

Concept FMEA

Section 3 Contents

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

Continued on next page

Concept FMEA

Section 3 Contents, Continued

In This Section

Description	See Page
Occurrence / Working Model Path/Step 3	
Occurrence	3-12
Working Model Path/Step 3	3-12
Current Controls	
Current Controls	3-13
Examples of Controls	3-13
Detection / Risk Priority Number	
Detection	3-14
Risk Priority Number	3-14
Recommended Actions	
Recommended Actions	3-15
How to Identify Recommended Actions	3-15
Examples of Recommended Actions	3-16
Actions Taken / Resulting RPNs	
Actions Taken	3-17
Revised Severity, Revised Occurrence, Revised Detection, and Revised RPN	3-17
Outputs from Concept FMEA	
Outputs from Concept FMEA	3-18
Design Concept FMEA Quick Reference	3-19
Process Concept FMEA Quick Reference	3-23

Concept FMEA

Introduction to Concept FMEAs

Introduction	The scope of a Concept FMEA can be a Design Concept at a system, subsystem, or component level, or a manufacturing or assembly Process Concept FMEA.
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Most of the Concept Design FMEA will be performed like a "normal" Design FMEA. Most of the Concept Process FMEA will be performed like a "normal" Process FMEA. Therefore, this section of the FMEA Handbook will only highlight the differences.

FMEA Team, FMEA Scope, and FMEA Extent	Refer to the relevant DFMEA or PFMEA section in the FMEA Handbook.
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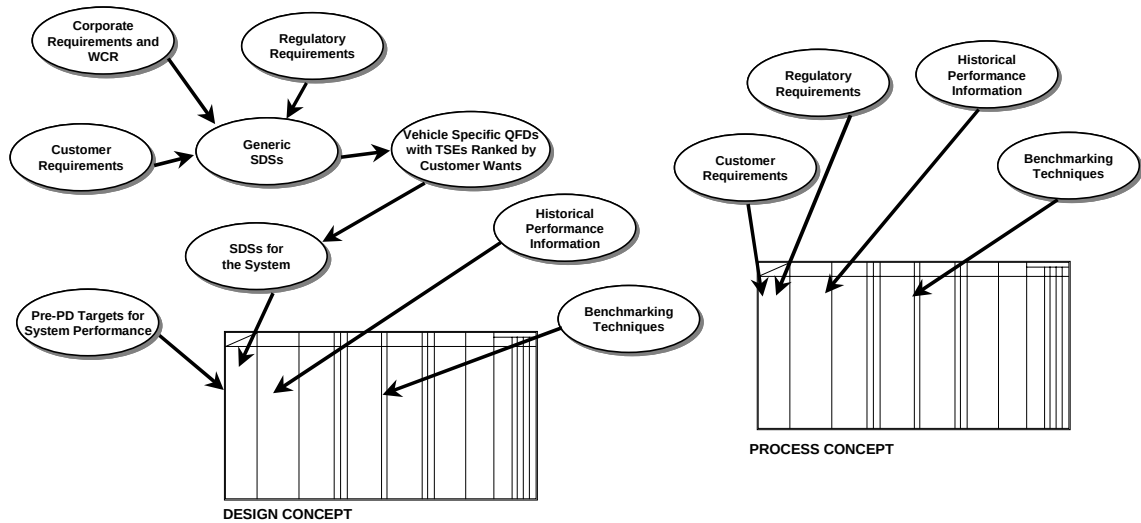
Process Flow	Refer to the relevant Process FMEA section in the FMEA Handbook.
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Concept FMEA

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.

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Concept FMEA

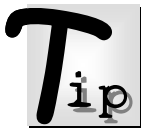
Inputs to Concept FMEA, Continued

P-Diagram

Refer to the relevant DFMEA or PFMEA section in the FMEA Handbook.

Characteristic Matrix

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



The process flow, 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.

Concept FMEA

FMEA Form Header

Filling In Header Information

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

<i>Ford Motor Company</i>		POTENTIAL FAILURE MODE AND EFFECTS ANALYSIS CONCEPT (DESIGN FMEA)										FMEA Number _____			
___ System												Page _____ of _____			
___ Subsystem												Prepared By _____			
___ Component _____		Design Responsibility _____										FMEA Date (Orig.) _____ (Rev.) _____			
Model Year(s)/Program(s) _____		Key Date _____													
Core Team: _____															
Item Function	Potential Failure Mode	Potential Effect(s) of Failure	S e v	C l a s s	Potential Cause(s)/ Mechanism(s) of Failure	O c c u r	Current Design Controls — Prevention — Detection	D e t e c t i v i t y	R. P. N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results			
												Actions Taken	S e v	O c c u r	D e t e c t i v i t y

Concept FMEA Form

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Concept FMEA

FMEA Model / Function

Ford FMEA Model

Refer to the relevant DFMEA or PFMEA section in the FMEA Handbook.

Working Model Path/Step 1

Refer to the relevant DFMEA or PFMEA section in the FMEA Handbook.

Function/ Requirements

Refer to the relevant DFMEA or PFMEA section in the FMEA Handbook.

Concept FMEA

Potential Failure Mode / Potential Effect(s) of Failures

**Potential
Failure Mode**

Refer to the relevant DFMEA or PFMEA section of the FMEA Handbook.

**Potential
Effect(s) of
Failures**

Refer to the relevant DFMEA or PFMEA section of the FMEA Handbook.

Note: There may be less detail available in this field in a Concept Design FMEA and a Concept Process FMEA than in a "normal" Design or Process FMEA.

Concept FMEA

Severity / Classification

Severity	Refer to the relevant DFMEA or PFMEA section of the FMEA Handbook.
Consider Recommended Actions	Refer to the relevant DFMEA or PFMEA section of the FMEA Handbook.
Classification	This column is not currently used for Concept Design or Concept Process 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 <u>potential</u> Special Characteristics or a Process FMEA to confirm Special Characteristics.
Working Model Path/Step 2	Refer to the relevant DFMEA or PFMEA section of the FMEA Handbook.

Concept FMEA

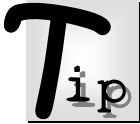
Potential Cause(s) / Mechanism(s) of Failure

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



Refer to the relevant DFMEA or PFMEA section of the FMEA Handbook.

Note: It is rarely possible to provide root cause in this field in a Concept Design or a Concept Process 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.

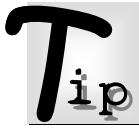
Some Failure Modes and Causes may be eliminated by major concept changes like adding a redundancy to the proposed system.

Concept FMEA

Occurrence / Working Model Path/Step 3

Occurrence See the relevant DFMEA or PFMEA 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
Path/Step 3**

Refer to the relevant DFMEA or PFMEA section of the FMEA Handbook.

Concept FMEA

Current Controls

Current Controls

See the relevant DFMEA or PFMEA section of the FMEA Handbook.

Note: The team will enter a description of the control method(s) that will be used to 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 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:

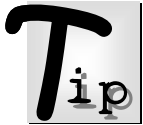
- Computer simulation
 - Mathematical models
 - Breadboard tests
 - Laboratory tests on surrogate elements
-

Concept FMEA

Detection / Risk Priority Number

Detection

See the relevant DFMEA or PFMEA section of the FMEA Handbook.



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

See the relevant DFMEA or PFMEA section of the FMEA Handbook.

Concept FMEA

Recommended Actions

Recommended Actions



See the relevant DFMEA or PFMEA 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.
-

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Concept FMEA

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.
-

Concept FMEA

Actions Taken / Resulting RPNs

**Actions
Taken**

See the relevant DFMEA or PFMEA section of the FMEA Handbook.

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

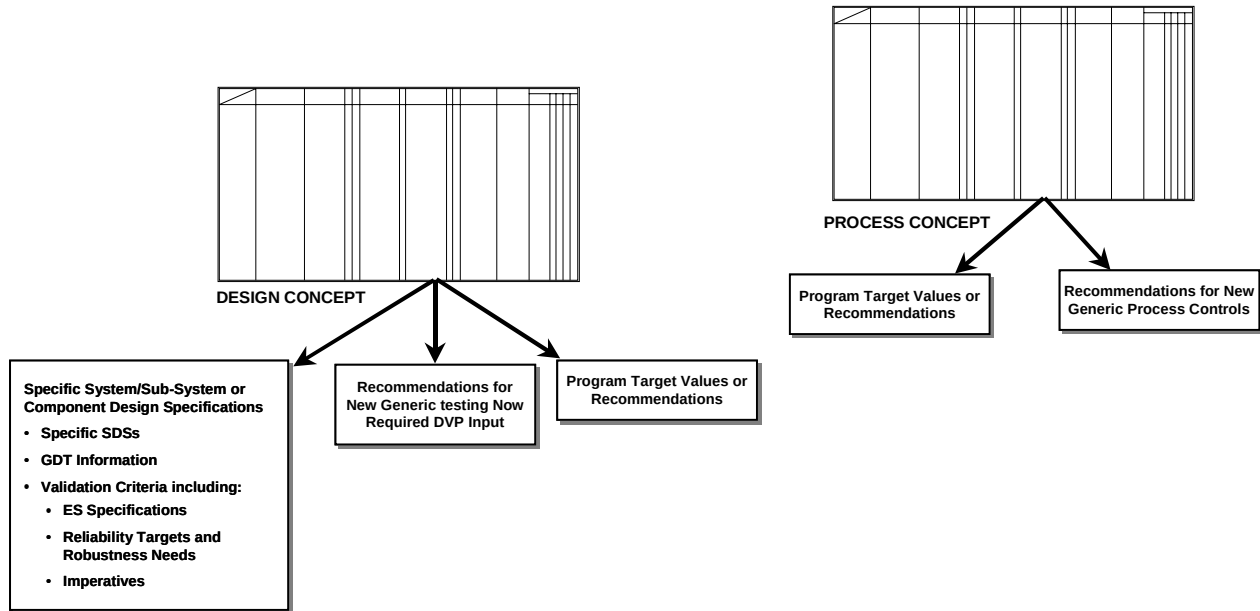
See the relevant DFMEA or PFMEA section of the FMEA Handbook.

