SURFACE VEHICLE STANDARD

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Potential Failure Mode and Effects Analysis (FMEA)
Including Design FMEA, Supplemental FMEA-MSR, and Process FMEA

RATIONALE

This technical report is being stabilized because the technical committee has determined that the using community is moving towards newer methodology and would like to alert users that this new methodology exists which may want to be considered for new designs. The committee recommends that users refer to SAE1025 for other information.

STABILIZED NOTICE

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FOREWORD

This document was revised by a balanced committee and represents current thoughts and practices on the subject from the viewpoint of OEMs (original equipment manufacturers), suppliers, and consultants. The rating charts and action priority charts are part of harmonization efforts between SAE, AIAG, and VDA. This document serves as a standard that includes requirements and additional recommendations for best practices in the application of FMEA. The goal of this document is to adhere to basic principles of FMEA knowing that procedures for how to perform FMEA will vary by company. This document is referenced in other publications by IATF, ISO, SAE, AIAG, and VDA.

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1. SCOPE

This FMEA standard describes potential failure mode and effects analysis in design (DFMEA), supplemental FMEA-MSR, and potential failure mode and effects analysis in manufacturing and assembly processes (PFMEA). It assists users in the identification and mitigation of risk by providing appropriate terms, requirements, rating charts, and worksheets. As a standard, this document contains requirements—"must"—and recommendations—"should"—to guide the user through the FMEA process. The FMEA process and documentation must comply with this standard as well as any corporate policy concerning this standard. Documented rationale and agreement with the customer are necessary for deviations in order to justify new work or changed methods during customer or third-party audit reviews.

1.1 Purpose

To assist designers and manufacturers in the identification and reduction of technical risk by providing appropriate terms, requirements, evaluation criteria, and worksheet formats.

2. REFERENCES

The following documents are additional references on the subject of this standard. Unless otherwise indicated, the latest issue of the SAE publications shall apply.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP5580 Recommended Failure Modes and Effects Analysis (FMEA) Practices for Non-Automobile Applications

AS9103 Aerospace Series - Quality Management Systems - Variation Management of Key Characteristics

AS13004 Process Failure Mode and Effects Analysis (PFMEA) and Control Plans

2.2 ISO Publications

Copies of these documents are available online at http://webstore.ansi.org/.

ISO 26262 Road Vehicles - Functional Safety

2.3 Other Publications

AIAG and VDA FMEA Handbook, First Edition, June 2019, available from Automotive Industry Action Group, 4400 Town Center, Southfield, MI 48075, Tel: 248-358-3570, www.aiag.org.

IATF 16949, "Automotive Quality Management System Standard," International Automotive Task Force (IATF), Supplement to, and in conjunction with, ISO 9001:2015. IATF 16949:2016 was revised as a standard, cancels and replaces ISO/TS 16949:2009.

3. DEFINITIONS, EXAMPLES, TERMS

The purpose of terms and definitions is to add clarity to some words used in this document that are not otherwise defined in the body of the text.

3.1 DESIGN FMEA FOR MECHANICAL AND ELECTRICAL

Design FMEA is a type of FMEA that analyzes the product design, focusing on potential design-related deficiencies, with emphasis on improving the design and ensuring product operation is safe and reliable during useful life.

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3.2 DESIGN FMEA FOR SOFTWARE

Software FMEA is a type of design FMEA that analyzes the software elements, focusing on potential software-related deficiencies, with emphasis on improving the software design and ensuring product operation is safe and reliable during useful life.

3.3 SUPPLEMENTAL FMEA FOR MONITORING AND SYSTEM RESPONSE

Supplemental FMEA for monitoring and system response (FMEA-MSR) enhances the DFMEA for selected mechatronic systems by providing a means of assessing risk reduction through diagnostic detection and response during customer operation.

3.4 FAULT

A fault is the occurrence or existence of an abnormal condition that can lead to an undesired state of an item. In the context of DFMEA, some causes of failure may be considered faults.

3.5 DESIGN VERIFICATION/VALIDATION

Analysis or testing executed to demonstrate that new or modified designs, or new applications of existing designs, will meet customer expectations, in the intended environment, over the useful life of the product.

3.6 DIAGNOSTIC MONITORING

Monitoring in FMEA-MSR assesses the effectiveness of fault detection performance in customer operation, assuming that specifications are fulfilled. The Monitoring rating also comprehends the safe performance and reliability of system reactions to monitored failures.

3.7 FAILURE MODE AND EFFECTS ANALYSIS

FMEA is a qualitative and systematic analysis method intended to identify, prioritize, and reduce technical risks of product or process failures to an acceptable level. Failures shown in FMEA are considered potential and may or may not occur.

3.8 GENERIC FMEA

A generic FMEA contains both historical and potential failure modes, causes, controls, etc., not related to a specific project. It is used as a starting point for a new DFMEA or PFMEA because, when maintained, it reflects failures that occur after product and process validation and start of regular production and beyond. Other commonly used terms for generic FMEAs include core, template, baseline, gold standard, etc., based on company procedures.

3.9 MECHATRONIC SYSTEM

Technology combining mechanical, electrical, and software into a single product. A mechatronic system is a set of components or subsystems that relates at least a sensor, a controller, and an actuator with one another.

NOTE: The related sensor or actuator can be included in the system or can be external to the system. Refer to ISO 26262-1:2018.

3.10 PROCESS FMEA

Process FMEA is a type of FMEA that analyzes the manufacturing or assembly process, focusing on potential manufacturing-related deficiencies, with emphasis on improving the manufacturing process and ensuring the product is built to design requirements in a safe manner, with minimal downtime, scrap and rework, etc.

