for developing component FMEAs.

List all Functions in the Function column in a Verb/Noun/Measurable format. Avoid the use of verbs like “provide", "facilitate", or "allow” which are too general. Refer to Appendix B for lists of verb and noun thought starters.

One tool to identify a Function is called Function Tree Analysis. Refer to Appendix B for more information on Function Tree Analysis. Also review the boundary diagram to assure all functions are listed.

Examples of Item/Functions

The following are examples of acceptable descriptions:

- Support transmission, X kilograms per specification xyz
- Store fluid, X liters with zero leaks
- Control flow, X cubic centimeters/second
- Conduct current, X amps
- Stops vehicle within X feet from Y speed to meet FMVSS xyz
- Send signal, X amps continuous in all WCR environmental conditions
- Open with X effort
- Maintain fluid quality for X years under all operating conditions

Continued on next page

Item/Function, Continued

Item/Function Worksheet

The Item/Function worksheet is one tool that may assist the team in determining Functions and its corresponding specifications and organizing its work effort prior to completing the Item/Function or Process/Function column of the FMEA Form.

ITEM FUNCTION	
DESCRIPTION	
FUNCTION: What is the item supposed to do? What is the item not supposed to do? List all the functions and separate them from the specifications.	
List All Functions	**Specifications**
Function Description: Verb - Noun	**How Much? When?**

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Potential Failure Modes

Potential Failure Modes

A potential Failure Mode is defined as the manner in which a component, subsystem, or system could potentially fail to meet or deliver the intended function described in the item/function column (i.e., intended function fails). The potential Failure Mode may also be the Cause of a potential Failure Mode in a higher level subsystem, or system, or be the effect of one in a lower level component.

List each potential Failure Mode associated with the particular item and item function. The assumption is made that the failure could occur, but may not necessarily occur. A recommended starting point is a review of past things-gone-wrong, concerns, reports, and group brainstorming.

Potential Failure Modes that could only occur under certain operating conditions (i.e., hot, cold, dry, dusty, etc.) and under certain usage conditions (i.e., above average mileage, rough terrain, only city driving, etc.) should be considered.

How to Identify Failure Mode Types

Four types of Failure Modes occur. The first and second types apply often and are the most commonly seen, and the third and fourth types are typically missed when performing the FMEA.

1. **No Function:** System or Design is totally non-functional or inoperative.
2. **Partial/Over Function/Degraded Over Time:** Degraded performance. Meets some of the function requirements, but does not fully comply with all attributes or characteristics. This category includes over function and degraded function over time.

   This Failure Mode thought starter is significant because high mileage customer satisfaction is a key Ford initiative. This Failure Mode has high leverage, and is often overlooked on many FMEAs.

Continued on next page

Potential Failure Modes, Continued

How to Identify Failure Mode Types (Continued)

3. **Intermittent Function**: Complies but loses some functionality or becomes inoperative often due to external factors such as temperature, moisture, environment, etc. This Failure Mode provides the condition of: on, suddenly off, recovered to on again function or starts/stops/starts again series of events.
4. **Unintended Function**: This means that the interaction of several elements whose independent performance is correct adversely affects the product or process. This will result in an unwanted outcome or consequence by the product, and hence the expression "unintended function". Includes failures caused by system interaction and results in those system behaviors that the customers hardly ever expect. These types of system behaviors may generate severe threat and negative impact. Examples are:
   - Unrequested operation: Wiper operates without command (due to short wire or sneak path).
   - Operation in an unintended direction: Vehicle moved backward although the driver selected D position; Power window moved up when pressing the button to lower the window down.
   - Inadvertent operation: Fuel cut off switch is supposed to work only when the vehicle is rolled over, but the switch is activated when the vehicle is driven on a rough road.

Each Failure Mode must have an associated function. A good check to discover “hidden” functions is to match all possible failures with the appropriate functions.

Ford FMEAs should be developed using the functional approach, which involves listing each function and the Failure Modes leading to the loss of each function.

For each function use the 4 Thought Starter Failure Modes to determine the Failure Modes for this function. Be sure to consider each function’s measurable or condition for its Failure Mode list.

Continued on next page

Potential Failure Modes, Continued

Sample Functions and Failures

The following table is a sample of functions and their failure modes:

Item/Function	Failure Mode(s)
Jack Assembly Part Number xxxx.xxxxxx.ab - Raise Vehicle for tire change to +X feet above ground level - Within Y minutes - Under Z force limits - In all weather conditions	<u>No Function:</u> - Does not raise the vehicle at all (inoperative)
	<u>Partial/Over Function/Degraded Over Time:</u> - Raises the vehicle to less than X feet above ground level initially - Raises the vehicle in greater than Y minutes - Requires more than Z force to raise the vehicle - Raises vehicle less than X feet over time
	<u>Intermittent Function:</u> - Inoperable in wet weather - Inoperable when below 0° C
	<u>Unintended Function:</u> - None known

Continued on next page

Potential Failure Modes, Continued

Sample Functions and Failures (Continued)

The following table is another sample of functions and their failure modes:

Item/Function	Failure Mode(s)
Wipers/Return to and retain at rest position after being switched off. - within ± xx mm from the rest position measured at the middle point of the wiper blade.	No Function: - Wiper movement can not be turned off by the switch. - Wipers do not retain at the rest position.
	Partial/Over Function/Degraded Over Time: - Wipers returning position out of spec. - Wipers do not retain at the same position over time.
	Intermittent Function: - Wipers returning position out of spec when below 0° C.
	Unintended Function: - Wiper operation turned off while actuating the turn signal lever.

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Potential Failure Modes, Continued

How to Identify Potential Failure Modes

Techniques can be used to identify potential Failure Modes for no function, partial/over function/degraded over time, intermittent function, and unintended function. In addition to ensuring that the degradation issues are covered in the P-Diagram, ask some of the following questions:

- In what way can this item fail to perform its intended function?
- What can go wrong, although the item is manufactured/assembled to print?
- When the function is tested, how would its Failure Mode be recognized?
- Where and how will the design operate?
- In what environmental conditions will it operate?
- Will the item be used in higher-level assemblies?
- How will the item interface/interact with other levels of the design?

Do not enter trivial Failure Modes, (Failure Modes that will not, or cannot occur). If you are not sure, add the Failure Mode to the list.

Functional Approach

Assume the function:

- Store fluid
- X liters
- 0 leaks
- 10 years, 150,000 miles

General types of Failure Modes for the component-level Design FMEA for the function above include:

- Stores < X liters
- Leaks

Potential Effect(s) of Failure

Potential Effect(s) of Failure

Potential Effect(s) of Failure are defined as the effects of the Failure Mode on the function, as perceived by the customer.

Describe the effects of the failure in terms of what the customer might notice or experience, remembering that the customer may be an internal customer as well as the ultimate end user. State clearly if the function could impact safety or noncompliance to regulations. The effects should always be stated in terms of the specific system, subsystems, or component being analyzed.

Remember that a hierarchical relationship exists between the component, subsystem, and system levels. For example, a part could fracture, which may cause the assembly to vibrate, resulting in an intermittent system operation. The intermittent system operation could cause performance to degrade, and ultimately lead to customer dissatisfaction. The intent is to forecast the failure effects to the team's level of knowledge.

How to Identify Potential Effect(s) of Failure

Identify the potential effects by asking "If this Failure Mode happens, what will be the consequences" on:

- The operation, function, or status of the item's subcomponents?
- The operation, function, or status of the next higher assembly?
- The operation, function, or status of the system?
- The operation, drive-ability, or safety of the vehicle?
- What the customer will see, feel, or experience?
- Compliance with government regulations?

If a potential Failure Mode could have an adverse effect on safe product or vehicle operation, or result in non-compliance with a government regulation, then enter an appropriate statement such as "May not comply with F/CMVSS #108."

Continued on next page

Potential Effect(s) of Failure, Continued

Describe the consequences of each Failure Mode identified on:

- Parts or subcomponents
- Next higher assembly
- System
- Vehicle
- Customer
- Government regulations

Place all effects for the Failure Mode being analyzed in one field or box.

Note: All error states from the P-Diagram need to be included in the Effects or Failure Mode column of the FMEA. However, the error states from the P-Diagram may not be comprehensive for the effects of the Failure Mode.

Examples of Potential Effect(s) of Failure

Typical failure effects could be, but are not limited to:

- *Noise*
- *Erratic Operation*
- *Poor Appearance*
- *Unstable*
- *Intermittent Operation*
- *Leaks*
- Electromagnetic Compatibility (EMC)
- *Rough*
- *Inoperative*
- *Unpleasant Odor*
- *Operation Impaired*
- *Thermal Event*
- *Regulatory Non Compliance*
- Radio Frequency Interface (RFI) noise

Severity

Severity

Severity is the rank associated with the most serious effect from the previous column. Severity is a relative ranking, within the scope of the individual FMEA. A reduction in Severity ranking index can be effected only through a design change. Severity should be estimated using the table on the following page.

How to Identify Severity

The FMEA team reaches consensus on Severity ratings using the Severity rating table. Enter the rating for only the most serious effect in the Severity column. Therefore, there will be one Severity column entry for each Failure Mode.

Assess the seriousness of each effect (listed in the Effects column). Optionally, enter a number behind the effect representing its Severity. The Severity rating must match the wording of the effect on the FMEA.

Describe a potential failure effect as precisely as possible. FMEA developers should consider carefully all effects directly attributable to a failure. However, they should avoid assigning severity ratings based on the secondary effects of failure, unless the failure causes immediate user injury or prevents safe operation of the vehicle. Take 'engine stall/cut out' as an example. Engine stall may cause loss of assistance to brake and steering. Loss of assistance to brake and steering does not constitute prevention of safe vehicle operation provided the relevant force requirements for control inputs are met (Homologation/Legal Requirements). The effect on the customer of engine stall or cut out should be described as a change in the expected vehicle response to control inputs (Customer). The effect on the vehicle of engine stall or cut out is that primary function of the vehicle is impaired (Vehicle primary function). Therefore, the overall severity rating for 'engine stall' may be considered as 8, at a minimum. Please consult with Automotive Safety Office to determine the safety and regulatory definition, as necessary.

Continued on next page

Severity, Continued

Design Severity Rating Table

Effect	*Criteria: Severity of Effect*	*Ranking*
Hazardous without warning	*Very high Severity ranking when a potential Failure Mode affects safe vehicle operation and/or involves noncompliance with government regulation without warning.*	*10*
Hazardous with warning	*Very high Severity ranking when a potential Failure Mode affects safe vehicle operation and/or involves noncompliance with government regulation with warning.*	*9*
Very high	*Vehicle/item inoperable (loss of primary function).*	*8*
High	*Vehicle/item operable but at a reduced level of performance. Customer very dissatisfied.*	*7*
Moderate	*Vehicle/item operable but comfort/convenience item(s) inoperable. Customer dissatisfied.*	*6*
Low	*Vehicle/item operable but comfort/convenience item(s) operable at a reduced level of performance. Customer somewhat dissatisfied.*	*5*
Very low	*Fit and finish/squeak and rattle item does not conform. Defect noticed by most customers (greater than 75%).*	*4*
Minor	*Fit and finish/squeak and rattle item does not conform. Defect noticed by 50 percent of customers.*	*3*
Very minor	*Fit and finish/squeak and rattle item does not conform. Defect noticed by discriminating customers (less than 25 percent).*	*2*
None	*No discernible effect.*	*1*

Classification

Classification

This column may be used to classify any special product characteristics (e.g., critical, key, major, significant) for components, subsystems, or systems that may require additional design or process controls.

This column may also be used to highlight high priority Failure Modes for engineering assessment, if the team finds this helpful, or if local management requires same.

Special Product or Process Characteristic symbols and their usage are directed by specific company policy.

YC Classification Rating

When a Failure Mode has a Severity rating of 9 or 10, then a potential Critical Characteristic exists. When a potential Critical Characteristic is identified, the letters “YC” are entered in this column and a Process FMEA is initiated.

These product characteristics affect safe vehicle or product function and/or compliance with government regulations, and may require special manufacturing, assembly, supplier, shipping, monitoring and/or inspection actions or controls.

Refer to Section 6 for further definitions and details of Special Characteristics and their required actions.

Recommended Actions

Consider Recommended Actions

Step 1 of the Working Model is completed by considering appropriate Recommended Actions to:

- Eliminate the Failure Mode
- Mitigate the Effect

Special emphasis on possible actions is required when Severity is 9 or 10. Lower Severities may also be considered for actions.

To eliminate failure mode(s), consider this action:

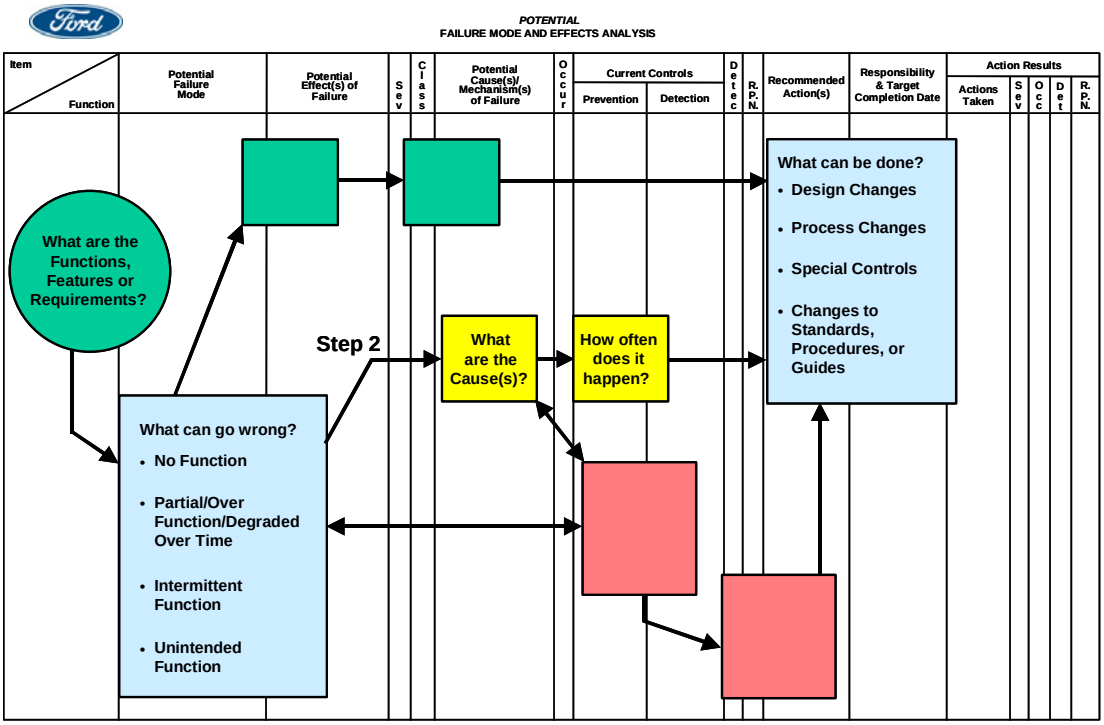
- Change the design (e.g., geometry, material) if related to a product characteristic.

If the Failure Mode cannot be eliminated, continue with the Working Model Step 2.

Working Model Step 2

Ford FMEA Working Model Step 2

For Failure Modes not able to be eliminated in Step 1, continue by following Step 2:



In Step 2, identify:

- The associated Cause(s) (first level and root).
- Their estimated Occurrence rating(s).
- The appropriate characteristic designation (if any) to be indicated in the Classification column.
- Recommended Actions for high Severity and Criticality (S x O).

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Potential Cause(s)/Mechanism(s) of Failure

Potential Cause(s)/ Mechanism(s) of Failure

Potential Cause of Failure is defined as an indication of a design weakness, the consequence of which is the Failure Mode.

List, to the extent possible, every conceivable Failure Cause and/or Failure Mechanism for each Failure Mode. The Cause/Mechanism should be listed as concisely and completely as possible so that remedial efforts can be aimed at pertinent Causes.

For a failure mode with severity 9 or 10, investigation to identify causes must be carried out to identify the design characteristics that cause this failure mode.

How to Identify Potential Cause(s) of Failure

Considering that manufacturing/assembly needs have been incorporated, the Design FMEA addresses the design intent and assumes the design will be manufactured/assembled to this intent. Potential Failure Modes and/or Causes/Mechanisms which can occur during the manufacturing or assembly process need not, but may be included in a Design FMEA. When not included, their identification, effect and control are covered by the Process FMEA.

Continued on next page

Potential Cause(s)/Mechanism(s) of Failure, Continued

How to Identify Potential Cause(s) of Failure (Continued)

This FMEA Handbook assumes a one-to-one correlation between a Cause and its resultant Failure Mode: i.e., if the Cause occurs, then the Failure Mode occurs.

Brainstorm potential Cause(s) of each Failure Mode by asking:

- What could cause the item to fail in this manner?
- What circumstance(s) could cause the item to fail to perform its function?
- How could the item fail to meet its engineering specifications?
- What could cause the item to fail to deliver its intended function?
- How could interacting items be incompatible or mismatched? What specifications drive compatibility?
- What information developed in the P-Diagram and interface matrix may identify potential Causes?
- What information in the boundary diagram may have been overlooked and which may provide causes for this Failure Mode?
- What can historic Global 8Ds and FMEAs provide for potential Causes?
- Are you considering subsystems or components that do not lead to the specified loss of function (or effect)?

Initially identify the first level Causes. A first level Cause is the immediate Cause of a Failure Mode. It will directly make the Failure Mode occur. In an Ishikawa “Fishbone” Diagram, the Failure Mode will be an item on the major “fishbone” of the diagram. In a Fault Tree Analysis (FTA), the first level Cause will be the first Cause identified below the Failure Mode.

Separate Causes are recorded and rated separately. Some design Failure Modes may result only when two or more Causes occur at the same time. If this is a concern, then these Causes should be listed together. Causes are never combined unless they must both occur together to have the failure occur (one will not cause the failure mechanism alone). They are joined by an AND condition not an OR condition.

Continued on next page

Potential Cause(s)/Mechanism(s) of Failure, Continued

How to Identify Potential Cause(s) of Failure (Continued)

As a minimum, enter all "first level" causes. Describe each Cause in concise engineering terms so that remedial design actions can be focused on eliminating the Cause or reducing its Occurrence.

While analyzing the Causes of the Failure Mode, part characteristic(s) (also referred to as root cause), should be identified when:

- An effect of a Failure Mode with Severity rated 9 or 10 (YC).
- The ranking of the Severity times Occurrence (Criticality) ratings results in a YS classification. If the FMEA does not have any YC or YS items, develop root cause for some of the highest Severity times Occurrence (Criticality) items. For more on YS items refer to page 3-45.

Assumption 1

Two assumptions should be used when developing Causes in a Design FMEA.

Assumption 1: The item is manufactured/assembled within engineering specifications.

If following Assumption 1, identify potential Cause(s) of each Failure Mode by asking:

- What could cause the item to fail in this manner?
- What circumstance(s) could cause the item to fail to perform its function?
- How or why can the item fail to meet its engineering intent?
- What can cause the item to fail to deliver its intended function?
- How can interacting items be incompatible or mismatched? What specifications drive compatibility?

Continued on next page

Potential Cause(s)/Mechanism(s) of Failure, Continued

Examples of Assumption 1

Examples for Assumption 1 include:

- Material porosity specification too high for application
- Edge radius designed too sharp for export market
- Material hardness specified too low
- Lubricant specified too viscous
- Actual stress load higher than assumed load
- Torque specified too low
- Too close to adjacent part
- Incorrect material specified
- Inadequate design life assumption
- Incorrect algorithm
- Sneak path (unwanted circuit)
- Improper EMC/RFI design
- Component parameter degradation or drift
- Excessive heat

Assumption 2

Assumption 2: Assume the design may include a deficiency that may cause unacceptable variation (e.g., misbuilds, errors) in the manufacturing or assembly process.

Review past design deficiencies that have caused manufacturing or assembly misbuilds that in turn have caused a Failure Mode.

If following Assumption 2, identify potential design deficiencies (Causes) by asking:

- Is orientation or alignment important to how the item will function?
- Can the component be assembled upside down or backwards?
- Are the engineering specifications/tolerances compatible with the manufacturing processes?
- What possible Causes may be identified by reviewing the P-Diagram noise factors?

If design deficiencies are identified that may cause unacceptable manufacturing/assembly variation, then they should be listed and remedial design actions should be taken. Information on manufacturing/assembly variability should be communicated to the responsible manufacturing/assembly activity.

Continued on next page

Potential Cause(s)/Mechanism(s) of Failure, Continued

Examples of Assumption 2

Examples of Assumption 2 include:

- Specifying a material heat treatment such that some material (on the high side of the tolerance limit) cannot be machined to conform to specification
- A symmetrical design that allows a part to be installed backwards
- Item installed upside down because design is symmetrical
- Torque incorrect because access hole is designed off-location
- Wrong fastener used because design is similar to standard fastener also in use

CAUTION

The Design FMEA does not rely on process controls to overcome potential design weaknesses, but it does take the technical/physical limits of a manufacturing/assembly process into consideration, e.g.:

- *Necessary mold drafts*
- *Limited surface finish*
- *Assembling space/access for tooling*
- *Limited hardenability of steels*
- *Tolerances/process capability/performance*
- *Limited ESD (electro-static discharge) control*

The Design FMEA can also take into consideration the technical/physical limits of product maintenance (service) and recycling, e.g.:

- *Tool access*
- *Diagnostic capability*
- *Material classification symbols (for recycling)*

One objective is to identify the design deficiencies that may cause unacceptable variation in the manufacturing or assembly process. With cross-functional representation on the FMEA team, manufacturing/assembly causes of variation that are NOT the direct result of design deficiencies may also be identified during the development of the Design FMEA. These should be addressed in the Process FMEA. Another objective is to identify those characteristics that may improve the robustness of a design. A robust design can compensate for expected process variation.

Occurrence

Occurrence

Occurrence is the likelihood that a specific Cause/Mechanism (listed in the previous column) will occur during the design life. The likelihood of Occurrence ranking number has a relative meaning rather than an absolute value. Preventing or controlling the Causes/Mechanisms of the Failure Mode through a design change or design process change (e.g. design checklist, design review, design guide) is the only way a reduction in the Occurrence ranking can be effected.

How to Identify Occurrence

Estimate the likelihood of Occurrence of potential failure Cause/Mechanism on a 1 to 10 scale. In determining this estimate, questions such as the following should be considered:

- *What is the service history/field experience with similar components, subsystems or systems?*
- *Is the component carryover or similar to a previous level component or subsystem or system?*
- *How significant are the changes from a previous level component, subsystem or system?*
- *Is the component radically different from a previous level component?*
- *Is the component completely new?*
- *Has the component application changed?*
- *What are the environmental changes?*
- *Has an engineering analysis (e.g., reliability) been used to estimate the expected comparable Occurrence rate for the application?*
- *Have preventive controls been put in place?*
- Has a reliability prediction been performed using analytical models to estimate the Occurrence rating?

Continued on next page

Occurrence, Continued

How to Identify Occurrence (Continued)

A consistent Occurrence ranking system should be used to ensure continuity. The Occurrence ranking number is a relative rating within the scope of the FMEA and may not reflect the actual likelihood of Occurrence.

The Occurrence table on the following page will be used without modification. Enhancements to the criteria for clarification are accepted and if utilized, should then be attached to the FMEA.

If the Failure rate cannot be estimated, then judge the likelihood that the Cause and its resultant Failure Mode will occur over the design life (150,000 miles or 10 years in service standard).

If the Failure rate is between ranges, use the next higher rating. If the Occurrence rating cannot be estimated, or the team cannot reach consensus, then enter a rating of 10.

An Occurrence value is entered for each Cause. After the Occurrence rating is established, the team then returns to the Classification column to designate potential Significant Characteristics (YS) in the Design FMEA.

This FMEA Handbook assumes a direct correlation between a Cause and its resultant Failure Mode (i.e., if the Cause occurs, then the Failure Mode occurs).

- There is a very large change between the Failure rates represented by ratings 1, 2, and 3.
- For a 100% cross-vehicle commodity (i.e., on 600,000 vehicles), an Occurrence = 1 would indicate only 6 failures per model year, whereas an Occurrence = 2 would represent 60 failures per model year and an Occurrence = 3 would represent 300 failures per model year.
- For this reason, ratings of 1 and 2 are examined very closely.

Determine whether your FMEA will be analyzed for Occurrence from the perspective of the vehicle or the item and remain consistent throughout the FMEA. Include in the notes of the FMEA which perspective was used.

Continued on next page

Occurrence, Continued

Occurrence Rating Table

The following table is used to estimate the failure rate and/or criteria to develop a rating for each Cause.

Probability of Failure	***Likely Failure Rates Over Design Life***	***Ranking***
Very High: Persistent failures	*≥100 per thousand vehicles/items*	*10*
	50 per thousand vehicles/items	*9*
High: Frequent failures	*20 per thousand vehicles/items*	*8*
	10 per thousand vehicles/items	*7*
Moderate: Occasional failures	*5 per thousand vehicles/items*	*6*
	2 per thousand vehicles/items	*5*
	1 per thousand vehicles/items	*4*
Low: Relatively few failures	*0.5 per thousand vehicles/items*	*3*
	0.1 per thousand vehicles/items	*2*
Remote: Failure is unlikely	*≤ 0.01 per thousand vehicles/items*	*1*

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Classification

YS Classification Rating

When a Failure Mode/Cause combination has a Severity rating 5 to 8 and an Occurrence rating of 4 or higher, then a potential Significant Characteristic exists. When a potential Significant Characteristic is identified, the letters “YS” are entered in this column and a Process FMEA is initiated.

These product characteristics affect product function and/or are important to customer satisfaction, and may require special manufacturing, assembly, supplier, shipping, monitoring and/or inspection actions or controls.

Refer to Section 6 for further definitions and details of Special Characteristics and their required actions.

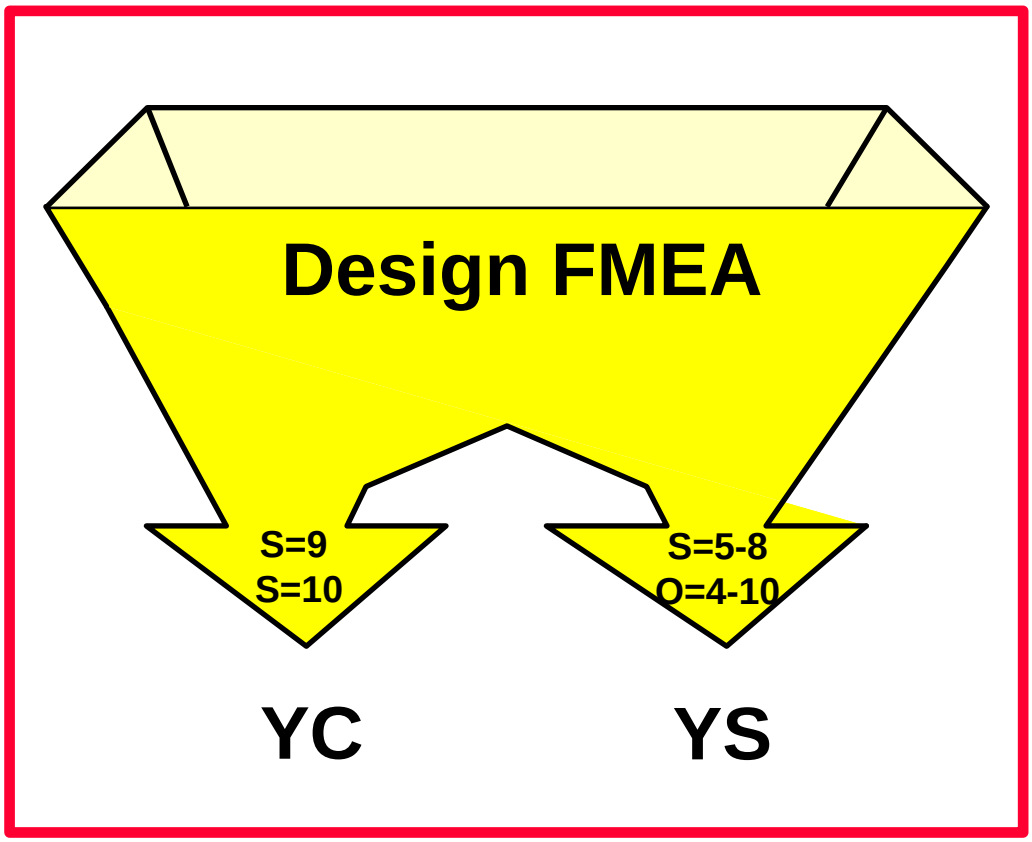
Continued on next page

Classification, Continued

Design Classification Possibilities

The following table contains the possible characteristic designations for a Design FMEA.

Classification	To Indicate	Criteria
YC	A potential Critical Characteristic (Initiate PFMEA)	Severity = 9, 10
YS	A potential Significant Characteristic (Initiate PFMEA)	Severity = 5 - 8 and Occurrence = 4 - 10
Blank	Not a potential Critical Characteristic or Significant Characteristic	Other



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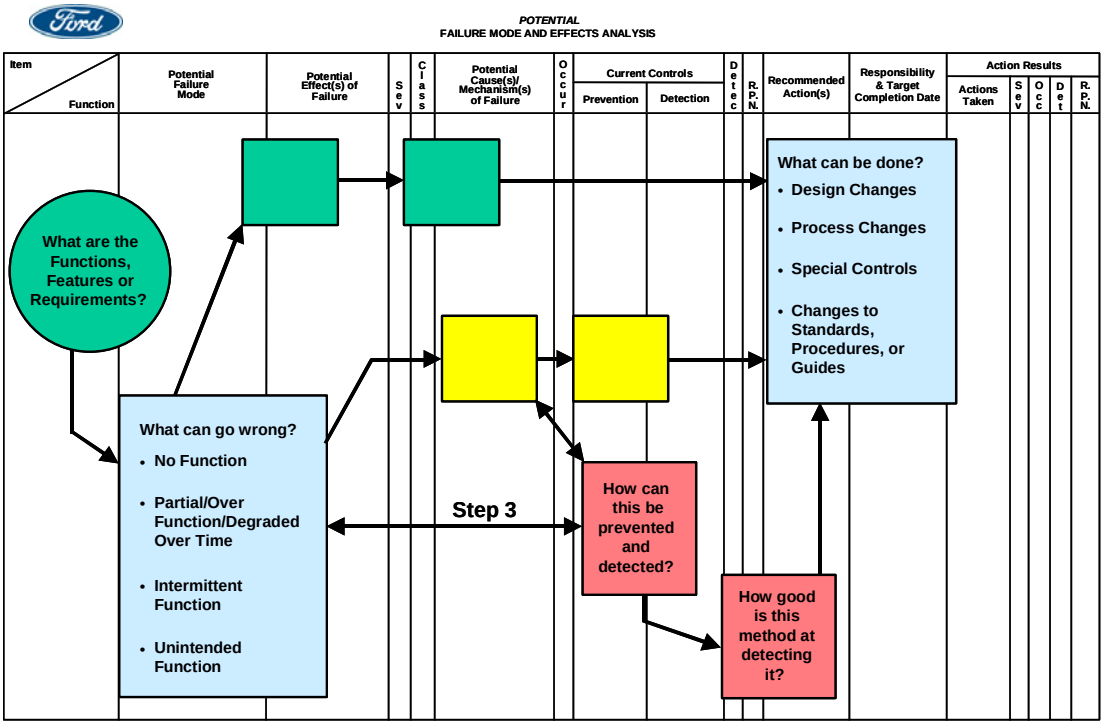
Working Model Step 3

Ford FMEA Working Model Step 3

For Failure Modes and their Causes that cannot be eliminated in Step 1 or in Step 2, continue by following Step 3:



In Step 3, identify:

- Current Prevention controls used to establish Occurrence.
- Current Detection controls (i.e., tests) used to establish Detection rating.
- Effectiveness of the Detection controls on a Detection rating scale of 1 to 10.
- The initial RPN (Risk Priority Number).
- Recommended Actions (Prevention and Detection).

Once the identified Recommended Actions are implemented, the FMEA form is revisited to identify the Action Results where the resulting Severity, Occurrence, Detection, and RPN are recalculated and entered.

Remember that Steps 1 and 2 must have been completed prior to moving on to Step 3.

Current Design Controls

Current Design Controls

List the prevention, design validation/verification (DV), or other activities which are completed or committed to and that will assure the design adequacy for the Failure Mode and/or Cause/Mechanism under consideration. Current controls (e.g., fail/safe designs such as pressure relief valve, design reviews, feasibility review, CAE, Sneak Path Analysis, Analytical Reliability and Robustness, other analytical studies, vehicle testing, rig/lab testing and other DVP or Key Life tests) *are those that have been or are being used with the same or similar designs. The team should always be focused on improving design controls, for example, the creation of new system tests in the lab, or the creation of new system modeling algorithms, etc.*

Types of Design Controls

There are two types of design controls/features to consider:

1. *Prevention: Prevent the Cause/Mechanism or Failure Mode/effect from occurring, or reduce the rate of Occurrence.*
2. *Detection: Detect the Cause/Mechanism or Failure Mode, either by analytical or physical methods, before the item is released to production.*

The preferred approach is to first use Prevention (Type 1) *controls if possible. The initial Occurrence rankings will be affected by the prevention controls provided they are integrated as part of the design intent. The initial Detection rankings will be based on the design* Detection (Type 2) *controls that either detect the cause/mechanism of failure, or detect the failure mode.*

If a one-column (for design controls) form is used, then the following prefixes should be used. Fro prevetion controls, place a "P" before each prevetion control listed. For detection controls, place a "D" before each detection control listed.

Note: New FMEA forms allow two separate columns for design controls: prevention and detection.

The desired outcome of applying a design control method is to expose a potential design deficiency (Cause). Then, corrective design actions can be taken to eliminate the Cause or reduce its rate of Occurrence. A thorough Design FMEA can lead to an effective design verification test program for new or changed designs.

Continued on next page

Current Design Controls, Continued

How to Identify Design Controls

If a potential Cause is overlooked, a product with a design deficiency may go into production. A way to detect the existence of an overlooked Cause is to detect its resultant Failure Mode. If the Failure Mode is detected, then the design engineer needs to look for an overlooked Cause (assuming all known Causes are accounted for by one or more design control methods). If an overlooked Cause can be identified, then corrective design action can be taken.

To identify design controls, proceed as follows:

1. Identify and list all historical methods that can be used to detect the Failure Mode listed. References include:
   - Previous FMEA
   - Previous DV Plans
   - Robustness Checklist
   - Global 8D (actions to correct “escape” root cause)
2. List all historical design controls that can be used to detect the first-level causes listed. Review historical test reports (proving ground, laboratory, etc.).
3. Identify other possible methods by asking:
   - In what way can the Cause of this Failure Mode be recognized?
   - How could I discover that this Cause has occurred?
   - In what way can this Failure Mode be recognized?
   - How could I discover that this Failure Mode has occurred?

Tip

Design control methods used to prevent Causes of Failure Modes may affect the Occurrence of the Cause. If this is the case, these methods should be taken into account when estimating the Occurrence rating. For instance, a method may lead to a design action that reduces the Occurrence. In this instance, the reduced Occurrence rating is entered in the Occurrence rating column.

The noise factors from the P-Diagram may permit the team to recognize that present testing/analysis is not adequate for 1 or more noise factors. If so, a Recommended Action should be entered to modify the testing/analysis to address this shortcoming.

Continued on next page

Current Design Controls, Continued

Examples of Design Controls

Design controls can include design reviews, analytical studies, and computer model programs, as well as tests derived from or equivalent to design verification tests.