Concept FMEA

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.



Concept FMEA

Design Concept FMEA Quick Reference

Design CFMEA Quick Reference

- 1. Conditions to do an FMEA and the FMEA scope assuming complete, accurate FMEA is available for current model.**
 - 1.1. For a new design, complete the entire FMEA
- 2. Inputs may include:**
 - 2.1. P-diagram (see FMEA Handbook page 4-12)
 - 2.2. Boundary diagram (see FMEA Handbook page 4-7)
 - 2.3. Interface matrix (see FMEA Handbook page 4-9)
 - 2.4. Perform SDS/regulatory requirement review
 - 2.5. Attach these documents to your FMEA
- 3. Team**
 - 3.1. Obtain a team facilitator (See Appendix B)
 - 3.2. To assure cross functionality, include Subject Matter Experts as required
 - 3.3. Assure names are in header
- 4. Function**
 - 4.1. List all functions remembering service, assembly, manufacturing, and disassembly
 - 4.2. Functions are verb-noun, measurable, and include special conditions
 - 4.3. Include all SDS requirements
- 5. Failure Mode: For each Function and all its measurables, use the 4 Thought Starters:**
 - 5.1. No Function
 - 5.2. Partial/Over Function/Degraded Over Time
 - 5.3. Intermittent Function
 - 5.4. Unintended Function

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Concept FMEA

Design Concept FMEA Quick Reference, Continued

- 6. **Effects: Include the Effects (all in the same data entry field) to:**
 - 6.1. Parts or sub-components
 - 6.2. Next higher assembly
 - 6.3. System
 - 6.4. Vehicle
 - 6.5. Customer
 - 6.6. Government regulations
 - 6.7. If the effect is non-compliance with a regulatory requirement or hazard, state this clearly

 - 7. **Severity**
 - 7.1. Use the rating table (see FMEA Handbook page 4-32)
 - 7.2. For the Effect set listed, and assign one Severity per Failure Mode
 - 7.3. Severity is based on the **highest** ranking (worst) effect in the Failure Mode set
 - 7.4. 9 and 10 are reserved for hazard or non compliance with a regulatory requirement

 - 8. **Classification**
 - 8.1. In all circumstances, leave this column blank in this FMEA

 - 9. **Cause**
 - 9.1. List all Causes for the Failure Mode, each in its own field
 - 9.2. Consider both “assumptions” for this Cause list:
 - 9.2.1. The item is manufactured/assembled within engineering specifications
 - 9.2.2. The design includes a deficiency that may cause unacceptable variation in the manufacturing or assembly process.
-

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Concept FMEA

Design Concept FMEA Quick Reference, Continued

10. Occurrence

- 10.1. Use the rating table (see FMEA Handbook page 4-43)
- 10.2. For the Cause listed, assign one Occurrence representing the likelihood that this Cause will Occur over the design life of the item
- 10.3. If between two values in the table, use the higher value
- 10.4. Use a 10 if the Occurrence cannot be estimated at this time
- 10.5. Use a 10 if the team cannot agree to the Occurrence

11. Current Design Controls

- 11.1. List those prevention controls that have already reduced or will reduce the Occurrence of this Failure Mode or Cause (identified by (P))
- 11.2. List the testing or other Detection methods best able to induce or discover this Failure Mode or Cause and which WILL be performed (identified by (D))

12. Detection

- 12.1. Use the rating table (see FMEA Handbook page 4-54)
- 12.2. For the Detection type controls listed, pick the **best** (most likely to detect) and assign the Detection representing the likelihood that this Cause or Failure Mode will be detected by this method
- 12.3. If between two values in the table, use the higher value
- 12.4. Use a 10 if there is no Detection method
- 12.5. Use a 1 only when this method is guaranteed to Detect
- 12.6. Remember that there is a difference between “if it happens this test will detect it” and “this test will make it happen if its ever going to happen in the field and we’ll know that it happened by this test.” The second is what we are rating in Detection

13. RPN – Multiply Severity times Occurrence times Detection

- 13.1. RPN is a value between 1 and 1000
- 13.2. There is no threshold value above which an action must be taken or below which we are excused from considering an action

Continued on next page

Concept FMEA

Design Concept FMEA Quick Reference, Continued

14. Recommended Action

- 14.1. Enter an action on any YS or YC classified item
- 14.2. If there are no YS or YC items in this FMEA, consider actions for the highest Severity times Occurrence combinations (Criticality) and the highest RPNs
- 14.3. If there is no action planned, enter "None" or "None at this time"

15. Responsibility and Target Completion Date

- 15.1. Enter the individual (name or job title) for this action
- 15.2. Enter a due date not "TBD" or "ongoing"

16. Action Taken

- 16.1. Enter a brief description of the completed action
- 16.2. Do not enter "completed" or "done"

17. Revised Severity, Revised Occurrence, Revised Detection and Revised RPN

- 17.1. Enter the numbers in the appropriate column for the Severity, Occurrence, and Detection and therefore the Revised RPN

18. Submit the FMEA to the FMEA core book at

WWW.CTIS.Ford.com

Concept FMEA

Process Concept FMEA Quick Reference

Process CFMEA Quick Reference

1. **Conditions to do an FMEA and the FMEA scope assuming complete, accurate FMEA is available for current model.**
 - 1.1. New process – complete entire FMEA
 2. **Inputs may include:**
 - 2.1. P-diagram (see FMEA Handbook page 5-8)
 - 2.2. Process flow with boundary indicated
 - 2.3. Process characteristic matrix
 - 2.4. Regulatory requirement review
 - 2.5. Attach these documents to your FMEA
 3. **Team**
 - 3.1. Obtain a team facilitator (see Appendix B)
 - 3.2. Assure cross functionality – include Subject Matter Experts as required
 - 3.3. Assure names are in header
 4. **Function**
 - 4.1. List all functions within scope
 - 4.2. Functions are verb, noun, measurable and include special conditions
 5. **Failure Mode: For each Function and all its measurables, use the 4 Thought Starters:**
 - 5.1. No Function
 - 5.2. Partial/Over Function/Degraded Over Time
 - 5.3. Intermittent function
 - 5.4. Unintended Function
-

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Concept FMEA

Process Concept FMEA Quick Reference, Continued

6. **Effects: Include the Effects (all in the same data entry field) to:**
 - 6.1. Operator safety
 - 6.2. Next user
 - 6.3. Downstream users
 - 6.4. Machines /equipment
 - 6.5. Vehicle operation
 - 6.6. Ultimate customer
 - 6.7. Government regulations
 - 6.8. If the effect is non-compliance with a regulatory requirement or hazard to a customer or to an in-plant operator, state this clearly
7. **Severity**
 - 7.1. Use the rating table (FMEA Handbook page 5-26)
 - 7.2. For the Effect set listed, assign one Severity per Failure Mode
 - 7.3. Severity is based on the **highest** ranking (worst) effect in the Failure Mode set
 - 7.4. 9 and 10 are reserved for hazard or non compliance with a regulatory requirement
8. **Cause**
 - 8.1. List all Causes for the Failure Mode, each in its own field
 - 8.2. Consider both “assumptions” for this Cause list:
 - 8.2.1. Incoming parts/materials to the operation are correct
 - 8.2.2. There are incoming sources of variation
9. **Occurrence**
 - 9.1. Use the rating table (FMEA Handbook page 5-38)
 - 9.2. For the Cause listed, and assign one Occurrence representing the likelihood that this Cause will Occur over the process life of the item
 - 9.3. If between two values in the table, use the higher value
 - 9.4. Use a 10 if the Occurrence cannot be estimated at this time
 - 9.5. Use a 10 if the team cannot agree to the Occurrence

Continued on next page

Concept FMEA

Process Concept FMEA Quick Reference, Continued

10. Current Process Controls

- 10.1. List those prevention controls that have already reduced or will reduce the Occurrence of this Failure Mode or Cause and are in the control plan (identified by (P))
- 10.2. List the testing or other Detection methods best able to induce or discover this Failure Mode or Cause and which WILL be performed (identified by (D))
- 10.3. Current controls can only be listed if they will be completed before the item leaves the production facility

11. Detection

- 11.1. Use the rating table (FMEA Handbook page 5-46)
- 11.2. For the Detection type controls listed, pick the **best** (most likely to detect) and assign the Detection representing the likelihood that this Cause or Failure Mode will be detected by this method
- 11.3. If between two values in the table, use the higher value
- 11.4. Use a 10 if there is no Detection method
- 11.5. Use a 1 only when this method is guaranteed to Detect

12. Classification

- 12.1. Leave the column blank in all circumstances

13. RPN – Multiply Severity times Occurrence times Detection

- 13.1. RPN is a value between 1 and 1000
- 13.2. There is no threshold value above which an action must be taken or below which we are excused from considering an action

Continued on next page

Concept FMEA

Process Concept FMEA Quick Reference, Continued

14. Recommended Action

- 14.1. Consider actions for the highest Severities, for the highest Severity times Occurrence combinations (Criticality), and the highest RPNs
- 14.2. If there is no action planned enter “None” or “None at this time”

15. Responsibility and Target Completion Date

- 15.1. Enter the individual (name or job title) for this action
- 15.2. Enter a due date, not “TBD” or “ongoing”

16. Action Taken

- 16.1. Enter a brief description of the completed action
- 16.2. Do not enter “completed” or “done”