3.11 RISK MITIGATION

The implementation of changes to designs that changes the effect and therefore reduces the severity of the effects of failure.

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3.12 PRODUCT VALIDATION

Engineering analysis or testing executed to demonstrate that products made from production tools and processes will meet customer expectations, in the intended environment, over the useful life of the product. PV is a requirement for the production part approval process (PPAP). Production validation is separate from plant equipment qualification and process control planning.

3.13 RISK REDUCTION

The primary objective of the FMEA process is to identify potential high risks and try to keep those high risks from occurring in the end product; or, if that cannot be accomplished, then to minimize the risk effect(s) to the end product user.

3.14 SYSTEM HIERARCHY

A “system” is an integrated set of constituent parts that are combined in an operational or support environment to accomplish a defined objective. System definition should include the interfaces between the subsystems/components and may include the interfaces with adjacent systems. Defining the system is a key part of identifying the scope of the FMEA project.

A “hierarchy” is a partitioning scheme that establishes an ordered relationship between the items in a system, where the items are represented as being “above,” “below,” or “at the same level as” one another. Each level of indentation—from system, to subsystem, to component, to part—comprises the hierarchy of the system.

3.15 TEST PLAN

The test plan provides the methodology to assure design verification and production validation of systems, assemblies, and components through application of a concise, yet comprehensive, test planning and test results reporting system. The test plan itemizes all tests and evaluations necessary to assure that functional (performance) and reliability (performance over time) criteria and target requirements are defined in specific measurable terms. The plan also specifies test responsibility, test quantities, and timing requirements.

3.16 TEST REPORT

The test report provides a means for reporting progress and test results made toward design targets specified by the plan. The test plan and test report may be contained within a single document, the design verification plan and report (DVP&R) form. The plan and reporting system cover the entire test development and quality/reliability growth period, inception through ongoing refinement.

3.17 Examples in this Standard

This edition of SAE J1739 will be using a series of examples to illustrate the concept of various portions of FMEA. The examples will be a single-line excerpt from different FMEAs. The following example excerpts will be used:

1. Windshield wiper system FMEA
2. Windshield wiper arm design FMEA
3. Windshield wiper motor design FMEA
4. Washer fluid-level sensing software FMEA
5. Windshield wiper motor FMEA-MSR

It is important to note that there is a one-to-many relationship between the different portions of the FMEA. Each item can potentially have many functions. Each function can potentially have many failure modes. Each failure mode can have many causes, etc. The single-line example excerpts are meant to show the various portions of FMEA in order to help the reader understand the concept being described and should not be construed to mean there is only one line in the FMEA. It is also important to understand that the example excerpts are not an actual FMEA. An actual FMEA must be done by the correct team, with all the correct inputs. The example excerpts are for illustration purposes.

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For example, the scope of the wiper motor DFMEA was expanded beyond the motor itself to include motor grounding, in order to illustrate a failure mode and cause relating to the grounding interface. The FMEA-MSR example was chosen to show the relationship between the wiper motor DFMEA and wiper motor FMEA-MSR, in order to illustrate how a supplemental FMEA for monitoring and system response flows from a DFMEA.

For these example FMEA excerpts, selected portions of FMEA preparation procedure were used, including a wiper system FMEA block/boundary diagram, assumptions about wiper system operating conditions, a wiper assembly process flow, and others.

Each of the five example excerpts are shown in the appropriate section of the standard, with only the portion of the example excerpt up to the sectional topic. For example, in the cause section, the five example excerpts will be shown up to cause (item, function/requirement, failure mode, effect, cause).

3.18 Terms

For the purposes of this document, the following terms apply.

- “MUST” indicates a requirement.
- “SHOULD” indicates a recommendation.
- “MAY” indicates a permission.
- “CAN” indicates a possibility.

Information marked as “NOTE:” is for guidance in understanding or clarifying the associated requirement.

4. GENERAL REQUIREMENTS

4.1 What is FMEA?

The fundamental value of the FMEA process is to identify potential risks, prioritize those risks, and then reduce risks over time to an acceptable level. Three categories of technical risks discussed during the FMEA process include design risks (i.e., risks related to requirements and specifications, engineering calculations, material selection, labelling, etc.), process risks (i.e., risks related to manufacturing, assembly, testing, rework, etc.), and monitoring and response risks (i.e., risks related to diagnostics, warnings, etc.).

FMEA is a qualitative and systematic analysis intended to:

a. Prepare for risk analysis: FMEA preparation steps including FMEA block/boundary diagram, functional analysis, gather information, etc.

b. Identify technical risks: Identify potential failures of a product/process and the effects and causes of failure.

c. Prioritize risks: Assess the risks of failure using subjective criteria and prioritize the need for action.

d. Reduce risks: Identify and execute actions in order to reduce risk to an acceptable level.

e. Communicate results: Document the analysis and communicate risk reduction strategy.

FMEA is:

- An analysis of potential technical risk of failure of a product or process.
- A method to analyze single-point failures (i.e., failure A or failure B may occur).
- A qualitative (subjective) discussion method.

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- Uses inductive reasoning (i.e., likelihood of future failure is based on occurrence of past failures and does not predict future failure with certainty).
- Uses deductive reasoning (i.e., development of conclusions based on premises agreed to by the team).

FMEA is not:

- Intended as an assessment tool for business, cost, or timing risk.
- A method to analyze multi-point failures that occur in tandem (i.e., failure A and B may occur together).
- A quantitative (computed) analysis.
- Intended for use as a validation test plan, or an advanced product quality planner.

4.2 Why FMEA?

The intended purpose of DFMEA and PFMEA is to ensure design and process robustness by thoroughly documenting and reducing the potential risks of failure to provide the intended functions and meet the necessary requirements of the product that is delivered to the customer.