Engineering specification tests or inspections conducted as part of the manufacturing and/or assembly process are NOT acceptable design controls. These are applied after the part is released for production.

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Detection

Detection

Detection is the rank associated with the best Detection (Type 2) *design control from the list in the previous column. Detection is a relative ranking, within the scope of the individual FMEA. In order to achieve a lower ranking, generally the planned design control (e.g. validation, and/or verification activities) has to be improved.*

Suggested Evaluation Criteria—The team should agree on an evaluation criteria and ranking system, which is consistent, even if modified for individual product analysis.

It is best to have Detection (Type 2) *design controls in place as early as possible in the design development process. Note: After making the Detection ranking, the team should review the Occurrence ranking and ensure that the Occurrence ranking is still appropriate.*

Detection should be estimated using the table on page 3-53.

Note: The ranking value of 1 is reserved for "almost certain."

How to Identify Detection Rating

When estimating a Detection rating, consider only those controls that will be used to detect the Failure Mode or its Cause. Controls intended to prevent or reduce the Occurrence of a Cause of a Failure Mode are considered when estimating the Occurrence rating. Since prevention controls do not detect, these controls would be rated 10.

Only methods that are used before engineering production release are to be considered when estimating the Detection rating. Design verification programs should be based on the overall effectiveness of the design controls.

The FMEA team should collectively rate the capability of each design control to detect the cause of the Failure Mode. When several Detection controls are listed, enter the lowest rating (the best Detection method or lowest in combined Detection ratings). Optionally, if all controls will be used concurrently, determine a composite Detection rating based upon the accumulated controls.

Continued on next page

Detection, Continued

Effectiveness Factors

When estimating the overall effectiveness of each design control, consider the following categories, and the factors in each category. The degree of effectiveness is listed from high to low in each category. The list below is for illustration only and is not intended to be all-inclusive.

- Design analysis methods:
  - Proven modeling/simulation (e.g., finite element analysis)
  - Tolerance stackup study (e.g., geometric dimensional tolerance)
  - Material compatibility study (e.g., thermal expansion, corrosion)
  - Subjective design review
- Development test methods:
  - Design of experiments/worst case experiment (e.g., noise)
  - Tests on pre-production samples or prototype samples
  - Mockup using similar parts
  - Vehicle durability (design verification) tests
- Experience with similar designs
- Number of samples planned to be tested
  - Statistically significant sample size
  - Small quantity, not statistically significant
- Timeliness of design control application
  - Early in design concept stage (e.g., theme decision)
  - At engineering prototype readiness
  - Just prior to engineering/manufacturing design sign-off

Continued on next page

Detection, Continued

Design Detection Rating Table

For each control method the following table is used to establish the Detection rating.

Detection	***Criteria: Likelihood of Detection by Design Control***	***Ranking***
Absolute Uncertainty	*Design control will not and/or cannot detect a potential Cause/Mechanism and subsequent Failure Mode; or there is no design control.*	*10*
Very Remote	*Very remote chance the Design Control will detect a potential Cause/Mechanism and subsequent Failure Mode.*	*9*
Remote	*Remote chance the Design Control will detect a potential Cause/Mechanism and subsequent Failure Mode.*	*8*
Very Low	*Very low chance the Design Control will detect a potential Cause/Mechanism and subsequent Failure Mode.*	*7*
Low	*Low chance the Design Control will detect a potential Cause/Mechanism and subsequent Failure Mode.*	*6*
Moderate	*Moderate chance the Design Control will detect a potential Cause/Mechanism and subsequent Failure Mode.*	*5*
Moderately High	*Moderately high chance the Design Control will detect a potential Cause/Mechanism and subsequent Failure Mode.*	*4*
High	*High chance the Design Control will detect a potential Cause/Mechanism and subsequent Failure Mode.*	*3*
Very High	*Very high chance the Design Control will detect a potential Cause/Mechanism and subsequent Failure Mode.*	*2*
Almost Certain	*Design Control will almost certainly detect a potential Cause/Mechanism and subsequent Failure Mode.*	*1*

Risk Priority Number

Risk Priority Number (RPN)

The Risk Priority Number (RPN) is the product of Severity (S), Occurrence (O), and Detection (D) ranking.

$$RPN = (S) \times (O) \times (D)$$

Within the scope of the individual FMEA, this value (between 1 and 1000) can be used to rank order the concerns in the design (e.g., in Pareto fashion).

Ford does not recommend a threshold value for RPNs. In other words, there is no value above which it is mandatory to take a Recommended Action or below which the team is automatically excused from an action.

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Recommended Actions

Recommended Actions

Engineering assessment for preventive/corrective action should be first directed at high Severity, high RPN and other items designated by the team. The intent of any recommended action is to reduce rankings, in the following preference order: Severity, Occurrence, and Detection rankings.

In general practice when the Severity is a 9 or 10, special attention must be given to assure that the risk is addressed through existing design controls or preventative or corrective action(s), regardless of the RPN. In all cases where the effect of an identified potential Failure Mode could be a hazard to the end-user, preventive/corrective actions should be considered to avoid the Failure Mode by eliminating, mitigating or controlling the Cause(s).

After special attention has been given to Severity(s) of 9 or 10, the team then addresses other Failure Modes, with the intent of reducing Severity, then Occurrence and then Detection.

The purpose is to reduce risk. This can be done by identifying preventive action(s) that reduce or eliminate potential Failure Modes, or with detective action(s) (e.g. testing) aimed at helping identify a weakness. The FMEA team should prioritize actions based on those Failure Modes:

- With effects that have the highest Severity ratings
- With Causes that have the highest Severity times Occurrence (Criticality) ratings
- With the highest RPNs

The control factors from the P-Diagram will provide insight to Recommended Actions. Some Recommended Actions may be modifications to the DV Plan. Be sure that these are included on both the DVP&R as well as the Robustness Checklist.

Continued on next page

Recommended Actions, Continued

How to Identify Recommended Actions

Actions such as, but not limited to, the following should be considered:

- *Revised design geometry and/or tolerances*
- *Revised material specification*
- *Design of experiments (particularly when multiple or interactive causes are present)/or other problem solving techniques*
- *Revised test plan*
- *Redundant systems — warning devices — failure status (fail to on or fail to off)*

The primary objective of recommended actions is to reduce risks and increase customer satisfaction by improving the design.

Only a design revision can bring about a reduction in the Severity ranking. A reduction in the Occurrence ranking can be effected only by removing or controlling one or more of the Causes/Mechanisms of the Failure Mode through a design revision. An increase in design validation/verification actions will result in a reduction in the Detection ranking only. Increasing the design validation/verification actions is a less desirable engineering action since it does not address the Severity or Occurrence of the Failure Mode.

If engineering assessment leads to no Recommended Actions for a specific Failure Mode/Cause/control combination, indicate this by entering a "NONE" or "None at this time" *in this column.*

Examples of Recommended Actions

Examples of potential actions are:

- Perform computer simulation to assure functioning in required temperature range.
- Revise hole depth to X.
- Implement strategy to revert to “on” condition if input signal is lost.
- Perform mud bath test.

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Actions Taken

Actions Taken

Responsibility for the Recommended Action – Enter the name of the organization and individual responsible for the recommended action and the target completion date.

After an action has been implemented, enter a brief description of the actual action and effective date.

Recommended Actions cannot be overemphasized. A thorough Design FMEA will be of limited value without positive and effective actions to prevent Failure Modes or mitigate their effects.

How to Identify Actions Taken

It is the responsibility of the DFMEA team leader, who is responsible for the Design FMEA, to implement a follow-up program to ensure all Recommended Actions have been implemented or adequately addressed.

Note: The design engineer's goal is to make design robust so that special manufacturing/assembly controls are not required. Detection controls do not decrease Criticality. Remember, the design engineer CANNOT rely on manufacturing/assembly process controls to overcome potential design weaknesses.

The DFMEA team leader is responsible for updating the Design FMEA. The FMEA is a living document and should reflect the latest item level and the latest relevant actions. The responsibility could also belong to a supplier.

It is not appropriate to compare the ratings of one team's FMEA with the ratings of another team's FMEA, even if the product/process appear to be identical, since each team environment is unique and thus their respective individual ratings will be unique (i.e., the ratings are subjective).

Review of the FMEA document against FMEA quality objectives is recommended including a management review. Refer to the SAE J1739 (Revised August 2002) standard for copies of the SAE FMEA Quality Objectives.

Continued on next page

Responsibility and Target Date Completion

Responsibility and Target Date Completion

Enter the individual responsible for the Recommended Action and the target completion date.

After an action has been implemented, enter a brief description of the action and effective date for the change.

To assure all Recommended Actions are implemented or adequately addressed, it is necessary to implement a follow-up and/or tracking program.

At a minimum:

- Develop a list of potential Special Characteristics and provide this list to the responsible engineer for appropriate consideration and action in the Design FMEA.
- Follow through on all Recommended Actions and update the FMEA actions.

Resulting RPN

Revised Severity, Revised Occurrence, Revised Detection, and Revised RPN

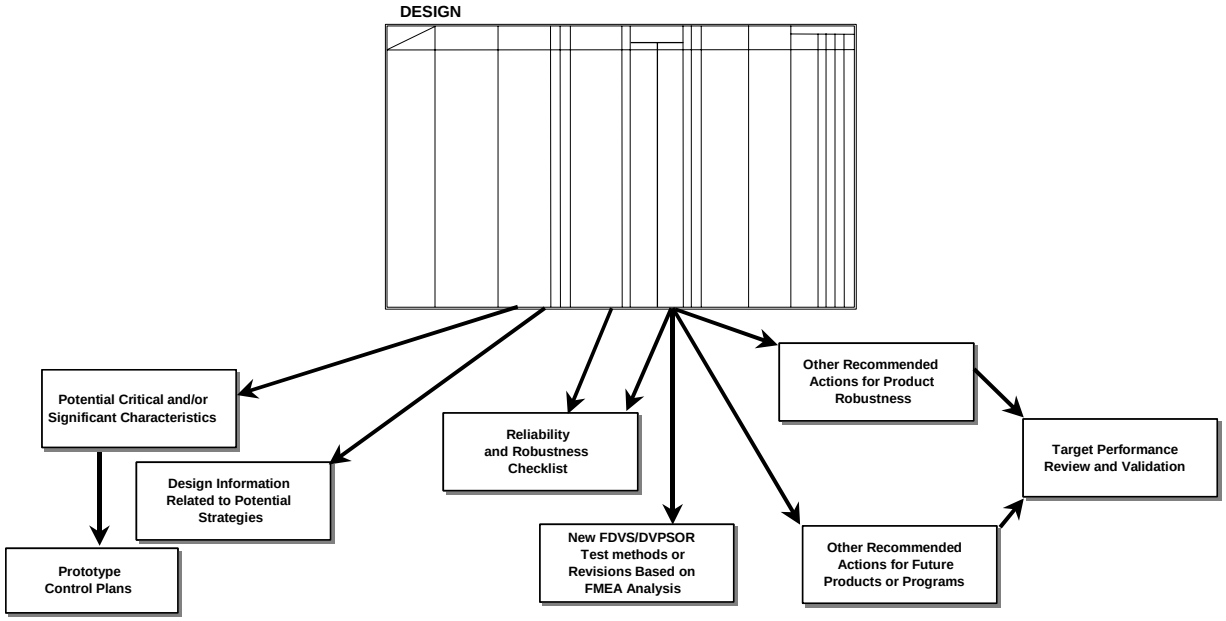
After the preventive/corrective action has been taken, record the resulting Severity, Occurrence, and Detection rankings. Calculate and record the resulting RPN. If no actions are taken, leave the related ranking columns blank. All revised ratings should be reviewed, and if further action is considered necessary, repeat the appropriate steps.

If no actions are listed, leave these columns blank. If the actions are completed, enter the revised Severity, Occurrence, or Detection rating, even if these actions did not result in a change to the ranking.

Outputs from Design FMEA

Outputs from Design FMEA

Typical outputs from a Design FMEA are shown in the graphic below. Many of these outputs will be inputs to the Process FMEA. Many of these output items are fed from the Design FMEA, or from the results of the Recommended Actions of the Design FMEA. There is also a strong correlation between many of the columns in a Design and Process FMEA. Effects and their corresponding Severity will relate directly, with unique process effects added to the Process FMEA. Other relationships are more subtle; for example, design causes often relate to process Failure Modes.



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Robustness Checklist

Robustness Checklist

The Robustness Checklist is an output of the integrated robustness process. The following page is an example of a Robustness Checklist. The Robustness Checklist:

- Summarizes key robustness Attributes and Design Controls.
- Links the DFMEA and the 5 noise factors to the Design Verification Plan (DVP); i.e., the Robustness Checklist is an input into the DVP.
- Should be a key document to review as part of the design review process.

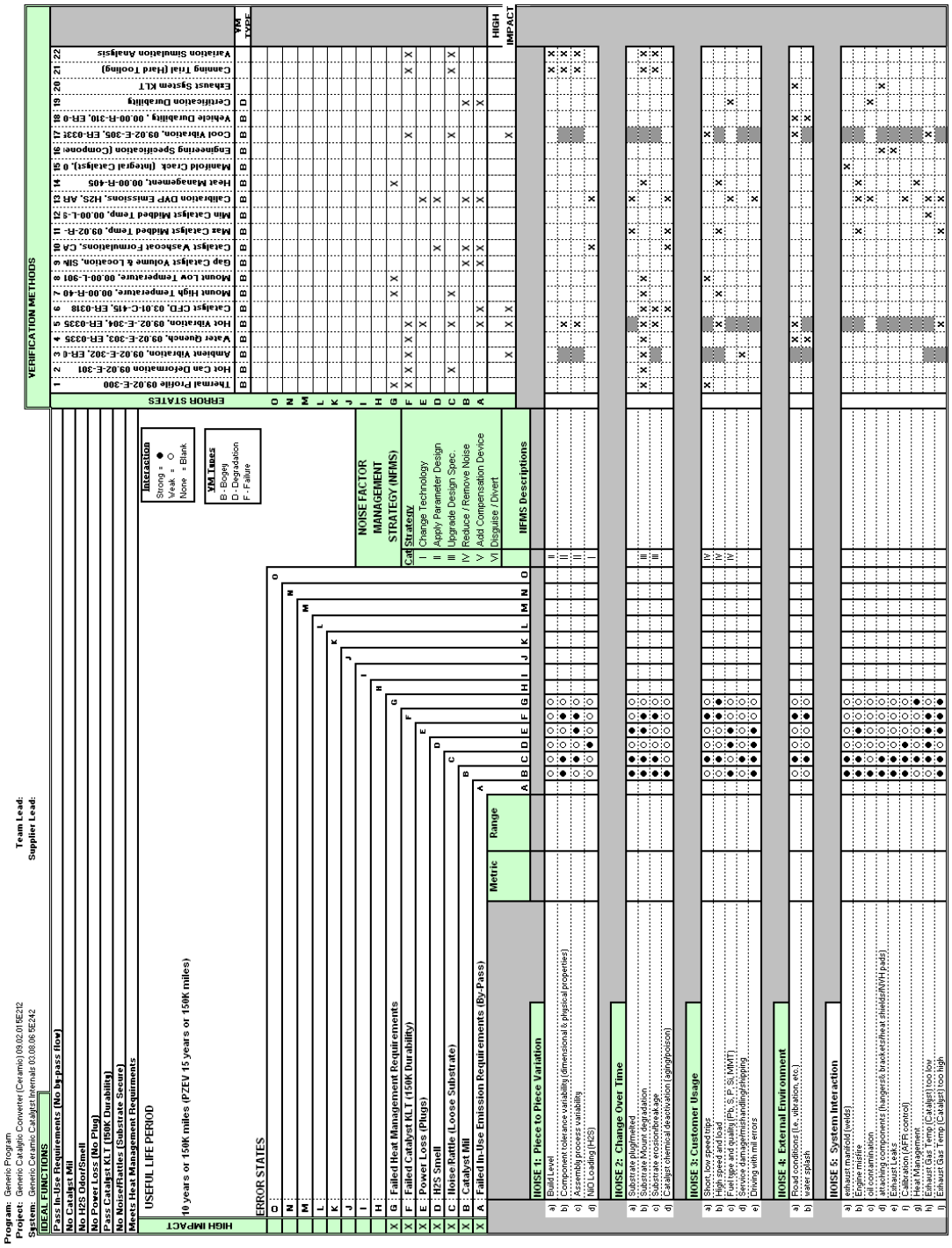
The Robustness Checklist can be accessed on the Ford Intranet at:

http://www.quality.ford.com/cpar/fmea/

Continued on next page

Robustness Checklist, Continued

Robustness Checklist Example



Sample Design FMEA

Sample Design FMEA

See a complete sample of a Design FMEA on the next two pages.

Disclaimer: This sample form is for example only and is not representative of any particular vehicle or vehicle program. This example is not intended to be construed as showing all possible failure modes, effects, or causes for the function indicated (only some samples are shown for each column) and may not show root cause.

Continued on next page

Sample Design FMEA (Continued)

___ System
_X_ Subsystem
___ Component __09.02.01 Catalytic Converter Assembly_____
Model Year(s)/Program(s): Generic / Typical Program_____
Core Team: Engineer 1, Person 1, Person 2, Engineer 2

POTENTIAL FAILURE MODE AND EFFECTS ANALYSIS DESIGN FMEA

Design Responsibility: Enter the Organization here_____
Key Date: 9/5/2004

FMEA Number: Design FMEA Catalytic Converter
Page _____ of _____
Prepared By: Engineer 1 (engineer1@ford.com)
FMEA Date: (Orig.) _1/22/2001___ (Rev.) _8/29/2003____

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control: Prevention	Current Control: Detection	Detec	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Sev	Occ	Det	R.P.N.
Function: Needs, Wants, Requirements Must be verb-noun measurable or constraints Methods: Brainstorm Input include: Function tree, Previous/similar FMEAs, SDS, Boundary Diagram, QFD	4 Thought Starters: No function Partial /over function /degraded over time Intermittent function Unintended function Methods: Brainstorm using 4 Thought starters List each in separate field Input include: P-diagram, Interface Matrix, Similar FMEAs, 8D's, Warranty, TGW	Including: Government/safety Ultimate Customer, Vehicle, Other systems, Subsystems, Components, Item, Manufacturing/ assembly/service Methods: Brainstorm, Rate each; put highest in next column Inputs include: P-diagram, Interface Matrix, Warranty, 8D's,TGW Previous similar FMEAs For classification: See FAP03-111 or Section 6 of this Handbook. As of this date = YC or YS or blank.			For cause: Why has this happened or how might this happen? Use 2 assumptions: 1) Item will be manufactured/ assembled to specification 2)Design includes a deficiency that may cause unacceptable variation Methods: 1) Brainstorm 2) Rate each occurrence-put in next column Inputs include: Warranty, 8D, TGW, Previous/ similar FMEAs, P-diagram, Interface matrix, test data		Controls are already planned, or are normal and customary for this type item Remember that Prevention Controls have an affect on the Occurrence Inputs include: Warranty, 8D, TGW, Previous/ similar FMEAs, test data, Previous DV plan, P-diagram	Current Controls are 2 types: 1. Prevent a cause/ mechanism of failure 2. Detect the failure mode or detect the cause/ mechanism of failure Methods: 1) Rate each detective control 2) Put best (lowest) or composite in the Detection column. 10 if no detection.			If no action planned, enter "None" or "None at this time". Must have a recommended action for any special Characteristic item.	Enter who (not just the department), will complete and when, 11/5/2003	Enter a brief description of the action after is has been completed. Enter the revised Severity, Occurrence, and Detection number to the right to reflect the result of the action. Recalculate				
											It is possible to have multiple actions against a cause or failure mode.	There should be a name here, XYZ department, 5/10/2003					
Catalytic Converter must suppress the generation of Sulfur odor (H2S) that can be detected by the customer (rotten egg smell) for target life of vehicle (10yr/150K Mi). (PZEV, 15yr/150K Mi) - (x ppm/test H2S) (It is assumed in this example that H2S is not a regulatory requirement.)	Excessive release of H2S	Customer dissatisfaction (Rotten Egg Smell) (7) Replace catalyst (6)	7	YS	Improper Calibration: Rich A/F excursions - during transients - at idle - Canister purge at idle and during low speed cruises	7	1. Review Calibration Guides for H2S prevention. 2. Review related G8D: # xxxxx Sulfur Odor. 3. Search Technical Service Bulletin (TSB) data base for H2S, Sulfur Smell, Rotten Egg Smell. 4. Campaign Prevention Reviews. 5. Calibration Technical Reviews.	VEHCAL ARL Emissions Attribute requirement 02-0260 for Calibration 10-pager (xx-0002) H2S Emissions tests (6) Associated DVM: DVM-xxxx-xx DVM-xxxx-xx DVM-xxxx-xx DVM-xxxx-xx Vehicle tests: Objective H2S Test NS31 Subjective H2S Test CETP 00.00-R-221	6	210	(1) Reduce APTL Mass Spec testing variability. (2) Develop ppm/test acceptance criteria that correlated to customer field concerns.	Engineer 1, Engineer 2, 1 May 2003	Released updated APTL Standard H2S Test For Sign-Off (NS33) CETP 00.00-L-931 Deleted subjective test CETP 00.00-R-221	7	3	2	42
											(Update, release & publish Corporate Quality Documents (DFMEA, Calibration Guides, CETP)	Engineer 1, Engineer 2, 1 May 2003	Released and published Corporate Quality Documents to EKB.				

Design FMEA

Sample Design FMEA (Continued)

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control: Prevention	Current Control: Detection	Detec	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Sev	Occ	Det	R.P.N.
					Catalyst Wash coats that contain: -Pt-Based Wash coats - High Ceria Loadings - Insufficient NiO Loading	6	1. Add NiO or other scavenger to wash coat 2. Review related G8D: # xxxxx Sulfur Odor. 3. Search Technical Service Bulletin (TSB) data base for H2S, Sulfur Smell, Rotten Egg Smell. 4. Campaign Prevention Reviews.	See above detection controls	6	252	1) Reduce APTL Mass Spec testing variability. 2) Develop ppm/test acceptance criteria that correlated to customer field concerns.	Engineer 1, 1 May 2003	Type Action 1 here	7	5	2	70
											Develop Calibration SDS H2S Emission Requirement Specifies standard NiO loading Formulation	Engineer 1, Engineer 2, 22 Nov 2003	Released Calibration SDS H2S Emissions CA-xxxx (2)	7	5	2	70
											Develop a Catalyst Wash coat prescreening H2S bench test qualifying wash coat submissions.	Engineer 2, 4 Aug 2003	Supplier Bench Test capability demonstrate in-process of finalizing procedure(4)	7	5	4	140
	Intermittent release of H2S	Customer dissatisfaction (Rotten Egg Smell)	6	YS	High Fuel Sulfur Level (95th Percentile Fuel)	9	1. Review related G8D: # xxxxx Sulfur Odor. 2. Search Technical Service Bulliten (TSB) data base for H2S, Sulfur Smell, Rotten Egg Smell. 3. Campaign Prevention Reviews.	See above Detection controls	6	324	See above Recommended action	Engineer 1, Engineer 2, 15 Apr 2003	Type Action 1 here	6	9	2	108
					Catalyst temperature low (<800 degrees f)	7	1. CAE SIMTWC Thermal modeling 2. Campaign Prevention Reviews. 3. Calibration Technical Reviews. 4. Review related G8D: # xxxxx Sulfur Odor.	Exhaust SDS ER-0031 For Catalyst Packaging location (8) Associated DVM: DVM-xxxx-ER DVM-xxxx-ER	8	336	Replace Catalyst Packaging Location ER-xxxx with objective minimum catalyst temperature specification.	Engineer 1, Engineer 2, 22 Nov 2003	Released Calibration SDS CA-xxxx (Minimum Wash coat Temperature s CA-0008 specification not fall to below <800F)(3)	6	5	3	90

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Section 4 – Process FMEA
Contents

In This Section

Description	See Page
Introduction to Process FMEA (PFMEA)	
Process FMEA Information Flow	4-4
FMEA Team	4-5
FMEA Scope	4-5
Inputs to Process FMEA	
Process Flow Diagram	4-6
Product Characteristic Matrix	4-7
P–Diagram	4-8
FMEA Form Header	
Filling In Header Information	4-9
Process FMEA Form	4-10
FMEA Model	
Ford FMEA Working Model	4-11
Working Model Step 1	
Ford FMEA Working Model Step 1	4-12
Process Function Requirements	
Process Function Requirements	4-13
Determine Function	4-13
How to Identify Process Function/Requirements	4-14
Process Flows, Characteristic Matrices and Characteristic Linkages	4-14
Components of Process Function Requirements	4-15
Examples of Process Function Requirements	4-15
Potential Failure Modes	
Potential Failure Modes	4-16
How to Identify Failure Mode Types	4-16
How to Identify Potential Failure Modes	4-17
Sample Functions and Failures	4-19

Continued on next page

Section 4 Contents, Continued

In This Section (Continued)

Description	See Page
Potential Effect(s) of Failure	
Potential Effect(s) of Failure	4-21
How to Identify Potential Effect(s) of Failure	4-21
Examples of Potential Effect(s) of Failure	4-22
Severity	
Severity	4-23
How to Identify Severity	4-23
Process Severity Rating Table	4-24
Consider Recommended Actions	4-25
Working Model Step 2	4-26
Ford FMEA Working Model Step 2	4-26
Potential Cause(s)/Mechanism(s) of Failure	
Potential Cause(s)/Mechanism(s) of Failure	4-27
How to Identify Potential Cause(s)/Mechanism(s) of Failure	4-28
Developing Causes	4-30
Definition for Assumption 1	4-31
How to Identify Potential Cause(s)/Mechanism(s) of Failure for Assumption 1	4-31
Caution for Assumption 1	4-32
Examples of Assumption 1	4-32
Definition for Assumption 2	4-33
How to Identify Potential Cause(s)/Mechanism(s) of Failure for Assumption 2	4-33
Examples of Assumption 2	4-33
Occurrence	
Occurrence	4-34
How to Identify Occurrence	4-34
Process Occurrence Rating Table	4-35
Classification	
Classification	4-36
Identifying Special Characteristics	4-36

Continued on next page

Section 4 Contents, Continued

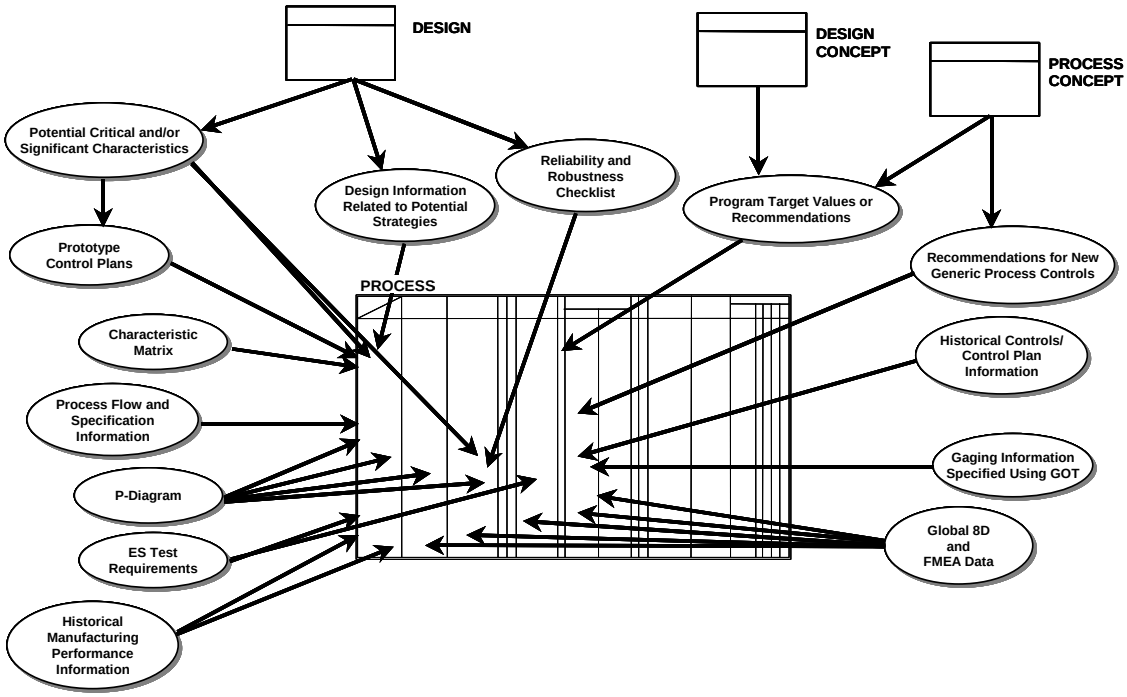
In This Section (Continued)

Description	See Page
Working Model Step 3	4-37
Ford FMEA Working Model Step 3	4-37
Process Controls	
Current Process Controls	4-38
Types of Process Controls	4-38
How to Identify Process Controls	4-38
Points to Consider	4-40
Examples of Process Controls	4-40
Detection	
Detection	4-41
How to Identify Detection Ratings	4-42
Effectiveness Factors	4-43
Process Detection Rating Table	4-44
Risk Priority Number (RPN)	4-45
Recommended Actions	
Recommended Actions	4-46
How to Identify Recommended Actions	4-47
Actions Taken	
Actions Taken	4-48
How to Ensure Recommended Actions	4-48
Responsibility and Target Completion Date	4-49
Resulting RPN	4-50
Outputs from Process FMEA	4-51
Sample Process FMEA	4-52

Introduction to Process FMEA (PFMEA)

Process FMEA Information Flow

The graphic below denotes some typical inputs to a Process FMEA (PFMEA). Many of these input items are fed from the Design FMEA, or from the results of the Recommended Actions of the Design FMEA. There is also a strong correlation between many of the columns in a Design and Process FMEA. Effects and their corresponding Severity will relate directly, with unique process effects added to the Process FMEA. Other relationships are more subtle, for example, design causes often relate to process Failure Modes.



Note: The full FMEA form is shown on page 4-10.

Appendix A has larger printable FMEA forms.

Introduction to Process FMEA (PFMEA), Continued

FMEA Team

Although responsibility for the preparation of the FMEA is usually assigned to an individual, FMEA input should be a team effort. A team of knowledgeable individuals should be assembled (e.g., engineers with expertise in design, analysis/testing, manufacturing, assembly, service, recycling, quality, and reliability). The FMEA is initiated by the engineer from the responsible activity, which can be the Original Equipment Manufacturer (i.e., produces the final product), supplier, or a subcontractor.

At Ford, the team is often separated into two distinct groups - the "core" team members and the "support" team members. Core members are typically involved in all phases of the FMEA, are stakeholders and decision-makers, and will be responsible for carrying out actions. Support team members are generally utilized on a sporadic or temporary basis to provide specific insight and input.

It is also important to have management support as described below.

- Early management support is crucial for getting the team started, generating motivation, and maintaining momentum.
- Support must be visible and active; for example, chief program engineer reviews of the FMEAs for high-priority systems or components.

FMEA Scope

Scope is the boundary or extent of the analysis. It defines what is included and excluded. Setting the wrong boundaries, expanding the FMEA analysis into areas not being revised or created will set the incorrect scope, lengthen or miss-target the analysis. Be sure to review each operation for new technology, past problems that could now be solved, and new environments, as well as any changes to the product design. An oversight may establish the wrong scope and team membership.

The FMEA scope is established by first creating a macro flow diagram, then identifying the boundary for the analysis. Finally, a micro flow diagram is created and analyzed for specific process purpose.

Inputs to Process FMEA

Process Flow Diagram

Analyze the flow of the process. A flow diagram must be used and attached to the FMEA. It is based upon the collective team knowledge of the manufacturing and assembly processes required. Ask questions such as “What is the process supposed to do?", "What is its purpose?", and "What is its function?”

A typical process flow diagram is shown below.

Sources of Variation	Purpose Process Identification	Graphical Flow of Operations	Product and Process Characteristics
• Air pressure • Tool calibration • Operator not stalling gun • Incorrect screw	30.1 Fix base plate to reflector	30.1	• Correct orientation • Correct location • Two (2) XYZ screws • Correct torque X +-y
• Incorrect detail formation from supplier • Operator not correctly seating • Operator not correctly positioning	30.2 Assemble screw and spring	30.2	• Correct orientation • Correct location • Positively located
•Operator not trained	30.3 Visually inspect trimmer assembly	30.3	• Suspect assemblies in quarantine • Approved assemblies ready to transport •350 assemblies/ hour to transport

Continued on next page

Inputs to Process FMEA, Continued

Product Characteristic Matrix

This matrix is recommended as an aid in developing product-to-process and product-to-product linkage. When compiling this matrix, identify all of the process steps that can "compromise" the part characteristics identified in the DFMEA. When completed or revised, attach the product characteristic matrix to the FMEA.

	Operations		
Product Characteristics	**30.1**	**30.2**	**30.3**
• Correct orientation – base plate	**A**		
• Correct location –base plate	**X**		
• Two (2) XYZ screws	**A**		
• Correct torque X ± Y	**X**		
• Correct orientation spring/screw assembly		**X**	
• Correct location spring/screw assembly		**X**	
• Positively located spring/screw assembly		**X**	

Legend

X – Characteristic is created or changed
C – Characteristic is used for clamping
L – Characteristic is used for locating
T – Common tool creates more than one characteristic
M – Characteristic is automatically monitored
A – One finished product characteristic has a strong effect on another

Continued on next page

Inputs to Process FMEA, Continued

P-Diagram

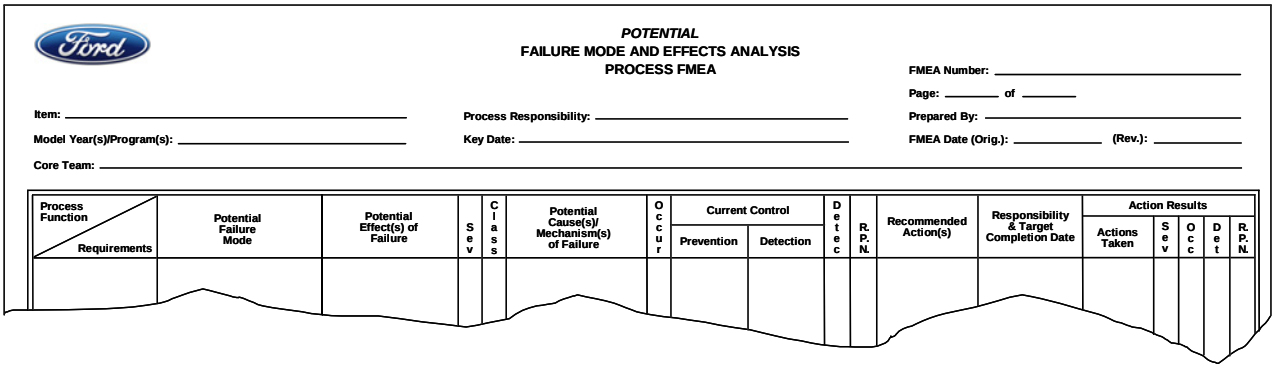
P-Diagram is optional for Process FMEA. For detailed info, please refer to P-Diagram in the Design FMEA section.

Continued on next page

FMEA Form Header

Filling In Header Information

The FMEA form, slightly different for each FMEA type, is a repository for FMEA data. Items defined below comprise the typical Process FMEA header.



POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
PROCESS FMEA

FMEA Number: _____
Page: _____ of _____
Item: _____
Process Responsibility: _____
Prepared By: _____
Model Year(s)/Program(s): _____
Key Date: _____
FMEA Date (Orig.): _____ (Rev.): _____
Core Team: _____

Process Function / Requirements	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control		Detec	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
							Prevention	Detection					Actions Taken	Sev	Occ	Det	R.P.N.