17. Revised Severity, Revised Occurrence, Revised Detection, and Revised RPN

- 17.1. Enter the numbers in the appropriate columns for Severity, Occurrence, or Detection, and therefore the Revised RPN

18. Submit the FMEA to the FMEA core book at

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Design FMEA

Section 4 Contents

In This Section

Description	See Page
FMEA Information Flow	
FMEA Information Flow	4-4
FMEA Team	4-5
FMEA Scope	4-6
Extent of FMEA	4-6
Inputs to Design FMEA	
Boundary Diagram	4-7
Interface Matrix	4-9
P-Diagram	4-12
FMEA Form Header	
Filling In Header Information	4-15
Design FMEA Form	4-18
FMEA Model	4-19
Working Model Path/Step 1	4-20
Item / Function	
Item/Function	4-21
Determine Function	4-21
How to Identify Item/Functions	4-22
Examples of Item/Functions	4-22
Item/Function Worksheet	4-23
Potential Failure Modes	
Potential Failure Modes	4-24
How to Identify Failure Mode Types	4-24
Sample Functions and Failures	4-26
How to Identify Potential Failure Modes	4-27
Functional Approach	4-28
Potential Effect(s) of Failure	
Potential Effect(s) of Failure	4-29
How to Identify Potential Effect(s) of Failure	4-29
Examples of Potential Effect(s) of Failure	4-30

Continued on next page

Design FMEA

Section 4 Contents, Continued

In This Section

Description	See Page
Severity	
Severity	4-31
How to Identify Severity	4-31
Design Severity Rating Table	4-32
Classification	
Classification	4-33
YC Classification Rating	4-33
Recommended Actions	4-34
Working Model Path/Step 2	4-35
Potential Cause(s) / Mechanism(s) of Failure	
Potential Cause(s) / Mechanism(s) of Failure	4-36
How to Identify Potential Cause(s) of Failure	4-36
Assumption 1	4-38
Examples of Assumption 1	4-39
Assumption 2	4-39
Examples of Assumption 2	4-40
Occurrence	
Occurrence	4-41
How to Identify Occurrence	4-41
Occurrence Rating Table	4-43
Classification	
YS Classification Rating	4-44
Design Classification Possibilities	4-45
Working Model Path/Step 3	4-46
Current Design Controls	
Current Design Controls	4-47
Types of Design Controls	4-47
How to Identify Design Controls	4-49
Examples of Design Controls	4-50

Continued on next page

Design FMEA

Section 4 Contents, Continued

In This Section

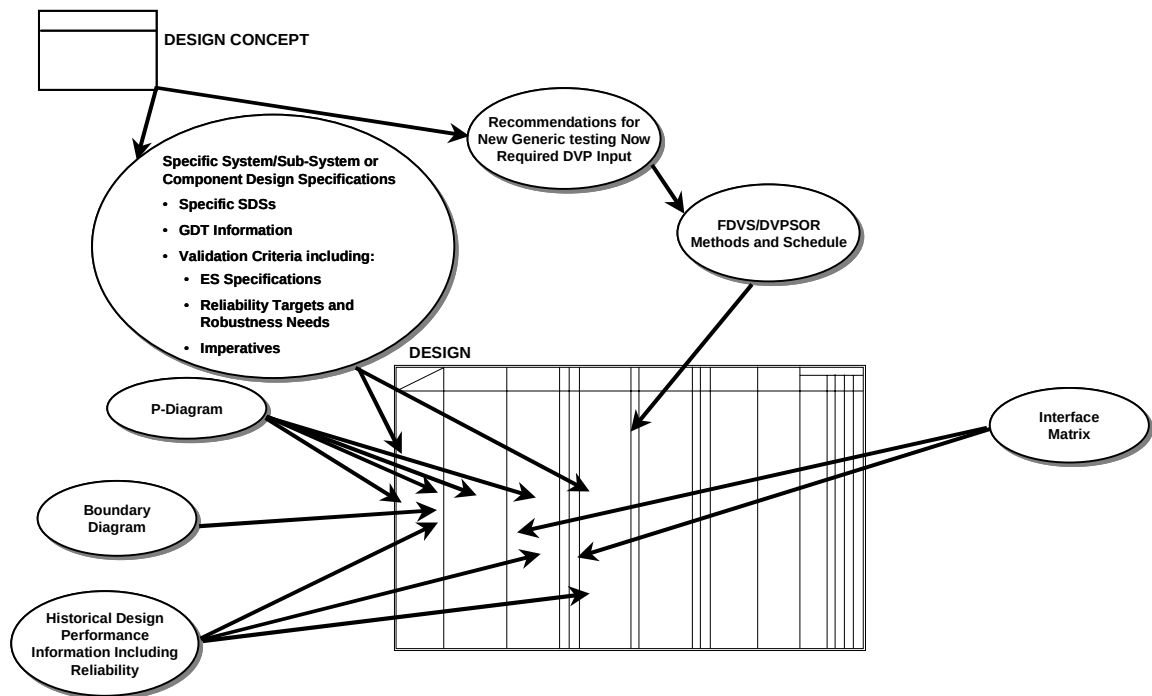
Description	See Page
Detection	
Detection	4-51
How to Identify Detection Rating	4-52
Effectiveness Factors	4-53
Design Detection Rating Table	4-54
Risk Priority Number	
Risk Priority Number	4-55
Recommended Actions	
Recommended Actions	4-56
How to Identify Recommended Actions	4-57
Examples of Recommended Actions	4-57
Actions Taken	
Actions Taken	4-58
How to Identify Actions Taken	4-58
Responsibility and Target Date Completion	4-59
Resulting RPN	
Revised Severity, Revised Occurrence, Revised Detection, and Revised RPN	4-60
Outputs from Design FMEA	
Outputs from Design FMEA	4-61
Reliability and Robustness Checklist	4-61
Sample Design FMEA	4-64
Design FMEA Quick Reference	4-67

Design FMEA

Design FMEA Information Flow

Design FMEA Information Flow

The graphic below denotes some typical inputs to a Design FMEA. Many of these input items are fed from the Concept FMEA, or from the results of the Recommended Actions of the Concept FMEA.



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.

One application of a DFMEA is an Attribute FMEA. This vehicle level FMEA assists the team in analyzing potential trade-offs as well as the present design for the risk of compromising customer satisfaction. For more on an Attribute FMEA, see Appendix E.

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Design FMEA

Design FMEA Information Flow, Continued

Design FMEA Information Flow Continued

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.

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. For more information, see Appendix B.

Design FMEA

FMEA Scope

- FMEA Scope** Scope is the boundary or extent of the analysis and defines what is included and 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 setting the incorrect scope, lengthening or missing the analysis and establishing the wrong team membership.
- 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.

Refer to Appendix B, page B-10 for more information.

- Extent of FMEA** 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 check point?
 - 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.

Design FMEA

Inputs to Design FMEA

Boundary Diagram

The FMEA's scope, is defined using a boundary diagram illustrating its subsystems/components. Further more, to insure that all sources of failure mode causes and effects are considered, It also illustrates elements outside the FMEA.

Boundary diagrams are mandatory breaking the FMEA into manageable levels. It does this by graphically illustrating the relationships between the subsystems, assemblies, subassemblies and system components. 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 must 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. 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.