4.3 Who Performs FMEA?

Although responsibility for the preparation of the FMEA varies by organization, FMEA should be a cross-functional team effort. A team of knowledgeable individuals should be consulted (e.g., engineers with expertise in design, analysis/testing, manufacturing, assembly, service, recycling, quality, reliability, and FMEA facilitation). The FMEA should be a catalyst to stimulate the interchange of ideas between the functions affected and thus promote a team approach.

4.3.1 Management

Management must establish a corporate policy regarding the application of FMEA as related to the corporation’s product development program from concept design through validation, start of production, and beyond. This includes FMEA planning in relation to engineering project management.

Management has the authority to manage resources and set priorities to delegate tasks for FMEA completion. Management must establish design and process FMEA ownership for each analysis. Management is responsible for supporting the cross-functional team by showing interest in project status and team attendance, participating in the management reviews, and asking thought-provoking questions.

Each company must establish ownership for FMEA procedures and methodology. Company procedures must take into account external FMEA requirements such as ISO, IEC, SAE, and VDA standards. Individual project teams must understand OEM (customer-specific) FMEA requirements in order to reach an agreement on an approach that will meet the basic elements of FMEA (identify risk, prioritize risk, reduce risk) and establish the acceptance criteria for FMEA reviews in order to avoid FMEA rework late in the process.

Management must ensure a system is in place for storage and retrieval of FMEA documents. Management or the FMEA owner must determine when a FMEA is deemed Confidential.

NOTE: Proprietary, confidential, and secret document handling is not prescribed by this document.

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4.3.2 Owner

The project engineer (system engineer, design engineer, etc.) is responsible for the technical content of a DFMEA. The manufacturing engineer (process engineer, assembly engineer, etc.) is responsible for the technical content of a PFMEA. The owner of the DFMEA is the person responsible for the design (i.e., product drawing/specification). The owner of the PFMEA is the person responsible for the process design (i.e., tooling specification, manufacturing process layout). Owners of FMEA are responsible for kicking off of the FMEA, technical leadership during the FMEA, and wrapping up meetings at completion of analysis: management review, review of related documents (e.g., test plans and control plans), summary of identified risks and assigned actions presented for information, consensus, and acceptance. They are responsible for recruiting the team and the facilitator.

4.3.3 Facilitator (Moderator)

The FMEA facilitator (moderator, coordinator, coach, etc.) is responsible for application of the FMEA method. In some cases, the technical content owner is also the facilitator. Facilitators determine the meeting agenda, session duration, and reoccurring schedules for the team to meet project timing. They invite core and support team members based on each agenda. They keep records of attendance and topics discussed. The facilitator works closely with the FMEA owner to complete each step of the analysis and report out to management and/or the customer.

4.3.4 Team Members

The owner of the FMEA will establish the FMEA team, as necessary, to suit the needs of the scope and ensure timely analysis. A team consists of knowledgeable individuals who perform the FMEA analysis. This may include, but is not limited to, representatives from: design (mechanical, electrical, software, safety), manufacturing, validation, suppliers, materials, service, quality, reliability and technical experts. Team members are responsible for preparing and participating during FMEA meetings.

NOTE: Due to logistics and responsibility differences, the entire team may not be able to meet at the same time. It is recommended to establish a core team where participation is required and a support team where participation is based on the agenda for a meeting or workshop.

4.3.5 Customer

Customer-specific requirements for FMEA should be discussed at the beginning of a new customer program: scope, timing, deliverables, special rating charts, special forms, etc. The customer is responsible for providing an FMEA audit worksheet at the beginning of a project if planned to be used to review the FMEA at the end of a project (to avoid misunderstandings).

4.3.6 Fully Owned Risks versus Partnership Interface Risks

When the product design is fully owned by an engineering group, the technical risk can be reduced or removed through adding preventive/detective controls or changing the design. For fully owned design risks, there is a single owner that owns this risk analysis.

“Fully owned” risks are defined as having sole responsibility for the risk by owning:

1. The engineering design responsibility, and

2. The key preventive control(s), and

3. The key detective controls to complete the mitigation process.

When the product design is not fully owned by an engineering group because of interfaces with products owned by others outside of their group, then partnership interfaces and multiple owners exist. Additional communication must be made about interface risks to understand and ensure that the risk mitigation process is thorough and completed. Poor communication or bad assumptions could lead to design deficiencies or manufacturing errors. Any uncertainties should be addressed in the Recommended Actions within the FMEA document.

“Partnership interface” risks are defined as owning only one or two of the three risk mitigating responsibilities (i.e., engineering/manufacturing design, preventive and/or detective controls).

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Key partnership interface risks are poor interaction, communication or bad assumptions between risk partners. In other words, incorrect or missing information “sent by YOU” to your risk partner(s), or incorrect or missing information “received by YOU” from your risk partner(s).

4.4 When is the FMEA Created?

One of the most crucial factors for the successful implementation of an FMEA program is timeliness. The FMEA is meant to be a “before-the-event” action, not an “after-the-fact” exercise. To achieve the greatest value, the FMEA should be done before a product or process failure mode has been incorporated into a product or process. Upfront time spent properly completing an FMEA, when product/process changes can be most easily and inexpensively implemented, will minimize late change crises. An FMEA can reduce or eliminate the chance of implementing a preventive/corrective change that could create an even larger concern (safety or regulatory).

4.4.1 Start

The FMEA should be started as soon as the design or process concept has been established. In general, a DFMEA for the product is started before the PFMEA. The company’s product development timeline shows the timing for design, validation, machine qualification, and production of the product. This timeline is useful for establishing milestones for DFMEA and PFMEA.