- ***Item*** *— Indicate the name and number of the system, subsystem or component for which the process is being analyzed.*
- ***Model Years/Program(s)*** *— Enter the intended model year(s) and programs that will use and/or be affected by the design/process being analyzed (if known).*
- ***Core Team*** *— List the names of core team members. It is recommended that all team members' names, departments, telephone numbers, addresses, etc. be included on a distribution list and attached to the FMEA.*
- ***Process Responsibility*** *— Enter the OEM, department and group. Also, include the supplier name if known.*
- ***Key Date*** *— Enter the initial FMEA due date, which should not exceed the scheduled start of production date.*
- ***FMEA Number*** *— Enter the FMEA document number, which may be used for tracking. It is recommended that each vehicle line and/or model year develop and maintain a discrete numbering system.*
- ***Prepared By*** *— Enter the name, telephone number and company of the engineer responsible for preparing the FMEA.*
- ***FMEA Date*** *— Enter the date the original FMEA was compiled and the latest revision date.*

Process FMEA Form

Process FMEA Form

The following is the standard format called out in the SAE Recommended Practice J1739 for Process FMEAs.

- New Form: two columns for Current Control.

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
PROCESS FMEA

FMEA Number: _____

Page _____ of _____

Prepared By: _____

FMEA Date: (Orig.) _____ (Rev.) _____

Item: _____

Model Year(s)/Program(s): _____

Core Team: _____

Process Responsibility: _____

Key Date: _____

Process Function / Requirements	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control		Det	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
							Prevention	Detection					Actions Taken	Sev	Occ	Det	R.P.N.

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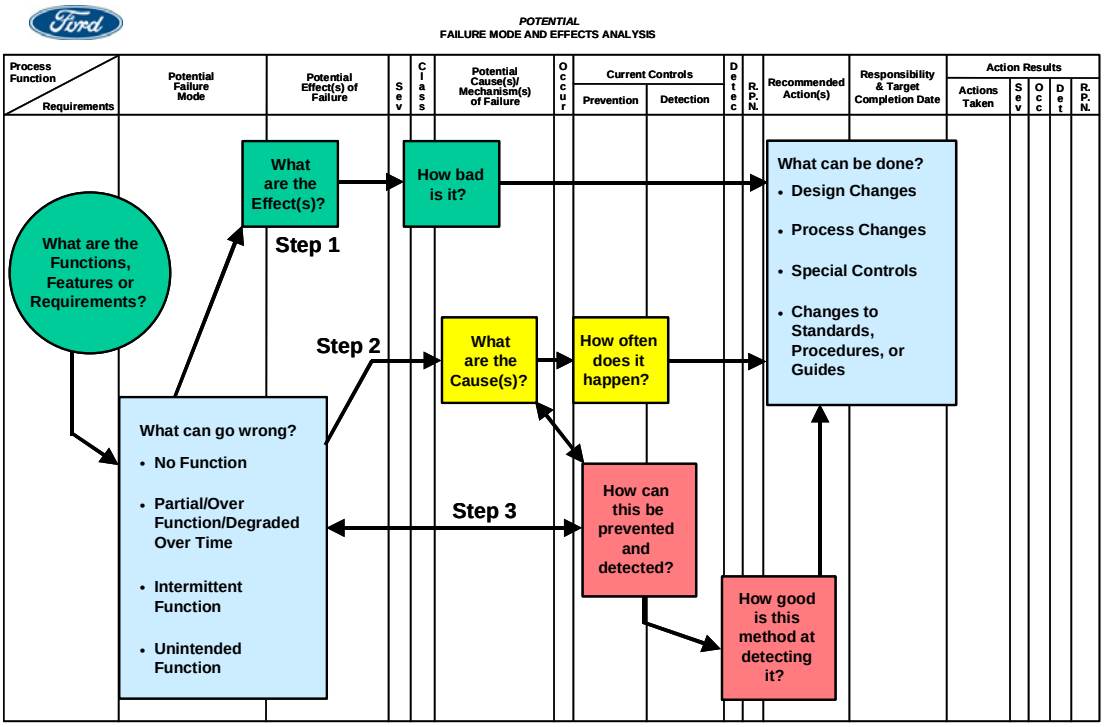
FMEA Model

Ford FMEA Working Model

The FMEA Methodology is not “form driven” but model driven. Note how the Ford FMEA Model components relate to the column headings on this FMEA form.

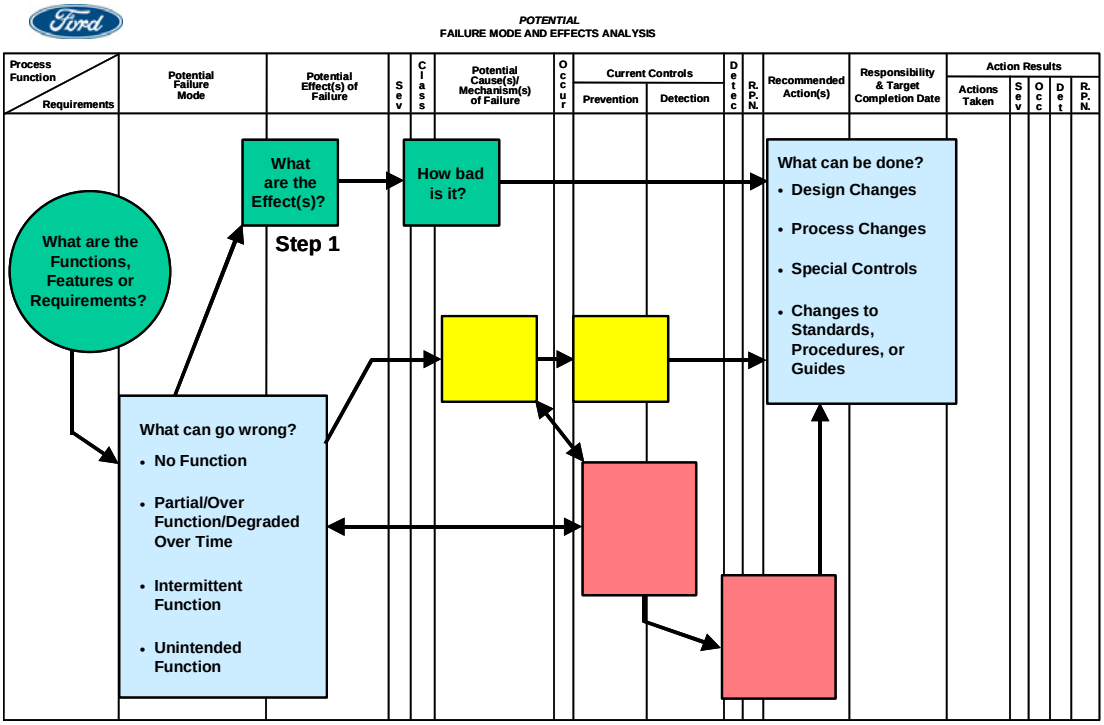


The Ford FMEA Model has three distinct steps that should be executed according to the directions on the following pages.

Working Model Step 1

Ford FMEA Working Model Step 1

The first step that should be followed is illustrated here:



Starting with Step 1:

- Identify all process Functional requirements within scope.
- Identify corresponding Failure Mode(s).
- Identify a group of associated Effects for each Failure Mode.
- Identify a Severity rating for each Effect group that prioritizes the Failure Mode(s).
- If possible, Recommend Actions to eliminate Failure Mode(s) without addressing "Causes".
  Note: This is a very rare event.

You will find that most often it is necessary to complete Steps 2 and 3, because rarely can a Failure Mode be completely eliminated.

Process Function Requirements

Process Function Requirements

Enter a simple description of the process or operation being analyzed (e.g., turning, drilling, tapping, welding, assembling). The team should review applicable performance, material, process, environmental, and safety standards. Indicate as concisely as possible the purpose of the process or operation being analyzed, including information about the design (metrics/measurables) describing the system, sub-system, or component. Where the process involves numerous operations (e.g., assembling) with different potential modes of failure, it may be desirable to list the operations as separate elements.

Process function contains both product and process characteristics.

Determine Function

Describe the Function in terms that can be measured. A description of the function should answer the question: "What is this step in the process supposed to do?"

Functions of the process are:

- Written in Verb/Noun/Measurable format.
- Measurable, which includes
  - All end product and in-process requirements.
  - Can be verified/validated.
  - Includes additional constraints or design parameters such as reliability specs, serviceability specs, special conditions, weight, size, location, and accessibility.
  - Includes part characteristics being created or modified including position, depth, diameter, and hardness.

Avoid the use of verbs like "provide, facilitate, allow," which are too general.

Remember, Functions cannot be "failed" if they do not have measurables/specifications. The Process/Requirements column should reflect the required parameters, specifications, or characteristics that the function must perform.

Continued on next page

Process Function Requirements, Continued

How to Identify Process Function Requirements

The Functions on the FMEA come from combining the Purpose/Process Identification column and Product and Process Characteristics column from a process flow diagram.

A product characteristic is a feature such as dimension, size, form, location, orientation, texture, hardness, tensile strength, appearance, coating or reflectivity. For example, a characteristic could be a dimension on an engineering drawing, or a hardness requirement in an engineering specification. In the flow diagram example on page 4-6, the orientation and the torque are product characteristics.

In the same flow diagram example, the required production volume and the suspect parts quarantined are process characteristics. Process characteristics include methods and procedures that permit the process operations to proceed smoothly to meet not only part quality requirements, but also other objectives including throughput.

A table that shows which part characteristics are affected by which process operations is referred to as a characteristic matrix. The purpose of this matrix is to ensure that all characteristics are considered and to identify those operations that directly or indirectly affect a part characteristic.

An example Product Characteristic Matrix can be found on page 4-7.

Process Flows, Characteristic Matrices and Characteristic Linkages

Detailed information on developing process flow diagrams, characteristic matrices or defining characteristic linkages can be found in the 1997 Strategy of Dynamic Control Planning Training and Reference Manual.

Continued on next page

Process Function Requirements, Continued

Components of Process Function Requirements

In Process FMEAs, functions have the following two components:

- Process characteristics or process requirements. These include operating conditions and process parameters like job rates and production maintenance requirements.
- Product specification requirements for the operations including the item dimensions and all associated engineering design requirements (i.e., engineering specifications, performance specifications).

Examples of Process Function Requirements

If the process involves many operations with different potential modes of failure, then list each operation separately.

For example, an operation for a multistation machine or sequential process in one piece of equipment may be listed in the FMEA form as:

- Operation #20: Drill hole size Xmm, through depth
- Operation #20A: Weld part A to part B forming subassembly X
- Operation #20B: Attach subassembly X to assembly Y

CAUTION

On a Process FMEA, the intermediate operations for the item are important (i.e., in process dimensions). The Failure Modes are also the reason a part/item can be rejected at the operation being analyzed with an FMEA or as an upstream process requirement.

Potential Failure Modes

Potential Failure Modes

Potential Failure Mode is defined as the manner in which the process could potentially fail to meet the process requirements and/or design intent as described in the Process Function/Requirements column. It is a description of the nonconformance at that specific operation. It can be a Cause associated with a potential Failure Mode in a subsequent (downstream) operation or an effect associated with a potential failure in a previous (upstream) operation. However, in preparation of the FMEA, the assumption may be made that the incoming part(s)/material(s) are correct. Exception can be made by the FMEA team where historical data indicates deficiencies in incoming part quality.

How to Identify Failure Mode Types

Four types of Failure Modes occur. The first and second types apply often and are the most commonly seen, and the third and fourth types are typically missed when performing the FMEA:

1. **No Function**: Process operation is totally non-functional or inoperative.
2. **Partial/Over Function/Degraded Over Time**: Degraded performance. Meets some of the specifications or some combination of the specifications but does not fully comply with all attributes or characteristics. This category includes over function. A degraded function over time is not generally a Failure Mode type in a PFMEA.
3. **Intermittent Function**: Complies but loses some functionality or becomes inoperative often due to external impacts such as temperature, moisture and environmental. This Failure Mode provides the condition of: on, suddenly off, recovered to on again function or starts/stops/starts again series of events.
4. **Unintended Function**: This means that the interaction of several elements whose independent performance is correct, adversely impacts the product or process. This will result in an unwanted outcome or consequence by the product, and hence the expression "unintended function". This type of failure mode is not common in PFMEA.

Each Failure Mode must have an associated function. A good check to discover “hidden” functions is to match all possible failures with the appropriate functions.

Continued on next page

Potential Failure Modes, Continued

How to Identify Potential Failure Modes

Review the Design FMEA to identify the function or purpose of the item being produced and the characteristics that define performance. Note any YC or YS on the Design FMEA. Review historical problems with processes of similar or surrogate parts. Also, review warranty data, concern reports and other applicable documents. Identify all known historical Failure Modes.

Examine the process flow diagram using no function, partial/over/degraded over time function, intermittent function and unintended function definitions to ask:

- Why would the item be rejected at this process operation?
- How would the item not conform to specification at this process operation?
- What would the next operator, or subsequent operators, consider unacceptable?
- What would the ultimate customer find unacceptable?
- Is there a possibility to fail regulatory compliance?

In general, process Failure Modes can be categorized as follows:

- Manufacturing: Dimensional (out of tolerance), surface finish
- Assembly: Relational, part missing, misoriented
- Receiving/Inspection: Accept bad purchased part, reject good parts when received
- Testing/Inspection: Accept bad part, reject good part

Continued on next page

Potential Failure Modes, Continued

How to Identify Potential Failure ModesHow to Identify Potential Failure Modes (Continued)

Identify potential Failure Modes. Consider the input to, and the output from, each process step. Remember, a Failure Mode at one operation can be an effect of a Failure Mode in a previous (upstream) operation.

List each potential Failure Mode for the particular operation in terms of a component, subsystem, system, or process characteristic. The assumption is made that the failure could occur, but may not necessarily occur. The process engineer/team should be able to pose and answer the following questions:

- *How can the process/part fail to meet specifications?*
- *Regardless of engineering specifications, what would a customer (end user, subsequent operations, or service) consider objectionable?*

The Failure Mode may also be the reason for variation around a desired process parameter. The description should be in terms of a part or process characteristic. Do not enter trivial Failure Modes (modes that do not impact product or process performance).

Continued on next page

Potential Failure Modes, Continued

Sample Functions and Failures

Item/Function	Failure Mode(s)
Secure Part A to Part B in correct position with two screws using power tool. To specified torque per illustration XYZ.	<u>No Function:</u> - Part A is not secured to Part B.
	<u>Partial/Over/Degraded Over Time Function:</u> - One or more screws not secured. - One or more screws under torque. - One or more screws over torque.
	<u>Intermittent Function:</u> - Part A is not secured to Part B occasionally.
	<u>Unintended Function:</u>

Continued on next page

Potential Failure Modes, Continued

If potential Special Characteristics have been identified in the Design FMEA (YS, YC), identify all operations that may impact those characteristics. Make sure all potential Special Characteristics are denoted, flagged and listed. Refer to Section 6 to determine how to proceed.

The Process FMEA assumes the product as designed will meet the design intent. Potential Failure Modes which can occur because of a design weakness may be included in a Process FMEA. Their effect and avoidance is covered by the Design FMEA.

The characteristic matrix will be used to track where the potential Special Characteristics are created, modified, verified, or utilized. Color-coding of the potential Special Characteristics could be employed to emphasize these characteristics.

Potential Effect(s) of Failure

Potential Effect(s) of Failure

Potential Effects of Failure are defined as the effects of the Failure Mode on the customer(s). The customer(s) in this context could be the next operation, subsequent operations or locations, the dealer, and/or the vehicle owner. Each must be considered when assessing the potential effect of a failure.

How to Identify Potential Effect(s) of Failure

Identify the consequences of each Failure Mode for:

- Operator safety
- Next user
- Downstream users
- Machines/equipment
- Vehicle operation
- Ultimate customer
- Compliance with government regulations

For a Process FMEA, downstream users can include an assembly operation/plant or a service (dealer) operation.

Place all effects for the Failure Mode being analyzed in one field or box.

CAUTION

A Process FMEA that does not list product functional effects or end customer effects is not complete or accurate.

Continued on next page

Potential Effect(s) of Failure, Continued

Examples of Potential Effect(s) of Failure

Describe the effects of the failure in terms of what the customer(s) might notice or experience. For the end user, the effects should always be stated in terms of product or system performance, such as:

- *Noise*
- *Erratic operation*
- *Inoperative*
- *Unstable*
- *Draft*
- *Poor Appearance*
- *Scrap*
- *Leaks*
- *Rough*
- *Excessive Effort*
- *Unpleasant Odor*
- *Operation Impaired*
- *Intermittent Operation*
- *Vehicle Control Impaired*
- *Rework/Repairs*
- *Customer Dissatisfaction*

If the customer is the next operation or subsequent operation(s)/location(s), the effects should be stated in terms of process/operation performance, such as:

- *Cannot fasten*
- *Cannot bore/tap*
- *Cannot mount*
- *Cannot face*
- *Endangers operator*
- *Does not fit*
- *Does not connect*
- *Does not match*
- *Damages equipment*
- *Causes Excessive Tool Wear*

CAUTION

If the Failure Mode could affect safe vehicle operation, or result in noncompliance with government regulations, then enter an appropriate statement. For example, if there is an adverse effect on an environmental regulation, enter “May not comply with government regulation XYZ.”

Severity

Severity

Severity is the rank associated with the most serious effect from the previous column. Severity is a relative ranking, within the scope of the individual FMEA. A reduction in Severity ranking index can be effected through a design change to system, sub-system or component, or a redesign of the process.

If the customer affected by a Failure Mode is the manufacturing or assembly plant or the product user, assessing the Severity may lie outside the immediate process engineer's/team's field of experience or knowledge. In these cases, the design FMEA, design engineer, and/or subsequent manufacturing or assembly plant process engineer, should be consulted.

How to Identify Severity

The FMEA team reaches consensus on Severity ratings using the Severity rating table. Enter the rating for only the most serious effect in the Severity column. Therefore, there will be one Severity column entry for each Failure Mode.

Assess the seriousness of each effect (listed in the Effects column). Optionally, enter a number behind the effect representing its Severity.

The Severity rating must match the wording of the effect on the FMEA.

Severity should be estimated using the table on the following page.

Note: It is not recommended to modify criteria for ranking values of 9 and 10. Failure Modes with rank Severity 1 need not be analyzed further.

Continued on next page

Severity, Continued

Process Severity Rating Table

The following table contains suggested PFMEA Severity evaluation criteria.

Effect	*Criteria: Severity of Effect* *This ranking results when a potential Failure Mode results in a final customer and/or a manufacturing/assembly plant defect. The final customer should always be considered first. If both occur, use the higher of the two severities.*		*Ranking*
	(Customer effect)	***(Manufacturing/ Assembly Effect)***	
Hazardous without warning	*Very high Severity ranking when a potential Failure Mode affects safe vehicle operation and/or involves noncompliance with government regulation without warning.*	*Or may endanger operator (machine or assembly) without warning.*	*10*
Hazardous with warning	*Very high Severity ranking when a potential Failure Mode affects safe vehicle operation and/or involves noncompliance with government regulation with warning.*	*Or may endanger operator (machine or assembly) with warning.*	*9*
Very High	*Vehicle/item inoperable (loss of primary function).*	*Or 100% of product may have to be scrapped, or vehicle/item repaired in repair department with a repair time greater than one hour.*	*8*
High	*Vehicle/Item operable but at a reduced level of performance. Customer very dissatisfied.*	*Or product may have to be sorted and a portion (less than 100%) scrapped, or vehicle/item repaired in repair department with a repair time between half an hour and an hour.*	*7*
Moderate	*Vehicle/Item operable but Comfort/Convenience item(s) inoperable. Customer dissatisfied.*	*Or a portion (less than 100%) of the product may have to be scrapped with no sorting, or vehicle/item repaired in repair department with a repair time less than half an hour.*	*6*
Low	*Vehicle/Item operable but Comfort/Convenience item(s) operable at a reduced level of performance. Customer somewhat dissatisfied.*	*Or 100% of product may have to be reworked, or vehicle/item repaired off-line but does not go to repair department.*	*5*
Very Low	*Fit and finish/Squeak and rattle item does not conform. Defect noticed by most customers (greater than 75%).*	*Or the product may have to be sorted, with no scrap, and a portion (less than 100%) reworked.*	*4*
Minor	*Fit and finish/Squeak and rattle item does not conform. Defect noticed by 50 percent of customers.*	*Or a portion (less than 100%) of the product may have to be reworked, with no scrap, on-line but out-of-station.*	*3*
Very Minor	*Fit and finish/Squeak and rattle item does not conform. Defect noticed by discriminating customers (less than 25 percent).*	*Or a portion (less than 100%) of the product may have to be reworked, with no scrap, on-line but in-station.*	*2*
None	*No discernible effect.*	*Or slight inconvenience to operation or operator, or no effect.*	*1*

Continued on next page

Severity, Continued

Consider Recommended Actions

Step 1 of the Working Model is completed by considering appropriate Recommended Actions to:

- Eliminate the Failure Mode
- Mitigate the effect

To reduce Severity or eliminate Failure Mode(s), consider this action:

- Change the design (e.g., geometry, material) if related to a product characteristic or change the process if operator safety is involved or if it relates to a process characteristic.

If the Failure Mode cannot be eliminated, continue with the Working Model Step 2.

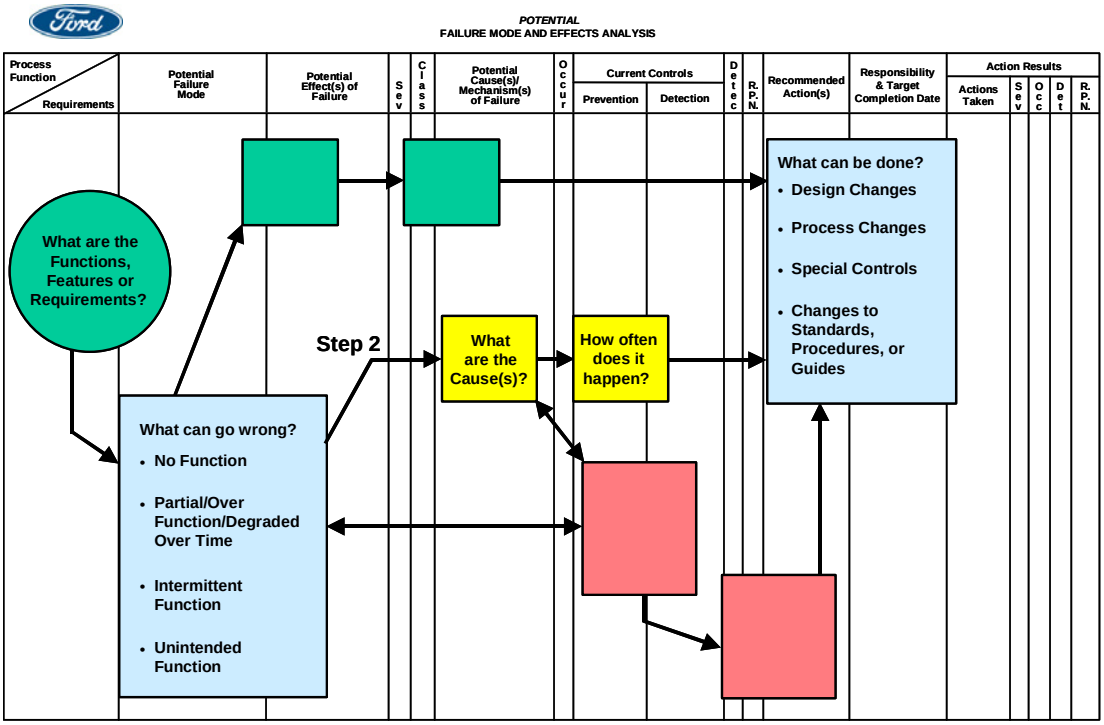
CAUTION

It is not recommended to modify criteria ranking values of 9 and 10. Failure Modes with rank Severity 1 should not be analyzed further. High Severity rankings can sometimes be reduced by making design revisions that compensate or mitigate the resultant Severity of failure.

Working Model Step 2

Ford FMEA Working Model Step 2

For Failure Modes not able to be eliminated in Step 1, continue by following Step 2:



In Step 2, identify:

- The associated Cause(s) (first level and root).
- Their estimated Occurrence rating(s).
- The appropriate characteristic designation (if any) to be indicated in the Classification column.
- Recommended Actions for high Severity and Criticality (S x O), as well as Operator Safety (OS) and High Impact (HI) process errors.

Continued on next page

Potential Cause(s)/Mechanism(s) of Failure

Potential Cause(s)/ Mechanism(s) of Failure

Potential Cause of failure is defined as how the failure could occur, described in terms of something that can be corrected or can be controlled.

For Severity rankings of 9 or 10, investigation must be carried out to identify the process characteristics that can cause this failure mode to occur, and entered on the FMEA form in this column.

Continued on next page

Potential Cause(s)/Mechanism(s) of Failure, Continued

How to Identify Potential Cause(s)/ Mechanism(s) of Failure

List, to the extent possible, every failure Cause assignable to each potential Failure Mode. If a Cause is exclusive to the Failure Mode, i.e., if correcting the Cause has a direct impact on the Failure Mode, then this portion of the FMEA thought process is completed. Many Causes, however, are not mutually exclusive, and to correct or control the Cause, a design of experiments, for example, may be considered to determine which root causes are the major contributors and which can be most easily controlled. The Causes should be described so that remedial efforts can be aimed at those Causes that are pertinent.

Typical failure Causes may include, but are not limited to:

- *Improper torque - over, under*
- *Improper weld - current, time, pressure*
- *Improper heat treat*
- *Inadequate or no lubrication*
- *Worn locator*
- *Chip on locator*
- *Improper machine setup*
- *Inadequate gating/venting*
- *Inaccurate gaging*
- *Time, temperature*
- *Part missing or mislocated*
- *Worn tool*
- *Broken tool*
- *Improper programming*

Only specific errors or malfunctions (e.g., operator fails to install seal) should be listed; ambiguous phrases (e.g., operator error, machine malfunction) should not be used.

Process and/or product characteristics (also referred to as root cause) that cause this concern must be determined when Severity is 9 or 10.

Continued on next page

Potential Cause(s)/Mechanism(s) of Failure, Continued

How to Identify Potential Cause(s)/ Mechanism(s) of Failure (Continued)

Identification of Causes should start with those Failure Modes that have the highest Severity rating. Process characteristics that cause this issue should be identified when:

- An effect of a Failure Mode has a Severity rated 9 or 10.
- The ranking of the Severity times Occurrence ratings results in a Failure Mode/first level cause combination that is ranked higher relative to other combinations. The affecting process characteristics under this condition are determined, after the prioritization, prior to taking Recommended Actions. This includes any Failure Mode/first level cause combinations that generate a Special Characteristic designation.

Process FMEA teams must investigate each Failure Mode for Cause in two iterations, using two assumptions.

Continued on next page

Potential Cause(s)/Mechanism(s) of Failure, Continued

Developing Causes

Potential Causes of failure are an indication of weakness, the consequences of which result in the Failure Mode.

This FMEA Handbook assumes a direct correlation between a Cause and its resultant Failure Mode: i.e., if the Cause occurs, then the Failure Mode occurs.

Brainstorm potential Cause(s) of each Failure Mode by asking:

- What could cause the item to fail in this manner?
- What circumstance(s) could cause the item to fail to perform its function?
- How could the item fail to meet its engineering specifications?
- What could cause the item to fail to deliver its intended function?
- How could interacting items be incompatible or mismatched? What specifications drive compatibility?
- What information developed in the P-Diagram and characteristic matrix may identify potential Causes?
- What information in the boundary diagram may have been overlooked and which may provide causes for this Failure Mode?
- What can historic Global 8Ds and FMEAs provide for potential Causes?

Initially identify the first level causes. A first level cause is the immediate cause of a Failure Mode. It will directly make the Failure Mode occur. In a Failure Mode and Effect diagram, the Failure Mode will be an item on the major “fishbone” of the diagram. In a Fault Tree Analysis (FTA), the first level cause will be the first cause identified below the Failure Mode.

Separate causes are recorded and rated separately. Some Failure Modes may result only when two or more causes occur at the same time. If this is a concern, then these causes should be listed together. Causes are never combined unless they must both occur together to have the failure occur (one will not cause the failure mechanism alone). They are joined by an AND condition not an OR condition.

Continued on next page

Potential Cause(s)/Mechanism(s) of Failure, Continued

Definition for Assumption 1

Two assumptions are made in identifying Causes in the Process FMEA.

Assumption 1: Incoming parts/materials to the operation are correct.

Start by assuming the design is robust to noise, that design is not sensitive, and the item will not fail because of an inherent design deficiency, or because of some upstream nonconformance (Supplier, manufacturing and/or assembly error). Identify the first level causes (process deficiencies) that may result in a Failure Mode. The first-level cause is the immediate cause of a Failure Mode. It will directly initiate Failure Mode. In an Ishikawa "Fishbone" diagram, it is an item on one of the major “fishbones.”

How to Identify Potential Cause(s)/ Mechanism(s) of Failure for Assumption 1

Brainstorming techniques can be used to identify potential cause(s) of each Failure Mode. Consider how the item may fail (i.e., part Failure Mode – why the part would be rejected at that operation), and what process characteristics in each operation may cause the item Failure Mode. Also consider sources of variability such as equipment, material, method, operator, and environment.

Continued on next page

Potential Cause(s)/Mechanism(s) of Failure, Continued

Caution for Assumption 1

Potential design concerns may be identified during the Process FMEA and, if appropriate, remedial design actions should be considered. Consider a situation where a substitute material has been approved by product engineering that meets all the design specifications. However, if this material is used in a proposed new improved process, it may cause a Failure Mode (e.g., deforms during a new high temperature curing operation). In this instance, it is appropriate to request that the design engineer investigate other substitute material alternatives. With cross-functional representation on the FMEA team, these potential problems should be identified and addressed in the Design FMEA. However, situations may arise where the problems will not appear until a Process FMEA is conducted.

Examples of Assumption 1

Examples of process characteristics based on Assumption 1:

- Tool set to wrong depth
- Tool worn
- Torque too low
- Oven temperature too high
- Cure time too short
- Air pressure too low
- Conveyor speed not constant
- Material feed too fast
- Limit switch installed off center
- Washer jets plugged

Continued on next page

Potential Cause(s)/Mechanism(s) of Failure, Continued

Definition for Assumption 2

Assumption 2: Consider incoming sources of variation.

Incoming sources of variability may include, for example, outside purchased parts/material, or parts/material from a prior operation.

How to Identify Potential Cause(s)/ Mechanism(s) of Failure for Assumption 2

Review the Process FMEA results from upstream operations. Decide if incoming sources of variation need to be considered. Incoming sources of variation may be important if upstream Failure Modes are not likely to be detected. Remember, a Failure Mode at an upstream operation may be the cause of a Failure Mode in a downstream operation. Identify those sources of variation that may cause a Failure Mode and will require remedial actions.

Examples of Assumption 2

Examples of incoming sources of variation based on Assumption 2:

- Material too hard/too soft/too brittle
- Dimension does not meet specification
- Surface finish does not meet specification from operation 10
- Locator hole off-location

Occurrence

Occurrence

Occurrence is the likelihood that a specific Cause/Mechanism (listed in the previous column) will occur. The likelihood of Occurrence ranking number has a relative meaning rather than an absolute value. Preventing or controlling the Causes/Mechanisms of the Failure Mode through a design or process change is the only way a reduction in the Occurrence ranking can be effected.

Estimate the likelihood of Occurrence of potential failure Cause/Mechanism on a 1 to 10 scale. A consistent Occurrence ranking system should be used to ensure continuity. The Occurrence ranking number is a relative rating within the scope of the FMEA and may not reflect the actual likelihood of Occurrence.

The "Possible Failure Rates" are based on the number of failures that are anticipated during the process execution. If available from a similar process, statistical data should be used to determine the Occurrence ranking. In all other cases, a subjective assessment can be made by utilizing the word descriptions in the left column of the table, along with any historical data available for similar processes.

How to Identify Occurrence

Estimate the rate of Occurrence for each Cause listed.

If the Occurrence of the Cause cannot be estimated, then estimate possible Failure rate. The Failure rate can be based upon historical manufacturing and assembly Failure rates experienced with similar or surrogate parts. If available from a similar process, statistical data should be used to determine the Occurrence ranking. In all other cases, a subjective assessment can be made by utilizing the word descriptions in the left column of the table, along with any historical data available for similar processes.

An Occurrence value is entered for each Cause. After the Occurrence rating is established, the team then returns to the Classification column to designate Significant Characteristics (SC) in the Process FMEA.

Consider existing process controls and/or methods that are intended to prevent, or reduce, the Occurrence of the Cause of the Failure Mode. Also, consider the quantity and magnitude of potential incoming sources of variation when estimating Occurrence.

Continued on next page

Occurrence, Continued

Process Occurrence Rating Table

The Occurrence table provided below will be used without modification. Enhancements to the criteria for clarification are accepted and if utilized, should then be attached to the FMEA.

Note: The ranking value of 1 is reserved for "Remote: Failure is unlikely".

Suggested PFMEA Occurrence Evaluation Criteria

Probability of Failure	***Likely Failure Rates***	***Ranking***
Very High: Persistent failures	*≥100 per thousand pieces*	*10*
	50 per thousand pieces	*9*
High: Frequent failures	*20 per thousand pieces*	*8*
	10 per thousand pieces	*7*
Moderate: Occasional failures	*5 per thousand pieces*	*6*
	2 per thousand pieces	*5*
	1 per thousand pieces	*4*
Low: Relatively few failures	*0.5 per thousand pieces*	*3*
	0.1 per thousand pieces	*2*
Remote: Failure is unlikely	*≤0.01 per thousand pieces*	*1*

Classification

Classification

This column may be used to classify any special product or process characteristics (e.g., critical, key, major, significant) for components, subsystems, or systems that may require additional process controls. This column may also be used to highlight high priority Failure Modes for engineering assessment.

If a classification is identified in the Process FMEA, notify the design responsible engineer since this may affect the engineering documents concerning control item identification.

Special product or process characteristic symbols and their usage is directed by specific company policy and is not standardized in this document.

These are product or process characteristics that affect:

- Safe vehicle/product function, compliance with government regulations, operator safety, or customer satisfaction

  AND
- Require special manufacturing, assembly, supplier, shipping, monitoring and/or inspection actions/controls or safety sign-offs

Identifying Special Characteristics

Refer to Section 6, which describes how to use the Process FMEA to identify a process (or product) characteristic that is a Special Characteristic.