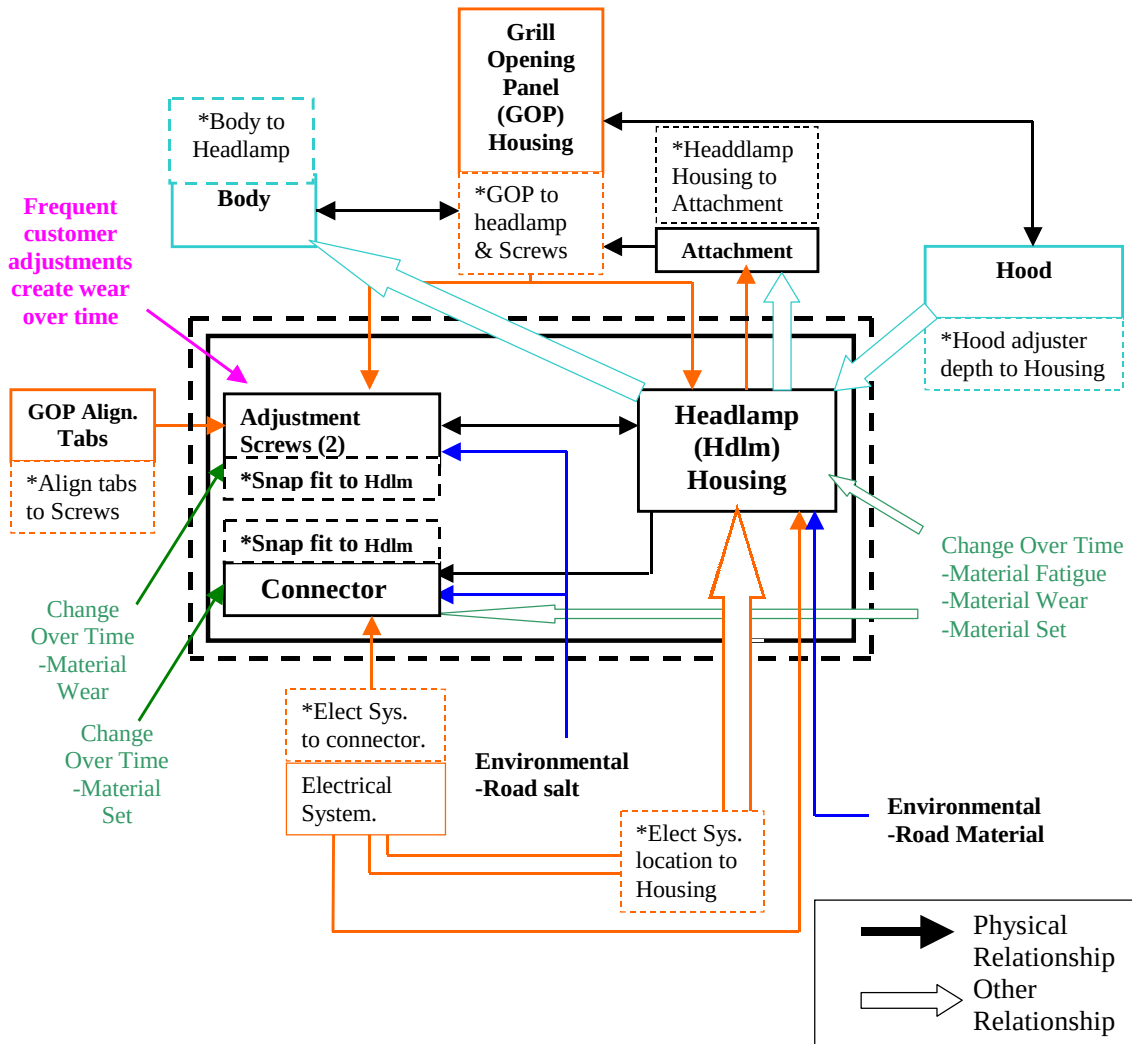
Continued on next page

Design FMEA

Inputs to Design FMEA, Continued

Boundary Diagram Continued

The following graphic is an example of a boundary diagram.



*** 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

Continued on next page

Design FMEA

Inputs to Design FMEA, Continued

Interface Matrix

The interface matrix shown on the following page is a recommended robustness tool that acts as an input to Design FMEA. The interface matrix identifies and quantifies the strength of system interactions. 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 interface matrix is also an input to the Potential Causes / Mechanisms Failure column of the DFMEA, the boundary diagram, and the P-diagram's noise section. When completed or revised, attach the interface matrix to the FMEA.

The example on the following page shows an 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 (e.g., energy transfer, information exchange, etc.)

The interface matrix is also used to check the validity of the completed Causes. In addition, every interaction, both positive and negative, should be verified. Then, negative values are analyzed for corrective action recommendations.

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

<http://www.dearborn2.ford.com/avtqual2/fmea/index.htm>

Continued on next page

Design FMEA

Inputs to Design FMEA, Continued

Interface Matrix Continued

Simple Headlamp Interface Matrix, partially completed to illustrate technique

	Grill Opening Panel	Hood	Headlamp Housing	Headlamp	Screws/fasteners	Wiring/electrical system	Connector	Body
Grill Opening Panel		-1 -2	-1 -1	2 -2				
Hood	-1 -2		-1 -1	1 2				
Headlamp Housing	-1 -1	-1 -1		2				
Headlamp	2 -2	-1 -1	2					
Screws/fasteners								
Wiring/electrical system								
Connector								
Body								

P	E	P: Physically touching	E: Energy transfer
I	M	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

Design FMEA

Inputs to Design FMEA, Continued

Interface Matrix Continued

The facing page shows an example of an 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 (e.g., energy transfer, information exchange, etc.)

The interface matrix is an input to the Potential Causes/Mechanisms Failure column of the DFMEA form.

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

Using the headlamp interface matrix as an example:

- The +2 in the Top-Left Quadrant means that there is physical contact between the systems and is necessary for function. Examples of system interactions include exhaust manifold and exhaust pipe.
- The -1 in the Top-Right Quadrant means that there is an energy transfer (e.g., vibration) which causes negative effects but does not prevent functionality.
- The +2 in the Bottom-Right Quadrant means that there is a material exchange (e.g., exhaust gases) that is necessary for function.

Negative values are analyzed for recommended actions.

Continued on next page

Design FMEA

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. After the error states are identified, the noise factors that could lead to the error states are listed (according to the five basic sources of noise):

- Piece to piece variation
- Changes in dimension over time or mileage/ e.g. wear, fatigue
- Customer usage
- External conditions of usage/ e.g. road, climate
- Internal conditions of usage, i.e. System interactions

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

Depending on the level of detail contained in the P-diagram, this information will input to various FMEA columns. When completed or revised, 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:
 - o Potential Causes for failure (i.e., system interactions, piece to piece variation, external climatic and road conditions, and customer usage)
 - o Failure Modes (i.e., degradation)
 - o Potential Effects of failure (i.e. error states)
 - o Current Controls (i.e., control factors)
 - o Recommended Actions (i.e. control factors)

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

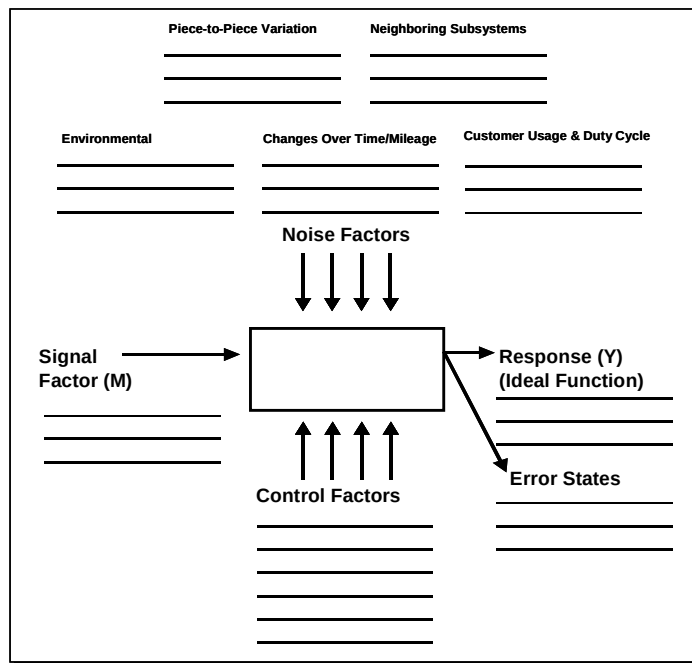
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Design FMEA

Inputs to Design FMEA, Continued

P-Diagram Continued

Blank P-Diagram



A **Control Factor** is a list of the factors already incorporated in the design that tend to reduce the likelihood of the Error States existing. Control Factors are the means to make the items' function more robust.

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

- Deviation of intended Function
Deviation of intended Function is equal to Potential Failure Modes in the FMEA.
Degrees of Potential Failure Modes are:
 - No Function,
 - Partial Function (including Degraded Function over time),
 - Intermittent Function,
 - Over function
- 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).

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

The following page is an example of a completed P-diagram.

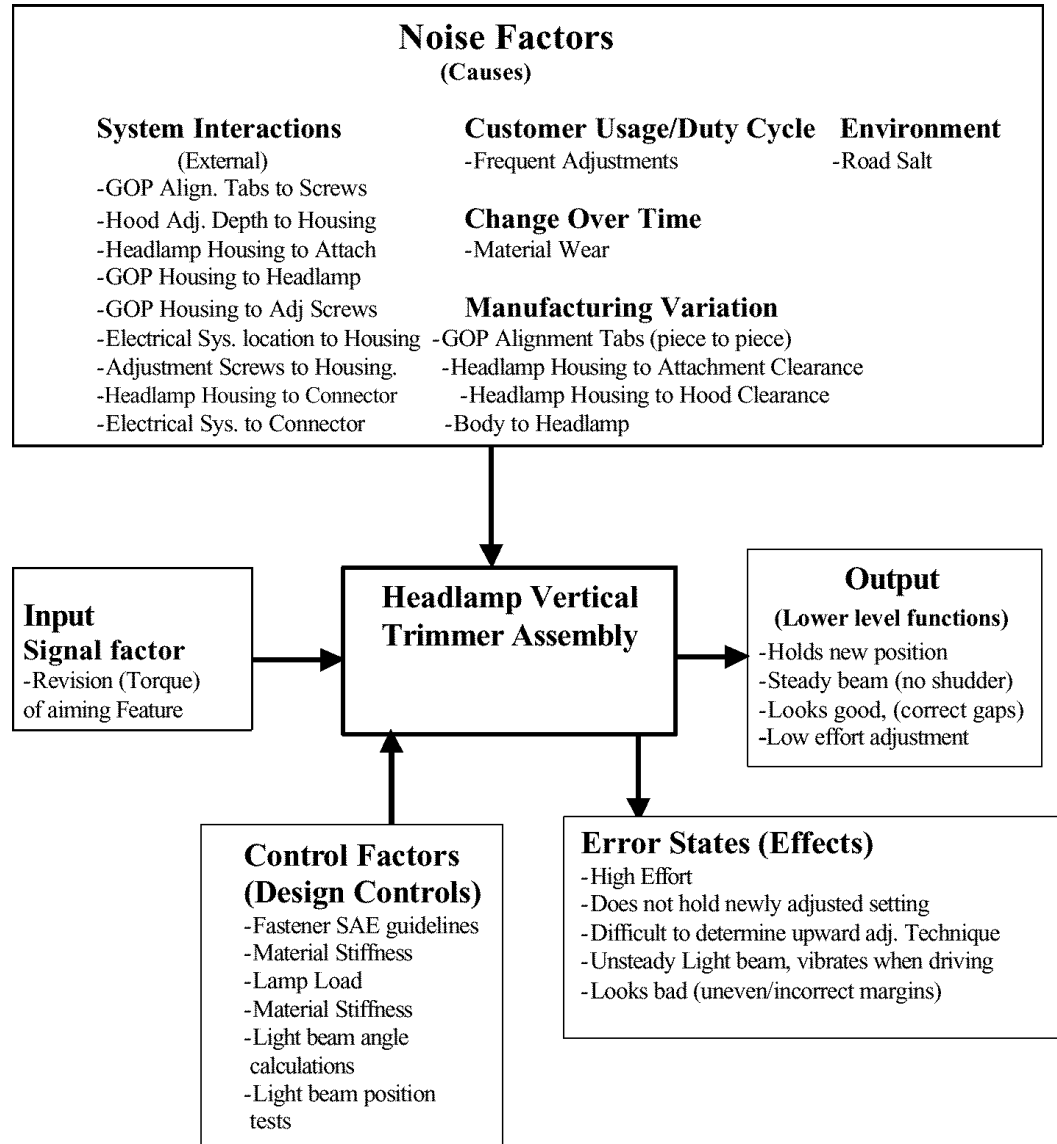
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Design FMEA

Inputs to Design FMEA, Continued

P-Diagram Continued

Sample Headlamp P-Diagram



Design FMEA

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.