4.4.2 Completion

The FMEA should be completed through action plan identification before the design or process has been finalized. In general, a DFMEA should be finished before validation testing begins. A process FMEA should be finished before machine qualification begins. Tracking of actions is based on their due dates. Refer to internal company procedures for target completion timing.

4.4.3 Revisions

See 5.6 and 6.6 for more information about when the DFMEA and PFMEA should be revised after is has been completed.

4.5 FMEA Worksheet

The steps of FMEA are created by using tools that provide structure to perform the analysis (e.g., FMEA form column headings or FMEA software). These worksheets can be modified to meet company or customer requirements (e.g., add or move columns). See Appendices L, M, N for recommended forms.

4.6 FMEA Rating Criteria

A suggested rating criteria for severity, occurrence, detection, frequency, and monitoring is included in this standard. Rating criteria should be agreed to at the beginning of a project with the customer to avoid rework late in the development process. The team should agree on an evaluation criteria and rating system, which is consistent, even if modified for individual analysis. The rating criteria must be included in the FMEA documentation.

4.7 FMEA Risk Prioritization

A risk prioritization method should be agreed-to at the beginning of a project to avoid rework later in the development process.

4.8 FMEA Process Steps

In general, FMEAs should be guided by the steps shown in Figure 1. The actual flow of analysis activities may be iterative, not necessarily sequential. Section 5 DFMEA and FMEA-MSR and Section 6 PFMEA define the details of each step.

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FMEA STEPS

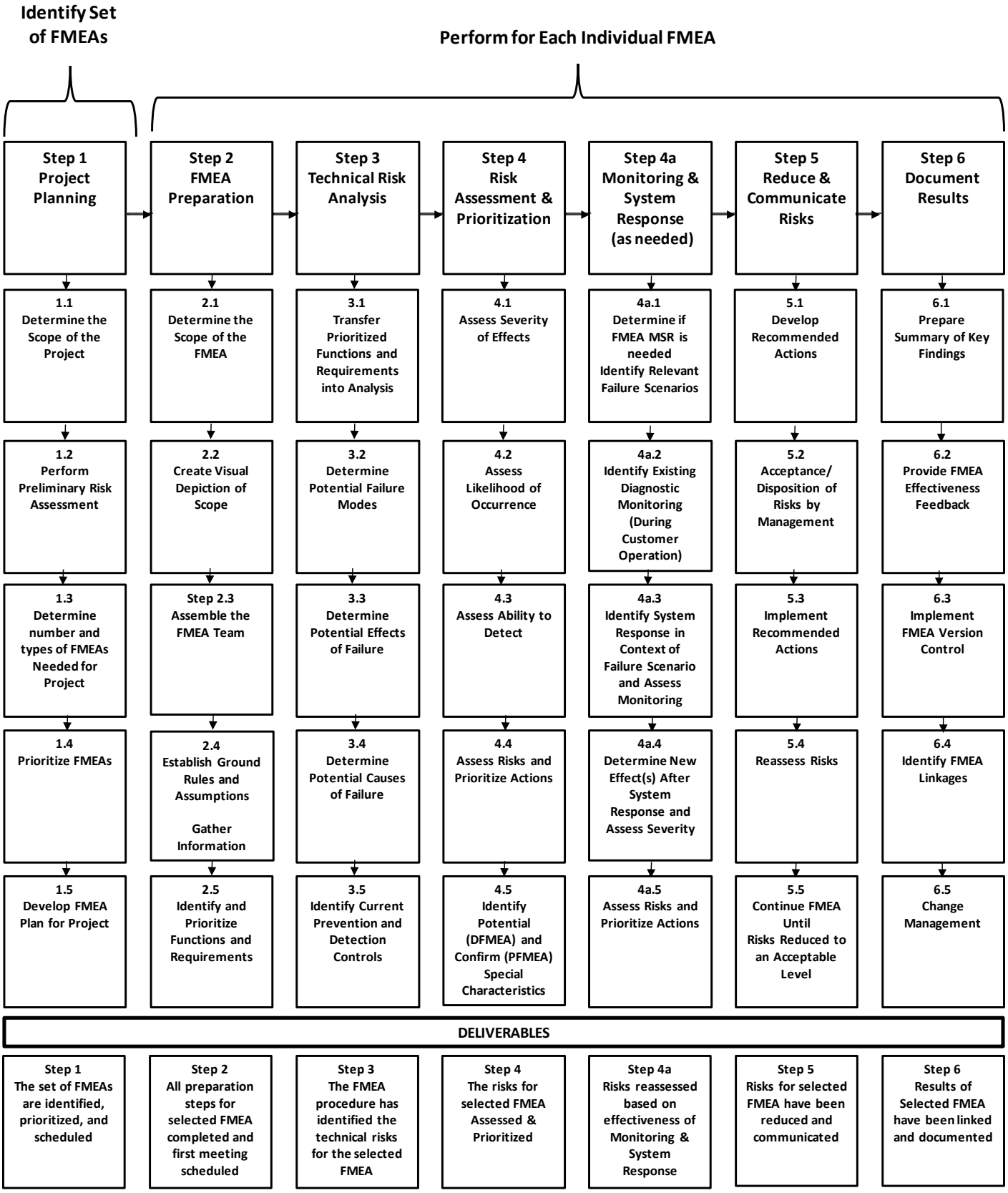


Figure 1 - FMEA six-step process map

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5. DESIGN FMEA

5.1 Project Planning (Step 1)



Figure 1A - Step 1 of the FMEA six-step process map

Deliverables: The set of DFMEAs are identified, prioritized, and scheduled.