PFMEA Special Characteristic Table

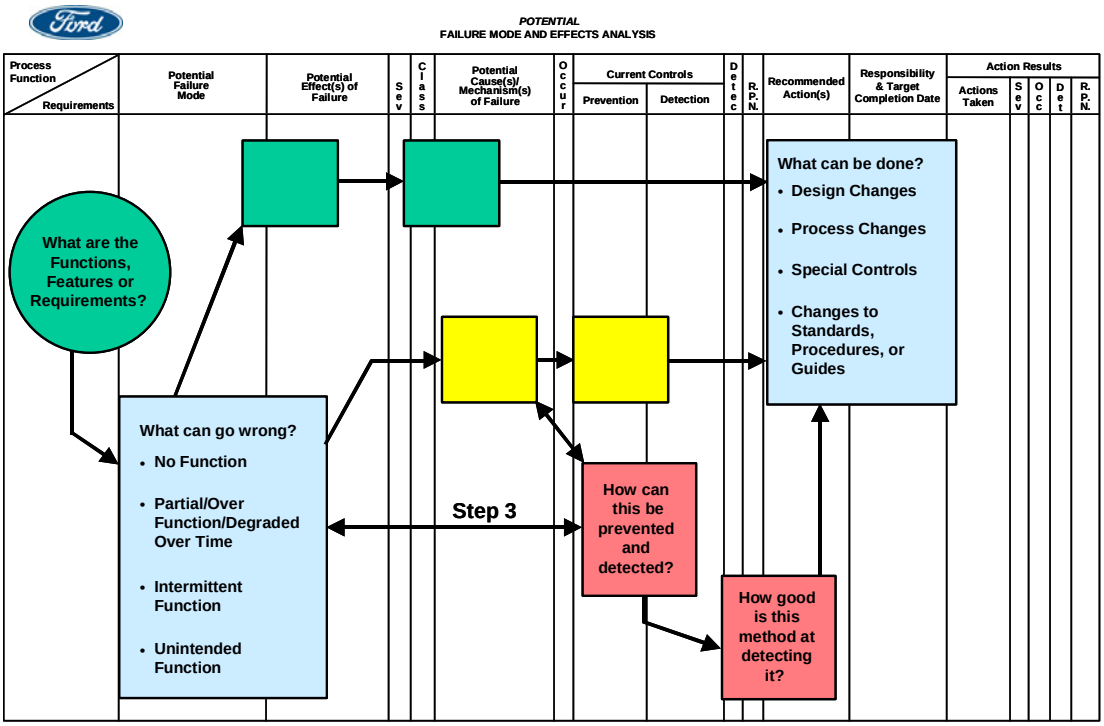
	FMEA Type	*Classification*	*To Indicate*	*Criteria*	*Actions Required*
Customer/ Product Effect	Process	∇	A Critical Characteristic	Severity = 9, 10	Special Control Required*
	Process	SC	A Significant Characteristic	Severity = 5 - 8 and Occurrence = 4 - 10	Special Control Required*
Manufacturing/ Assembly Effect	Process	HI	High Impact	Severity = 5 - 8 and Occurrence = 4 - 10	Emphasis
	Process	OS	Operator Safety	Severity = 9, 10	Safety Sign-Off
	Process	Blank	Not a Special Characteristic	Other	Does Not Apply

* Included in the Control Plan

Working Model Step 3

Ford FMEA Working Model Step 3

For Failure Modes and their Causes that cannot be eliminated in Step 1 or in Step 2, continue by following Step 3:



In Step 3, identify:

- Current Process Prevention controls (design and/or process action) used to establish Occurrence.
- Current Process Detection controls (i.e., inspection) used to establish Detection rating.
- Effectiveness of the Process Detection controls on a Detection rating scale of 1 to 10.
- The initial RPN (Risk Priority Number).
- Recommended Actions (Prevention and Detection).

Once the identified Recommended Actions are implemented, the FMEA form is revisited to identify the Action Results where the resulting Severity, Occurrence, Detection, and RPN are recalculated and entered.

Remember that Steps 1 and 2 must have been completed prior to moving on to Step 3.

Process Controls

Current Process Controls

Current Process Controls are descriptions of the controls that either prevent to the extent possible the Failure Mode/Cause from occurring or detect the Failure Mode or Cause should it occur. These controls can be process controls such as error/mistake proofing or Statistical Process Control (SPC), or can be post-process evaluation. The evaluation may occur at the subject operation or at subsequent operations.

Types of Process Controls

There are two types of process controls/features to consider:

1. *Prevention: Prevent the Cause/Mechanism or Failure Mode/Effect from occurring or reduce their rate of Occurrence.*
2. *Detection: Detect the Cause/Mechanism and lead to corrective actions.*

How to Identify Process Controls

The preferred approach is to first use Prevention (Type 1) *controls if possible. The initial Occurrence rankings will be affected by the Prevention* (Type 1) *controls provided they are integrated as part of the process intent. The initial rankings for Detection will be based on the process* Detection (Type 2) *controls that either detect the cause/mechanism of failure, or detect the failure mode.*

Once the process controls have been identified, review all preventive controls to determine if any occurrence rankings need to be revised.

Review FMEAs on surrogate processes and other applicable documents. The FMEA team should review the proposed control strategy and list planned controls used to prevent or reduce the Occurrence of a Cause and those controls aimed at detecting the Failure Mode.

Continued on next page

Process Controls, Continued

How to Identify Process Controls (Continued)

If a potential Cause is overlooked, a product with a deficiency may go further into the production process. A way to detect an overlooked Cause is to detect its resultant Failure Mode. If the Failure Mode is detected, then the process engineer needs to look for an overlooked Cause (assuming all known Causes are accounted for by one or more process control methods). If an overlooked Cause can be identified, then corrective action can be taken to remove this "escape" Cause.

To identify process controls, proceed as follows:

1. Identify and list all historical methods that can be used to detect the Failure Mode listed. References include:
   - Previous FMEAs
   - Previous Control Plans
   - Robustness Checklists
   - Global 8Ds (Actions to correct root cause)
2. List all historical process controls that can be used to detect the first-level causes listed. Review historical reports.
3. Identify other possible methods by asking:
   - In what way can the cause of this Failure Mode be recognized?
   - How could I discover that this cause has occurred?
   - In what way can this Failure Mode be recognized?
   - How could I discover that this Failure Mode has occurred?

Tip

Process control methods used to prevent causes of Failure Modes may affect the Occurrence of the cause. If this is the case, these methods should be taken into account when estimating the Occurrence rating. For instance, a method may lead to an action that reduces the Occurrence. In this instance, the reduced Occurrence rating is entered in the Occurrence rating column.

Continued on next page

Process Controls, Continued

Points to Consider

The following points should be considered:

- To increase the probability of Detection, process and/or design revisions are required.
- Generally, improving Detection controls is costly and ineffective for quality improvements.
- Increasing quality control or inspection frequency is not a positive corrective action and should only be utilized as a temporary measure. Permanent corrective action is required.
- In some cases, a design change to a specific part may be required to assist in the Detection.
- Changes to the current control system may be implemented to increase the probability of Detection.
- Emphasis must, however, be placed on preventing defects (i.e., reducing the Occurrence) rather than detecting them. An example would be the use of Statistical Process Control and process improvement rather than random quality checks or associated inspection.

Examples of Process Controls

Examples of process controls might include:

Type	Control Methods
Audits	• Dock/dispatch/teardown • Process parameter/characteristic
Checking	• Operator (used with SPC) • 100% automatic (gaging) • Manual/visual
Inspection	• In-process • Final (dimensional, functional)
Other	• Engineering specification tests • Setup verification (after tool or die change) • Poke-a-yoke or error proofing • In-process, or post operation laboratory tests • Audible/visual warning devices

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Detection

Detection

Detection is the rank associated with the best Detection (Type 2) *control listed in the process control column. Detection is a relative ranking, within the scope of the individual FMEA. In order to achieve a lower ranking, generally the planned process control has to be improved.*

Assume the failure has occurred and then assess the capabilities of all "Current Process Controls" to prevent shipment of the part having this Failure Mode or defect. Do not automatically presume that the Detection ranking is low because the Occurrence is low (e.g., when Control Charts are used), but do assess the ability of the process controls to detect low frequency Failure Modes or prevent them from going further in the process.

Random quality checks are unlikely to detect the existence of an isolated defect and should not influence the Detection ranking. Sampling done on a statistical basis is a valid Detection control.

Continued on next page

Detection, Continued

How to Identify Detection Ratings

When estimating a Detection rating, consider only those controls that will be used to detect the Failure Mode or its cause. Controls intended to prevent or reduce the Occurrence of a Cause of a Failure Mode are considered when estimating the Occurrence rating. Since prevention controls do not detect, these controls would be rated 10.

The FMEA team should collectively rate the capability of each process control to detect the Cause of the Failure Mode. When several Detection controls are listed, enter the lowest rating (the best Detection method or lowest in combined Detection ratings). Optionally, if all controls will be used concurrently, determine a composite Detection rating based upon the accumulated controls.

First, determine if any of the process controls listed can be used to prevent the Cause of a Failure Mode. If a control is a prevention control, enter it into the prevention section of the Controls column. Remember that the Occurrence rating may be affected.

Next, estimate the effectiveness of each Type 2 process control mode listed. When estimating effectiveness, consider the effectiveness factors on the next page. Estimate the capability of each process control to detect the Failure Mode or the Cause. Assume the Failure Mode has occurred. Rate the Detection control based upon its overall effectiveness.

Continued on next page

Detection, Continued

Effectiveness Factors

Use the Detection ranking table for Process FMEA to select a Detection rating number. Rate only those controls intended to detect. If the ability of the controls to detect is unknown, or cannot be estimated, then use a Detection rating of 10. If there is no detective control, use a 10.

If 100% automatic gaging is listed as a control, the FMEA team should consider its effectiveness based upon the following factors:

- Condition of gage
- Calibration of gage
- Variation of gage measurement system
- Likelihood of gage failure
- Likelihood gaging system will be bypassed

If 100% visual inspection is listed, the team should consider its effectiveness based upon the following factors:

- 100% visual inspection is 80% – 100% effective depending upon local conditions
- The number of individuals who may potentially observe the Failure Mode
- The nature of the Failure Mode – is it obvious, or is it obscure?

Single visual inspection is typically rated for Detection not lower (not better) than 8.

Continued on next page

Detection, Continued

Process Detection Rating Table

For each control method, the following table is used to establish the Detection rating.

Detection should be estimated using the following table as a guideline.

Note: The ranking value of 1 is reserved for "Controls Certain to detect."

Suggested PFMEA Detection Evaluation Criteria

Inspection Types:

Detection	Criteria	A	B	C	Suggested Range of Detection Methods	Ranking
Almost Impossible	Absolute certainty of non-Detection.				Cannot detect or is not checked.	10
Very Remote	Controls will probably not detect.				Control is achieved with indirect or random checks only.	9
Remote	Controls have poor chance of Detection.				Control is achieved with visual inspection only.	8
Very Low	Controls have poor chance of Detection.				Control is achieved with double visual inspection only.	7
Low	Controls may detect.				Control is achieved with charting methods, such as SPC {Statistical Process Control}.	6
Moderate	Controls may detect.				Control is based on variable gaging after parts have left the station, OR Go/No Go gaging performed on 100% of the parts after parts have left the station.	5
Moderately High	Controls have a good chance to detect.				Error Detection in subsequent operations, OR gaging performed on setup and first-piece check (for set-up Causes only).	4
High	Controls have a good chance to detect.				Error Detection in-station, OR error Detection in subsequent operations by multiple layers of acceptance: supply, select, install, verify. Cannot accept discrepant part.	3
Very High	Controls almost certain to detect.				Error Detection in-station (automatic gaging with automatic stop feature). Cannot pass discrepant part.	2
Very High	Controls certain to detect.				Discrepant parts cannot be made because item has been error proofed by process/product design.	1

Inspection Types:
A Error Proofed
B. Gaging
C. Manual Inspection

Note: Shaded areas indicate the inspection type(s) used for a given rank.

Risk Priority Number

Risk Priority Number (RPN)

The Risk Priority Number (RPN) is the product of Severity (S), Occurrence (O), and Detection (D) ranking.

$$RPN = (S) \times (O) \times (D)$$

Within the scope of the individual FMEA, this value (between 1 and 1000) can be used to rank order the concerns in the process (e.g., in Pareto fashion).

Ford does not recommend a threshold value for RPNs. In other words, there is no value above which it is mandatory to take a Recommended Action or below which the team is automatically excused from an action.

Recommended Actions

Recommended Actions

Engineering assessment for corrective action should be first directed at high Severity, high RPN and other items designated by the team. The intent of any recommended action is to reduce rankings, in the following preference order: Severity, Occurrence, and Detection rankings.

In general practice when the Severity is 9 or 10, special attention must be given to assure that the risk is addressed through existing design actions/controls or process preventive/corrective action(s), regardless of the RPN. In all cases where the effect of an identified potential Failure Mode could be a hazard to manufacturing/ assembly personnel, preventive/corrective actions should be taken to avoid the Failure Mode by eliminating or controlling the Cause(s), or appropriate operator protection should be specified.

After special attention has been given to Severity(s) of 9 or 10, the team then addresses other Failure Modes, with the intent of reducing Severity, then Occurrence, and then Detection.

Remedial process actions or controls are most effective when they are preventive and directed at eliminating or reducing the Causes of Failure Modes.

The purpose is to reduce risk. This can be done by identifying preventive action(s) that reduce or eliminate the occurrence of potential Failure Modes, or with detective action(s) (e.g. inspection) aimed at helping identify a weakness. The FMEA team should prioritize actions based on those Failure Modes:

- With effects that have the highest Severity ratings
- With Causes that have the highest Severity times Occurrence (Criticality) ratings
- With the highest RPNs

The control factors from the P-Diagram may provide insight to Recommended Actions.

Some Recommended Actions may be modifications to the Control Plan. Be sure that these are included on the Control Plan.

Continued on next page

Recommended Actions, Continued

How to Identify Recommended Actions

Actions such as, but not limited to, the following should be considered:

- *To reduce the probability of Occurrence, process and/or design revisions are required. An action-oriented study of the process using statistical methods could be implemented with an ongoing feedback of information to the appropriate operations for continuous improvement and defect prevention.*
- *Only a design and/or process revision can bring about a reduction in the Severity ranking.*
- *To increase the probability of Detection, process and/or design revisions are required. Generally, improving Detection controls is costly and ineffective for quality improvements. Increasing quality controls inspection frequency is not positive preventive/ corrective action and should only be utilized as a temporary measure, permanent preventive/corrective action is required. In some cases, a design change to a specific part may be required to assist in the Detection. Changes to the current control system may be implemented to increase this probability.*

Emphasis must, however, be placed on preventing defects (i.e., reducing the Occurrence) rather than detecting them. An example would be the use of Statistical Process Control and process improvement rather than random quality checks or associated inspection.

Whenever Failure Modes have Severity ratings of 9 or 10, process (and/or design) actions must be considered to reduce the criticality (Severity and/or Occurrence ratings).

If engineering assessment leads to no Recommended Actions for a specific Failure Mode/Cause/control combination, indicate this by entering a "NONE" or "None at this time" in this column.

Actions Taken

Actions Taken

Enter the individual responsible for the recommended action and the target completion date.

After an action has been implemented, enter a brief description of the actual action and effective date.

Recommended Actions cannot be overemphasized. A thorough Process FMEA will be of limited value without positive and effective actions to prevent Failure Modes or mitigate their effects.

How to Ensure Recommended Actions

It is the responsibility of the PFMEA team leader, who is responsible for the Process FMEA, to implement a follow-up program to ensure all Recommended Actions have been implemented or adequately addressed.

The PFMEA team leader is responsible for updating the Process FMEA. The FMEA is a living document and should reflect the latest item level and the latest relevant actions. The responsibility could also belong to a supplier.

It is not appropriate to compare the ratings of one team's FMEA with the ratings of another team's FMEA, even if the product/process appear to be identical, since each team environment is unique and thus their respective individual ratings will be unique (i.e., the ratings are subjective).

Review of the FMEA document against FMEA quality objectives is recommended including a management review. Refer to the SAE J1739 (Revised August 2002) standard for copies of the SAE FMEA Quality Objectives.

Responsibility and Target Completion Date

Responsibility and Target Completion Date

Enter the individual responsible for the Recommended Action and the target completion date.

After an action has been implemented, enter a brief description of the action and effective date for the change.

To assure all Recommended Actions are implemented or adequately addressed, it is necessary to implement a follow-up and/or tracking program.

At a minimum:

- Develop a list of potential Special Characteristics and provide this list to the responsible engineer for appropriate consideration and action in the Design FMEA.
- Follow through on all Recommended Actions and update the FMEA for those actions.

Resulting RPN

Resulting RPN

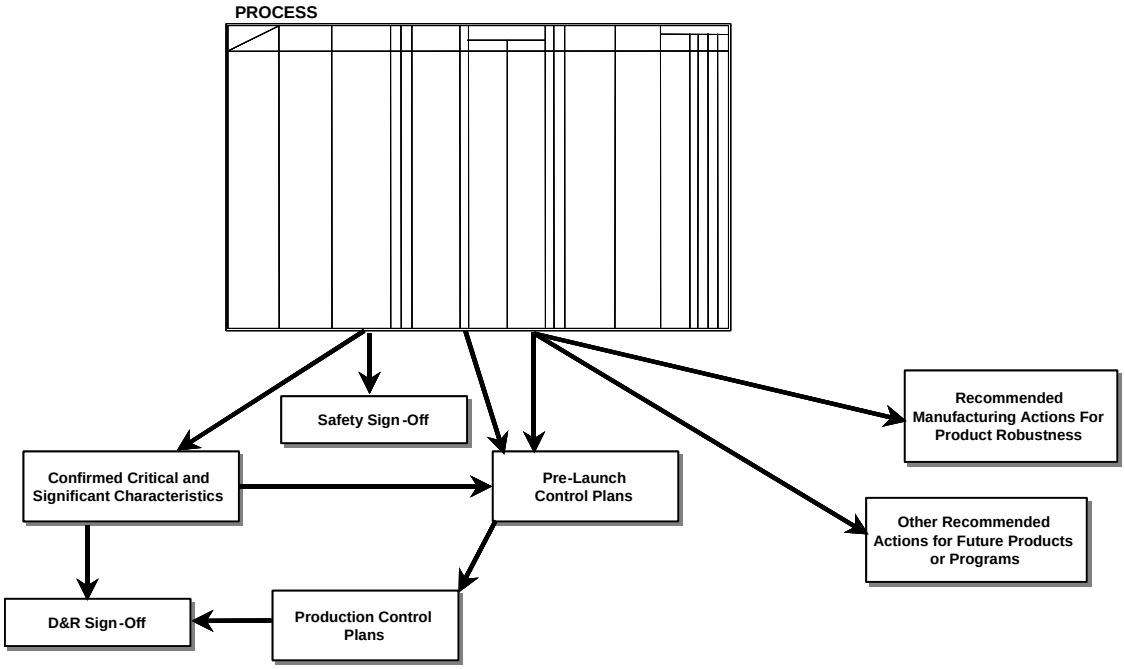
After corrective actions have been identified, estimate and record the resulting Occurrence, Severity and Detection rankings. Calculate and record the resulting RPN. If no actions are taken, leave the Resulting RPN and related ranking columns blank.

If no actions are listed, leave these columns blank. If the action is completed, enter the Severity, Occurrence, or Detection rating, even if the action did not result in a change to the ranking.

Outputs from Process FMEA

Outputs from Process FMEA

Typical outputs from a Process FMEA are shown in the graphic below. It is important to note that there is a direct relationship from the Process FMEA to a Process Control Plan.



Sample Process FMEA

Sample Process FMEA

See a complete sample of a Process FMEA on the next two pages.

Disclaimer: This sample form is for example only and is not representative of any particular vehicle or vehicle program. This example is not intended to be construed as showing all possible failure modes, effects, or causes for the function indicated (only some samples are shown for each column) and may not show root cause.

Continued on next page

Sample Process FMEA (Continued)

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
PROCESS FMEA

FMEA Number: 42-14

Page 1 **of** 1

Item: Connector Assembly

Process Responsibility: XYZ Manufacturing, Dept. 42

Prepared By: Engineer 2/555-5555-Mfg. Engineering

Model Year(s)/Program(s): 2000/AB12,CD24

Key Date: 2/99

FMEA Date: (Orig.) 98.08.16 **(Rev.)** 98.10.07

Core Team: Engineer 1, Person 1, Person 2, Engineer 2

Process Function / Requirements	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control: Prevention	Current Control: Detection	Detec	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Sev	Occ	Det	R.P.N.
Automation: Assemble case onto relay -fully seated to meet height requirement	Case assembled but not to correct height	Fails height check causing rework (3) If not detected, connector corrosion, leading to intermittence, premature part failure (8)	8	SC	Insufficient machine press force -incorrect set up	4	Pressure monitored by PLC	Go/no go gauge check in station (3)	3	96	Decrease acceptable pressure range to high end of specification	Engineer 1 Date: 8/27/98 Determine new pressure range specification	Acceptable pressure range decreased to high end of specification	8	2	3	48
					Insufficient machine press force -machine regulator failure	2	Pressure monitored by PLC	Go/no go gauge check in station (3)	3	48	None at this time						
					Foreign material on case	2	Standard Operating Process 123 (cleanliness)	Go/no go gauge check in station (3)	3	48	None at this time						

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Section 5 – Concept FMEA
Contents

In This Section

Description	See Page
Introduction to Concept FMEAs	
Introduction	5-3
FMEA Team and FMEA Scope	5-3
Inputs to Concept FMEA	
Inputs to Concept FMEA	5-4
Boundary Diagram and Interface Matrix	5-4
Process Flow Diagram	5-4
P-Diagram	5-4
Characteristic Matrix	5-4
FMEA Form Header	
Filling In Header Information	5-6
Concept FMEA Form	5-7
FMEA Model	5-8
Working Model Step 1	5-8
Item/Process Function Requirements	5-8
Potential Failure Modes	5-9
Potential Effect(s) of Failure	5-9
Severity	
Severity	5-10
Consider Recommended Actions	5-10
Classification	5-10
Working Model Step 2	5-10
Potential Cause(s)/Mechanism(s) of Failure	5-11
Occurrence	5-12
Ford FMEA Working Model Step 3	5-12
Current Controls	
Current Controls	5-13
Examples of Controls	5-13

Continued on next page

Section 5 – Concept FMEA, Continued

In This Section (Continued)

Description	See Page
Detection	5-14
Risk Priority Number	5-14
Recommended Actions	
Recommended Actions	5-15
How to Identify Recommended Actions	5-15
Examples of Recommended Actions	5-16
Actions Taken	5-17
Resulting RPN	5-17
Revised Severity, Revised Occurrence, Revised Detection, and Revised RPN	5-17
Outputs from Concept FMEA	5-18

Introduction to Concept FMEAs

Introduction

The scope of a Concept FMEA (CFMEA) can be a Design Concept FMEA at a system, subsystem, or component level, or a manufacturing or assembly Process Concept FMEA.

The scope of a CFMEA should include the technology/product/ process. It should address the interactions on the system level, but could be extended up to the vehicle level as necessary.

CAUTION

Most of the Design Concept FMEA will be performed like a "normal" Design FMEA. Most of the Process Concept FMEA will be performed like a "normal" Process FMEA. Therefore, this section of the FMEA Handbook will only highlight the differences.

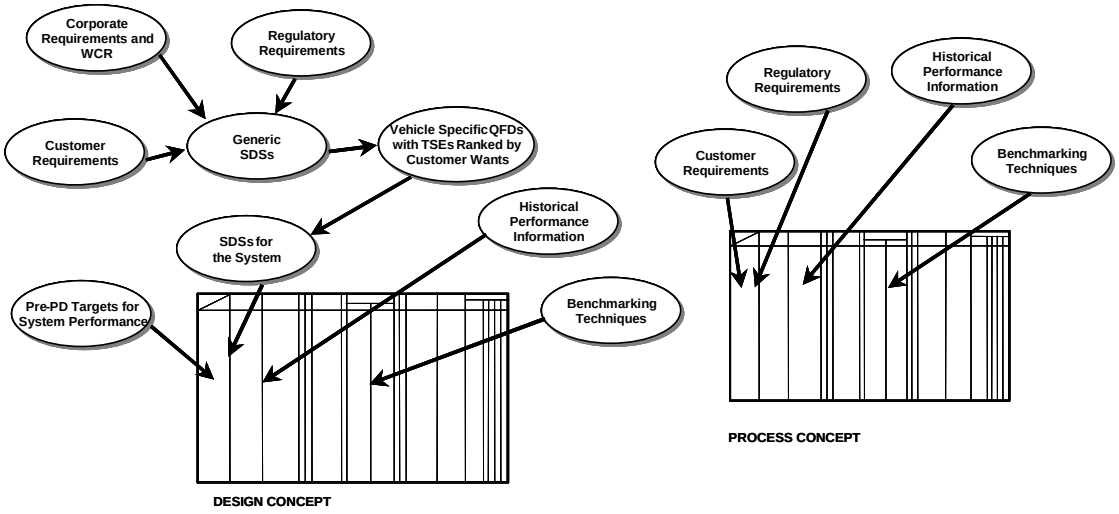
FMEA Team and FMEA Scope

Refer to the relevant Design FMEA or Process FMEA section in the FMEA Handbook.

Inputs to Concept FMEA

Inputs to Concept FMEA

The graphic below denotes typical inputs to a Design Concept FMEA.



Boundary Diagram and Interface Matrix

Refer to the relevant Design FMEA section in the FMEA Handbook.

Process Flow Diagram

Refer to the relevant Process FMEA section in the FMEA Handbook.

P-Diagram

Refer to the relevant Design FMEA or Process FMEA section in the FMEA Handbook.

Characteristic Matrix

Refer to the relevant Process FMEA section in the FMEA Handbook.

Continued on next page

Inputs to Concept FMEA, Continued

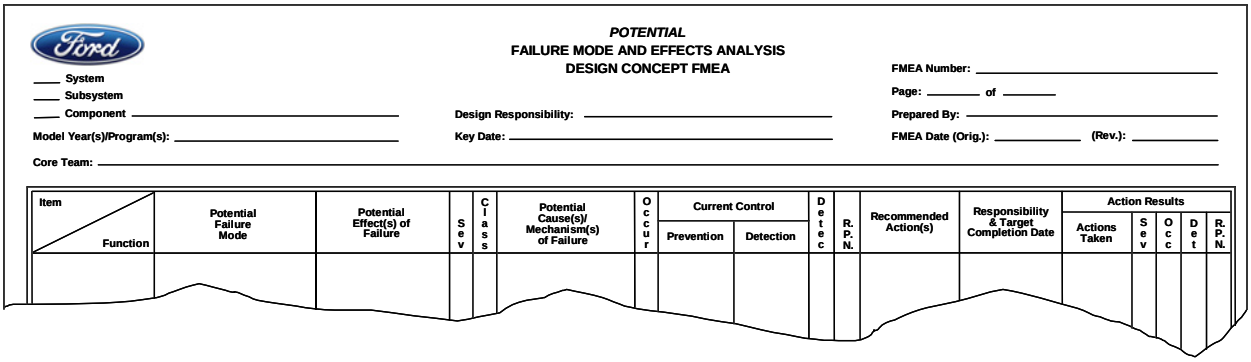
Tip

The process flow diagram, boundary diagram, interface matrix, and P-Diagram may be less detailed in a CFMEA than in a normal DFMEA or PFMEA. Also, their creation may be in several iterations with input from the other tools.

FMEA Form Header

Filling In Header Information

The graphic below is a Design Concept FMEA form header. Refer to the relevant Design FMEA or Process FMEA section in the FMEA Handbook for definitions of the header items.



POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
DESIGN CONCEPT FMEA

____ System
____ Subsystem
____ Component _____
Model Year(s)/Program(s): _____

Design Responsibility: _____
Key Date: _____

FMEA Number: _____
Page: _____ of _____
Prepared By: _____
FMEA Date (Orig.): _____ (Rev.): _____

Core Team: _____

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control		Detec	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
							Prevention	Detection					Actions Taken	Sev	Occ	Det	R.P.N.

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Concept FMEA Form

Concept FMEA Form

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
DESIGN CONCEPT FMEA

___ System
___ Subsystem
___ Component ___ Design Responsibility: ___ Key Date: ___
Model Year(s)/Program(s): ___
Core Team: ___

FMEA Number: ___
Page ___ of ___
Prepared By: ___
FMEA Date: (Orig.) ___ (Rev.) ___

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control: Prevention	Current Control: Detection	Det	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Sev	Occ	Det	R.P.N.

FMEA Model

Ford FMEA Model	Refer to the relevant Design FMEA or Process FMEA section in the FMEA Handbook.

Working Model Step 1

Ford FMEA Working Model Step 1	Refer to the relevant Design FMEA or Process FMEA section in the FMEA Handbook.

Item/Process Function Requirements

Item/Process Function Requirements	Refer to the relevant Design FMEA or Process FMEA section in the FMEA Handbook.

Potential Failure Modes

Potential Failure Modes	Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.

Potential Effect(s) of Failures

Potential Effect(s) of Failure	Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook. Note: There may be less detail available in this field in a Design Concept FMEA or a Process Concept FMEA than in a "normal" Design or Process FMEA.

Severity

Severity	Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.
Consider Recommended Actions	Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.

Classification

Classification	This column is not currently used for Design Concept or Process Concept FMEAs. In the early stages of development, hardware has not yet been defined. Therefore, until hardware is defined, potential Special Characteristics cannot be identified because Special Characteristics are hardware-specific. After hardware is defined, a Design FMEA can be used to identify potential Special Characteristics or a Process FMEA to confirm Special Characteristics.

Working Model Step 2

Ford FMEA Working Model Step 2	Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.

Potential Cause(s)/Mechanism(s) of Failure

Potential Cause(s)/ Mechanism(s) of Failure

Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.

Note: It is rarely possible to provide cause in this field in a Design Concept or a Process Concept FMEA because hardware has not yet been defined.

Analyzing the interfaces and interactions is especially important. A major benefit of the Concept FMEA is the identifying of potential failure modes caused by interactions that must be addressed before the concept can be approved and implemented.

Human factors are sources of potential failure modes at the concept level and must be included in the analysis. Remember, the customer may interface with an element in the boundary diagram or an element in the process flow diagram.

Some Failure Modes and Causes may be eliminated by major concept changes like adding a redundancy to the proposed system.

Occurrence

Occurrence

Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.

Note: A Concept FMEA often has an Occurrence of 10 because the rating cannot be estimated at this time.

If an Occurrence rating of 10 is entered because the rating cannot be estimated at the present time, a Recommended Action should be immediately entered. The first priority of the action should be to eliminate the Cause. If elimination of the Cause is not possible or practical, enter an action that will permit the team to determine a rating to better assess risk.

Any unacceptably high Occurrence rating will **require** an action to reduce the Occurrence.

Working Model Step 3

Ford FMEA Working Model Step 3

Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.

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Current Controls

Current Controls

Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.

Note: The team will enter a description of the control method(s) that will be used to prevent or detect the first-level causes (element failure modes) of the Failure Mode. If a method, test, or technique cannot be identified, then enter “None identified at this time” or "No known prevention or detection."

Examples of Controls

Examples of controls include engineering analysis tools (e.g., load calculation, finite element analysis), tests, design review, or other advanced inspection or control methods.

Specific examples of methods may include some of the following:

- Computer simulation
- Mathematical models
- Breadboard tests
- Laboratory tests on surrogate elements

Detection

Detection

Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.

Tip

In a Concept FMEA, there may be instances of "no detection at this time," which requires a rating of 10 to be entered in the Current Controls column. If a Detection rating of 10 is entered, a Recommended Action should also be listed to identify and implement a detection method.

Risk Priority Number

Risk Priority Number

Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.

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Recommended Actions

Recommended Actions

Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.

Note: Corrective action should be first directed at the highest ranked concerns and critical items. Only a product design revision can bring about a reduction in the Severity ranking if the effect is due to the failure of a product function. A process change can reduce the severity for in-process effects only (i.e., machinery operator safety concerns). A reduction in the Occurrence ranking can be effected only by removing or controlling one or more of the causes/mechanisms of the failure mode through a concept proposal revision. An increase in validation/verification actions will reduce the Detection ranking only. The intent of any Recommended Action is to reduce one or all of the Severity, Occurrence, and/or Detection rankings, in that order.

Design requirements may be translated into system or hardware Engineering Specifications and incorporated into a System Design Specification for future programs. Process Concept FMEAs may determine actions that include changes to machinery and equipment specifications.

If no actions are recommended for a specific cause, indicate this by entering a “None” or “None at this time” in this column.

How to Identify Recommended Actions

Typical actions may include the following:

- Modify the proposal to eliminate its failure mode or reduce its rate of occurrence.
- Add a redundant system that allows system operation to continue at the same or at a degraded functional level.
- Provide other modes of operation that allow proposed operation to continue at the same or at a degraded functional level.
- Add built-in detection devices to alert the customer to take action that will prevent a failure mode, or reduce its rate of occurrence.
- Specify a certain type of material.
- Utilize alternate concept.

Continued on next page

Recommended Actions, Continued

Examples of Recommended Actions

Examples of potential actions are:

- Revise SDS to include temperature range requirements.
- Perform computer simulation to assure functioning in required temperature range.
- Add an audible and illuminated dashboard warning to indicate imminent system failure.
- Implement strategy to disable automatic operation and revert to full manual upon failure.
- Revise specifications to add a safety curtain.
- Review present operator training plans for adequacy and determine necessary modifications.

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Actions Taken

Actions Taken	Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.

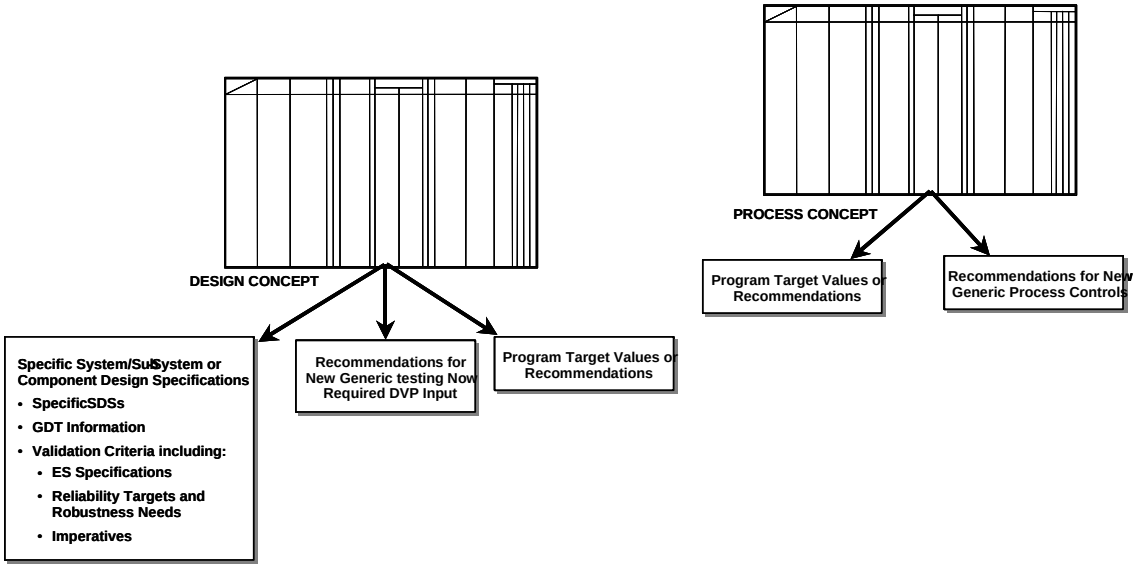
Resulting RPN

Revised Severity, Revised Occurrence, Revised Detection, and Revised RPN	Refer to the relevant Design FMEA or Process FMEA section of the FMEA Handbook.

Outputs from Concept FMEA

Outputs from Concept FMEA

Typical outputs from a Concept FMEA developed for a design proposal are shown in the graphic below. Many of these outputs are inputs to the Design FMEA.



Section 6 – Special Characteristics
Contents

In This Section

Description	See Page
Introduction to Special Characteristics	6-2
Characteristics Classification	
Characteristic Classification Hierarchy	6-3
Special Characteristic Classification	6-4
Classifications	6-4
Definition of Critical Characteristics	6-5
Definition of Significant Characteristics	6-5
OS Characteristics	6-6
HI Characteristics	6-6
Special Controls	
Special Controls	6-7
Special Characteristic Needs	6-7
Special Characteristic Identification	
Special Characteristic Identification Strategy	6-8
Process Steps	6-8
Documentation and Communication	
Control Plans	6-9
Critical Characteristics	6-9

Introduction to Special Characteristics

Introduction to Special Characteristics

All products and processes have features described by characteristics that are important and need to be controlled. However, some characteristics (called Special Characteristics) require extra attention/efforts to minimize the risk of adverse consequences.