Ford Motor Company

____System
____Subsystem
____Component
Model Year(s)/Program(s) _____
Core Team: _____

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
(DESIGN FMEA)

Design Responsibility _____
Key Date _____

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

Item Function	Potential Failure Mode	Potential Effect(s) of Failure	S e v e r i t y	C a u s e s	Potential Cause(s)/ Mechanism(s) of Failure	O c c u r r e n c e	Current Design Controls — Prevention — Detection	D e t e c t i v e R. P. N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results			
											Actions Taken	S e v e r i t y	O c c u r r e n c e	R. P. N.

Continued on next page

Design FMEA

FMEA Form Header, Continued

Filling In Header Information Continued

- **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 and number of the system or subsystem being analyzed.**

Continued on next page

Design FMEA

FMEA Form Header, Continued

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.

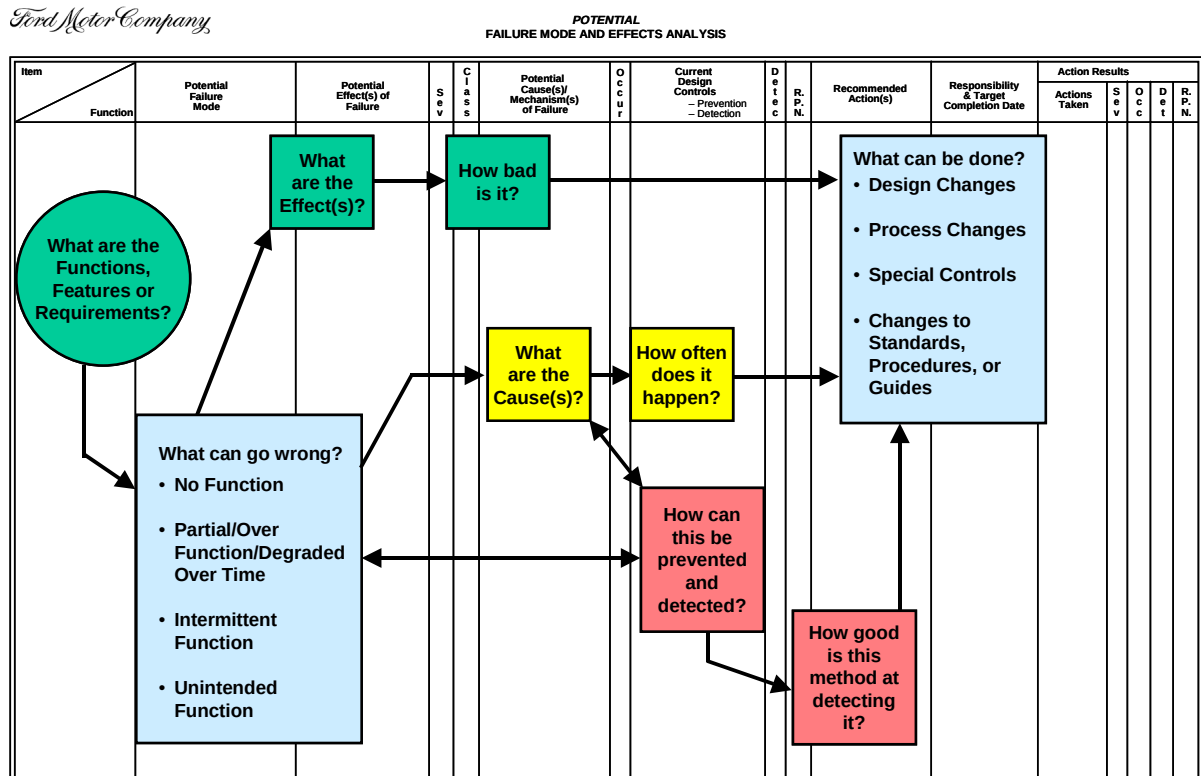
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Design FMEA

FMEA Model

Ford FMEA 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.

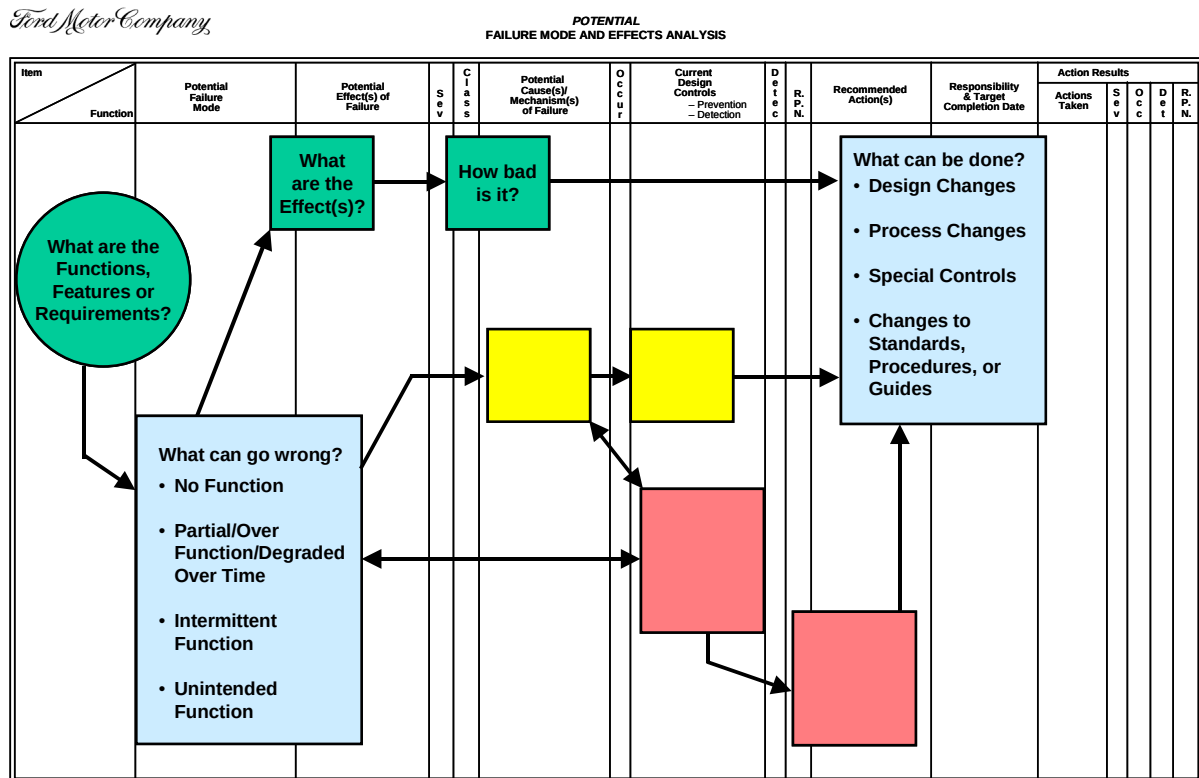


The Ford FMEA Model has three distinct paths/steps that should be executed according to the directions on the following pages.

Design FMEA

Working Model Path/Step 1

Path/Step 1 The first path/step that should be followed is illustrated here:



Starting with Path/Step 1, identify the:

- Functional Requirements within scope.
- Corresponding Failure Modes for each function.
- Effects of each Failure Mode.
- Severity (S) rating with highest Severity for each effect set recorded in Severity column which prioritizes the Failure Modes.
- Recommended Actions to change the design of the product to eliminate failure or reduce/mitigate the effects.

Note: Only a small number of Failure Modes will typically be resolved at Path/Step 1.

Design FMEA

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.



This information should be contained in the form header as system, subsystem, or component including the CPSC code.

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

Design FMEA

Item/Function, Continued

How to Identify Item/Functions



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



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. See Appendix B for lists of verb and noun thought starters

One tool to identify a Function is called Function Tree Analysis. See 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

Design FMEA

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?

Design FMEA

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 should be the most commonly seen. The third and fourth types are typically missed when performing the FMEA.

1. **No Function:** System or design is totally dysfunctional 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 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

Design FMEA

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 impacts such as temperature, moisture, environmental, 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 impacts the product or process when synergy exists. Their combination performance leads to an undesirable performance and hence “unintended function.”

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

Design FMEA

Potential Failure Modes, Continued

Sample Functions and Failures



The following table is a sample of functions and their failures:

Item / Function	Failure Mode(s)
<i>Jack Assembly</i> <i>Part Number xxxx.xxxxxx.ab</i> <i>Raise Vehicle for tire change</i> <i>To + X feet above ground level</i> <i>Within Y minutes</i> <i>Under Z force limits</i> <i>In all weather conditions</i>	<u>No Function:</u> <i>Does not raise the vehicle at all (inoperative)</i>
	<u>Partial/Over Function/Degraded Over Time:</u> <i>Raises the vehicle to less than X feet above ground level initially</i> <i>Raises the vehicle in greater than Y minutes</i> <i>Requires more than Z force to raise the vehicle</i> <i>Raises vehicle less than X feet over time</i>
	<u>Intermittent Function:</u> <i>Inoperable in wet weather</i> <i>Inoperable when below 0° C</i>
	<u>Unintended Function:</u> <i>Positions, raises but cannot support other vehicle</i> <i>Raises lighter, smaller vehicle</i> <i>Vehicle unstable</i>

Continued on next page

Design FMEA

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.