5.1.1 Determine the Scope of the Project

An FMEA project is the entire set of FMEAs that need to be performed during product development timeframe to support the safety, reliability and performance objectives of the product design.

For system and design FMEAs, the scope of the project can be described textually, such as new widget project, along with appropriate level of detail about the project definition. It can also be visually represented by the system hierarchy, sometimes called the bill of materials.

System hierarchy is defined as follows:

A “system” is an integrated set of constituent parts that are combined in an operational or support environment to accomplish a defined objective. System definition should include the interfaces between the subsystems/components and may include the interfaces with adjacent systems. Defining the system is a key part of identifying the scope of the FMEA project.

A “hierarchy” is a partitioning scheme that establishes an ordered relationship between the items in a system, where the items are represented as being “above,” “below,” or “at the same level as” one another. Each level of indentation, from system, to subsystem, to component, to part, comprises the hierarchy of the system.

The partitioning of the overall project into individual FMEAs depends on who is responsible for the design. For system and design FMEAs, the general rule is whomever has design responsibility has ownership for the corresponding system or design FMEAs. If company “A” has responsibility for the windshield washer system, then they have responsibility for the System FMEA on the windshield washer system. If they also have responsibility for the wiper arm and wiper motor, they would also have responsibility for any needed DFMEAs on the wiper arm and motor. System FMEAs are a type of design FMEA that focus on functions that are unique to the system, and interfaces between subsystems and adjacent systems (which may include multiple ownership responsibilities). Software FMEAs are a type of design FMEA that focus on functions (sometimes referred to as vehicle features such as lane keeping assist) that require software to perform the function.

When defining the scope of an FMEA project, a portion of the system configuration could look like Figure 2, with as many subsystems and components as needed.

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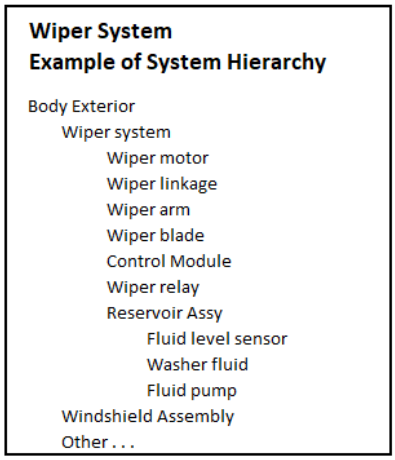


Figure 2 - System hierarchy example for windshield wiper system

Although the scope of the project is visually depicted by the system hierarchy (e.g., use of a structure tree), 5.1.2 and 5.1.3 describe how to select which FMEAs will be done from the system hierarchy.

5.1.2 Perform Preliminary Risk Assessment for Design FMEA

DFMEAs can be resource intensive. They should be performed when a certain level of change or other risk factors can be effectively addressed by the DFMEA methodology. New product designs can include hundreds or even thousands of subsystems and components. Few companies have the resources to properly do DFMEAs on everything. New or modified designs usually require a system FMEA. Lower-level FMEA projects can be identified based on well-defined selection criteria.

Some companies consider three basic cases for which DFMEAs are generated, each with a different scope or focus.

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

Case 2: Modifications to existing design (assumes there is a DFMEA for the existing design). The scope of the revision efforts should focus on the modification to design, possible interactions due to the modification, and field performance. Modifications include removal or addition of new parts. Modifications also include changes to existing product functions or performance requirements.

Case 3: Use of existing design in a new environment, location, or application (assumes there is an DFMEA for the existing design). The scope of the revision is the impact of the new environment, location, application, duty cycle, or usage profile of the existing design.

Cases 1, 2, and 3 provide some guidance for scope identification; however, additional factors should be considered. The preliminary risk assessment can be used to determine which DFMEAs need to be done, to support prioritization, and to enhance the use of Cases 1, 2, and 3 for DFMEA project planning.

Preliminary risk assessment has three stages:

1. Companies identify important criteria and weight for selection of DFMEA projects. Example selection criteria may include:
    - Potential for safety issues
    - Degree of new technology
    - Degree of design or application change
    - History of significant field problems

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- Potential for important regulation issues
- Supplier capability
- Other risk criteria such as complexity, cybersecurity issues, safety-related software functions, high-risk interfaces, etc.

2. The risk criteria can each be assessed on a variable scale (such as high 3, moderate 2, or low 1) for each of the items being considered for FMEAs. Preliminary risk assessment criteria can be tailored to the unique needs of any company. The prioritization metric column is a multiplication of the risk columns.

3. Based on this assessment, the team can select FMEAs to be performed on the wiper project. The team may choose to do all the FMEAs or select ones that have the highest scores. Determine number and types of FMEAs needed for project.

Figure 3 shows a fictitious example of preliminary risk assessment done on a wiper system. The example above applies to system or design FMEAs.

Preliminary Risk Assessment
Wiper System Example
Method:
1. Project team agrees on risk factors
2. For each level of system hierarchy, assess risk related to associated risk factor (1, 2, 3*)
3. Multiply risk assessments together to get prioritization metric
4. When the team decides which items will receive an FMEA, enter Y/N in last column
* Assessment key: 1 = low risk, 2 = moderate risk, 3 = high risk

Item	Safety Concerns	New Technology	Degree of Change	Field Problems	Regulatory Risk	Supplier Concerns	Other risk factors[1]	Prioritization Metric	Create/update DFMEA Y/N
Wiper system	3	3	2	3	2	3		324	Y
Wiper motor	2	3	2	3	2	3		216	Y
Wiper linkage	1	1	1	2	1	2		4	N
Wiper arm	3	1	3	3	2	2		108	Y
Wiper blade	2	2	1	2	2	1		16	N
Control Module	2	1	1	1	1	1		2	N
Wiper relay	3	1	1	2	2	3		36	N
Reservoir Assy (incl sensor)	2	2	2	3	2	3		144	Y

[1] Project team may add other risk factors, as well as modify above risk factors.