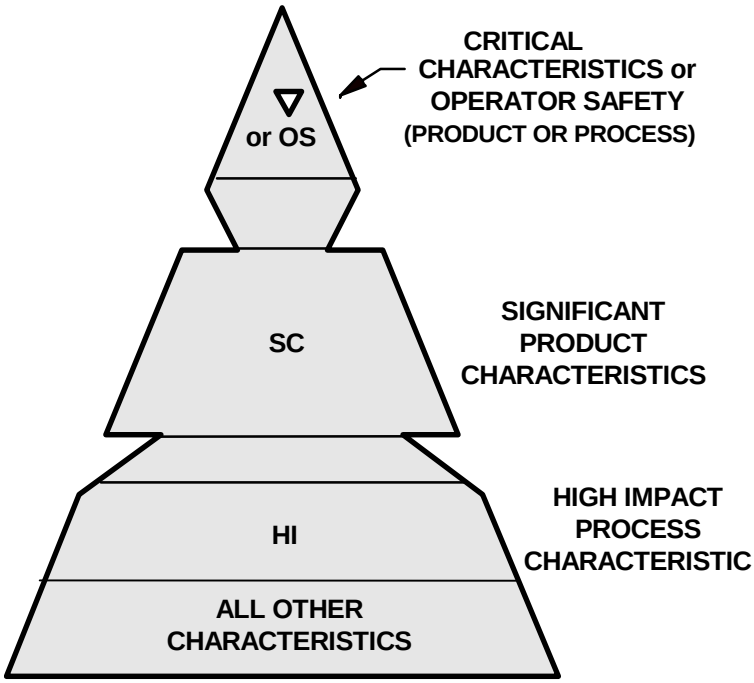
Special Characteristics are those product or process characteristics that affect vehicle or process safety, compliance with government regulations, or customer satisfaction, and for which specific actions are required to ensure products will meet all engineering requirements as well as requirements for operator safety.

FAP 03 –111, Selection and Identification of Significant and Critical Characteristics, establishes the process using FMEA for the selection, identification, rationale, and control of product and process Critical Characteristics (∇, sometimes referred to as CC) and Significant Characteristics (SC). In this section, in addition to Significant and Critical Characteristics, two other special processes related characteristics, High Impact (HI) and Operator Safety (OS), have been also defined.

Characteristic Classification

Characteristic Classification Hierarchy

The characteristic classification hierarchy is as follows:



- Characteristics are either Special or not.
- Special Characteristics can be classified as Critical, Significant, Operator Safety, or High Impact.
- Special Product Characteristics (∇ and SC) must be designated and included in Control Plans.
- All other characteristics are not designated.

Continued on next page

Special Characteristic Classification

Classifications The following table contains the possible characteristic designations for both Design and Process FMEAs.

DFMEA/PFMEA Special Characteristic Table					
	FMEA Type	***Classification***	***To Indicate***	***Criteria***	***Actions Required***
Customer/Product Effect	Design	YC	A potential Critical Characteristic (Initiate PFMEA)	Severity = 9, 10	Highlight for PFMEA Team Focus
	Design	YS	A potential Significant Characteristic (Initiate PFMEA)	Severity = 5 - 8 and Occurrence = 4 - 10	Highlight for PFMEA Team Focus
	Design	Blank	Not a potential Critical Characteristic or Significant Characteristic	Other	Not Required
	Process	∇	A Critical Characteristic	Severity = 9, 10	Special Control Required*
	Process	SC	A Significant Characteristic	Severity = 5 - 8 and Occurrence = 4 - 10	Special Control Required*
Manufacturing/ Assembly Effect	Process	HI	High Impact	Severity = 5 - 8 and Occurrence = 4 - 10	Emphasis
	Process	OS	Operator Safety	Severity = 9, 10	Safety Sign-Off
	Process	Blank	Not a Special Characteristic	Other	Does Not Apply

* Included in the Control Plan

Continued on next page

Special Characteristic Classification, Continued

Definition of Critical Characteristics

Critical Characteristics (∇) are those product parameters and requirements that can affect compliance with government regulation or safe vehicle/product function, and require special actions or controls that must be listed on a Control Plan.

- Product or process parameters and requirements can include dimensions, specification tests, processes, assembly sequences, tooling, joints, torques, and other characteristics.
- Special actions/controls can include manufacturing, assembly, supplier, shipping, monitoring, and/or inspection.
- A Design FMEA indicates potential Critical Characteristics (YC). A Process FMEA confirms whether a characteristic is Critical and the implementation of Special Controls.
- The design responsible organization must sign off on all Control Plans as part of the Process FMEA team.

Definition of Significant Characteristics

Significant Characteristics (SC) are those product parameters and requirements that are important for customer satisfaction and for which Quality Planning actions must be addressed on a Control Plan.

- A Design FMEA indicates potential Significant Characteristics (YS). A Process FMEA confirms whether a characteristic is Significant and the need for the implementation of Special Controls.
- All Significant Characteristics should be included in the Control Plan.

Continued on next page

Special Characteristic Classification, Continued

The classification of the Operator Safety (OS) and High Impact (HI) are two Special Characteristics that have not been defined in FAP 03-111.

OS Characteristics

Operator Safety (OS) characteristics are related to parameters that do not affect the product but may have an impact on the safety or governmental regulations applicable for the process operation, e.g., Occupational Safety and Health Administration [OSHA] requirements, Ford Health and Safety Specifications. This is a hazard for in-plant operators. These characteristics should be included on a safety sign-off.

These are failure modes with a severity rating of 9 or 10 due to an effect of the process on the process operator.

HI Characteristics

High Impact (HI) Characteristics are related to parameters that severely affect the operation of the process or subsequent operations if they are outside of the specification tolerance.

When characteristics are related to improper manufacturing and/or assembly operations that may result in subsequent operations being precluded, or mis-performed, these characteristics should not be designated as Critical or Significant but High Impact. Manufacturing/ Assembly operations should be keyed (error-proofed) to preclude misbuilds.

Continued on next page

Special Controls

Special Controls

Special Controls are those manufacturing and assembly process methods, administrative actions, techniques and tests beyond the normal and customary controls used to detect and/or contain Special Characteristic-related product defects. This type of controls will prevent the shipment of a product not acceptable to the end customer and is part of the Quality System shown on the control plan.

Special Controls are:

- Aimed at detecting and containing a Special Characteristic-related (∇ and SC) defect prior to shipment.
- Documented on Control Plans.

CAUTION

The designation criteria for Product (Critical or Significant) Characteristics cannot be changed.

Special Characteristic Needs

Each Special Characteristic should be considered independently; ∇, SC, OS, or HI symbols should never be applied in a “blanket” fashion.

Every ∇ and SC must have an associated Process Control listed on the Control Plan.

Special Characteristic Identification

Special Characteristic Identification Strategy

- Every effort must be made to eliminate Special Characteristics and Special Controls through design actions to improve product robustness, or through process improvements that focus on improving process capability and safety.
- Special Characteristics are confirmed only after all design/process alternatives are exhausted and when necessary associated Special Controls are identified or safety sign-off is required.

Process Steps

- For the designation of the Critical and Significant Characteristics, follow the procedure described in FAP 03-111.
- For the designation of the Operator Safety and High Impact Characteristics, use the following procedure:
  - The Manufacturing Team is responsible for the designation of both OS and HI characteristics.
  - From the Process FMEA conducted, for the operator safety related process characteristics with final severity ratings of 9 & 10, they should be confirmed as OS.
  - From the Process FMEA conducted, for the product or process characteristics that severely affect the operation of the process or subsequent operations when outside of the specification tolerance with severity ratings of 5-8, and occurrence rating of 4-10, they should be confirmed as HI.

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Documentation and Communication

Control Plans

Special Controls associated with Critical and Significant Characteristics that are confirmed in the Process FMEA must be documented and communicated. Refer to the Advanced Product Quality Planning (APQP) Reference Manual for further details on control plans.

Every confirmed product Special Characteristic must be shown on a completed control plan that has been approved by the responsible Ford engineer(s) and the Supplier.

Control Plans are discussed in more detail in Appendix page B-31.

Critical Characteristics

- Critical Characteristic folder located at www.ekb.ford.com (EKB Home > Product Development > Quality & Reliability) is the corporate repository for the Critical Characteristics identified for all the vehicle systems. The Critical Characteristic list stored in this folder is a minimum mandatory list for the related systems. Additional Critical Characteristics should be added per the programs needs.
- Program teams having concerns about individual items on the list must contact the affected Campaign Prevention Specialist (CPS) or Tech Club leader, and follow the change control process established in FAP 03-111.

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Appendix A – FMEA Forms Contents

In This Section

Description	See Page
Design Concept FMEA Form	A-2
Process Concept FMEA Form	A-3
Design FMEA Form	A-4
Process FMEA Form	A-5
Machinery FMEA Form	A-6

Design Concept FMEA Form

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
DESIGN CONCEPT FMEA

___ System
___ Subsystem
___ Component _____ Design Responsibility: _____
Model Year(s)/Program(s): _____ Key Date: _____
Core Team: _____

FMEA Number: _____
Page _____ of _____
Prepared By: _____
FMEA Date: (Orig.) _____ (Rev.) _____

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control: Prevention	Current Control: Detection	Detect	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Action Results: Sev	Action Results: Occ	Action Results: Det	Action Results: R.P.N.

FMEA Forms

Process Concept FMEA Form

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
PROCESS CONCEPT FMEA

FMEA Number: _____

Page _____ of _____

Item: _____ Process Responsibility: _____ Prepared By: _____

Model Year(s)/Program(s): _____ Key Date: _____ FMEA Date: (Orig.) _____ (Rev.) _____

Core Team: _____

Process Function / Requirements	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control		Detec	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
							Prevention	Detection					Actions Taken	Sev	Occ	Det	R.P.N.

FMEA Forms

Design FMEA Form

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
DESIGN FMEA

___ System
___ Subsystem
___ Component _____
Model Year(s)/Program(s): _____

Design Responsibility: _____
Key Date: _____

FMEA Number: _____
Page _____ of _____
Prepared By: _____
FMEA Date: (Orig.) _____ (Rev.) _____

Core Team: _____

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control		Detec	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
							Prevention	Detection					Actions Taken	Sev	Occ	Det	R.P.N.

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Process FMEA Form

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
PROCESS FMEA

FMEA Number: _____

Page _____ of _____

Item: _____ Process Responsibility: _____ Prepared By: _____

Model Year(s)/Program(s): _____ Key Date: _____ FMEA Date: (Orig.) _____ (Rev.) _____

Core Team: _____

Process Function / Requirements	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control		Detec	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
							Prevention	Detection					Actions Taken	Sev	Occ	Det	R.P.N.

Machinery FMEA

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
MACHINERY FMEA

___ System
___ Subsystem

Machinery/System: _____ Design Responsibility: _____

Model Year(s)/Program(s): _____ Key Date: _____

Core Team: _____

FMEA Number: _____

Page _____ of _____

Prepared By: _____

FMEA Date: (Orig.) _____ (Rev.) _____

Subsystem / Function Requirements	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Control: Prevention	Current Control: Detection	Detect	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Action Results: Sev	Action Results: Occ	Action Results: Det	Action Results: R.P.N.

Appendix B – Helpful Tools for FMEA
Contents

In This Section

Description	See Page
Boundary Diagrams	
Major Types of Boundary Diagrams	B-4
Rules and Guidelines for Creating Boundary Diagrams	B-4
Functional Boundary Diagram Example	B-5
Functional/Hardware Boundary Diagram Example	B-6
Process Flow Diagram Example for Process FMEA	B-6
Additional Boundary Diagram Example	B-7
Process Flow Diagram	B-8
Characteristic Matrix	B-9
Function Description: Verb-Noun Thought Starters	B-10
Verbs	B-10
Nouns	B-11
Brainstorming	
Introduction	B-12
Generating Ideas	B-12
Step 1 - Warm-Up	B-13
Step 2 - Suspend Judgement	B-13
Step 3 - Anything Goes	B-14
Step 4 - Quality Counts	B-14
Step 5 - Springboard	B-14
Step 6 - Keep Going!	B-14
Step 7 - Warm-Down	B-14
Pitfalls	B-15
Getting to Agreement	B-16
Important Points	B-17

Continued on next page

Appendix B – Helpful Tools for FMEA, Continued

In This Section (Continued)

Function Trees	
Describing Function	B-18
Kano Model	B-18
Function Tree Construction	B-18
Driver Seat Function Tree	B-19
Function Tree Development	B-20
Function Tree Diagram	B-21
Effects List: Design FMEA	B-22
Effects List: Process FMEA	B-23
Ishikawa "Fishbone" Diagram	
What is an Ishikawa "Fishbone" Diagram?	B-24
How is an Ishikawa "Fishbone" Diagram Used?	B-24
When Should an Ishikawa "Fishbone" Diagram Be Used?	B-24
Generic "Fishbone" Diagram	B-24
Example Failure Causes	B-24
Sentencing Technique	
Confusion about Failure Mode, Cause and Effect	B-25
Sentencing Technique	B-25
Graphic Illustration of the Sentencing Technique	B-25
How to Use the Sentencing Technique	B-26
Fault Tree Analysis (FTA)	
What is Fault Tree Analysis?	B-27
How is FTA Used?	B-27
When to Use FTA and When to Use FMEA?	B-27
Failure Mode Analysis (FMA)	
What is Failure Mode Analysis?	B-28
How is FMA Used?	B-28
When is FMA Used Instead of FMEA?	B-28
Design of Experiments (DOE)	
What is Design of Experiments?	B-29
How is DOE Used?	B-29
When is DOE Used?	B-29

Continued on next page

Appendix B – Helpful Tools for FMEA, Continued

In This Section (Continued)

Global 8D	
What is Global 8D Approach?	B-30
How is Global 8D Used?	B-30
When is Global 8D Used Instead of FMEA?	B-30
Control Plans	
What is a Control Plan?	B-31
When Are Control Plans Used?	B-31
First Application	B-31
Second Application	B-32
Third Application	B-32
Why Are Control Plans Used?	B-32
Control Plan Example	B-33
Dynamic Control Planning (DCP)	
What is Dynamic Control Planning (DCP)?	B-34
Dynamic Control Planning Process Steps	B-34
Quality Function Deployment (QFD)	
What is Quality Function Deployment (QFD)?	B-37
How is QFD Used?	B-37
Value Analysis/Value Engineering (VA/VE)	
What is Value Analysis (VA)/ Value Engineering (VE)?	B-38
How is VA/VE Used?	B-38
REDPEPR	
What is REDPEPR?	B-39
Where to Get More Info and Software	B-39
FMEA Express	
What is FMEA Express?	B-40
How Does the FMEA Express Process Work?	B-40
How to Get Started With FMEA Express	B-40
FMEA Software	
Available FMEA Software	B-41

Boundary Diagrams

Major Types of Boundary Diagrams

The two major types of Boundary Diagrams are:

1. **Function Boundary Diagrams**: Function boundary diagrams are the output of a function analysis. They are used when a system is in the conceptual phase. They illustrate functions instead of parts and are used primarily to explain what system functions are achieved. This type is most commonly used for Concept FMEA development.
2. **Functional/Hardware Boundary Diagrams**: Functional boundary diagrams are used to divide a system into its smaller elements from a functional standpoint. They are used to show physical relationships. They illustrate the composition of a system in terms of function and physical structure. These are most often used in DFMEAs.

Rules and Guidelines for Creating Boundary Diagrams

There are no hard rules for constructing functional boundary diagrams. Some basic guidelines are listed below:

- Start at the highest level of interest. If you are interested in a system, start there. If you are interested in an assembly, start there.
- Determine the next lower level elements (blocks) that make up the system, subsystem, assembly, etc. Go to succeeding lower levels according to the detail available.
- Make sure every function is included within one or more blocks. Show functions in the sequence in which they are performed.
  - For the functional approach: list all the required functions and show the interactions of the proposed system elements.
  - For the hardware approach: obtain a component-level drawing showing all hardware and how these elements interact.
- Identify inputs to the system (including inputs from the customer) and outputs from the system. Use a P-diagram and an interface matrix in this process.
- Determine the interrelationships among elements (blocks) of the system.
  - Illustrate the flow of information, signals, fluid, energy, etc.
  - Draw lines showing inputs, outputs, relationships, and flow.
  - Show a dashed box around the boundary.

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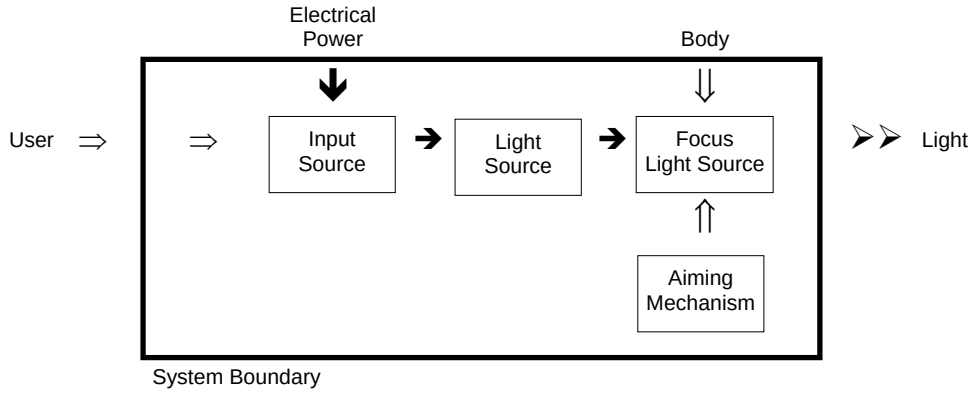
Boundary Diagrams, Continued

Functional Boundary Diagram Example

Concept or Design FMEA at system level:

HEADLAMP SYSTEM
FUNCTIONAL BOUNDARY DIAGRAM



Legend

Interface Key:		Interfacing Systems:
➔	Electrical (wire/connector)	Body
⇒	Mechanical	Electrical
➢	Light	

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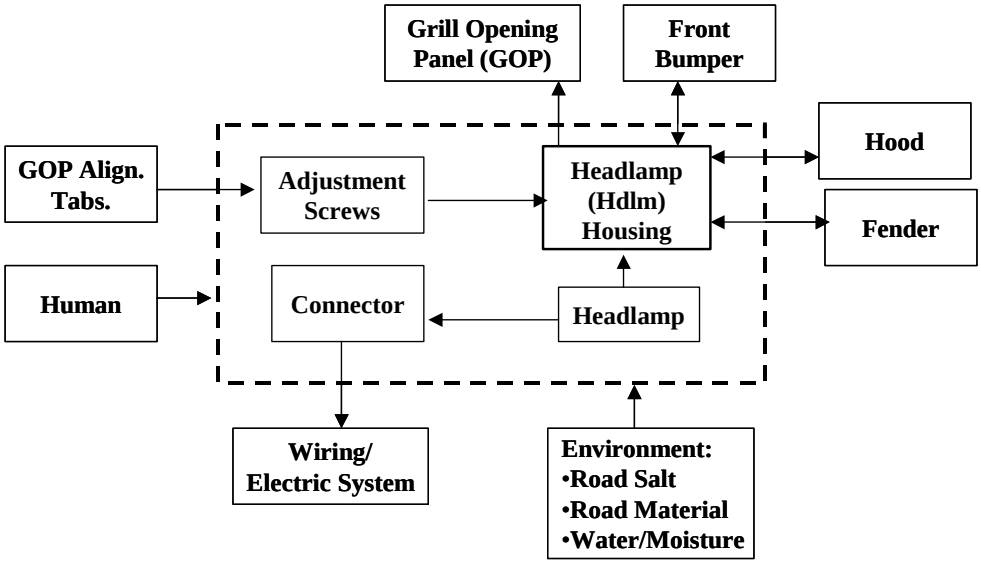
Boundary Diagrams, Continued

Functional/ Hardware Boundary Diagram Example



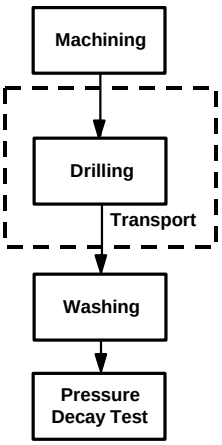
* Denotes Relationship between hardware that goes on Interface Matrix

Note: Only the hardware components appear in boxes on a boundary diagram. Once all of the hardware is identified by blocks, the relationships between the blocks, indicated by a box with a dotted line and an "*", are then transferred to the Interface Matrix.

Note: Boundary Diagram items not shown in boxes are P-Diagram noise factors that can lead to failures.

Note: GOP is the abbreviation for Grill Opening Panel

Process Flow Diagram Example for Process FMEA



Note: This technique, covered in more detail in the following chapter, is similar to a boundary diagram. It is used as a preliminary planning tool for a new process.

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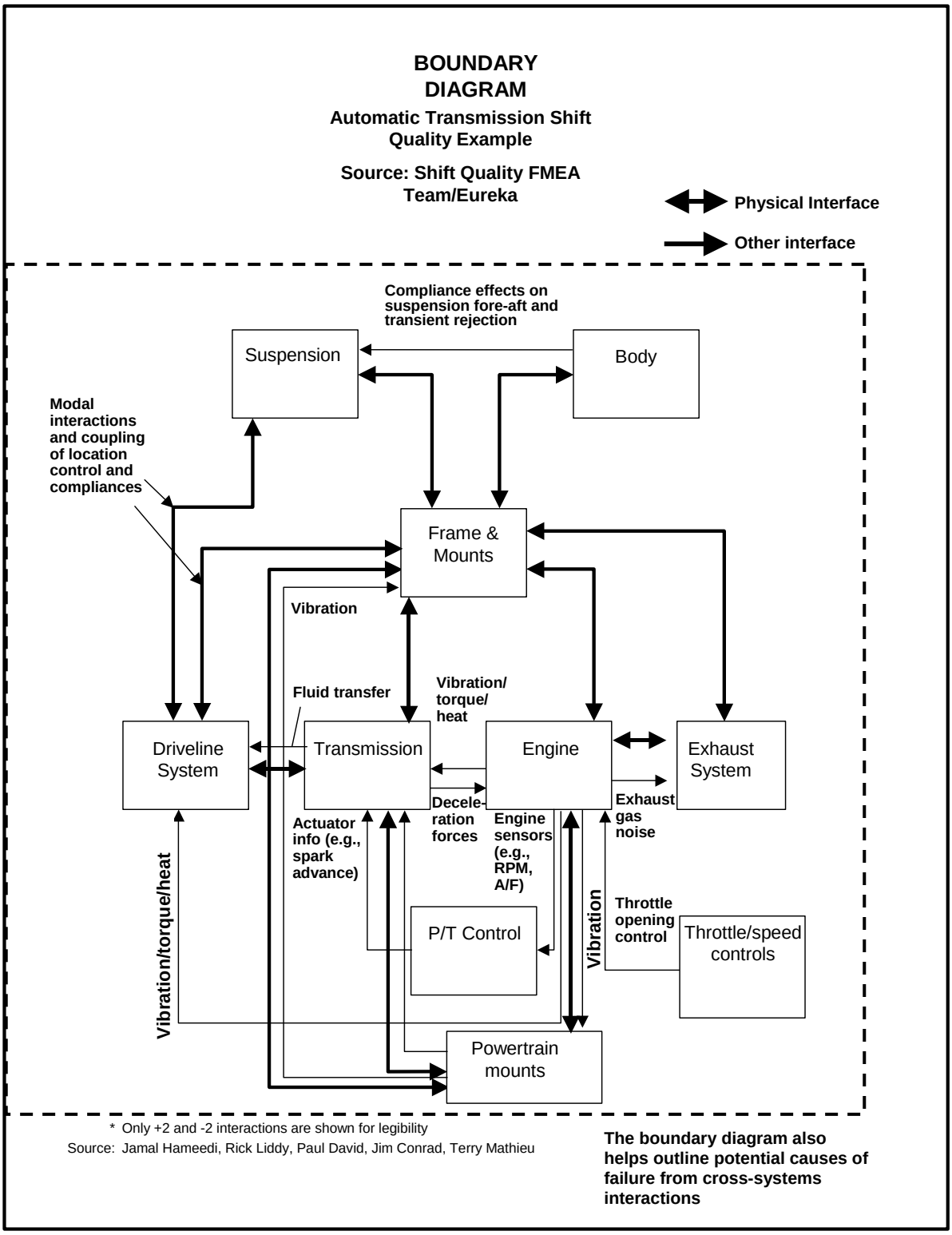
Boundary Diagrams, Continued

Additional Boundary Diagram Example



Process Flow Diagram

Process Flow Diagram

Analyze the flow of the process. A flow diagram can be used and is based upon the collective team knowledge of the manufacturing and assembly processes required. Ask questions such as "What is the process supposed to do? What is its purpose? What is its function?"

A typical process flow diagram is shown below.

Sources of Variation	Purpose Process Identification	Graphical Flow of Operations	Product & Process Characteristics
• Supplier responsibility	005-1: Frozen ham-burger patties	005-1	• Supplier responsibility
• Circuit breaker pops out in summer • Too busy to pull burgers out of cooler	010: Thaw in cooler	010	1 • Bacteria count < federal maximum 2 • Thawed temperature 32 to 40 °F 3 • Use in <60 hours
• High turnover so operator is not trained	020: Place patties on grill conveyor	020 2	4 • Two patties on grill conveyor
• Operator too busy to pay attention • Grill hard to clean • Operator has a cold and cough • Grill heating elements burn out rapidly	030: Cook patties on grill conveyor	030 2	• Bacteria count < Max 5 • Cooked diameter 3.750" ± 0.125" 6 • Cooked temperature 170 ± 5 °F 7 • Grill temperature X conveyor speed interaction per Equation 30-1
• Sensors hard to calibrate • Boss over-rules scrap decision	040: Measure cooked patties	Scrap 040 OK	• Cooked diameter information
• Supplier DCP responsibility	005-2: Buns	005-2	8 • Bun diameter 3.875" ± 0.125"
• Operator hurries & drops patties • Patties stick to dirty spatula	050: Remove patties from grill	050	9 • Two patties off grill, on wide spatula
• High turnover so operator is not trained • Buns hard to separate, top from bottom	060: Place buns on assembly table	060 2 To OP70	10 • Two bun bottoms on assembly tray

Characteristic Matrix

Characteristic Matrix

This matrix is an aid in developing product-to-process and product-to-product linkage.

Legend

- X -- Characteristic is created or changed
- C -- Characteristic is used for clamping
- L -- Characteristic is used for locating
- T -- Common tool creates more than one characteristic
- M -- Characteristic is automatically monitored
- A -- One finished product characteristic has a strong affect on another

Characteristic Matrix

Product Characteristics	Operations													
	010	020	030	040	050	060	070	080	090A	090B	100	110	120A	120B	130
Bacteria count < Federal maximum	X		X												X
Two patties on grill conveyor		X T													
Cooked temperature, ≥165° F			X												
Cooked diameter, 3.750" ± 0.125"			X	M			C								
Two patties off grill, on wide spatula					X T										
Two bun bottoms on assembly tray						X									
Bun diameter, 3.875" ± 0.125"							C L				C L				
Two cooked patties, one per bun							X								
Patty to bun concentricity, 0.125"							X								
Correctly place cheeseburger or hamburger on demand								X				X			
Amount of sauce, 3 tsp. ± 0.5 tsp. Location of sauce, center 2" of patty									X T						
Cheese, 3.5" ± 0.1", square shape										C L					
All 4 corners of cheese in patty circle Assemble cheese, then sauce										X					
Top bun to bottom bun concentricity, 0.125"											X				
Yellow wrapper for cheeseburger, white wrapper for hamburger												X			
One wrapper per burger Wrapper folded per visual aid													X T		
Burger hold temperature, >120° F			A										A		X
Bun softness rating, ≤ 3															X
FIFO timing															X

Helpful Tools for FMEA

Function Description: Verb-Noun Thought Starters

Verbs

absorb
accelerate
access
accommodate
actuate
adapt
add
adjust
advise
aid
alert
align
apply
assemble
assure
attach
attenuate
attract
balance
blend
bore
carry
check
circulate
clean
conceal
conduct
connect
conserve
control
convert
convey
cover
create
dampen
decrease
deflect
deliver
demonstrate
depress
differentiate
direct
dispense
display
distribute
drill
eliminate
emit
enclose
encourage
enhance
extend
fasten
feel
fill
finish
flash
flow
force
form
fuel
generate
grasp
grind
grip
guide
hinder
hold
house
identify
illuminate
impede
improve
increase
injure
inspect
insulate
integrate
isolate
join
limit
load
locate
lock
look
lubricate
maintain
manage
meet
mill
modulate
move
notify
obtain
organize
orient
output
paint
perform
permit
pivot
position
preserve
press
prevent
produce
promote
protect
receive
reduce
regulate
release
relocate
remove
repair
reserve
resist
rest
restrain
retain
rework
rotate
route
satisfy
scrap
seal
seat
secure
select
sense
shelter
shift
sound
space
squeeze
store
suggest
supply
support
tap
torque
transfer
transmit
transport
trim
verify
warn
weld
wet
wipe

Try to avoid using these words:

- **allow**
- **facilitate**
- **provide**

Continued on next page

Function Description: Verb-Noun Thought Starters, Continued

Nouns

access
aesthetics
air
alarm
alignment
appearance
assembly
attachment
balance
bending
bin
bolt
burr
casting
cause
circuit
cleanliness
climate
cold
color
comfort
component
consumer
container
control
convenience
correction
corrosion
cover
craftsmanship
current
customer
damage
defect
device
dimension
dirt
disc
door
drag
driver
egress
electronics
element
energy
entertainment
enthusiasm
entry
environment
equipment
ergonomics
fastener
features
feedback
finish
fixture
flash
flow
fluid
FMVSS
force
frequency
friction
fuel
gage
gas
glue
head
headlamp
heads
hole
identification
illumination
impact
indicator
information
injury
inside diameter (ID)
installation
instruments
interchange
interior
inventory
label
lamp
length
light
locator
lock
lubricant
luxury
machine
mass
message
module
moisture
mold
motion
mount
mounting
noise
obstacles
occupant
operations
operator
options
outside diameter (OD)
panel
part
passenger
path
performance
pressure
priority
quality
radiation
recyclability
reflectivity
resonance
restore
rust
safety
sail
sale
satisfaction
schedule
scrap
screw
seat
seat track
security
service
serviceability
shape
sheet metal
shifter
signal
snap ring
sounds
speed
stability
steering
storage
structure
style
styling
surface
switch
taillamp
tap
tell-tale
texture
theme
tool
torque
torsion
travel
trim
uniformity
unit
utility
vehicle
vibration
visibility
vision
visor
warning
waste
weight
wheel
wiring

Brainstorming

Introduction

As children we think creatively. Just watch a child playing with his/her toys (or even with the box that they came in) and you will notice not only the range of ideas but also the vivid imaginations.

When children enter the educational system something changes. They are trained to be more disciplined in their approach and to seek the right answer rather than the wide choice of possibilities that they experienced in play. We enter school as question marks and leave as full stops.

A linear, single answer approach is a powerful tool when we need to consider, analyze, and judge. It is appropriate for most of the steps in problem solving, but in problem prevention we need to shift into possibility thinking. We change the emphasis from "Why did this happen?" to "What might go wrong?"

Generating Ideas

Brainstorming, a term invented by advertising consultant Alex Osborn, is an exercise in creative thinking and a method of generating ideas. In a brainstorm, we deliberately set out to build a creative environment conducive to innovative thinking.

Continued on next page

Brainstorming, Continued

Step 1
Warm-Up

Find a quiet place where there will be no interruptions. Arrange the seats to allow for open interaction among team members. Use some method, such as a flip chart or Post-it© notes, to capture the ideas. The method of capturing information needs to be flexible and unstructured.

The warm up might include a short exercise to loosen up the mental muscles. Don't forget to appoint a scribe – it is important that all the ideas generated are captured – and a time manager. But you won't need a leader; once the process starts all members of the team are equal and are encouraged to pitch in.

There should be a clear statement of purpose and the question(s) being asked of the group should be written up so they can be easily referred to during the brainstorm. Be careful with the phrasing of the questions, "What might go wrong?" is quite different from "Can anything go wrong?" and will lead to very different ideas. If we are going to "take the brakes off" let's make sure wee are heading in the right direction!

The agenda should include a time limit. It may be anything between 10 minutes and two hours, but during longer brainstorms it can be difficult to maintain the momentum.

Step 2
Suspend
Judgment

Research showed that less creative people tend to criticize and undervalue their own performance. Criticism, whether from self or others, inhibits the generation of ideas. Less experienced or not-so-confident team members fall silent. The atmosphere deteriorates as team spirit dwindles and more time is spent in defending ideas than in generating them.

Continued on next page

Brainstorming, Continued

Step 3
Anything Goes

Everyone is encouraged to let go, loosen up, free wheel and express whatever wild suggestions come to mind. Evaluative internal judgments are inhibited. Reservoirs of new ideas are tapped. Associative thinking comes to the fore. Old boundaries are crossed.

Step 4
Quality Counts

Go for quantity! Quality will be easily recognized at a later stage.

Step 5
Springboard

Combinations or modifications of previously suggested ideas lead to new ideas that may be better. But don't attempt to negotiate or explain during the brainstorm, just put out your ideas and make sure they are recorded. Explanations can come later (and often aren't even needed).

Sometimes your ideas will seem to be irrelevant and make no apparent sense. Say it anyway – it may feed someone else in the group.

Step 6
Keep Going

A time limit is important because it not only tells you when to finish but it also tells you when to keep going. In a brainstorm there is usually a point reached when ideas begin to dry up and it's important to keep going, to drive through the resistance. It is often the case that following a quiet period, ideas begin to flow that are particularly insightful or creative. Remember that the darkest hour is just before the dawn.

Step 7
Warm-Down

Following the generative stage of brainstorming there needs to be a reflective stage. This requires a change of pace and style. It would be appropriate to congratulate each other on the quantity of ideas generated and perhaps to take a break before resuming.

Continued on next page

Brainstorming, Continued

Pitfalls

A brainstorm can quickly go off course when some basic rules are forgotten. Here are some of the most common pitfalls:

- Low Team Trust: Half-hearted participation in a mistrustful team produces consistently shallow ideas or ideas of questionable taste. Nobody lets go for fear of criticism and ridicule.
- Broad Task Definition: If the actual objective or task is defined too broadly, it is difficult to generate specific, applicable, ideas. It will help if the task is repeated at regular intervals during the brainstorm.
- Criticism, Competition and Defensiveness: As the rules are forgotten, team members begin to compete, defend, dominate and criticize.
- Silliness: Sometimes a brainstorm can degenerate into silliness. While good humor can aid the creative process we need to make sure that we achieve the task.
- Questions and Explanations: When we put an idea forward we are used to “explaining ourselves,” why we think it will work, exactly what we mean. We often try to anticipate the questions that usually follow ideas. In brainstorming we need to let go of this norm, to simply express ideas and move on. Only the scribe should ask questions when he or she needs clarification or restatement.

Continued on next page

Brainstorming, Continued

Getting to Agreement

It is important to recognize that brainstorming is only part of the process – the ideas generated need to be moved forward.

During a brainstorm we don't question or comment – but we can now. We need to reach agreement on which ideas we wish to develop further. If this is to happen, members of the team (and especially the owner of the issue or concern) need to *understand* the ideas that have been generated.