Continued on next page

Design FMEA

Potential Failure Modes, Continued

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
-

Design FMEA

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

Design FMEA

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)

Radio Frequency Interface (RFI) noise

Rough

Inoperative

Unpleasant Odor

Operation Impaired

Thermal Event

Regulatory Non Compliance

Design FMEA

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.

Continued on next page

Design FMEA

Severity, Continued

Design
Severity
Rating Table

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

Design FMEA

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.

Design FMEA

Recommended Actions

Consider Recommended Actions



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

- a. Eliminate the Failure Mode
- b. 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 reduce Severity, consider this action:

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

To accomplish this:

- Eliminate Failure Mode(s) or change its effect on the product performance.

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

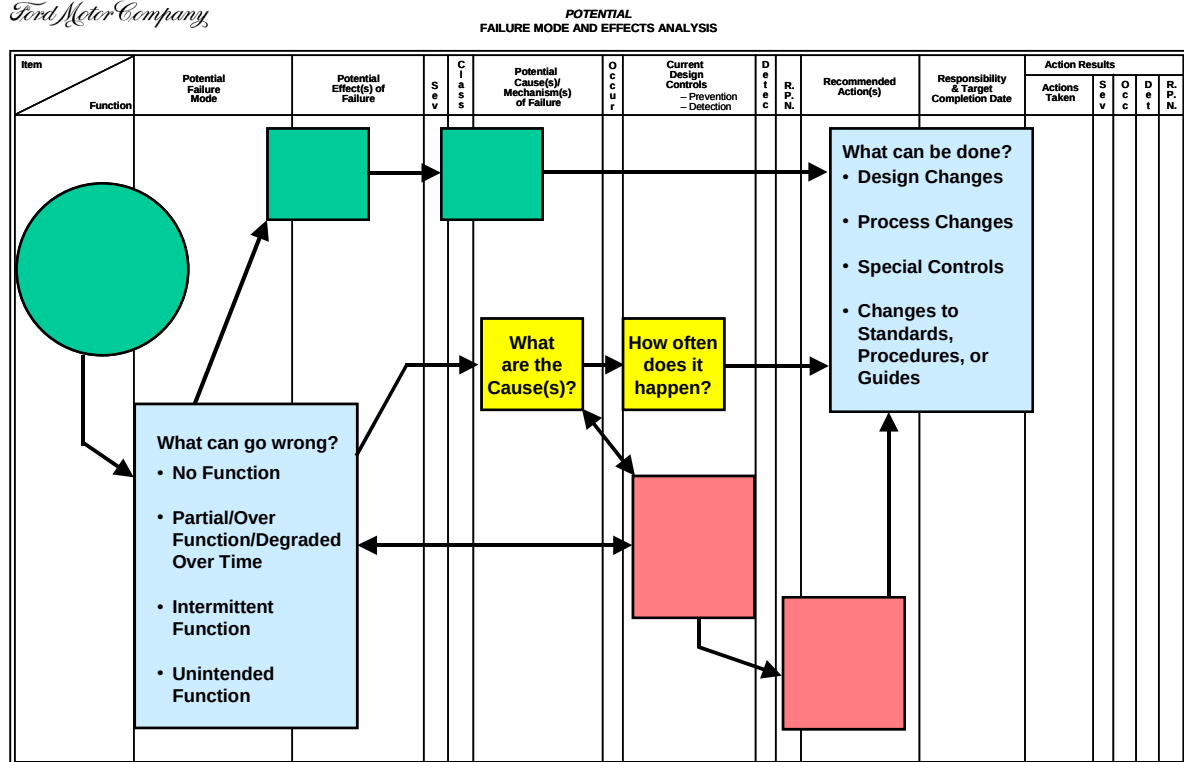
Design FMEA

Working Model Path/Step 2

Ford FMEA Model Path/Step 2

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

Ford Motor Company



Identify:

- The associated Causes (first level and root).
- Their estimated Occurrence ratings.
- Prioritization by Failure Mode/Causes by the product of Severity (S) rating and Occurrence (O) rating.
- Recommended Actions to change the design of the product to reduce Occurrence or impact the prioritization of the S x O (Criticality) combinations.

Design FMEA

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.



Root cause must be determined when Severity is 9 or 10. Use a "why ladder" to determine root cause. On a component DFMEA, root cause is a part characteristic.

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

Design FMEA

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 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 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 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

Design FMEA

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.

Root causes, described in terms of part characteristic(s), 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 see page 4-43.

For additional assistance in determining root cause, review the Global 8D methodology.

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

Design FMEA

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 (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

Design FMEA

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.
-



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.

Continued on next page

Design FMEA

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:

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

Continued on next page

Design FMEA

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.

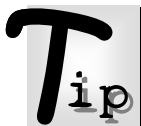


If the Failure rate cannot be estimated, then judge the likelihood that the Cause and its resultant Failure Mode will occur over the design life (150,000 miles or 10 years in service standard).

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 Special Characteristics in the Design FMEA.



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).

- 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 all 6M vehicles), an Occurrence = 1 would indicate only 4 failures per model year, whereas an Occurrence = 2 would represent 40 failures per model year and an Occurrence = 3 would represent 400 failures per 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

Design FMEA

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.

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

Continued on next page

Design FMEA

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 safe vehicle or product function, compliance with government regulations, or customer satisfaction, and may require special manufacturing, assembly, supplier, shipping monitoring and/or inspection actions or controls. These characteristics become potential “Critical Characteristics” or potential “Significant Characteristics.”

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

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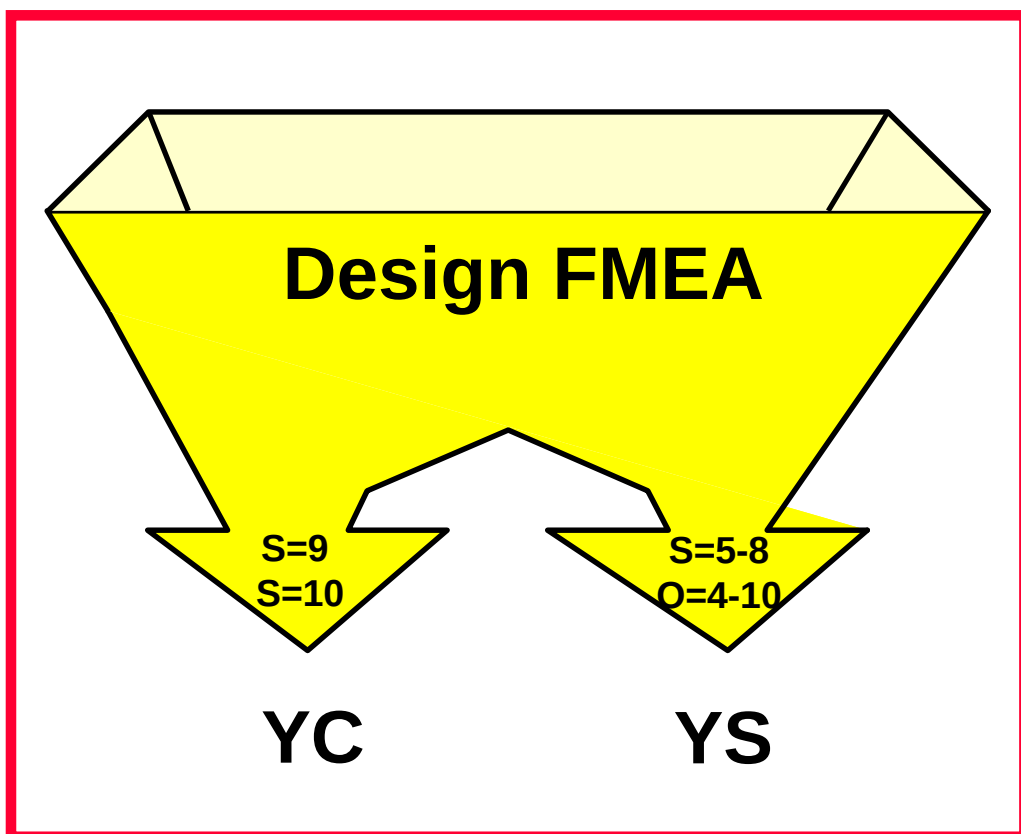
Design FMEA