Figure 3 - Preliminary risk assessment example for windshield wiper system

5.1.3 Determine Number and Types of FMEAs Needed for Project

The project team, with management agreement, determines the number and type of FMEAs needed for the project based on the preliminary risk assessment. The number of FMEAs is influenced by scope and responsibilities within or outside the organization. Types of DFMEAs include system, subsystem, or component and can include designation of mechanical, electrical, or software.

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5.1.4 Prioritize Design FMEAs

Prioritization should emphasize conducting FMEAs for which the scopes are of greatest risk to the project based on the results of a preliminary risk assessment. Prioritization allows the project team to determine which FMEAs to do and define the order so they can be scheduled.

5.1.5 Develop DFMEA Plan for Project

The FMEA plan is the output of prioritization with added detail. By definition, a “plan” is a written account of intended future course of action aimed at achieving specific goal(s) or objective(s) within a specific timeframe. It explains in detail what needs to be done, when, how, and by whom.

An FMEA plan is the set of FMEAs that need to be done on a given program, including the types of FMEA (system, design, process, DFMEA-MSR, supplier FMEAs, or others), when they will be done, and by whom.

5.2 DFMEA Preparation (Step 2)



Figure 1B - Step 2 of the FMEA six-step process map

Deliverables: All preparation steps for selected DFMEA have been completed and first meeting scheduled.

5.2.1 Determine the Scope of the FMEA

The scope of a DFMEA can be defined by using diagrams, system hierarchy, bills-of-material, illustrations, or similar tools that represent items (also referred to as system elements) being analyzed to facilitate the analysis of interfaces and close clearance conditions. The DFMEA team is empowered to choose the scope of the analysis with management and customer concurrence.

The item is the subject of the analysis. The item (system, subsystem, component, or software unit “algorithm”) must be specified in the DFMEA. Once the item has been determined to be within the scope of the analysis (e.g., per the block/boundary diagram or bill-of-material) then the team can identify the functions and requirements for that item. The scope should define the hardware or software for which the team is responsible for designing. This defines the item that will be analyzed. This is the item for which the engineering team has design ownership and risk reduction responsibility.

Examples of items include: wiper system, wiper arm, wiper motor, wash fluid-level sensing software, etc.

There are assemblies and components that are outside a company’s design and development responsibility. The common term is “black box.” The team may use the FMEA block/boundary diagram to show which components are make/buy.

5.2.2 Create Visual Depiction of Scope

A visual depiction can be achieved using a block/boundary diagram. A system hierarchy created from a part list or bill-of-material is recommended as an input to the block/boundary diagram.

5.2.2.1 Block/Boundary Diagram

The block/boundary diagram is a pictorial tool to facilitate analysis of system or subsystem. A block/boundary diagram is required.

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In the context of the selected DFMEA, the block/boundary diagram does the following:

- Visually depicts scope of analysis
- Provides a foundation for Interface analysis, item/function analysis, P-diagram, and DFMEA
- Identifies internal and external interfaces which can then be shown as functions in DFMEA
- Enables application of system, sub-system, and component hierarchy

The diagram may be in the form of boxes connected by lines as shown in Figure 4. Each box corresponding to a major sub-system/component of a product. The lines correspond with how the product sub-systems/components are related to, or interface with, each other; for additional clarity, arrows can be used at the end point(s) to indicate the direction of flow, when appropriate. It is recommended to label the blocks and interfaces with an alpha-numeric label.

Interfaces and interactions may be analyzed using an interface FMEA or included in a component, subsystem, or system analysis. Additional interfaces and interactions include human-machine interface (HMI) and human-vehicle interface (HVI). This diagram illustrates the primary relationship between the items covered in the analysis.

Types of relationships:

- P: Physically touching
  - Welded, bolted, clamped, adhesion, clearance
- E: Energy transfer
  - Electricity, heat, kinetic energy, torque, force
- I: Information/data transfer
  - Data, CAN messages, analogue signals, tell-tales
- M: Material exchange
  - Coolants, fuels, liquids/gases/solid, material abrasion

Block/boundary diagrams are created as early as possible in the product development cycle—as soon as a basic definition of the system or subsystem exists. Block/boundary diagrams are steadily refined as the design matures.

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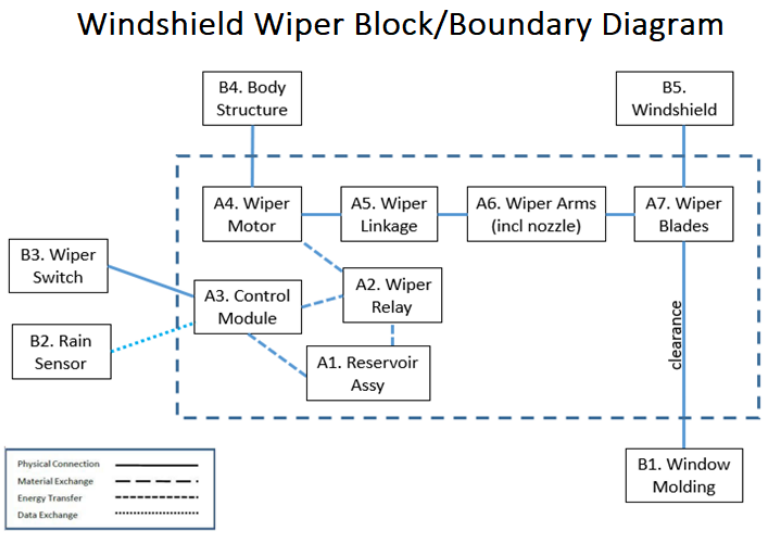