In FMEA, we have a precise way of measuring the result of the brainstorm which is using the Risk Priority Number (RPN) and we need to examine all possible causes – we can't afford to miss any. When we work with the RPN, we need to decide on the severity of a failure, how likely it is to happen, and what the chance is of detecting the failure if it does happen.

Whether working with RPNs or not we will inevitably experience a range of views within the team about the ideas generated and there is inevitably a temptation to "go for the average" or to allow one or two strong views to drive the whole process.

Continued on next page

Brainstorming, Continued

Important Points

There may be disagreements and even conflict. Should there be conflict or deadlock at this stage, it is important to keep the team together and moving toward the best solution. It is useful to remember the following points:

- Everyone should be given the opportunity to explain his/her views. Team members will tend to listen, question, and give feedback.
- Identify the needs of the individual and look for ways to meet them. The need of the individual may not be what it first appears to be and very often is not what the individual says it is.
- If you can't meet a need – say so! Don't mislead or make promises you can't keep.
- Check out feelings – yours and others. Expressing feelings raises awareness of ourselves and of the team. It moves the team on.
- Don't go for compromise, averages, or "splitting the difference." To do so is often to take the middle ground, a position that no one in the team really supports. Averages do not reflect the range of views. Find out why people hold their views; allow them time to explain to the team. They may just be right!
- Use task, maintenance, and process checks.

Function Trees

Describing Function

A function tree can help to assure that the unspoken yet expected customer requirements of a product or process are met. It provides an organized approach to identifying the essential features of a product or process that must be addressed by its design.

It is convenient to describe the functions of a product or process by a verb-noun-measurable combination. For example, consider the functions of a vehicle heating and ventilation system. These are to:

- Warm the interior to xº
- Cool the occupants to xº
- Demist or defog the windshield in x seconds
- Etc.

Kano Model

In terms of the Kano model of quality features the functions listed above are basic features. This means that a poor performance or the failure of a product in terms of these functions will lead to customer dissatisfaction. By themselves, a good performance in terms of these functions will not result in customer satisfaction. Because a customer would not typically mention these items when asked for his or her requirements, the engineer must ensure that these basic quality requirements are met by a product or process through its design. Once these functions have been addressed through the design of a product or process, it is important to ensure that there are no failure modes associated with any of them.

Function Tree Construction

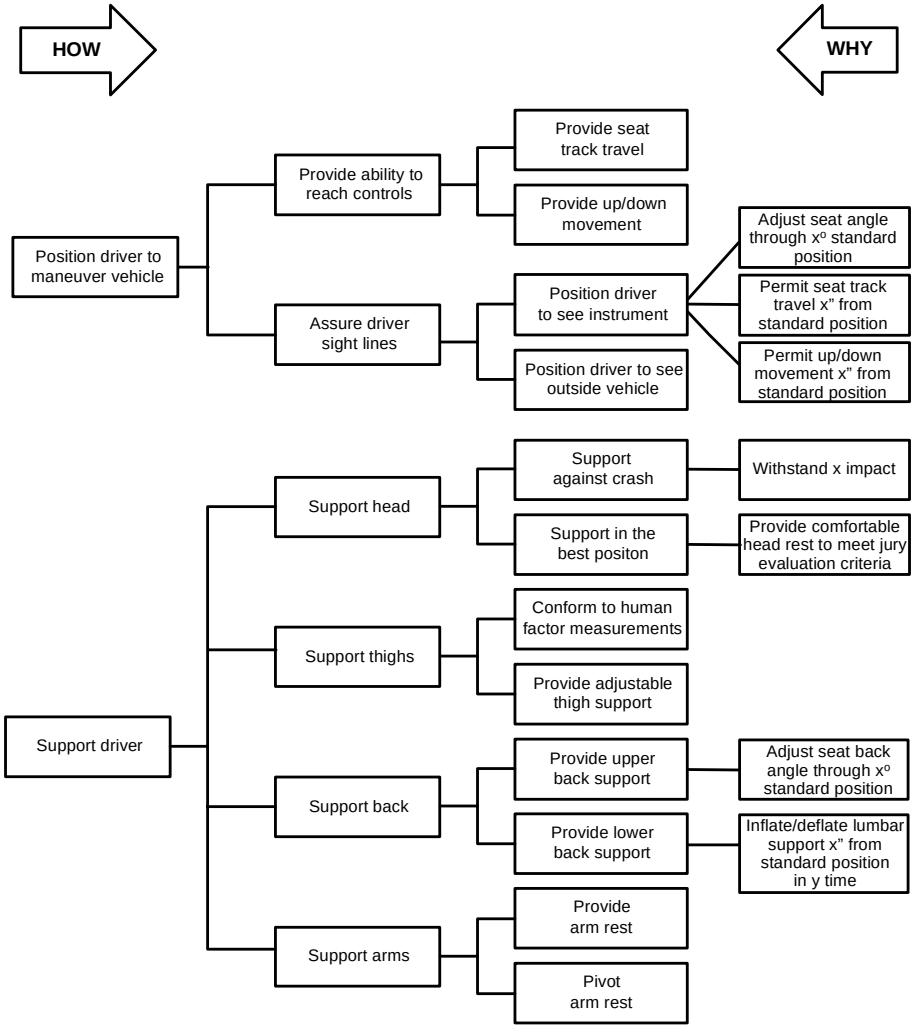
A function tree is constructed on a hierarchical basis with the hierarchy corresponding to increasing levels of functional detail. Typically the diagram builds from left to right and as it builds, the level of detail expands until it terminates at an "actionable level." An actionable or measurable level of detail is one on which an engineer can begin development work. Any given function, whether very general or very detailed, exists to describe how to accomplish the function that precedes it. As is shown by the function tree below for a car driver's seat, the reason for including a particular *function* is given by reading the function to its *left*. The way in which a particular function is *accomplished* is given by the function to its *right*.

Continued on next page

Function Trees, Continued

Driver Seat Function Tree

Driver Seat Function Tree Example



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Function Trees, Continued

Function Tree Development

A function tree can be developed by an FMEA team by completing the following steps:

1. Brainstorm all the functions of a product or process using a verb-noun-measurement combination to describe the function.
   - All functions include functions that are sometimes called primary functions as well as those called secondary or supporting functions. There may be more than one primary function. Primary functions are the most obvious reasons for the existence of the item under analysis.
   - Secondary or supporting functions are typically those which improve or enhance the item under analysis.
2. Record the individual functions on cards or Post-it™ notes.
3. Identify the first-level functions, record on cards or Post-it™ notes and place them to the left of the individual functions.
4. For each first-level function, ask the question, “How is this function to be achieved?” Place those functions that answer this question to the right of the first level function.
5. Repeat step 4 until a measurable level of function is identified.
6. Check that each actionable level function has been achieved by ensuring that it is measurable. Where this is not the case, continue to lower levels of function until a measurable level is identified.
7. Verify the structure of the function tree by starting at the measurable-level functions on the right and asking the question, “Why is this function included?” The function to the immediate left of the function being considered should answer this question.

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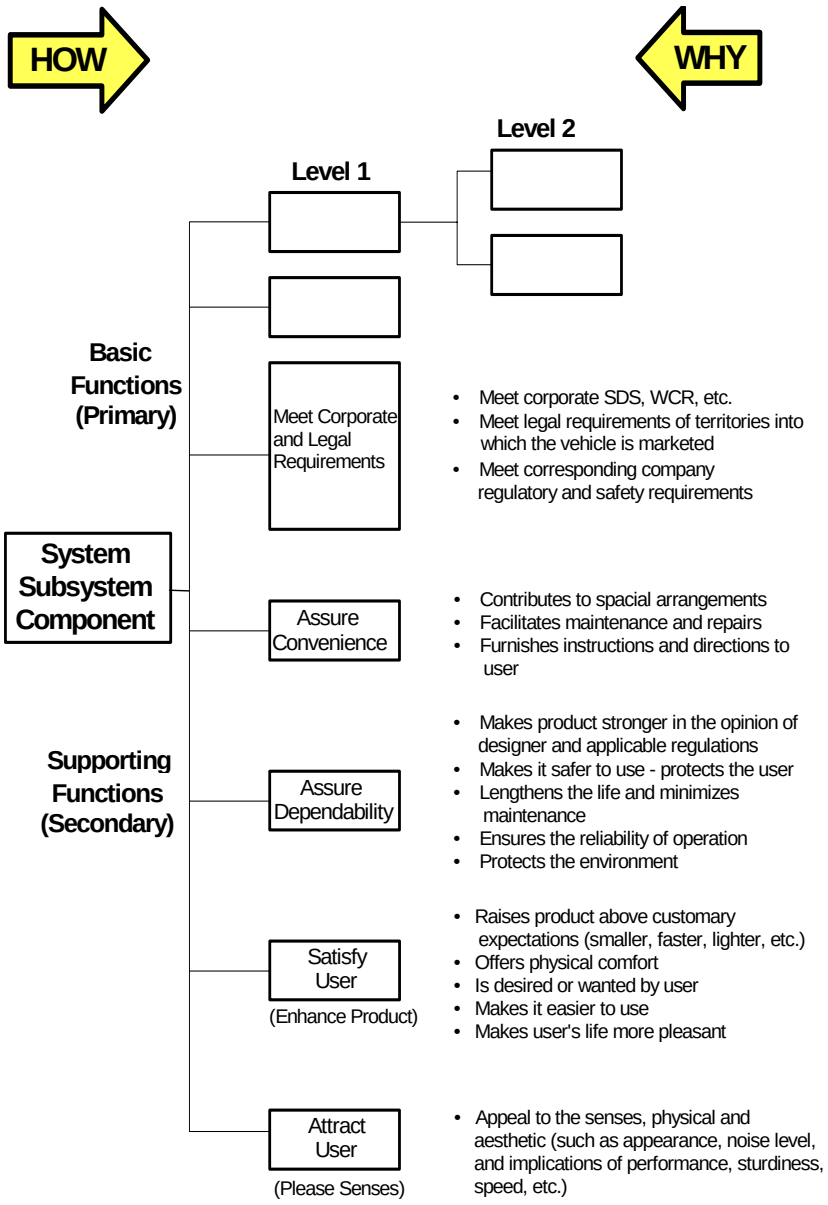
Function Trees, Continued

Function Tree Diagram



Helpful Tools for FMEA

Component/System:	Team:
Function:	Date:

Effects List: Design FMEA

		Effects					
Failure Mode	Part / Subcomponent	Next Higher Assembly	System	Vehicle	Customer	Government Regulations	Other

Helpful Tools for FMEA

Process Step:	Team:
Purpose:	Date:

Effects List: Process FMEA

		Effects					
Failure Mode	Next User	Downstream Users	Ultimate Customer	Vehicle Operation	Operator Safety	Government Regulations	Machines / Equipment

Helpful Tools for FMEA

Ishikawa "Fishbone" Diagram

What is an Ishikawa "Fishbone" Diagram?

An Ishikawa "Fishbone" diagram, also known as a Cause & Effect diagram, is a deductive analytical technique. It uses a graphical "fishbone" diagram to show the cause, failure modes, and effects relationships between an undesired event (Failure Mode) and the various contributing causes.

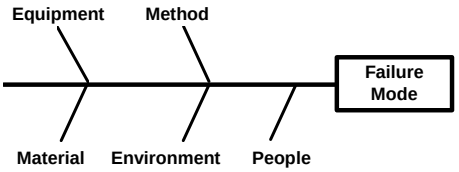
How is an Ishikawa "Fishbone" Diagram Used?

The effect, or Failure Mode, is shown on the right side of the fishbone chart, and the major causes are listed to the left. Often, the major causes (first-level causes) are shown as the major "bones" and can be summarized under one of five categories: Materials, Environment, People, machines (Equipment) and Methods (MEPEM).

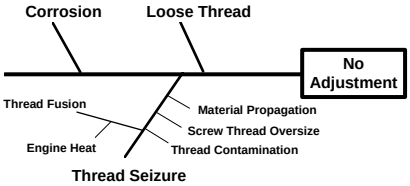
When Should an Ishikawa "Fishbone" Diagram Be Used?

Both the FMEA and the Ishikawa "Fishbone" Diagram deal with causes, failure modes, and/or effects.

Generic "Fishbone" Diagram



Example Failure Causes



Sentencing Technique

Confusion about Failure Mode, Cause and Effect

One problem encountered with FMEA is getting failure modes, effects and causes mixed up. The level the analysis is being carried out can complicate this.

Note that in FMEA, the cause is of the failure mode and never of the effect.

Sentencing Technique

Sentencing technique is to make a sentence using failure mode, cause and effect, and to see if the sentence makes sense. A failure mode is due to a cause. The failure mode could result in effects.

Example:

Failure Mode: No adjustment of headlamp

Q: What could "no adjustment of headlamp" result in?

A: Misaligned headlamp beams → Effect

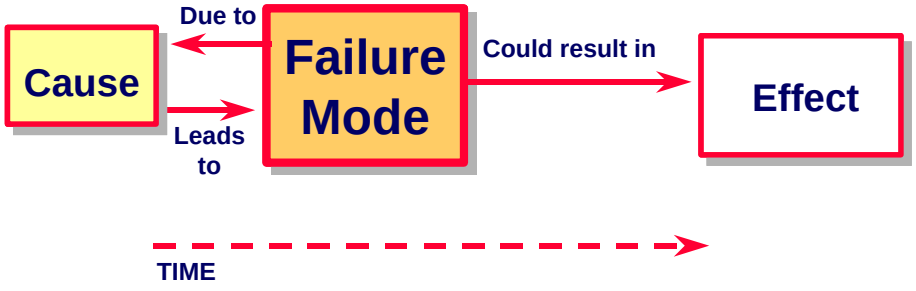
Q: What could "no adjustment of headlamp" be due to?

A: Thread seizure at adjustment screw → Cause

"No adjustment of headlamp" is due to "thread seizure at adjustment screw."

"No adjustment of headlamp" could result in "misaligned headlamp beams."

Graphic Illustration of the Sentencing Technique



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Sentencing Technique, Continued

How to Use the Sentencing Technique

To guarantee proper identification, use the sentencing technique to relate cause back to failure mode, not back to effect.

1. State the failure mode.
2. Ask what could that failure mode result in - the answer will be the effect.
3. Ask what could that failure mode be due to - the answer will be the cause.

Fault Tree Analysis (FTA)

What is Fault Tree Analysis?

Fault Tree Analysis (FTA) is a deductive analytical technique. It uses a graphical "tree" to show the cause-effect relationships between a single undesired event (failure) and the various contributing causes. The tree shows the logical branches from the single failure at the top of the tree, to the root cause(s) at the bottom of the tree. Standard logic symbols can be used to interconnect the branches for the various contributing cause(s). Use of these symbols helps identify when causes are independent of one another, or dependent.

How is FTA Used?

After the tree has been constructed and root causes identified, the corrective actions required to prevent or control the causes can be determined. Another common use of FTA is to determine the probabilities of the contributing causes and propagate them back up to the undesired failure. Through statistical methods, the individual probabilities can be combined into an overall probability for the undesired failure.

When to Use FTA and When to Use FMEA?

Both the FTA and the FMEA deal with causes and effects. The FTA technique can supplement the FMEA.

- In general, use FTA when one or more of the following conditions exist:
  - The primary objective is to identify the root factor(s) that could cause a failure and their interdependent relationships. The second objective is to determine the probabilities of occurrence for each causal factor.
  - There is a benefit to visualizing the analysis.
  - There is a need to determine the reliability of higher level assemblies, or of the system.
- In general, use FMEA when one or more of the following conditions exist:
  - The primary objective is to identify single-point failure modes that can have a serious effect on the customer or on compliance with a government regulation.
  - Preliminary engineering drawings are being prepared.
  - Manufacturing/assembly processes are being planned.

Failure Mode Analysis (FMA)

What is Failure Mode Analysis?

Failure Mode Analysis (FMA) is a disciplined systematic approach to quantify the failure modes, failure rate, and root causes of known failures. FMA is based upon historical information including warranty data, field data, service data, and/or process data.

How is FMA Used?

FMA is used to identify the operation, failure modes, failure rates and critical design parameters of existing hardware or processes. FMAs are used to identify corrective actions to eliminate or control the root causes of existing problems on the current production product or process.

When is FMA Used Instead of FMEA?

Both the FMA and the FMEA deal with failure modes and causes. The FMA of existing products usually precedes and feeds information into the FMEA for new products.

In general:

- FMA is used on current designs and/or processes when failure or repair rates are known.
- FMEA is used on new or changed designs and/or processes when failure or repair information is not available.

Design of Experiments (DOE)

What is Design of Experiments?

Design of Experiments (DOE) is a method to define the arrangement in which an experiment is to be conducted. An experiment is a study by which certain independent variables are varied according to a pre-defined plan and the effects are determined. DOE is also known as Experimental Design.

How is DOE Used?

For reliability tests, DOE uses a statistical approach to design a test that will identify the primary factors causing an undesired event.

When is DOE Used?

DOE is used as a technique to design an experiment that will identify the root cause(s) of a failure mode, when several causal factors may be contributing to the failure. It is also used when the causal factors are interrelated and it is necessary to learn how the interactions affect the failure mode.

Global 8D

What is Global 8D Approach?

The Global 8D Approach, formerly known as team Oriented Problem Solving (TOPS), is a team-oriented process whose primary function is problem solving. Global 8D is a reactive approach to resolving problems.

How is Global 8D Used?

The Global 8D disciplines are in a checklist of questions that must be continually addressed and answered during the problem-solving process. The disciplines are:

- Prepare for the Ford Global 8D process
- Establish the team
- Describe the problem
- Develop the interim containment action
- Diagnose problem: define and verify root cause and escape point
- Choose and verify Permanent Corrective Actions (PCAs) for root cause and escape point
- Implement and validate PCAs
- Prevent recurrence
- Recognize team and individual contributions

When is Global 8D Used Instead of FMEA?

Both the Global 8D and the FMEA deal with identifying problems and developing a solution to resolve the problem. Global 8D applies to any type of problem and is used as an approach to solve problems when creative, permanent solutions require input from, and participation by, many activities. FMEA is used as an approach to prevent potential problems from occurring. The Global 8D technique can supplement the FMEA.

Control Plans

What is a Control Plan?

A Control Plan is a written description of the system for controlling production processes. A Control Plan describes a producer's quality planning actions for a specific product or process. The Control Plan lists all process parameters and part characteristics that require specific quality planning actions. A Control Plan contains all applicable Critical and Significant Characteristics.

When Are Control Plans Used?

Control Plans are used at three phases within the Product Quality Planning Cycle. The initial application of the Control Plan is at prototype. A prototype is a description of the dimensional measurements, material and performance tests that will occur during prototype build.

First Application

This Control Plan is used when prototype builds are being performed. It measures the preliminary capability of the potential Special Characteristics identified early in the Design FMEA process. It provides information to the process planning group to select the best manufacturing and/or assembly processes simultaneously with product design.

Prototype production provides data from fabrication that can be used in quality planning. When the producer is also sourced with the production of prototypes, effective use should be made of data from prototype fabrication to plan the production process. The producer is responsible for the quality of prototypes provided to Ford. Specific requirements and supporting data (PIPC – Percent Indices that are Process Capable) may be required to support prototype vehicle evaluations (Reference: Supplier Quality Improvement Guidelines For Prototypes – Vehicle Operations SQE Office).

Continued on next page

Control Plans, Continued

When Are Control Plans Used?

Second Application

The second application of the Control Plan is at pre-launch. Pre-launch is a description of the dimensional measurements, material and performance tests that will occur after prototype and before full production.

This stage of Control Planning is crucial. It is within this time-frame that final processes are established for ongoing production. By selecting capable processes (as indicated by PIPC data) and striving for process controls that are normal and customary for all production, the number of Special Controls decreases. Eliminating the need for Special Controls changes the Special Characteristics to Normal/Other. Reaction plans for remaining Special Characteristics must be confirmed and forwarded to the Production Control Plan.

When Are Control Plans Used?

Third Application

The last and ongoing application of the Control Plan is at production. Production is comprehensive documentation of product/process characteristics, process controls, tests and measurements systems that will occur during mass production.

This final document summarizes the ongoing Special Controls still required after all design and process Recommended Actions have been taken. Further refinements to the Control Plan are made as new processes are implemented and capability is established.

Why Are Control Plans Used?

Control Plans are used to:

- Evaluate the preliminary capability of planned or recommended processes.
- Document sampling plans for production.
- Document reaction strategies for out-of-control product.

Properly deployed/implemented Control Plans will prevent process and product quality concerns from occurring at final manufacturing/assembly.

Continued on next page

Control Plans, Continued

Control Plan Example

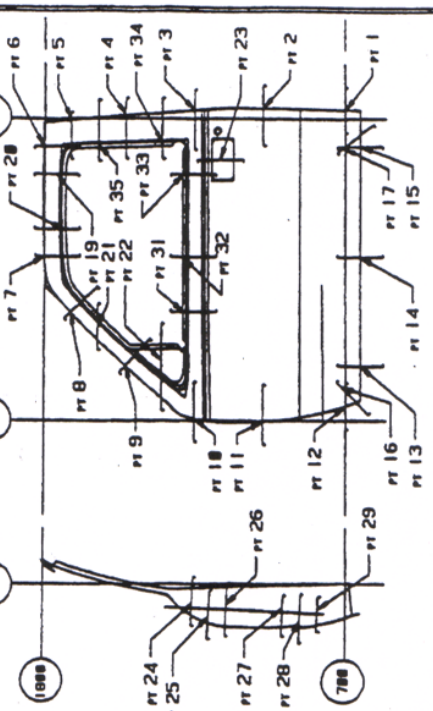
CONTROL PLAN (Part 1 - SC LIST)

Part Name Door Assembly, RH & LH	Product Engrg Designated Control Item (▽) ☒ Yes ☐ No	Issued Date 91 Mar 28	Revised Date 91 May 28
Part Number/Latest Release Date XXXX-XXXXXXX-XX, 91 Jan 31	Producer/Plant B&AO / Monroe Stamping Plant	Plant Approval/Date PLANT	
Product Engineering Approval/Date PRODUCT ENGINEER	Ford Quality Approval/Date QUALITY	Producer Approval Date SUPPLIER	
Other Team Member Approval/Date ASSEMBLY	Other Team Member Approval/Date TOOL SERVICES	Other Team Member Approval/Date DIMENSIONAL CONTROL DEPT	

Item No.	Description/Rationale	Tolerance	Class
1	Margin - Required for fit, finish and proper set of door at assy plant (SC-1)	1.0 Total	SC
2	Flushness - Required for fit, finish and proper set of door at assy plant (SC-2)	1.0 Total	SC
3	Glass Run Flange Depth - fit of run which affects water leaks & wind noise (SC-3)	1.0 Total	SC
4	Reinforcement Beam - Weld Strength	See Engrg Spec	▽
5	Glass Run Flange Length - affects position of glass run, potential wind & water leaks, or high glass moving efforts (SC-4)	1.0 Total	SC
6	Primary Seal Surface - determines collapse of seal bulb. (SC-5, SC-6)	1.0 Total 1.0 Total	SC SC
7	Flatness of Hinge Mounting Surface - affects smooth hinge operation & door closing efforts (SC-7)	0.5 Total	SC
8	Hole Location, Hinge Mounting - affects smooth hinge operation & door closing efforts (SC-8)	Ø 2.26 MMC Location Ø 0.7 MMC Pattern	SC
9	Position, Inner/Outer Belt Flanges - determines glass opening width. Affects window effort, NVH & Fit issues.(SC-9, SC-10)	1.0 Total 1.0 Total	SC SC
10	Position, Outer Panel Master Control Holes, Datums B & C. Locate door in assembly. (SC-11)	Ø 0.25 MMC	SC

Sketch / Pictorial

Data points and coordinates related to SC numbers are listed on the attached sheet.



Dynamic Control Planning (DCP)

What is Dynamic Control Planning (DCP)?

Dynamic Control Planning (DCP) is a process that links quality tools to build robust control plans. It strategically uses elements like flow charts, FMEAs, and control plans together, rather than separately, in a whole system approach to process planning. Quality analysis and planning tools are used, along with team experience, to produce a cohesive system of knowledge. Process controls are developed from this cohesive system of knowledge.

Dynamic Control Planning Process Steps

1. Launch
   - Define Resource Requirements
     - Certified DCP facilitator candidate
     - Process engineer/expert
     - Production personnel
     - Product support
     - Meeting facilities
2. Team Structure
   - Identify cross-functional core team
     - Certified facilitator/candidate
     - Process engineer/expert
     - Production personnel
   - Identify support personnel
     - Operators
     - Suppliers
     - Customers
     - Problem-solving experts
3. Question Log
   - Start question log for documenting questions and concerns

Continued on next page

Dynamic Control Planning (DCP), Continued

Dynamic Control Planning Process Steps (Continued)

4. Support Information
   - Collect, as available, the following:
     - Blueprint or equivalent information
     - Engineering specifications
     - DFMEAs
     - Prototype control plans
     - Design Validation Plan and Results
     - Special Characteristics list - SCs and CCs
     - DVP&R
     - Process sheets
     - Flowcharts
     - PFMEAs
     - DOEs
     - Control Plans, illustrations and instructions
     - Performance data - warranty, scrap, rework
     - Operational and maintenance data
     - Gauging/measurement techniques and performance
5. Flowchart and Characteristic Linkage
   - Define graphical representation and process identification
   - List written requirements
   - Identify linkages
     - Product families
     - Product characteristics relationships
     - Process-to-product characteristics relationships
   - Add key process parameters
   - Develop control relationships
   - Complete gauging and capability work
   - Define sources of variation
   - Eliminate obvious failure modes and causes
   - Preliminary process capabilities
6. Pre-launch or Preliminary Controls
   - Develop process controls
     - Install or deploy identified control methods

Continued on next page

Dynamic Control Planning (DCP), Continued

Dynamic Control Planning Process Steps (Continued)

7. PFMEA
   - Review existing PFMEAs
   - Test controls with PFMEA
   - Follow up on recommended actions
   - Define Critical and Significant Characteristics and their Special Controls
   - Close PFMEA until changes occur in process or product
   - Finalize production process controls
     - Develop reaction plans for each control
8. Control Plan
   - Write control plans
9. Develop Illustrations and Instructions
   - Cover setup, operation, gauging, controls, and reaction to controls
10. Implement and Maintain
    - Deploy Control Plan, illustrations and instructions to the workstation
    - Implement training and use of workstation documents
    - DCP maintenance activity
      - Minimum meeting requirements
      - Updating control plans
      - Linking performance to the Control Plan

Quality Function Deployment (QFD)

What is Quality Function Deployment (QFD)?

A structured method in which customer requirements are translated into appropriate technical requirements for each stage of product development and production.

Note that this is replaced by the new Applied Consumer Focus (ACF) training course.

How is QFD Used?

QFD data is input to the Design FMEA or the Concept Design FMEA. The data enters the FMEA as measurables in the Function column. The need to obtain QFD data may also be an output of a Concept FMEA.

Value Analysis / Value Engineering (VA/VE)

What is Value Analysis (VA)/ Value Engineering (VE)?

Value Analysis (VA) and Value Engineering (VE) are two commonly deployed value methodologies. Value Engineering is performed before production tooling is committed. Value Analysis (VA) is performed after tooling. Both techniques utilize the formula, Value = function/cost. Functions are inclusive in these methodologies and include primary functions and secondary functions.

How is VA/VE Used?

VA/VE data is most often an input to Design or Process FMEAs in the Function column as primary and secondary functions. Additionally, VA/VE data could be input as causes, controls or recommended actions.

VA methodology should include the review of existing FMEAs to assist in assessing risk and benefits when the various proposals are analyzed in T-charting and also in the action-planning phase.

REDPEPR

What is REDPEPR?

REDPEPR (Robust Engineering Design Product Enhancement PRocess) is a tool to provide:

- D&R engineers and their teams with a step-by-step process for applying RED.
- Engineering teams with the tools necessary to complete the P-Diagram, Reliability and Robustness Checklist (RRCL), Reliability and Robustness Demonstration Matrix (RRDM).
- Questions and helpful hints to lead the team through the process.
- Capability to generate MS Excel based reports.
- A process for improving communication within the engineering team.

Standard, best practice formats with simple, easy to use data entry screens.

Where to Get More Info and Software

Please visit the following website for more info or to download the software:

http://www.redpepr.ford.com/

FMEA Express

What is FMEA Express?

FMEA Express is a process that applies FMEA techniques simultaneously to both the design and manufacturing aspects of an engineering project. Engineers, assisted by certified facilitators, are able to identify Potential Critical or Significant Characteristics early on and therefore design robustness into the product.

How Does the FMEA Express Process Work?

The FMEA Express approach consists of four phases:

1. Prework – A steering team is formed to define the project scope, identify the cross-functional team members, collect background information, and document known Failure Modes, Causes, Effects and Controls.
2. FMEA Development – This phase is the responsibility of the cross-functional team with the facilitator monitoring progress against objectives established by the steering team. The cross-functional team completes the FMEA using industry standard forms and definitions.
3. Post-Work – The facilitator and steering team produces a final report and a follow-up action plan. The FMEA team leader or champion is responsible for monitoring the progress on the follow-up plan.
4. Quality Audit – After a quality check a certificate is provided that states that the FMEA complies with the Ford FMEA Handbook.

How to Get Started With FMEA Express

For more information on FMEA Express, contact:

- Global FMEA Express Coordinator
  Tel.: +49 221-90-12547
  Fax: +49 221-90-21144
  e-mail: FMEAExpr@Ford.com

- Global FMEA Express Administrator
  Tel.: +49 221-90-18542
  Fax: +49 221-90-21144
  e-mail: FMEAExpr@Ford.com

FMEA Software

Available FMEA Software

There are software packages available to help complete the FMEA paperwork. The software simplifies the completion of the FMEA form throughout the development of an FMEA. It works in a manner similar to other Windows-based software by allowing you to copy, cut, and paste text in a block. Software is the common method used for starting and completing FMEAs.

Further information about the Ford recommended software and downloading instructions are available on the Ford Intranet at:

http://www.quality.ford.com/cpar/fmea/

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Appendix C - FMEA Checklist

Note

"P" refers to Process FMEA and "D" refers to Design FMEA.

For a Concept FMEA, use the Design or Process checkbox column that is appropriate for the Concept proposal format.

Change Point Approach

P	D	
☐	☐	Was change point approach used to select an item for FMEA?

Team

P	D	
☐	☐	Has a cross-functional FMEA team (including PMST leader, supplier, manufacturing, quality, and (optional) facilitator) been formed?

Background Info

P	D	
☐	☐	Has the team reviewed relevant information including VDS, SDS, WCR, regulatory requirement, campaign/warranty/TGW data (also from other car lines), user plant concerns, and related FMEAs?

Continued on next page

FMEA Checklist, Continued

Inputs

P	D	
	☐	Has scope of FMEA defined by a comprehensive boundary diagram and attached to the FMEA? (Required)
	☐	Has an interface matrix been created and attached to the FMEA?
☐	☐	Has a comprehensive P-diagram been created and attached to the FMEA?
☐	☐	Have the functions been established?
☐		Has a process flowchart with boundary indicated prepared and attached? (Required)
☐		Has a characteristic matrix been created and attached to the FMEA?
☐		Are the sources of incoming variation identified, where applicable on the process flow?

Form

P	D	
☐	☐	Is the correct form used?

Header Information

P	D	
☐	☐	Are all the applicable entries in the header completed?

Function

P	D	
☐	☐	Are all the functions or purposes listed in physical/technical/measurable (verb/noun) terms using the functional (not hardware) approach within the scope?

Continued on next page

FMEA Checklist, Continued

Failure Modes

P	D	
☐	☐	Are failure modes identified using the 4 Thought Starters? (No, Partial/Over/Degraded, Intermittent, Unintended)?)
☐	☐	Do the failure modes relate directly to the functions?
☐		Are process failure modes listed in terms of accepting a bad part/reject a good part, or as a negative impact on process capability or integrity?
☐		Do the failure modes list part characteristics produced at the operation for which the part would be rejected if the part characteristic were outside the specification limits?

Failure Effects

P	D	
☐	☐	Have the potential effects of failure on the part, the next higher assembly, system, vehicle, machines/equipments, operator safety, next operation, downstream operations, customer requirements & government regulations been identified?
☐	☐	Are all effects listed in one box or field?

Severity Rating

P	D	
☐	☐	Is there one severity rating per failure mode by taking the most serious case for the failure mode and using the rating table?
☐	☐	Are severity ratings of 9 or 10 only and always shown when the effects include regulatory non-compliance or hazard?

Continued on next page

FMEA Checklist, Continued

Classification

P	D	
☐	☐	Are Special Characteristics identified as a part/process characteristic?
☐		Were Special Characteristics and their Special Controls communicated to the responsible design engineer?
☐	☐	Have all the types of Special Sharacteristics been correctly identified? (YC/YS for DFMEA, OS/HI/∇/SC for PFMEA)
☐	☐	Have all potential Critical & Significant Characteristics items from the DFMEA been agreed with manufacturing (supplier or plant) & are included in the PFMEA?

Failure Causes/ Mechanisms

P	D	
	☐	Is there evidence that the interface matrix has been used to determine causes?
☐	☐	Is there evidence the P-Diagram has been used to determine causes?
☐	☐	Are all causes for each failure mode identified?
	☐	Are causes in terms of element failure modes or a part characteristic, where appropriate?
☐	☐	Are causes described in terms of a characteristic that can be fixed or controlled?
☐	☐	Are process characteristics considered?
☐		Are material or parts incoming to each operation considered?
☐		Are operator actions considered?
	☐	Are design deficiencies considered that may induce manufacturing/assembly variation? (Cause Assumption 2)
	☐	Are manufacturing/assembly causes excluded from the DFMEA (but addressed in Process FMEA)?
☐		Are design causes excluded (but addressed in the Design FMEA)?
☐		Are possible downstream failure modes identified?

Continued on next page

FMEA Checklist, Continued

Occurrence Rating

P	D	
☐	☐	Is there one Occurrence rating per cause?
☐	☐	Are ratings based on the occurrence of the cause?
☐	☐	Do ratings consider the ability of prevention controls to reduce the occurrence of a failure mode?
	☐	Are ratings based on the cumulative number of failures that could occur for each cause over the proposed life of the system?
☐	☐	Do ratings of 1 have documentation to support the rating?

Current Controls

P	D	
☐	☐	Have preventative controls been considered where applicable?
☐	☐	Can methods listed detect the causes or failure modes?
	☐	Can design controls listed detect the cause(s) of failure modes before engineering release?
	☐	Are manufacturing/assembly detection methods excluded?
☐		Are the controls to be implemented to detect bad parts listed?
☐	☐	Are both detection and prevention controls properly identified in the Current Controls column?

Detection Rating

P	D	
☐	☐	Was the best (lowest) rating used to provide one detection per control set?
☐	☐	Are ratings based on the likelihood of detecting the first level causes (element failure modes) or the failure mode prior to engineering, manufacturing, or assembly release?
☐	☐	Do ratings of 1 have documentation to support the rating?

Continued on next page

FMEA Checklist, Continued

Risk Priority Number (RPN)

P	D	
☐	☐	Are the Risk Priority Numbers calculated?
☐	☐	Does it appear that an RPN threshold strategy has been incorrectly applied?

Recommended Actions

P	D	
☐	☐	Are remedial actions considered that reduce the ratings prioritized by Severity, Occurrence, and Detection?
☐	☐	Are responsibility and timing for the Recommended Actions listed?
☐	☐	Are actions directed at eliminating causes or reducing the occurrence of the causes of the failure modes?
	☐	Do actions address all potential Critical Characteristics?
	☐	Are actions aimed at making the design more robust?
	☐	Are the actions listed design actions, not manufacturing/ assembly controls?
☐		Are special manufacturing/assembly controls identified for Special Characteristics?
☐	☐	Are preventative, instead of detection, actions listed where appropriate?
☐	☐	Are actions considered to eliminate/reduce the occurrence of potentially hazardous failure modes, where applicable?