Classification, Continued

Design Classification Possibilities

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

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



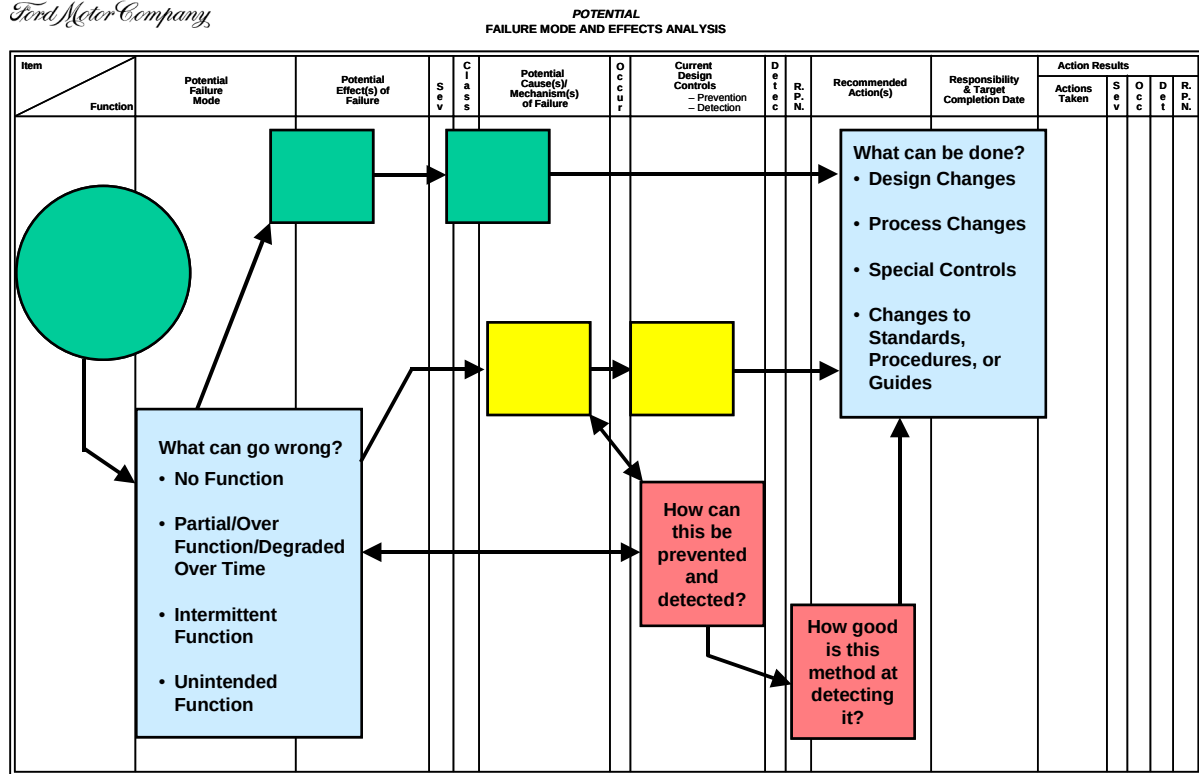
Design FMEA

Working Model Path/Step 3

**Working
Model
Path/Step 3**

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

Ford Motor Company



Identify the:

- Design verification actions (Detection methods) to ensure readiness to release.
- Corresponding Detection (D) ratings.
- Associated Recommended Actions.
- The Risk Priority Number (RPN).

Continued on next page

Design FMEA

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.*
-

Continued on next page

Design FMEA

Current Design Controls, Continued

Types of Design Controls Continued

The preferred approach is to first use Type 1 controls if possible. The initial Occurrence rankings will be affected by the Type 1 controls provided they are integrated as part of the design intent. The initial Detection rankings will be based on the Type 2 current controls, assuming the prototypes and models being used are representative of design intent.

When entering the design controls, place a 'P' before the prevention type controls and place a 'D' before the detection type controls. The Occurrence ranking may need to be revised after the identification of Type 1 prevention controls.



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.

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Design FMEA

Current Design Controls, Continued

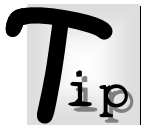
How to Identify Design Controls



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 FMEAs
 - Previous DV Plans
 - Reliability and robustness checklists
 - 8Ds (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?



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

Design FMEA

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.

Design FMEA

Detection

Detection



Detection is the rank associated with the best 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 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 4-54.

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

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Design FMEA

Detection, Continued

How to Identify Detection Rating



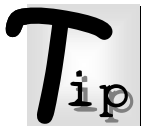
When estimating a Detection rating, consider only those controls that will be used to detect the Failure Mode or its Cause. Controls intended to prevent or reduce the Occurrence of a Cause of a Failure Mode are considered when estimating the Occurrence rating. Since prevention controls do not detect,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

First, determine if any of the design controls listed can be used to prevent the cause of a Failure Mode. If a control is a prevention control, place a (P) after it and enter it in the Current Controls column. Remember that the Occurrence rating may be affected.



Next, estimate the effectiveness of each Type 2 design control mode listed. When estimating effectiveness, consider the effectiveness factors on the next page. Estimate the capability of each design 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

Design FMEA

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

Design FMEA

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

Design FMEA

Risk Priority Number

Risk Priority Number



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

$$\text{FORMULA: } RPN = (S) \times (O) \times (D)$$



There is no 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.

Design FMEA

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.

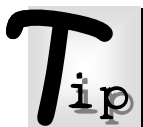
In general practice when the Severity is a 9 or 10, special attention must be given to assure that the risk is addressed through existing design controls or preventative or corrective action(s), regardless of the RPN. In all cases where the effect of an identified potential Failure Mode could be a hazard 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 of an action is to eliminate potential Failure Modes. 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 reliability and robustness checklist.

Continued on next page

Design FMEA

Recommended Actions, Continued

How to Identify Recommended Actions



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

- a. *Revised design geometry and/or tolerances*
- b. *Revised material specification*
- c. *Design of experiments (particularly when multiple or interactive causes are present)/or other problem solving techniques*
- d. *Revised test plan*
- e. *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.

Design FMEA

Actions Taken

Actions Taken



Responsibility for the Recommended Action – 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 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 Appendix B for copies of the SAE FMEA Quality Objectives.

Continued on next page

Design FMEA

Actions Taken, Continued

**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.
-

Design FMEA

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.

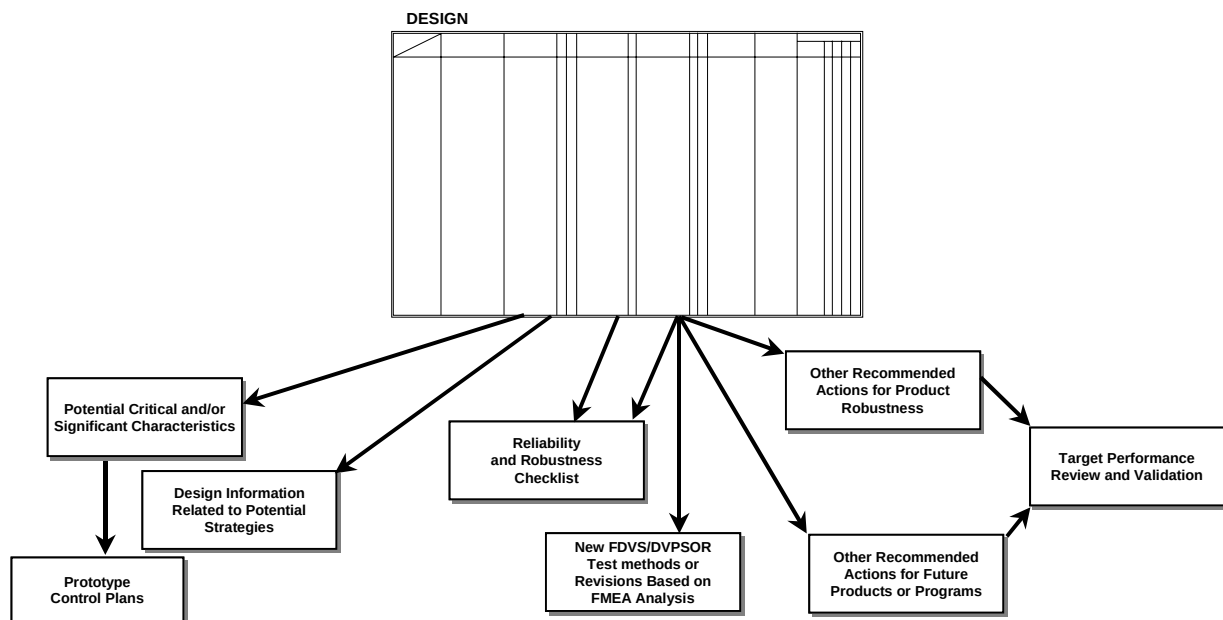
If no actions are listed, leave these columns blank. If the actions are completed, enter the revised Severity, Occurrence, or Detection rating, even if these actions did not result in a change to the ranking.

Design FMEA

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.