Figure 4 - Block/boundary diagram example for windshield wiper system

5.2.3 Assemble the FMEA Team

The owner of the FMEA will establish the FMEA team, as necessary, to suit the needs of the scope and ensure timely analysis. The DFMEA team consists of subject matter experts who represent cross functional knowledge associated with the design and are trained in the DFMEA process. DFMEA is a team effort and each team member contribute with their unique knowledge and experience to identify risk in the design. The DFMEA team should include a core team, as appropriate, who meet regularly and understand the details and history of the design to take the analysis from start to finish. The functional safety engineer and on-board diagnostic engineer may be added to the FMEA-MSR core team as needed. This core team should expand based on the needs of the team (e.g., add disciplines, add more experienced people, etc.). See 4.3 for more information.

The reason for a cross-functional team is simply because one person cannot know everything. Multiple disciplines minimize the potential for “blind spots” while conducting the analysis. The project leader, who may be a system/product engineer, quality engineer, or DFMEA engineer (facilitator/moderator) should develop a team roster that includes resources assigned to the overall project/program along with additional subject matter experts to ensure the proper expertise is applied to the DFMEA. One of the indispensable values of DFMEA is the journey of discovery. The cross talk and synergy between team members allows them to discover things that individuals often miss.

5.2.4 Establish Ground Rules and Assumptions/Gather FMEA Information

Ground rules, assumptions, and engineering inputs/information help the DFMEA team conduct the analysis in an efficient and effective manner.

5.2.4.1 Ground Rules

Suggested ground rules to help DFMEA teams operate efficiently include:

- Keep the focus of the DFMEA on the item identified in the preliminary risk assessment, and stay within the agreed-upon scope
- The block/boundary diagram will be updated based on additions and changes during the development of the DFMEA
- Identify potential failures that are reasonable and controllable by design
- Work within the team’s knowledge and ask for input from others when needed

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5.2.4.2 Assumptions

The DFMEA should address the design intent and assume the design will be manufactured/assembled to this intent. The PFMEA should address manufacturing and assembly risk. The DFMEA, as an analytical engineering tool, records the ideas and concerns of a design team; therefore, it is understood that failures shown in the DFMEA are potential. As such, failures described in the DFMEA may or may not occur. The DFMEA team should agree on a set of assumptions for the analysis. These assumptions are used to keep the team focused on what they have control over.

5.2.4.3 Gather Information

The purpose of this step is to gather the information that is necessary to perform the technical risk analysis for the selected FMEA.

One of the more important steps in FMEA preparation is gathering all the relevant information, as available. If this step is missed or done inadequately, FMEA meetings can be burdened with extra tasks related to missing information, and FMEA results potentially compromised. The specific list of information that needs to be gathered when preparing for an FMEA should be determined by the company. The following are some of the categories of information to research and gather prior to the first FMEA meeting.

- Bill of materials, as covered in 5.2.1
- Past DFMEAs and/or generic DFMEA, with similar scope to the selected FMEA
- Warranty, recalls, and other field history, preferably prioritized, so the FMEA team knows the most important issues
- Engineering requirements (functional, performance, functional safety, operating environments, etc.)
- Drawings, schematics, software architecture models
- Applicable government or safety regulations
- Test procedures
- Lessons learned/best practices
- Industry standards
- Preliminary design verification plan
- FMEA block/boundary diagram
- P-diagram (if performed)
- List of specific design changes and changes to operating environment
- List of concerns relating to the item being analyzed
- Other documents and information that highlight the nature of the design concept

NOTE: If new DFMEA being built from a past or generic DFMEA, the team needs to ensure it is an adequate DFMEA to be used as a starting point.

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5.2.4.4 Identifying Information

The DFMEA documentation contains important information about the analysis. The identifying information must include a project name, latest revision date, organization, department, and group or individual who is design responsible. Additional information such as DFMEA number, start date, model year, program number, system/sub-system/component, core and support team member names, and team facilitator, etc., may be documented to provide useful information for tracking or storage and retrieval purposes. A team member list including names and departments is recommended.

5.2.5 Identify and Prioritize Functions and Requirements

Functions and requirements provide a foundation for each of the selected items to be analyzed.

5.2.5.1 Functions

The function describes what the item is intended to do. An item (e.g., product) may have more than one function. Function statements in the form of “action verb” followed by “measurable noun” are key to accurately describe the functions of the items. Examples for the windshield wiper DFMEA are shown in Figure 5.

System and DFMEAs must consider basic and interface functions. Basic functions are what the item is supposed to do (including associated requirements) and can be summarized from technical specifications or subject matter experts. Interface functions are what the identified interface is supposed to do (including associated requirements) and come from reviewing the FMEA block/boundary diagram.

The more precise the function, the easier it is to identify potential failure modes for preventive/corrective action. If the item has more than one function with different potential modes of failure, then the functions should be listed separately.

5.2.5.2 Requirements

A requirement is a measurable characteristic of a function. A product function may have multiple requirements. Product requirements (at a system and subsystem level) relate to the desired output of a function such as power or fluid flow. Product requirements (at a component or part level) relate to product characteristics such as features on a product drawing. Examples for the Windshield Wiper DFMEA are shown in Figure 5.

Where possible, measurable values for requirements are preferred in the DFMEA, as they help define acceptance criteria for the validation test plan. Measurable values may be obtained from the product drawing and/or technical specification.