Follow Up

P	D	
☐	☐	Was the FMEA updated after Recommended Actions were implemented?
☐		Did the Process FMEA team determine whether normal and customary or whether special controls were required for the identified Critical Characteristics?
☐	☐	Has the FMEA been submitted to the core book?
	☐	Has the Robustness Checklist been updated?

Appendix D – Ford Automotive Procedures (FAP) Contents

In This Section

Description	See Page
FAP 07-005	D-2
FAP 03-111	D-2

Ford Automotive Procedures (FAP)

FAP 07-005

FAP 07-005

Vehicle Program Quality/Reliability/Robustness Planning Authorized by Vehicle Operations Quality Compliance (VOQC)

http://www.ctis.ford.com/fap/secure1/data/5876735.pdf

FAP 03-111

FAP 03-111

Selection and Identification of Significant and Critical Characteristics

http://www.ctis.ford.com/fap/secure1/data/5873860.pdf

Appendix E – FMEA Applications Contents

In This Section

Description	See Page
Environment FMEA	E-2
Machinery FMEA	E-15
Software FMEA	E-25

Environment FMEA

Home Page

More detail on Environment FMEAs can be found using the following link:

http://www-ese.ta.ford.com/~vee_e/strategy/dfe_intro.html

This is the home page for Design for Environment (DfE) information.

Input

Ford Motor Company is dedicated to providing ingenious environmental solutions that will position us as a leader in the automotive industry of the 21st century. Our actions will demonstrate that we care about preserving the environment for future generations. This environmental pledge for our company leads to the necessity of broadening the scope of FMEAs to environmental risks. The Environment-FMEA is used to check whether environmental objectives are fulfilled by the analyzed design, process or machinery. Inputs are derived from the 12 panel chart (in particular Panels 4, 5, 6), the Engineering Material Specification WSS-M99P9999-A1, the seven Design for Environment items (Refer to page E-3), the Customer Wants, the Corporate Environmental Strategy, Environmental benchmarking etc. (For more information: Refer to attachment on intranet links).

Form

The Design FMEA form is most commonly used for an Environment FMEA (at the time this FMEA Handbook was revised). However, a Process FMEA form may be appropriate in some circumstances (e.g., toxicology).

Function

Enter as precisely as possible the aims that the analyzed component/sub-system/system must fulfill in order to meet the environment objective. Add information on which region the component/sub-system/system is to be used and produced. If the component/sub-system/system has several objectives (e.g., from various regions or various environmental areas) with various potential failures, list each objective separately.

Use the nomenclature and state the design condition in accordance with the technical drawing. Before initial approval, provisional numbers must be entered.

Continued on next page

Environment FMEA, Continued

How Functions or Objectives are Defined

Start with the requirements, needs, and requests stated in respect of the component/sub-system/system. These may be derived from QFD Studies, System Design Specifications (SDS), Worldwide Customer Requirements (WCR) Manual, 12 panel chart, FORD Engineering Material Spec. WSS-M99P9999-A1, and other suitable documents (emerging toxicology issues, etc.).

Many objectives of the 12 panel chart, relate to the entire vehicle and must therefore, where applicable, be based on components and must be measurable.

In general, the functions/objectives are the Seven Design for Environment Guidelines:

1. Compliance with FPDS objectives
2. Minimal use of substances listed in hex9 and energy-intensive materials (Refer to attachment) as far as technological and economically feasible
3. Best recycling performance:
   - High recyclability
   - Use of recycled materials
   - Parts marking of non-metals
   - Think about how to dismantle
   - Reduce complexity of materials/design
4. Best fuel economy by:
   - Minimal frictional losses by low viscosity lubricants/engine oil, transmission fluids, low rolling resistance tires
   - Minimal energy consumption of electrical /electronic/climate control equipment
   - Lightweight construction/materials
   - Minimal aerodynamics/frontal area
   - Aids to help driver optimize fuel consumption performance (fuel computer)
5. Minimal fogging, smell, etc. (e.g., by avoiding phenolic and formaldehyde resins, not properly molded Polystyrene (PS))
6. Use of renewable fibers as hemp, flax, sisal as a reinforcement for plastics instead of glass fibers (if not heavier and feasible)
7. Consider green features (e.g., heat-reflecting glass, solar-powered vent fans, and seats that let air circulate to downsize A/C): be creative!

Continued on next page

Environment FMEA, Continued

Examples of Potential Failures

Assuming you have the following objectives:

- Dismantling ability for recycling
  - Within x minutes
  - Non-destructive
  - After 10 years of use, 240,000 kilometers

General failure types for an Environment FMEA on the component level would be the following for the above function:

- More than x minutes to dismantle
- Is destroyed by dismantling process

Potential Effects of the Failure

Potential effects of the failure described from the point of view of the customer / legislator / supplier / disposal company / residents and other affected parties, i.e., effects along the entire life are taken into consideration (Refer to graphic on the following page).

Describe the identified effects for each failure in terms of:

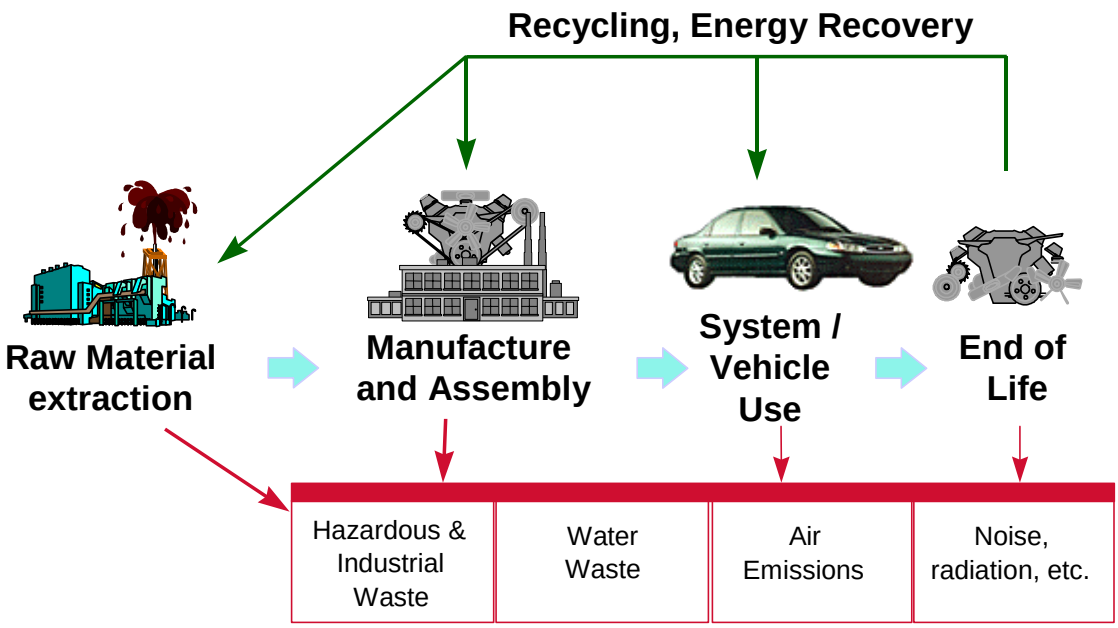
- Raw material recovery
- Material production
- Component production
- Assembly
- Customer
- Repair and maintenance
- Vehicle recycler
- Transport between the above sections of the life

Continued on next page

Environment FMEA, Continued

E-FMEA Life Cycle

By performing an E-FMEA keep in mind the whole life cycle that is affected by your choice of materials, design and processes.



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Environment FMEA, Continued

Assessment Criteria for Severity

Use the appropriate Design FMEA or Process FMEA Severity Rating table (Refer to pages 4-33 or 5-24) with the following amplifications to the criteria column:

10 = This very high assessment is awarded when the potential failure leads to non-compliance with legal regulations or internal Ford standards. Failure occurs without warning.

9 = This very high assessment is awarded when the potential failure leads to non-compliance with legal regulations or internal Ford standards. Failure occurs with warning.

8 = FPDS objectives and standards fulfilled, however, fuel economy still affected.

7 = Objectives fulfilled, however, use of restricted materials according to WSS-M99P9999-A1. Usage of energy-intensive materials without positive effect on fuel economy. Recycling could be better above FPDS objectives affecting a major amount of material

6 = Objectives fulfilled, however, recycling could be better above FPDS objectives. Use of allergenic materials in interior parts.

5 = Objectives fulfilled, however, renewable not used although listed in the DfE specifications list. Usage of reportable substances according to WSS-M99P9999-A1. Recycling could be better above FPDS objectives affecting a minor amount of material

4 = Objectives and standards fulfilled, however, vehicle interior air quality improvement would have been possible.

3 = Objectives are fulfilled. Use of energy-intensive materials that are significantly contributing to lightweight.

2 = Objectives are fulfilled, very minor environmental effects.

1 = Failure has no adverse effects (e.g., odor in exterior parts)

Continued on next page

Environment FMEA, Continued

Classification

Every item identified in the Environment FMEA must be checked for the necessity to implement special control measures and integrated into the Design and/or Process FMEA for further processing.

The rating of occurrence for design related Environment follows the DFMEA Occurrence Table and for process related environment FMEAs follows the PFMEA Occurrence Table.

However, there is no classification designation used on an Environment FMEA.

Cause Examples

Typical processes which may lead to failure causes occurring include:

- Treatment (difficulties with recycling, solvent emissions)
- Corrosion/wear (difficulties with subsequent dismantling)
- Transport
- Intensive energy processes (e.g., when using primary aluminum)
- Bonding, welding, etc. (permanent connections)
- Use of rare/noble alloys (high energy consuming raw material extraction)
- Use of strong greenhouse gases in magnesium production and casting (SF6) of plastic foaming (HFC)

Continued on next page

Environment FMEA, Continued

Warning

The Environment FMEA must not rely on process measures to take care of possible environmental weaknesses. It must, however, take into consideration the technical/physical limits of a product/production/installation/recycling/cleaning process such as:

- Dismantling ability
- Cleaning ability
- Disposal ability
- Effect on the environment
- Processing ability/efficiency

One objective is to identify weaknesses from material, design, process, and disposal sections, which could cause acceptable deviations throughout the life of the product or process (e.g., high energy consumption, high emissions).

Occurrence

Estimate the occurrence probability of a potential cause on a scale of 1 to 10, asking the following questions for example:

- What do customer service reports/field data/dismantling reports tell us about environmental compatibility and customer acceptance of similar components and sub-systems?
- How great is the risk that the failure will actually occur?
- How far can the framework conditions be changed (e.g., more stringent legislation, alternative dismantling methods)?
- Has a technical analysis (including test data) been carried out?

Continued on next page

Environment FMEA, Continued

Current Environmental Test Methods

An environmental test method is a process or test used to identify the most likely cause of the failure or to identify the failure itself. There are two types of current test methods:

1. Those that check the entire life cycle
2. Those that check certain environmental parameters

These test methods include:

- Multi-Criteria Requirement Matrix (MCRM)
- Eco-Compass
- Life Cycle Assessment (performed by Environmental & Safety Engineering, Research Lab or other experts)
- Density tests
- Dismantling tests
- Customer surveys
- Benchmarking
- Design reviews

How Environmental Test Methods are Determined

To identify environmental test methods, proceed as follows:

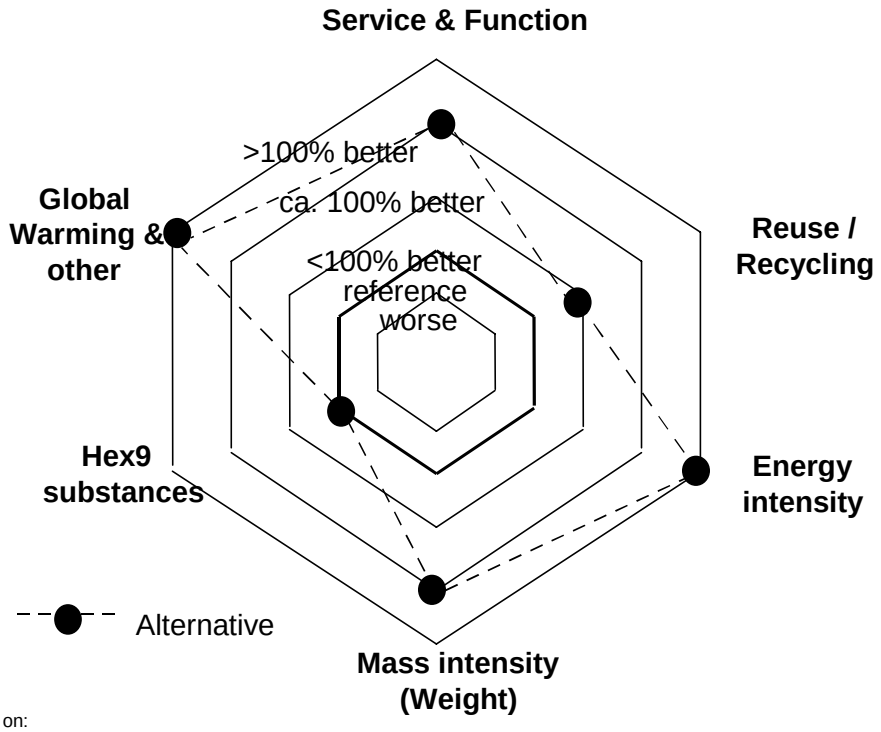
- Visualize the relevant environmental aspect using an Eco-Compass
- Set up a Multi Criteria Requirement Matrix
- Establish and list all other known methods by which the failure can be identified
- List all known environmental test methods by which the failure and the most likely cause can be identified
- Identify other possible methods with the aid of the following questions:
    - How can the cause of this failure be identified?
    - How can occurrence of this cause be identified?
    - How can this failure be identified?
    - How can occurrence of this failure be identified?

Continued on next page

Environment FMEA, Continued

Examples of Environmental Test Methods

The Eco-Compass supports the assessment of various environmental aspects in the initial assessment of alternatives, including measures to remedy the failure. Based on the reference design, (Actual condition; thicker line in Eco-Compass) the level of achieved improvement or deterioration is tested semi-qualitatively. This semi-qualitative method can often support an assessment with a moderate data basis (also helps to structure brainstorming ideas for assessing design alternatives).



based on:
Claude Fussler : Driving Eco-Innovation

Note: Hex9 substances are substances listed in the Engineering Material Specification, WSS-M99P9999-A1.

Continued on next page

Environment FMEA, Continued

Examples of Environmental Test Methods (Continued)

Environmental Multi-Criteria Requirement Matrix (Refer to form on the following page)

For each design alternative, summarize the information into the following issues:

- Use of substances which are banned or subject to limitations
- Type and quantity of waste (reflects the level of material use)
- Energy consumption per component
- Water consumption per component
- Other objectives based on your environmental objectives list

This information is established and evaluated for every life cycle stage (raw material extraction / material production / production at Ford, use of components, disposal of components). The assessment is always made within a range of 1-10. Since the use phase of an average C-Class vehicle for example makes up approximately 80% of the total energy consumption, this life phase is weighted the highest.

Environment FMEA Detection Ranking Table

	100 % detection potential of the method	50 % detection potential of the method	Highly subjective test method
The environmental test methods will not or cannot detect the potential cause or resultant failure, or no environmental test method is available.	10		
The environmental test methods is suitable and available but is not used on an regular basis (resource, knowledge reasons or lack of information)	5	6-8	8-9
The environmental test methods is suitable and available. Test applied too late in FPDS / no regular information from test people to designer, etc.	2	3-5	5-6
Test suitable, available and applied by correct people at the best time	1	1-3	3

Continued on next page

FMEA Applications

Environmental Multi-Criteria Requirement Matrix

		Alternatives			
Raw Materials		Design A	Design B	Design C	Score range
Product	Contains Ford internal listed substance of concern* or other stringently regulated substance				1-3 no issue 4-6 coming issue 7-10 restricted-ban
Process	Substance of concern* or other stringently regulated substance are used in manufacturing / process operations prior to Ford control (e.g. SF6 for magnesium production, CFC use for cleaning)				1-3 no issue 4-6 coming issue / image problem 7-10 restricted (7) - legally banned (10)
Waste	Type of waste				**
Energy	Energy used to acquire & manufacture raw material inputs (if data available for each)				3-7 (3 lowest figure of the alternatives)
Water	Water used per unit production				1-4 (1 reduction from current, 2 status)
Raw Materials Total					
Raw Materials Total Weight Factor		2	2	2	
Raw Materials Total, weighted					Range: 10 - 82
Manufacturing & Assembly		Design A	Design B	Design C	Score range
Product	Applies/adds Ford internal listed substance of concern* or other stringently regulated substance				see above
Process	Substance of concern* or other stringently regulated substance are used or generated				see above
Waste	Amount and Type of waste				**
Energy	Energy used per unit production				see above
Water	Water used per unit production				see above
Manufacturing & Assembly Total					
Manufacturing & Assembly Total Weight Factor		2	2	2	
Manufacturing & Assembly Total, weighted					Range: 10 - 82
System Use		Design A	Design B	Design C	Notes
Energy	Energy required to move part weight over life of vehicle (e.g. 150 000 miles (US), 120 000 km (Europe))				1-10 relative energy demand (current: 5)
Maintenance / Operation	Use of substances of concern* or other stringently regulated substances or if applicable evaporation (e.g. interior material: smell, VOC; R134 emission etc.)				1-3 no issue 4-6 coming issue 7-10 restricted (7) - legally banned (10)
System Use Total					
System Use Total Weight Factor		10	10	10	
System Use Total, weighted					Range: 20-200
End of Life		Design A	Design B	Design C	Notes
Waste	Type of waste (recyclable, for landfilling, for incineration)				**
	Effort for additional treatment (energy, processes etc.)				3-7 (3 lowest figure of the alternatives)
Dismantling	Easiness of dismantling (if necessary)				***
End of Life Total					
End of Life Total Weight Factor		2	2	2	
End of Life Total, weighted					Range: 6 (4) - 54
Design Total					

* Engineering Material Specification WSS-M99P9999-A1 (Refer to http://www.dearborn.ford.com/tox/hex9indx.htm)
** 1-2 returnable or easy recyclable waste, 3-4 energy recovery, 5-6 normal landfilling, 8-10 hazardous waste (higher score for bigger amount)
*** 1-2: w/o tools, 3-4 with tools, 5-7: special tools needed (higher score for time needed), 8-10: not possible

Environment FMEA, Continued

Examples of Recommended Actions

Examples of Recommended Actions are:

- Alternative connection systems
- Use recyclate
- Alternative disposal routes
- Use of natural materials
- Revise transport routes
- Reduce processing paths
- Optimize energy and water consumption

Warning

Before taking the Recommended Action, its effect on the entire life must be checked. In the event of a trade-off, i.e., if the benefit of the Recommended Action is counteracted by a disadvantage in another part of the life or environmental area, the relevant technical department (Vehicle Environmental Engineering or Environmental Quality Office) should be contacted. One example of a trade-off is reduced recyclability but lower weight of composites.

Environment FMEA Outputs

Some Environment FMEA outputs are:

- Material recommendation
- Design recommendations (e.g., type of link)
- Process recommendation (e.g., energy saving potential)
- Recommendations for disposal routes

Continued on next page

Environment FMEA, Continued

Useful Links for Environmental FMEAs

- MATS Materials and Toxicology System: http://pms996.pd9.ford.com:8080/home.html
- Hex9 Substance Use Restrictions -- WSS-M99P9999-A1: http://www.dearborn.ford.com/tox/hex9uk.htm
- MRSIT Material Restrictions Strategy Implementation Team: http://www.dearborn.ford.com/tox/mrsit/mrsit.htm
- Ford Emerging Chemical Issues: http://www.dearborn.ford.com/tox/emerissu.htm
- Recycling Projects/ Existing Applications: http://www-ese.ta.ford.com/here_dir/recycle/rat/rat_p.html
- Ford Environmental System ISO 14001 http://www-ese.ta.ford.com/~ese_eqo/ecm/fes/fes.html
- Design for Environment information http://www-ese.ta.ford.com/~vee_e/strategy/dfe_intro.html
- VEE Global Regulatory Databases and FPDS
- Engineering Draft Standard E-4-1 – Plastic Parts Material Identification
- Policy Letter: No.17, Subject: Protecting Health and the Environment: http://ese412.ta.ford.com/~ese_eqo/policy_letters/pol_17.html
- Directive A-119: Chlorofluorocarbon Phaseout Program http://ese412.ta.ford.com/~ese_eqo/directives/a119.html
- Directive A120: Environmental Strategy, Planning and Implementation: http://ese412.ta.ford.com/~ese_eqo/directives/a120.html
- Company Directive B-108 Occupational Health and Safety Protection Planning and Implementation: http://www.dearborn.ford.com/tox/oldb108.htm
- Directive D101: Energy Planning and Control: http://ese412.ta.ford.com/~ese_eqo/directives/d101.html
- DirectiveD109: Waste Minimization Program http://ese412.ta.ford.com/~ese_eqo/directives/d109.html
- Directive F-111: Vehicle Recycling

Machinery FMEA

Introduction

A Machinery FMEA (MFMEA) for tooling and equipment is an analytical technique utilized primarily by an engineering team. The purpose of the FMEA is to assure that potential failure modes and their associated causes/mechanisms have been addressed. In its most rigorous form, an FMEA is a summary of the team's thoughts (including analysis of items that could go wrong based on experience and past concerns) as the machinery is designed. The systematic approach parallels, formalizes, and documents the mental disciplines that an engineer/team normally goes through in any design/development process.

The MFMEA supports the design process in reducing risk of failures by:

- Aiding in the objective evaluation of equipment functions, design requirements, and design alternatives.
- Increasing the probability that potential failure modes and their effects on machinery have been considered in the design and development process.
- Providing additional information to aid in the planning of thorough and efficient design, test, and development programs.
- Developing a list of potential failure modes ranked according to their effect on the customer, thus establishing a priority system for design improvements and development testing.
- Providing documentation for future reference to aid in analyzing field concerns, evaluating design changes and developing advanced machinery designs.

When fully implemented, the MFMEA process can be performed on new, modified, or carry-over designs in new applications or environments. An engineer from the responsible design source (which may be the supplier for a proprietary design) should initiate the MFMEA process.

Continued on next page

Machinery FMEA, Continued

How to Identify Functions and Performance Requirements

Start by listing the wants, needs, or requirements of a system. Function analysis should be used to ensure requirements are defined in terms that can be measured.

Wants, needs, and requirements can be identified from the Customer Requirements, Machinery Specifications, legal requirements, and other applicable documents.

When a subsystem must function under certain conditions, these conditions must be specified and may include environmental parameters, engineering specifications, and/or machine performance specifications (e.g., operating temperature, capability, cycle-time, mean time between failure (MTBF), or mean time to repair (MTTR).

Examples of Functions and Performance Requirements

Examples of suitable descriptions for functions and performance requirements:

Function	Performance Requirement
Load part	120 jobs/hr
Index head	MTBF>200 hrs.
Control hydraulic flow	80 cl/sec
Position system	Rotation angle 30°
Drill a hole	First run %=99,9%

Continued on next page

Machinery FMEA, Continued

Functional Approach

Assume the function:

- Load parts
  - 120 jobs/hour
  - Exact position

General types of failure modes for the component-level Machinery FMEA for the function above include:

- Jobs/hour < 120
- Wrong position (x-, y-, z- direction)

Potential Effects of the Failure

The effects should be stated in terms of a specific system or subsystem being analyzed and the impact of the failure mode on upstream and downstream processes. For every potential failure an action is required to bring the machinery back to its intended production capability.

State clearly if the function could impact safety or regulation compliance.

Potential Effects are consequences of the failure for the subsystem with regards to the aspect of Safety and the “Seven Big Losses.”

Continued on next page

Machinery FMEA, Continued

Definition of the Seven Big Losses

1. **Breakdowns:** Losses that are a result of a functional loss (e.g., mechanical, chemical, or electrical) or function reduction (e.g., one spindle not operating on a multispindle drill) on a piece of equipment requiring maintenance intervention.
2. **Setup and Adjustment:** Losses that are a result of setup procedures such as retooling, changeover, or die/mold change. Adjustments include the amount of time production is stopped to adjust process or machinery to avoid defect and yield losses, requiring operator or job setter intervention.
3. **Idling and Minor Stops:** Losses that are a result of minor interruptions in the process flow (such as a part jammed in a chute or a sticking limit switch) requiring only operator or job setter intervention. Idling is a result of process flow blockage (downstream of the focus operation) or starvation (upstream of the focus process). Idling can only be resolved by looking at the entire line/system.
4. **Reduce capacity:** Losses that are a result of differences between the ideal cycle time of a piece of machinery and its actual cycle time. Ideal cycle time is determined by: a) original line speed b) optimal conditions and c) highest cycle time achieved on similar machinery.
5. **Startup Losses:** Losses that occur during the early stages of production after extended shutdowns (weekends, holidays, or between shifts), resulting in decreased yield or increased scrap and rejects.
   This may also include non-value activities required prior to production, such as bringing process to temperature.
6. **Defective Parts:** Losses that are a result of defects resulting in re-work, repair, and/or non-useable parts.
7. **Tooling:** Losses that are a result of tooling failures, breakage, deterioration, or wear (e.g., cutting tools, fixtures, welding tips, punches).

Continued on next page

Machinery FMEA, Continued

Assessment Criteria for Severity

Select the most serious effect of each failure and use the Severity Rating Table from Design FMEA (Refer to page 3-32). Use the following additional criteria to calculate a severity assessment to categorize the potential failure.

8 = Downtime of more than 8 hours or the production of defective parts for more than 4 hours.

7 = Downtime of between 4 and 8 hours or the production of defective parts for 2 to 4 hours.

6 = Downtime of 1 to 4 hours or the production of defective parts for 1 to 2 hours.

5 = Downtime of between 30 minutes and 1 hour or the production of defective parts for up to 1 hour.

4 = Downtime of 10 to 30 minutes but no production of defective parts.

3 = Downtime of up to 10 minutes but no production of defective parts.

2 = Process parameter variability not within specification limits. Adjustment or other process controls need to be taken during production. No downtime and no production of defective parts.

1 = Process parameter variability within specification limits. Adjustment or other process controls can be taken during normal maintenance.

Continued on next page

Machinery FMEA, Continued

Cause Assumption

When creating a Machinery FMEA, it is assumed the machinery has been produced, installed, used, and disposed of in accordance with the specification.

Identify potential causes of each failure with the aid of the following questions:

- What are the circumstances that can lead to the component, subsystem, and system not fulfilling its function/performance requirements?
- To what degrees can interactive components, subsystems, and systems be incompatible?
- Which specifications guarantee compatibility?

Caution

The Machinery FMEA must not rely on process measures to resolve potential environmental weakness. It must take into consideration the technical and physical limits of a product, production, installation, recycling, and cleaning process such as:

- Dismantling ability
- Cleaning ability
- Disposal ability
- Effect on the environment
- Processing ability/efficiency

One objective is to identify weaknesses from material, design, process, and disposal sections, which would cause unacceptable deviations throughout the life of the machine.

Continued on next page

Machinery FMEA, Continued

Assessment Criteria for Occurrence

Use the DFMEA Occurrence table (Refer to page 3-44) with the following enhancements to criteria:

10 =	1 in 1	OR	R(t) <1 %: MTBF is about 10% of the user's required time.
9 =	1 in 8	OR	R(t) = 5%: MTBF is about 30% of user's required time.
8 =	1 in 24	OR	R(t) = 20%: MTBF is about 60% of the user's required time.
7 =	1 in 80	OR	R(t) = 37%: MTBF is equal to the user's required time.
6 =	1 in 350	OR	R(t) = 60%: MTBF is 2 times greater than the user's required time.
5 =	1 in 1000	OR	R(t) = 78%: MTBF is 4 times greater than the user's required time.
4 =	1 in 2500	OR	R(t) = 85%: MTBF is 6 times greater than the user's required time.
3 =	1 in 5000	OR	R(t) = 90%: MTBF is 10 times greater than the user's required time.
2 =	1 in 10,000	OR	R(t) = 95%: MTBF is 20 times greater than the user's required time.
1 =	1 in 25,000	OR	R(t) = 98%: MTBF is 50 times greater than the user's required time.

Continued on next page

Machinery FMEA, Continued

Current Design/ Equipment Controls

Refer to the Design FMEA section (Section 4) of this FMEA Handbook for more information.

Caution

Engineering specification tests or inspections conducted as part of the manufacturing and/or assembly process are **not** acceptable design/equipment controls. These are applied **after** the machinery is released into production.

Continued on next page

Machinery FMEA, Continued

Design / Equipment Detection Rating Table

Use the Design FMEA Detection Table (Refer to page 3-53) with the following criteria enhancements:

10 = Design/equipment control will not and/or cannot detect a potential cause/mechanism and subsequent failure mode; or there is no design/equipment control.

9 = Very remote chance the design/equipment control will detect a potential cause/mechanism and subsequent failure mode.

8 = Remote chance the design/equipment control will detect a potential cause/mechanism and subsequent failure mode.

7 = Very low chance the design/equipment control will detect a potential cause/mechanism and subsequent failure mode.

6 = Low chance the design/equipment control will detect a potential cause/mechanism and subsequent failure mode.

5 = Moderate chance the design/equipment control will detect a potential cause/mechanism and subsequent failure mode.

4 = Moderately high chance the design/equipment control will detect a potential cause/mechanism and subsequent failure mode.

3 = High chance the design/equipment control will detect a potential cause/mechanism and subsequent failure mode.

2 = Very high chance the design/equipment control will detect a potential cause/mechanism and subsequent failure mode.

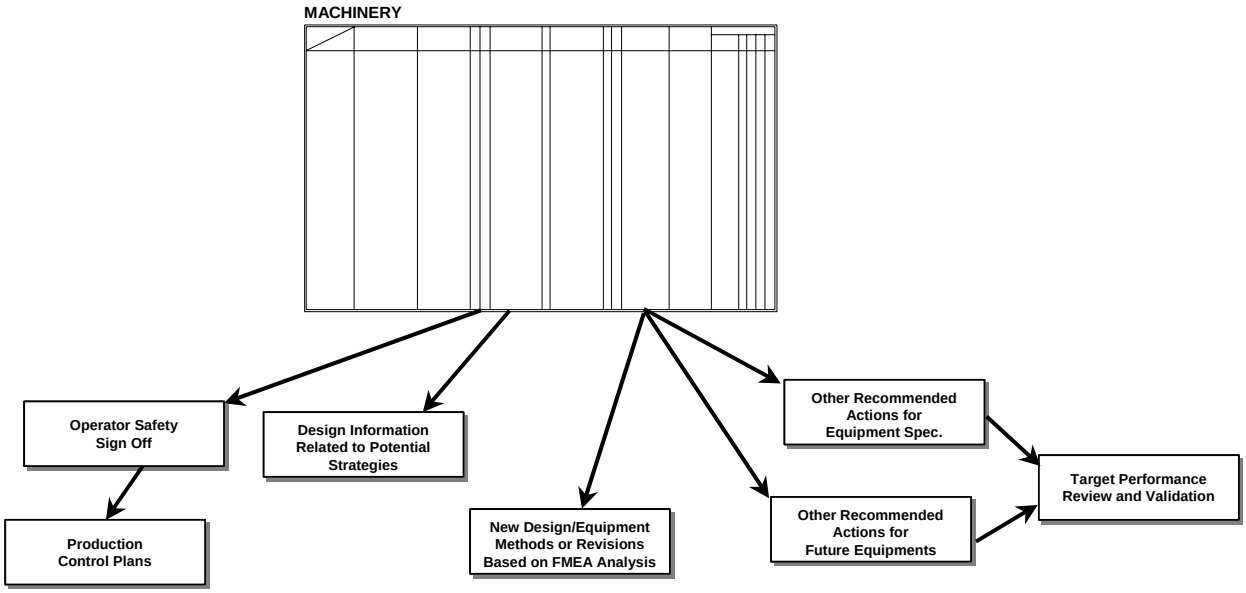
1 = Design/equipment control will almost certainly detect a potential cause/mechanism and subsequent failure mode.

Continued on next page

Machinery FMEA, Continued

Outputs from Machinery FMEA

Typical outputs from a Machinery FMEA are shown in the graphic below. Many of these outputs will be inputs to the Process FMEA. Many of these output items are fed from the Machinery FMEA, or from the results of the Recommended actions of the Machinery FMEA. There is a strong correlation between many of the columns in a Design and Process FMEA. Effects and their corresponding Severity will relate directly, with unique process effects added to the Process FMEA. Other relationships are more subtle. For example, Design causes often relate to Process failure modes.



Software FMEA

Introduction

A Software FMEA is a variety or application of a Design FMEA. Follow the information in the Design FMEA section of this FMEA Handbook (Section 3) for developing this Design FMEA application. Only exceptions, cautions, or emphasis items are noted here.

Form

Use the Design FMEA form.

Inputs

As in all Design FMEAs, begin by creating a boundary diagram. For software, the diagram will be a functional boundary diagram. That is, the functions that the software must perform are shown as individual blocks inside the dashed box representing the boundary or scope. Outbound arrows will cross the boundary to a box representing the component or system receiving the software output. Inbound arrows will indicate inputs to the function from other components or systems.

An interface matrix and P-diagram will also provide useful input and will be created in the normal manner for a Design FMEA.

Function

Functions will still be verb/noun/measurable.

A software function might be:

- Receive speed signal from output shaft sensor; and
- Calculate ratio using XYZ table; and
- Output calculated value to ABC:
  - Within x ms
  - With no errors
  - When speed is 3-150 mph

This function as illustrated could, at the team option, also be broken into the three component portions of the function represented by the three individual sentences.

Continued on next page

Software FMEA, Continued

Failure Mode	Use the normal Four Thought Starter Failure Modes. Place a special emphasis on Intermittent and Unintended. Use the P-diagram and interface matrix to thoroughly assess the risks from other systems (including the degradation of those other systems or the environmental impact to those other systems) as well as customer use which might not be design intent, yet still possible and perhaps probable. In regarding these supporting documents, the team may first raise issues that are causes (e.g., customer performs incorrect button activation sequence). The team needs to ask, “If the customer does that, what happens?” in order to determine the Failure Mode (unintended signal output).
Effects	Depending on the software analyzed, the team may need to call on SMEs from other areas to assess the effects to the vehicle and end customer when software outputs are not correct.
Severity	Use the Design FMEA Severity rating table located on page 3-33 of this FMEA Handbook.
Step 1 Recommended Action	Search for actions to eliminate Failure Modes whenever possible.
Cause	Depending on the software analyzed, the team may need to call on SMEs from other areas to assess the likelihood that inputs to the software will be incorrect, out of range, intermittent or missing. Do not overlook Causes arising from new applications and environments.

Continued on next page

Software FMEA, Continued

Controls

Detective controls include software validation. Other Detective controls are the appropriate validation tests for the module that the software resides in.

Preventative controls include using “bookshelf” coding which has already been proven in other applications and environments.

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FMEA Glossary

Glossary

Actions Taken	The section of an FMEA in which a description of the action(s) taken and corresponding effective date(s) are recorded.
Assembly Variation	Differences in product characteristics caused by the inherent assembly process variability.
Attachments	A software feature that allows you to store notes and files directly in the FMEA. These attachments stay with the FMEA, but do not appear on the standard FMEA printout.
Black Box	An assembly purchased by Ford. The Supplier is responsible for the design of the components, but Ford Product Engineering is responsible for providing design or material specifications. All aspects of the assembly's function are directed by a Ford engineering specification.
Block Diagram	Now known as **Boundary Diagram**. An illustration that represents the scope of the FMEA, including interfaces. It is usually used in a Design FMEA.
Boundary Diagram	Formerly known as a **Block Diagram**. An illustration that represents the scope of the FMEA, including interfaces. It is usually used in a Design FMEA.