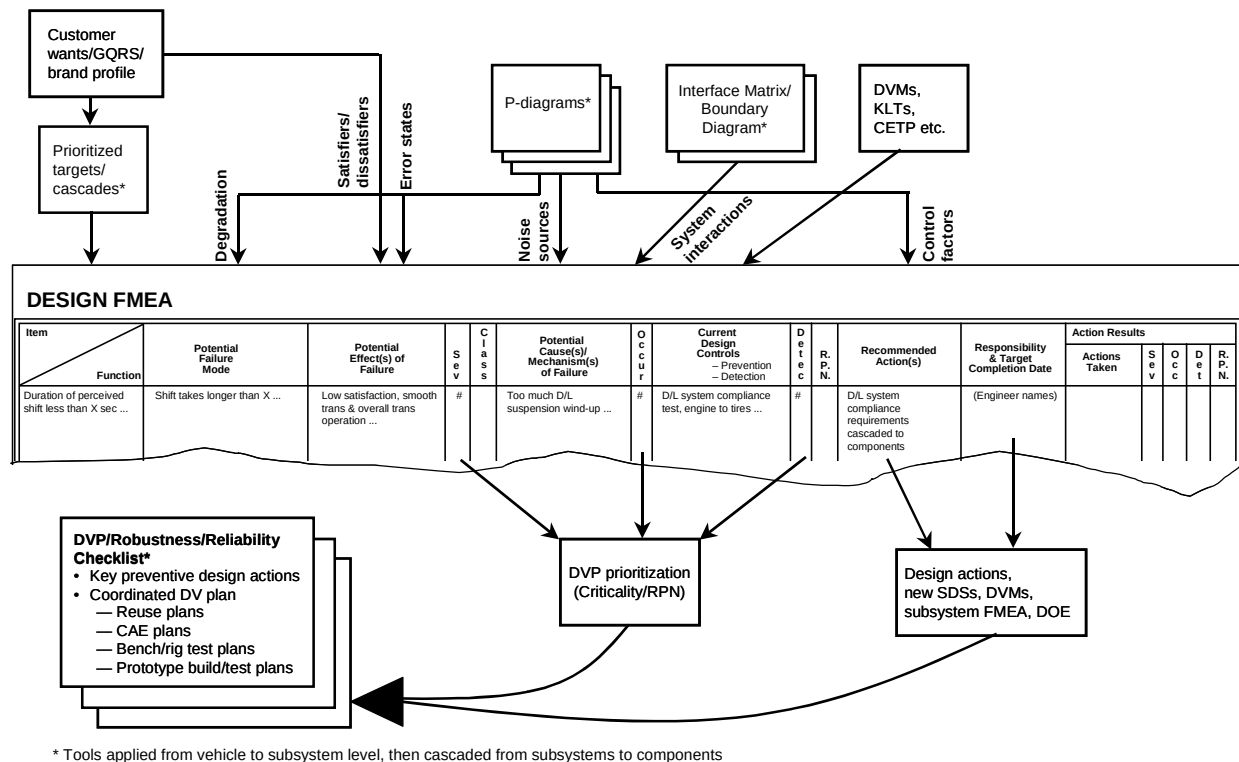
Reliability and Robustness Checklist

The robustness and reliability checklist is an output of the robustness integrated FMEA process. The following page is an example of a robustness and reliability checklist. The robustness and reliability checklist:

- Summarizes key robustness Attributes and Design Controls.
- Links the DFMEA to the Design Verification Plan (DVP), (an input into the DVP).
- Should be a key document to review as part of the design review process.

Design FMEA

Tool Integration



Tool Integration

The illustration above shows where the Robustness Tools are input into the DFMEA.

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

- Failure Mode — Degradation from the P-diagram
- Effect — Error States from the P-diagram
- Cause of Failure — Noise Factors from the P-diagram and Systems Interactions from the boundary diagram and interface matrix
- Actions — Control Factors from the P-diagram

Design FMEA

ROBUSTNESS and RELIABILITY CHECKLIST

Source: Shift Quality FMEA Team/Eureka

EXAMPLE

The image shows a screenshot of the CD132 software interface, which is a Design Failure Mode and Effects Analysis (DFMEA) tool. The interface is divided into several sections:

- Inputs from other tools:** A section at the top right for integrating data from other tools.
- P-diagram DFMEA:** A section on the left for creating a P-diagram (Problem Statement, Potential Failure Modes, and Effects Analysis).
- NOISE FACTOR MANAGEMENT:** A central section for managing noise factors, including a table for "NOISE FACTOR MANAGEMENT" with columns for "Cat", "Strategy", and "Specifics".
- Test Conditions:** Several sections for defining test conditions, including:
 - MANUFACTURING VARIABILITY:** A table for manufacturing variability factors.
 - STRESS OVER TIME / MILEAGE -- over Useful Life Period:** A table for stress over time/mileage.
 - CUSTOMER USAGE -- over Useful Life Period:** A table for customer usage.
 - ENVIRONMENT:** A table for environmental conditions.
- Legend:** A legend at the bottom explaining the symbols used for error states and noise factors.

The legend at the bottom explains the symbols used for error states and noise factors:

- IF1, IF2, IF3 ...:** Ideal Functions
- A, B, C, ...:** Error States
- A:** Noise Factor incorporated in the test - letter(s) indicates the Error State(s)
- A:** Noise Factor scheduled, but not yet incorporated in the test - letter(s) indicates the Error State(s)

Source: CD132 Program; Toni Brockers; Tim Davis

Design FMEA

Sample Design FMEA

**Sample
Design FMEA**

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

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Design FMEA

[illegible]

Design FMEA

Design FMEA Quick Reference

Design FMEA Quick Reference

- 1. Conditions to do an FMEA and the FMEA scope assuming complete, accurate FMEA is available for current model**
 - 1.1. New design – complete entire FMEA
 - 1.2. Existing design in new application or environment – revise current model FMEA for impact and change due to new application of environment
 - 1.3. Existing design is being changed for any reason – revise current model FMEA for impact and change due to design change
- 2. Inputs**
 - 2.1. P-diagram (see FMEA Handbook page 4-12)
 - 2.2. Boundary diagram (see FMEA Handbook page 4-7)
 - 2.3. Interface matrix (see FMEA Handbook page 4-9)
 - 2.4. Perform SDS/regulatory requirement review
 - 2.5. Attach these documents to your FMEA
- 3. Team**
 - 3.1. Obtain a team facilitator (see Appendix B)
 - 3.2. Assure cross functionality – include Subject Matter Experts as required
 - 3.3. Assure names are in header
- 4. Function**
 - 4.1. List all functions remembering service, assembly, and manufacturing
 - 4.2. Functions are verb, noun, measurable and include special conditions
 - 4.3. Include all SDS requirements
- 5. Failure Mode: For each Function and all its measurables, use the 4 Thought Starters of:**
 - 5.1. No Function
 - 5.2. Partial/Over Function/Degraded Over Time
 - 5.3. Intermittent Function
 - 5.4. Unintended Function

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Design FMEA

Design FMEA Quick Reference, Continued

6. **Effects: Include the Effects (all in the same data entry field) to:**
 - 6.1. Parts or sub-components
 - 6.2. Next higher assembly
 - 6.3. System
 - 6.4. Vehicle
 - 6.5. Customer
 - 6.6. Government regulations
 - 6.7. If the effect is non compliance with a regulatory requirement or hazard, state this clearly

 7. **Severity**
 - 7.1. Use the rating table (see FMEA Handbook page 4-32)
 - 7.2. For the Effect set listed assign one Severity per Failure Mode
 - 7.3. Severity is based on the **highest** ranking (worst) effect in the Failure Mode set
 - 7.4. 9 and 10 are reserved for hazard or non compliance with a regulatory requirement

 8. **Classification from Working Model Path 1**
 - 8.1. Enter YC in Classification column if Severity is 9 or 10
 - 8.2. If possible, determine and list a Recommended Action to change the design to eliminate this Failure Mode or mitigate the effects

 9. **Cause**
 - 9.1. List all Causes for the Failure Mode, each in its own field
 - 9.2. List Root Cause (part characteristic) for any Failure Modes with a YC classification
 - 9.3. List Root Cause (part characteristic) for any Failure Mode/ Cause combinations with a YS classification
 - 9.4. Consider both “assumptions” for this Cause list:
 - 9.4.1. The item is manufactured / assembled within engineering specifications
 - 9.4.2. The design includes a deficiency that may Cause unacceptable variation in the manufacturing or assembly process
-

Continued on next page

Design FMEA

Design FMEA Quick Reference, Continued

10. Occurrence

- 10.1. Use the rating table (FMEA Handbook page 4-43)
- 10.2. For the Cause listed assign one Occurrence representing the likelihood that this Cause will occur over the design life of the item
- 10.3. If between two values in the table, go higher
- 10.4. Use a 10 if the Occurrence cannot be estimated at this time
- 10.5. Use a 10 if the team cannot agree to the Occurrence
- 10.6. Ratings of 1 are reserved for “theoretically possible, but it's never happened before and won't this time either”

11. Classification

- 11.1. Enter YS in Classification column if Severity is 5 through 8 AND Occurrence is 4 through 10
- 11.2. If possible, determine and list a Recommended Action to change the design to eliminate this Cause or reduce its Occurrence

12. Current Design Controls

- 12.1. List those prevention controls that have already reduced or will reduce the Occurrence of this Failure Mode or Cause (identified by (P))
- 12.2. List the testing or other Detection methods best able to induce or discover this Failure Mode or Cause and which WILL be performed (identified by (D))
- 12.3. Current controls can only be listed if they will be completed before the design is released for production

Continued on next page

Design FMEA

Design FMEA Quick Reference, Continued

13. Detection

- 13.1. Use the rating table (FMEA Handbook page 4-54)
- 13.2. For the Detection type controls listed, pick the **best** (most likely to detect) and assign the Detection representing the likelihood that this Cause or Failure Mode will be detected by this method
- 13.3. If between two values in the table, go higher
- 13.4. Use a 10 if there is no Detection method
- 13.5. Use a 1 only when this method is guaranteed to Detect
- 13.6. Remember that there is a difference between “if it happens this test will detect it” and “this test will make it happen if it's ever going to happen in the field and we'll know that it happened by this test.” The second is what we're rating in Detection.

14. RPN: Multiply Severity times Occurrence times Detection

- 14.1. RPN is a value 1 to 1000
- 14.2. There is no threshold value above which an action must be taken or below which we are excused from considering an action

15. Recommended Action

- 15.1. Enter an action on any YS or YC classified items
- 15.2. If there are no YS or YC items in this FMEA, consider actions for the highest Severity times Occurrence (Criticality) combinations and the highest RPNs
- 15.3. If there is no action planned, enter “None” or “None at this time”

16. Responsibility and Target Completion Date

- 16.1. Enter the individual (by name or job title) responsible for this action
- 16.2. Enter a due date – not “TBD” or “ongoing”

17. Action Taken

- 17.1. Enter a brief description of the completed action
- 17.2. Do not just enter “completed” or “done”

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Design FMEA

Design FMEA Quick Reference, Continued

18. Revised Severity, Revised Occurrence, Revised Detection, and Revised RPN

18.1. Enter the number in the appropriate column for the Severity, Occurrence, and Detection and therefore the Revised RPN

19. Submit the FMEA to the FMEA core book at www.CTIS.Ford.com

20. Complete/update the robustness and reliability checklist