Glossary, (Continued)

Campaign

Campaign is another term for Vehicle recall. Before an automotive manufacturer engages in a campaign, there has been thorough investigation and analysis of the issue. Often this analysis begins with a Global 8D where the root cause which generated the in field defect to occur is determined. Additionally, the "escape" root cause is determined. In other words, how did the product testing miss this defect?

Corrective actions are targeted at both items and implemented as part of the correction to the vehicles in question. When an issue is raised to a recall, the Global 8D will have additional information added, and it will become a 14D. In your FMEA, indicate any applicable historic recall numbers in the "campaign" field in the header. Also clearly indicate the control(s) that was/were implemented to "detect" the defect in the detection portion of the controls column preceded with: "Control initiated / revised due to vehicle campaign:" followed by the control(s).

Capability Index

Ratios that show the ability of a process to produce products that conform to a given specification. These indices provide a convenient way to refer to the capabilities of a process after the process has been verified to be in a state of statistical control.
(See also C_p, C_{pk}, P_p and P_{pk}.)

Capability

The ability of a process to produce product within specification. The capability of a process may be measured by indices, such as, C_p, C_{pk}, Z score etc.

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Glossary, (Continued)

Cause	The “How” or “Why” that leads to the Failure Mode. In a Design FMEA and Design Concept FMEA, Cause is a description of the factor(s) contributing to the Failure Mode. These include design deficiencies that prevent performance to specification, create incorrect inputs, or result in adverse interactions between elements in a system. It is the manifestation of a design weakness, the consequence(s) of which is a Failure Mode. In a Process FMEA and Process Concept FMEA, Cause is a manufacturing or assembly deficit that impacts the functionality of the item or the process and results in an unacceptable condition.
Cause and Effect Diagram	A diagram that depicts the relationship between an effect and all the possible causes. Often referred to as an Ishikawa "Fishbone" Diagram. See also Ishikawa "Fishbone" Diagram.
C_p	A capability index is the ratio of the part specification tolerance to the Six-Sigma process spread without regard to the location of the data. It is calculated after verifying that the process is in a state of statistical control.
C_{pk}	A capability index that considers both the process spread and the proximity of the process spread to specification limits. It is calculated after verifying that the process is in a state of statistical control.
Control Factors	Design or process variables which are inherently controllable and may be examined for their level of impact on the performance of the system.
Corporate Product System Codes (CPSC)	A six-digit number that divides the vehicle into systems, subsystems, and features. This information is placed in the header of a DFMEA or a CFMEA Design.

Glossary, (Continued)

Critical Characteristic (∇ or CC)	It is a product requirement (dimension, specification, test) or process parameter that can affect compliance with government regulations or safe vehicle or product function. It requires special actions for manufacturing, assembly, shipping, or monitoring. Critical Characteristics must be included in Control Plans. When all producers require special controls, they are identified on Ford drawings and specifications with the Inverted Delta (∇) symbol (sometimes also referred to as CC). The "Potential" for a Critical Characteristic is determined in a DFMEA. The Critical Characteristic is confirmed in the PFMEA.
Criticality (C)	A relative measure of the combined influence of the consequences of a Failure Mode (Severity or S) and its frequency (Occurrence or O). It is a product of Severity times Occurrence.
Criticality Report	A report that lists just those items in a FMEA that contain a "Classification Symbol" in the classification column. This program automatically calculates the appropriate classification code or symbol for a particular type of FMEA.
Current Controls	Refers to those controls associated with standard commercial practice and includes the normal and customary methods, practices, techniques, and tests used by a producer for a given product. These controls would typically be found on historic DVP&Rs for a DFMEA and on historic Control Plans for a PFMEA.
Customer	A general term that is used to refer to the consumer purchasing a vehicle or to a person or organization receiving the output of the item, analyzed by the FMEA. It includes a downstream operator in a manufacturing or assembly process, and service operators.
Design Classification	A symbol that reflects Special Characteristics identified against a potential Cause.

Glossary, (Continued)

Design Controls	A description of the engineering tools, methods, calculations, reviews, tests, etc. intended to detect the identified potential Failure Modes prior to engineering release. These methods can include DV tests. (See Design Verification.)
Design Failure Mode	The failure of a function to meet design intent completely and correctly. There are four Thought-starter Failure Mode categories that can be seen on the Working Model.
Design FMEA (DFMEA)	An FMEA used to analyze a product at the system, subsystem or component level before it is released for production.
Design for Assembly (DFA)	When comprehensively applied, this discipline seeks to reduce assembly variability and assembly costs while improving product quality. The intended outcome is improvement in the design to reduce assembly difficulties or potential defects. For example, analysis of attaching and fastening schemes may lead to a redesign to eliminate some fasteners. DFA might be seen in the controls column of a Design FMEA. If DFA is not performed or not well performed, the remaining issues will often appear in the Cause column of the FMEA as Second Assumption of Causes type issues.
Design for Manufacturing (DFM)	When comprehensively applied, this discipline seeks to reduce manufacturing variability and manufacturing costs while improving product quality. The intended outcome is improvement in the design to reduce manufacturing difficulties or potential defects. For example, analysis of fixturing and holding schemes may lead to a redesign to improve a clamping detail to improve machining operations. DFM might be seen in the controls column of a Design FMEA. If DFM is not performed or not well performed, the remaining issues will often appear in the Cause column of the FMEA as Second Assumption of Causes issues.

Glossary, (Continued)

Design for Recycling (DFR)	When comprehensively applied, this discipline seeks to improve recycling and reusability for Ford products. Sometimes this is also called Design for the Environment. See Appendix E in this FMEA Handbook on "Environment FMEA Application Example" for additional insight on this topic.
Design for Service (DFS)	When comprehensively applied, this discipline seeks to reduce service related issues. The intended outcome is improvement in the design to reduce service costs, frequency or time for the ultimate customer or eliminate the need for special tools for the Service customer. DFS might be seen in the controls column of a Design FMEA, most often as a "Service sign-off" or "FCSD review".
Design Intent	A description of what a given component/subsystem/ system is expected to do or not to do.
Design Life	The period for which the design is intended to perform its requirements. (The durability target of the item.) After the target period, the item is expected to be discarded because it ceases to function, or the item becomes too expensive to repair. Design life can be expressed in terms of kilometers, time (months or years), cycles, or a combination thereof.
Design of Experiments	A set of statistical techniques for laying out an experimental plan, data acquisition, data analysis and drawing conclusions.
Design Validation/ Verification	A program intended to assure that the design meets its requirements (FDVS, DVP&R, and DVPSOR).
Design Verification Tests (DV)	A description of the tests that are used to detect identified potential Failure Modes prior to engineering release.

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Glossary, (Continued)

Design Weakness	A design deficiency such as wrong geometry, incorrect material, sensitivity to the environment, design life less than service life, apparent part symmetry where correct orientation is required, etc. In an FMEA, these are typically the Causes of failure.
Design Verification Plan and Report (DVP&R)	The formalized testing performed on a product to assure the product's compliance with all requirements. On successful completion the design is signed off and released. Alternately deviations are secured and the design is released. The elements of the DVP&R are found in the Current Control column of a DFMEA and in the Recommended Actions that modify that plan. Also known as Design Verification Plan, Sign Off Report (DVPSOR).
Design Verification Plan, Signoff Report (DVPSOR)	See DVP&R.
Detection (D)	Design FMEA: a rating of the ability of the proposed design control to detect a potential Failure Mode or Cause before engineering release. Process FMEA: a rating of the ability of the current process control(s) to detect a Failure Mode or Cause before the item leaves the manufacturing or assembly facility.
Dynamic Control Planning (DCP)	A process that links quality tools to build robust control plans. It strategically uses elements like flowcharts, FMEAs, and Control Plans together with the in-depth knowledge of process experts to seek to indirectly controlling many product and process characteristics by linking and directly controlling a few characteristics.

Glossary, (Continued)

Effect	A description of the impact of a Failure Mode on the operation, function, or status of the part, assembly, subsystem, system, vehicle, customer, manufacturing operations, manufacturing operators, manufacturing tooling and equipment, or government regulations.
Element	A general term used to refer to a subset of a system, subsystem, assembly, or subassembly. A part or group of parts comprising a system.
Error State	The undesirable output of the engineering system, including variation and/or degradation of the ideal function, or loss of the intended function or the presence of undesirable conditions.
Failure Mechanism	(1) The process that results in failure. These processes can include chemical, electrical, physical, thermal, and informational. (2) The process of degradation, or a chain of events, leading to and resulting in a particular Failure Mode.
Failure Mode	A design failure is the manner in which a system, subsystem, or part fails to meet its intended purpose or function. A process failure is the manner in which a process fails to meet its intended purpose.
Failure Mode Analysis (FMA)	A disciplined approach to identify the Failure Modes, Failure Rates, and Root Causes of known failures.
Failure Rate	The probability that the product will fail in the next unit measure of life (such as cycles, time, miles, etc.) given that it has survived up to that life.
Fault Tree Analysis (FTA)	A deductive analytical technique that uses a graphical tree to show cause-effect relationships between a single undesired event (failure) and the various contributing causes.

Glossary, (Continued)

Feature	A product characteristic (e.g., radius, hardness) or a process characteristic (e.g., insertion force, temperature).
Fishbone Diagram	See Ishikawa "Fishbone" Diagram.
FMEA Review	A feature that generates an on-screen analysis of simple deficiencies like blank FMEA header and data fields or missing Recommended Actions under conditions that require one, and so forth. This report can be printed using the icon at the top of its panel.
Ford Customer Service Division (FCSD)	The organization within Ford responsible for reviewing designs for the ease of service and assisting in determining service procedures and maintenance schedules.
Ford Design Verification System (FDVS)	Software system that houses the Design Verification Plan (DVP).
Function	The intended purpose or characteristic action of a system, subsystem, or part. A primary function is the specific purpose or action for which a product is designed. There may be more than one primary function. A secondary function is another function the product performs that is subordinate to, but supports, the primary function.
Global Eight Discipline Approach (Global 8D)	An orderly, team-oriented approach to problem solving. Formerly referred to as TOPS (Team Oriented Problem Solving).
Graphics	Drawings, diagrams, etc. created or revised in an FMEA session to assure that all the interfaces have been considered.

Glossary, (Continued)

Gray Box	An assembly purchased by Ford, for which the supplier has design, development, and engineering drawing responsibility. Ford Product Engineering has responsibility to provide design or material specifications. All aspects of the assembly's function are specified by a Ford Engineering Specification.
Hardware	A term used to describe a physical part, assembly, or system.
High Impact (HI)	A designation in the PFMEA that denotes a characteristic to be controlled in the process because of its importance to an operation. This designation may also be given to YSs or YCs identified in the DFMEA. It does not require special controls but is still deemed operationally important to the process and will be listed on the Control Plan.
Interaction	The effect of one part, element, subsystem, or system on another.
Interface	The common boundary between the system, subsystem, and/or parts being analyzed. This information should be displayed as part of the Boundary Diagram created in DFMEA pre-work. The Boundary Diagram should be included in the software FMEA as a Note/Attachment.
Interface Matrix	A robustness tool that identifies and quantifies the strength of system interactions. It shows whether the relationship is necessary or adverse. It also identifies the type of relationship (e.g., energy transfer and information exchange).
Ishikawa "Fishbone" Diagram	An Ishikawa "Fishbone" Diagram is a deductive analytical technique. It is used to brainstorm causes of failure. The Failure Mode would typically be entered into the "head" of the fish, and the "bones" would be used to list the causes. Refer to Appendix B for an example Ishikawa diagram.

Glossary, (Continued)

Item	A generic term used to designate a system, subsystem, assembly, part or component, which is the scope of the analysis of the FMEA.
Loss of Function	Degraded performance or operation outside the design specification limits. Loss of Function is usually the anti-function or the "no function" type of Failure Mode.
Manufacturing Variation	Differences in product characteristic caused by the inherent manufacturing process variability.
Noise Factors	Uncontrollable factors which disrupt ideal function and cause error states. The noise factors are listed according to the five basic sources of noise: • Piece to Piece Variation • Changes Over Time/Mileage (e.g. wear) • Customer Usage • External Environment (e.g. road type, weather) • System Interactions The five noise factors, if not identified and addressed, cause vehicle campaigns.
Normal Controls	Refers to those controls associated with standard commercial practice and includes the normal and customary methods, practices, techniques, and tests used by a producer for a given product. These controls would typically be found on historic DVP&Rs for a DFMEA and on historic Control Plans for a PFMEA.
Occurrence (O)	Design FMEA and Concept-Design FMEA: a rating corresponding to the cumulative number of failures that could occur for a given Cause over the design life of a system or part. Process FMEA and Concept-Process FMEA: a rating corresponding to the estimated number of cumulative failures that could occur for a given Cause over a given quantity of elements produced with the current controls.

Glossary, (Continued)

Operator Safety (OS)	The designation for Operator Safety items in a PFMEA. These are Failure Modes with a severity rating of 9 or 10, and affect the process only.
Pareto	A simple tool for problem solving that involves ranking all potential problem areas.
Part	Any physical hardware of the vehicle that is considered a single replaceable piece with respect to field service. The least subdivision before assembly into a subsystem or system, e.g., a shock absorber, a switch, or a radio. An end item.
Part Characteristics	See Product Characteristic.
P-Diagram	A schematic representation of the relationship among the signal factors, control factors, noise factors, responses, and error states of an engineering system.
Potential Critical Characteristics	A symbol generated in a DFMEA classification that may become a designated Critical Characteristic after a PFMEA is completed. Severity ranking is 9 or 10.
P_p	An index similar to C_p but based on data from early, short-term studies of new processes. P_p can be calculated only when the data from the study indicate that process stability has been achieved. (P_p = Process Capability).
P_{pk}	An index similar to C_{pk} but based on data from early, short-term studies of new processes. Data from at least 20 subgroups are required for preliminary assessments. P_{pk} can be calculated only when the data from the studies indicate that stability has been achieved. (P_{pk} = Preliminary Process Capability).
Primary Function	See Function.

Glossary, (Continued)

Process Change	A change in a process that could alter the capability of the process to meet the design requirements or durability of the product.
Process	The combination of people, machines and equipment, raw materials, methods, and environment that produces a given product or service.
Process Characteristic	Measurable characteristics of process inputs and their interactions that affect the process output. Examples of process parameters include speeds, feeds, temperatures, chemical concentrations, pressures, and voltages.
Process Control	See Statistical Process Control (SPC).
Process Failure Mode	The failure of a manufacturing or assembly process to meet the requirements of the intended process function.
Process Flow Diagram	An illustration created or revised in an FMEA session to assure that all interface and incoming variations are considered. Refer to Section 4, Process FMEA, for more information.
Process FMEA (PFMEA)	An FMEA used to analyze manufacturing and assembly processes and output Control Plans.
Process Parameters	See Process Characteristic.
Process Variation	Process variation is represented by a normal distribution curve that shows the characteristic variation expected or measured during a manufacturing or assembly operation.
Producer	A Ford manufacturing or assembly plant or outside Supplier providing products or services to Ford.

Glossary, (Continued)

Product	A general term that refers to a component, part, assembly, subsystem, or system.
Product Characteristic	Quantifiable/measurable features such as dimension, size, form, location, orientation, texture, hardness, tensile strength, coating, reflectivity, finish, color, or chemistry.
Quality Function Deployment (QFD)	A structured method in which customer requirements are translated into appropriate technical requirements for each stage of product development and production.
Risk Priority Number (RPN)	The Risk Priority Number is the product of the Severity, Occurrence, and Detection ratings (S x O x D). It is a value from 1 to 1000.
Response	Measured characteristics representing the desired function performance.
Revised Detection (RD)	A value entered in the Action Results Detection field when the Recommended Action is completed and the action has improved the Detection of the Failure Mode or Cause.
Revised Occurrence (RO)	A value entered in the Action Results Occurrence field when the Recommended Action is completed and the action had reduced the likelihood that this Cause will occur and generate the Failure Mode.
Revised Severity (RS)	A value entered in the Action Results Severity field when the Recommended Action is completed and the action had reduced the Severity of the Failure Mode. This can only occur when there is a change in design.
Revised RPN (RRPN)	The generated product of the Revised Severity (RS), Occurrence (RO), and Detection (RD) ratings (RS x RO x RD). It is a value from 1 to 1000 and is calculated and entered in the Action Results RPN field of the FMEA form when the ratings are entered.

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Glossary, (Continued)

Robust Design	A producer's capability to manufacture and/or assemble with a low sensitivity to manufacturing and/or assembly process variation. A robust design assumes there are no design weaknesses. If a design is not robust, sensitivity to process variation is high and this implies special process controls may be necessary.
Robustness Checklist	Summarizes key robustness attributes and design controls. It is an input into the Design Verification Plan (DVP). It is a key element for review in the Design Review Process.
Root Cause	*The root cause is the reason for the primary non-conformance and is the item that requires change to achieve permanent preventive/corrective action.* The primary singular event that results in a Failure Mode. In a component-level Design FMEA (DFMEA) this will be a part characteristic.
Secondary Function	A function the product performs that is secondary to, but supports, the primary function.
Severity (S)	In a Design FMEA*:* a rating of the seriousness of the effect of a Failure Mode on the next assembly, system, vehicle, customer, or government regulation. In a Process FMEA: a rating of the seriousness of the effect of a Failure Mode on a downstream operation, the equipment and tooling of the process operation, operator safety or next assembly, system, vehicle, customer, or government regulation. Severity applies to the most serious effect of a Failure Mode.
Scope	Is the boundary or extent of the analysis and it defines what is included and excluded in a FMEA.

Glossary, (Continued)

Sigma	The Greek letter used to designate the standard deviation of the distribution of individual values for a process parameter or a product characteristic.
Signal Factor	What the input which triggers the function being analyzed is. Refer to P-Diagram in Section 3.
Significant Characteristic (SC)	Product, process, and test requirements important for customer satisfaction and for which Quality Planning actions must be summarized on a Control Plan.
Statistical Control	The condition describing a process from which all special causes of variation have been eliminated and only common causes remain. A special process cause is a source of variation that is intermittent and unpredictable, sometimes called assignable causes. Special causes are signaled by a point beyond the control limits, a run, or other non-random pattern of points within the control limits. Statistical control is evident on a control chart by the absence of points beyond the control limits and by the absence of any non-random patterns of trends. A synonym for statistical control is “stability.”
Statistical Process Control (SPC)	The use of statistical techniques, such as control charts, to analyze a process or its output. The analysis is used to take appropriate actions to achieve and maintain a state of statistical control and to improve the capability of the process.
Subsystem	A set of interdependent elements or parts organized to achieve a defined objective by performing a specified function(s). The Corporate Product Systems Classification (CPSC) defines major systems and subsystems.
System	A set of interdependent subsystems or parts organized and linked in a coherent way to each other and to the whole. The Corporate Product Systems Classification (CPSC) defines major systems and subsystems.

Glossary, (Continued)

System Design Specification (SDS)	Regulatory and other requirements that systems, subsystems, and components must meet. Testing requirements are often included in SDSs.
Value Analysis (VA)	Performed after tooling and utilizes the formula, Value = Function/Cost. Functions are inclusive in these methodologies and include primary functions and secondary functions.
Value Engineering (VE)	Performed before production tooling is committed and utilizes the formula, Value = Function/Cost. Functions are inclusive in these methodologies and include primary functions and secondary functions.
Vehicle Campaign	See Campaign.
Wants List	A list that describes the purposes, objectives, or functions of a particular system or part from the customer's viewpoint. Wants are generally determined from QFD studies and/or the SDS and WCR.
Worldwide Customer Requirements (WCR)	Translation of global customer requirements into common worldwide vehicle design standards and product acceptance specifications for development and sign-off.

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Index

Actions Taken
- Definition 3-57, 4-48
- Identification 3-57

Applied Consumer Focus (ACF) B-37

Boundary Diagram 1-6, 2-8, 2-10, 3-7–9, 3-12, 3-23, 3-38, 4-30, 5-4–5, 5-11, B-4–7, C-2, E-25, G-1, G-10
- Definition 2-8, 3-8
- Examples 3-9, B-5, B-7
- Rules and Guidelines B-4
- Types B-4

Brainstorming 3-38, 4-30, B-12–16, B-20, G-10
- Definition B-12

Classification 1-4, 3-17, 3-34, 3-36, 3-43, 3-45–46, 4-26, 4-34, 4-36, 5-10, 6-3–6, C-4, E-7, G-4, G-16
- Definition 3-34, 5-10
- Design Classification Possibilities 3-46
- Process 4-36
- Process Special Characteristic Table 4-36
- YC Classification Rating 3-34
- YS Classification Rating 3-45

Control Plan 2-3, 2-21, 4-36, 4-39, 4-46, 6-3–5, 6-7, 6-9, B-31–33, B-35–36, G-4, G-7, G-10–11, G-13, G-16
- Definition B-31
- Example B-33

Current Controls 2-9, 3-14, 3-19, 3-48, 4-10, 4-40, 4-47, 5-13–14, C-5, G-4, G-7, G-11
- Definition 3-48, 4-38, 5-13
- Design 1-5, 2-10, 3-48–53, 3-55, 3-61, C-5, G-5, G-7, G-15
- Examples 3-50, 4-40, 5-13
- Identification 3-48–49, 4-38–39
- Points to Consider 4-40, 4-47
- Process 2-3, 2-15, 3-34, 3-41, 3-57, 4-34, 4-36, 4-38–42, 4-44, 4-47, 4-51, 6-7, B-32, B-34–36, E-19, G-7, G-13, G-15–16
- Types 3-48, 4-38

Design Verification Plan (DVP) 2-3, 2-5, 2-9–10, 2-13–14, 3-48, 3-55, 3-61, B-35, G-4, G-6–7, G-9, G-11, G-15
- Definition 2-9

Design of Experiments (DOE) B-29, G-6

Detection 1-4, 2-14–16, 3-47–48, 3-51–57, 3-59, 4-37–38, 4-40–47, 4-50, 5-13–15, 5-17, C-5–6, E-11, E-23, G-2, G-7, G-14
- Definition 3-51, 4-41, 5-14
- Effectiveness Factors 3-52, 4-43
- Identification 3-51, 4-42
- Rating Tables 3-53, 4-44

Dynamic Control Planning (DCP) 4-14, B-34, B-36, G-7

Effects List
- Design FMEA B-22
- Process FMEA B-23

FMEA
- Applications 1-2
- Benefits and Best Practice 2-6, 2-12–13, 2-15
- Change Point Approach 2-11
- Checklist 1-2, 1-6, C-1–6
- Concept FMEA (CFMEA) 1-2–4, 1-6, 2-7, 2-12, 2-19–21, 3-5, 5-3–7, 5-9–11, 5-15, 5-18, A-2–3, B-4, B-37, G-3
- Definition 2-3

Index

FMEA (continued)
- Design FMEA (DFMEA) 1-2–6, 2-7, 2-9–10, 2-13–15, 2-17, 2-19–21, 3-4–5, 3-8–17, 3-19, 3-29, 3-37, 3-39, 3-41, 3-43, 3-46, 3-48, 3-57–58, 3-60–61, 3-63–65, 4-4, 4-7–8, 4-17, 4-20, 4-32, 4-49, 5-3–6, 5-8–15, 5-17–18, 6-4–5, A-4, B-31, B-37, C-1, C-4, E-2, E-6–7, E-19, E-21–23, E-25–26, G-1, G-3–7, G-10–12, G-15
- Environmental FMEA E-2–11, E-13–14, G-6
- FPDS Timing 2-20
- Flow 2-8
- Form Header Information 3-17, 4-9
- Forms 1-2, 3-19, 4-10
- Helpful Tools 1-2
- How to Start or Update 2-18
- Implementation 2-4
- Inputs to 2-10, 3-5, 4-4
- Introduction 3-4, 4-4, 5-3
- Machinery FMEA (MFMEA) 1-4, 2-7, A-6, E-15–24
- Outputs 2-12, 2-14, 2-16, 3-60, 4-51, 5-18
- Process FMEA (PFMEA) 1-2–6, 2-6–7, 2-15–17, 2-19–21, 3-34, 3-37, 3-41, 3-45–46, 3-60, 4-4, 4-6–10, 4-15–16, 4-20–21, 4-24, 4-29, 4-31–36, 4-43–44, 4-48, 4-51–53, 5-3–6, 5-8–15, 5-17, 6-4–5, 6-8–9, A-5, B-6, B-36, B-38, C-1, C-4, C-6, E-2, E-6–7, E-24, G-3–4, G-7, G-10–13, G-15
- Purposes 2-5
- Relationships 2-22
- Samples 3-63, 4-52
- Scope 3-7, 4-5, 5-3
- Software B-40
- Software FMEA E-25–27
- Team 3-6, 4-5, 5-3
- Types of 2-7
- When is it Complete 2-21
- When to Discard 2-21
- When to Start or Update 2-19
- Who Initiates 2-17
- Who Prepares 2-17
- Who Updates 2-18
- Who is the Customer 2-20

FMEA Handbook
- Contents 1-3
- Icons 1-7
- Purpose 1-3
- Supplemental Information 1-4–5
- Suppliers 1-3
- What's New 1-5
- Why Revised 1-5

Failure Mode Analysis (FMA) B-28, G-8
Fault Tree Analysis (FTA) 3-38, 4-30, B-27, G-8
Ford Automotive Procedures (FAPs)
- FAP 1-2–3, 1-5–6, 6-2, 6-6, 6-8–9, D-2
- FAP 03-111 ..... 1-3, 1-6, 6-6, 6-8–9, D-2
- FAP 07-005 ..... 1-5–6, D-2

Ford Product Development System (FPDS) 2-20, 2-22, E-3, E-6, E-11, E-14

Index

Function
- Components 4-15
- Definition 3-22, 4-13
- Describing 3-22, 4-13
- Examples 3-23
- Identification 3-23, 4-14
- Item/Function Worksheet 3-24

Function Description
- Nouns 3-23, B-11, B-18, B-20, C-2, E-25
- Verbs 3-23, B-10, B-18, B-20, C-2, E-25

Function Tree 3-23, B-18–21
- Definition B-18
- Development B-20
- Examples B-19

Global 8D 3-38, 3-49, 4-30, 4-39, B-30, G-2, G-9
Glossary 1-2, 1-6, G-1–2
Interface Matrix 1-6, 2-8, 2-10, 3-8, 3-10–12, 3-38, 5-4–5, B-4, C-2, C-4, E-25–26, G-10
- Definition 2-8, 3-10
- Examples 3-11
- System Interface Analyzer (SIA) 3-10, 3-12

Ishikawa "Fishbone" Diagram 3-38, 4-31, B-24, G-3, G-9–10
Kano Model of Quality B-18
Noise Factors 2-6, 2-9, 3-8, 3-10, 3-14–15, 3-40, 3-49, 3-61, G-11–12
Occurrence 1-4, 2-12, 2-14–16, 3-36, 3-39, 3-42–49, 3-51, 3-54–56, 3-59, 4-26, 4-29, 4-34–42, 4-45–47, 4-50, 5-12, 5-15, 5-17, 6-4, 6-8, B-27, C-5–6, E-7–9, E-21, G-4, G-11, G-14
- Definition 3-42, 4-34, 5-12
- Identification 3-42–43, 4-34
- Rating Tables 3-44, 4-35

P-Diagram 2-6, 2-9–10, 3-8, 3-10, 3-14–16, 3-29, 3-31, 3-38, 3-40, 3-49, 3-55, 4-8, 4-30, 4-46, 5-4–5, B-4, B-39, C-2, C-4, E-25–26, G-12, G-16
- Definition 2-9, 3-14–15, 4-8
- Examples 3-16

Part Characteristic 3-39, 4-7, 4-13–14, B-31, C-3–4, G-12, G-15
Potential Cause(s)/Mechanism(s) of Failure 2-9–10, 2-12, 2-14–16, 3-4, 3-10, 3-14, 3-21, 3-25, 3-30, 3-32, 3-36–44, 3-48–49, 3-51, 3-53, 3-55–56, 3-60, 3-63, 4-4, 4-12, 4-16, 4-22, 4-26–34, 4-38–39, 4-42, 4-44, 4-46–47, 4-52, 5-11–13, 5-15, B-11, B-16, B-24–30, B-35, B-38, B-40, C-4–6, E-7–9, E-11, E-15, E-20, E-23–24, E-26, G-2–5, G-7–8, G-10–11, G-14–16
- Assumption 1 ..... 3-39–40, 4-31–32
- Assumption 2 ..... 3-40–41, 4-33, C-4
- Definition 3-37, 5-11
- Developing Causes 4-30
- Identification 3-37–39, 4-28–29

Potential Effect(s) of Failure 2-3, 2-9, 2-12–13, 2-15, 3-10, 3-21, 3-25, 3-30–33, 3-35, 3-37–39, 3-48, 3-55, 3-57, 3-60, 3-63, 4-4, 4-7, 4-12, 4-16, 4-18, 4-20–25, 4-29–30, 4-36, 4-38, 4-46, 4-48, 4-52, 5-9, 5-15, 6-4, 6-6, B-24–27, B-29, C-3, E-4, E-6, E-8, E-13, E-15, E-17, E-19–20, E-24, E-26, G-3, G-8, G-10, G-15
- Definition 4-21, 5-9
- Describing 3-31
- Examples 3-30–31, 4-22
- Identification 3-30, 4-21

Index

Potential Failure Modes 1-3–5, 2-4, 2-7–10, 2-12–16, 2-18, 3-4, 3-14–15, 3-21, 3-23, 3-25–35, 3-37–40, 3-42–43, 3-48–49, 3-51, 3-53, 3-55–57, 3-60, 3-63, 4-4, 4-12, 4-15–25, 4-27–34, 4-36, 4-38–39, 4-41–43, 4-46–48, 4-52, 5-9, 5-11, 5-13, 5-15, 6-6, B-18, B-22, B-24–29, B-35, B-40, C-3–6, E-15, E-17, E-23–24, E-26, G-3–8, G-10–15
- Unintended Function 3-26–28, 4-16, 4-19
- Definition 3-25, 4-16
- Examples 3-27–29, 4-19, E-17
- Identification 3-29, 4-17–18
- Intermittent Function 3-15, 3-26–28, 4-16, 4-19
- No Function 3-15, 3-25, 3-27–28, 4-16, 4-19
- Partial/Over Function/Degraded Over Time 3-25, 3-27–28, 4-16
- Types 3-25, 4-16

Process Characteristic 1-3, 3-34, 4-13–15, 4-18, 4-25, 4-27, 4-29, 4-31–32, 4-36, 6-2, 6-8, B-32, C-4, G-7, G-9, G-13
Process Flow Diagram 4-6, 4-14, 4-17, 5-4–5, 5-11, B-6, B-8, G-13
- Definition 4-6, 4-14, B-8
- Examples 4-6, B-6, B-8

Product Characteristic Matrix 4-14, 4-20, 4-30, 5-4, B-9, C-2
Product Characteristic 3-34–35, 3-45, 4-7, 4-14, 4-25, 4-28, 6-3, B-35, G-1, G-9, G-11–12, G-14, G-16
Product Characteristic Matrix 4-14
- Definition 4-7, B-9

Quality Function Deployment (QFD) 3-4, B-37, E-3, G-14, G-17
REDPEPR 1-5, 2-8–9, B-39
Recommended Actions 2-6, 2-10, 2-14, 2-18, 3-5, 3-7, 3-14, 3-35–36, 3-47, 3-49, 3-54–58, 3-60, 4-4, 4-25–26, 4-29, 4-37, 4-45–49, 5-10, 5-14–16, B-32, B-36, B-38, C-6, E-13, E-24, E-26, G-7, G-9, G-14
- Definition 3-55, 4-46, 5-15
- Ensuring 3-57–58, 4-48–49
- Examples 3-56, 5-16
- Identification 3-56, 4-47, 5-15
- In Step 1 ..... 3-35, 4-25
- In Step 2 ..... 3-36, 4-26, 5-12

Responses 3-15
Responsibility and Target Completion Date 3-58, 4-49
Risk Priority Number (RPN) 1-4, 3-47, 3-54–55, 3-59, 4-37, 4-45–46, 4-50, 5-14, 5-17, B-16, C-6, G-14
- Definition 3-54, 4-45
- Resulting RPN 3-59, 4-50

Robustness Checklist 2-10, 3-49, 3-55, 3-61–62, 4-39, B-39, C-6, G-15
- Definition 2-9, 3-61

Robustness Demonstration Matrix 2-9
Robustness Engineering (REDPEPR) 1-5, 2-8–9, B-39
Robustness Tools (Robustness Linkages) 1-4, 2-5, 3-8
- Definition 3-8

SAE
- J1739 ..... 1-3–7, 2-21, 3-57, 4-48
- Society of Automotive Engineers 1-3–7, 2-21, 3-19, 3-57, 4-10, 4-48

Sentencing Technique B-25–26
Severity 1-4, 2-14, 2-16, 3-21, 3-32–33, 3-35, 3-37, 3-39, 3-46–47, 3-54–56, 3-59–60, 4-4, 4-12, 4-23–25, 4-27–29, 4-36–37, 4-45–47, 4-50, 5-10, 5-15, 5-17, 6-4, 6-6, 6-8, B-16, C-3, C-6, E-6, E-19, E-24, E-26, G-4, G-12, G-14–15
- Definition 3-32, 4-23
- Identification 3-32, 4-23
- Rating Tables 3-33, 4-24

Index

Signal Factors 3-15, G-12
Special Characteristics 1-2–3, 1-5, 2-5, 2-13, 2-15–16, 2-21, 3-34, 3-45, 3-58, 4-20, 4-29, 4-36, 4-49, 5-10, 6-2–4, 6-6–9, B-31–32, B-35, C-4, C-6, G-4
- Classification Hierarchy 6-3
- Classifications 1-4, 3-17, 3-34, 3-36, 3-39, 3-41, 3-43, 3-45–46, 4-26, 4-34, 4-36, 5-10, 6-3–6, C-4, E-7, G-4, G-12, G-16
- Critical Characteristic (YC and ∇ or CC) 1-5, 2-5, 2-13–16, 3-34, 3-39, 3-46, 4-17, 4-20, 4-36, 6-2, 6-4–5, 6-9, C-4, C-6, D-2, G-4, G-12
- Definition of Critical Characteristics 6-5
- Definition of Significant Characteristics 6-5
- High Impact (HI) 2-15, 4-26, 4-36, 6-2, 6-4, 6-6–8, C-4, G-10
- Identification 6-8
- Introduction 6-2
- Operator Safety (OS) 2-15, 4-26, 4-36, 6-2, 6-4, 6-6–8, C-4, G-12
- Significant Characteristic (YS and SC) 1-5, 2-20, 3-39, 3-43, 3-45–46, 4-17, 4-20, 4-34, 4-36, 6-2–5, 6-7, C-4, G-16
- Special Characteristics Table 6-4
Special Controls 2-15–16, 4-36, 6-4–5, 6-7–9, B-32, B-36, C-4
- Definition 6-7
VA/VE B-38
Working Model 3-20–21, 3-35–36, 3-47, 4-11–12, 4-25–26, 4-37, 5-8, 5-10, 5-12, G-5
- Ford FMEA Model 3-20, 4-11
- Step 1 ..... 3-21, 4-12, 5-8
- Step 2 ..... 3-35–36, 4-25–26, 5-10
- Step 3 ..... 3-47, 4-37, 5-12

Index

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