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Item	Function(s)	Requirement(s)
Wiper System	Clear windshield of debris and water on all wiper speed settings	1. Wipe quality is defined in document #XYZ 2. Blades must not contact windshield or body moldings at any time. 3. Reference FMVSS 104
Wiper arm	Transfer angular motion from wiper pivot to wiper blade	1. Blade-glass pressure X 2. Wiper arm length Y 3. Wiper arm bending stiffness Z [Reference wiper arm specification #abc]
Low washer fluid-level warning software	Communicate low fluid level to instrument display	Send 5 volt signal to the instrument display when the fluid level goes below 25% of its reservoir capacity
Wiper Motor (includes motor grounding)	Provides operational power to operate the wiper system.	1. Minimum output torque "X" Nm 2. maximum current (Amps) 3. minimum rotational RPM Y

DFMEA columns truncated

DFMEA rows truncated

Figure 5 - Functions and requirements examples for windshield wiper DFMEA

5.2.5.3 Design for Assembly/Manufacturing

The DFMEA team should consider the design and its characteristics that help ensure the design can easily be manufactured without failures. One example might be a requirement to align two parts in a manner that is error proofed. In this example there needs to be a self-aligning feature. This can be described by a function/requirement.

DFMEA function: product assembly of Part A attaches to Part B with the requirement of A and B parallel edges. The measurable requirement might be: Part A to Part B parallel edges within 0.2 mm.

The DFMEA for this function/requirement would identify potential failure modes, effects, causes and possibly end up with a design improvement with the use of recesses or bosses to properly locate components in a self-aligning manner.

5.2.5.4 Item/Function Matrix

An item/function matrix is a tool to identify and prioritize functions and requirements. Items that are graphically displayed on the block/boundary diagram are correlated to the appropriate function. The windshield wiper item/function matrix example is shown in Figure 6.

An item/function matrix has the following objectives:

1. Provide a visual listing of the basic and interface functions (and associated requirements) for the item being analyzed.

2. Provide a visual listing of lower-level items from the FMEA block/boundary diagram, and associated functions/requirements for those lower-level items that will be getting FMEAs (see preliminary risk assessment).

3. Provide a visual listing of the interfaces and type of interface (from FMEA block/boundary diagram) and list the associated interface function for the highest-priority interfaces.

4. Prioritize each of the listed basic and interface functions for the item being analyzed (for inclusion in the FMEA), as well as the lower-level functions that will be getting FMEAs.

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An item/function matrix is developed as follows:

1. List the items from the FMEA block/boundary diagram.
2. List the basic functions for the item being analyzed.
3. List the lower-level items that will be receiving FMEAs, based on preliminary risk assessment. Other items that will not be getting FMEAs (such as component FMEAs) can be grayed out.
4. List the functions and associated requirements for each of the lower-level items that will be getting FMEAs.
5. List the interfaces from FMEA block/boundary diagram and identify the type of interface.
6. Prioritize the basic and interface functions, based on company-specific criteria, such as past field problems, changes to the design, and new technology.
7. Assign the interface type for each of the interfaces based on FMEA block/boundary diagram.
8. List the functions for each of the higher-priority interfaces.

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Wiper System Item-Function Matrix Example

Interface Key: Physical connection = P, Material exchange = M, Energy transfer = E, Data exchange = D, Physical clearance = P_C

Items / Interfaces	Functions (for items considered higher risk based on prelim risk assessment)	Requirements	Function Priority	External Interface Type	Internal Interface Type
Item: Wiper System	Clear windshield of precipitation on all wiper speed settings	1. Wipe quality defined in doc. #XYZ 2. Blades must not contact windshield or body moldings at any time. 3. Swept Area (Reference FMVSS 104) 4. Cyclic wipe rate on low speed, high speed, and intermittent settings	H		
	Provide quiet operation	Noise less than X decibels	M		
A1. Reservoir Assy	Contain supply of washer fluid	Contains X liters of washer fluid	L		
	Deliver washer fluid to nozzle	Delivers X ml/sec of washer fluid	M		
	Detect low washer fluid level	Detects 25% volume threshhold	H		
A2. Wiper Relay	Complete circuit to supply power to wiper motor when signal from controller is present	1. 5 V signal 2. 12 V XX A fused power 3. Isolated ground	M		
A3. Control Module			L		
A4. Wiper Motor	Provide operational power to articulate the wiper system	1. Torque specification 2. Stall resistance performance specification	H		
A5. Wiper Linkage			L		
A6. Wiper Arm	Transfer motion from wiper pivot to wiper blade	1. Force-Deflection Spec 2. Wind Lift Spec 3. Blade angle Spec 4. Durability	H		
A7. Wiper Blade	Sweep precipitation from windshield	1. Contact glass throughout sweep, along entire blade 2. Durability	M		
Interface: B1-A6 Wdo Mldg-Wiper Blade	Maintain Clearance on all wipe cycles	1. 25 mm clearance spec	M	P_C	
Interface: A1-A3 Ctrl Mod - Reservoir	Communicates signal from fluid level sensor	1. 0.XX voltage drop max	H	E	
Interface: A2-A3 Ctrl Mod - Wpr Relay	Send signal to wiper relay according to wiper switch position	1. 5 V signal	M	E	
Interface: A4-B4 Body Struct - Wiper Motor	Locate, secure, and isolate wiper motor	1. Noise transmission requirements 2. Electrical grounding	H	P	
Interface: B5-A7 Windshield - Wiper Blade	Clear windshield of precipitation	1. Blade angle specification 2. SAE Blade pivot spec	M	P	
Interface: A2-A4 Wpr Relay - Wpr Motor	Switch wiper motor power supply according to stalk switch position	1. 5V input, 12V Output 2. Durability	M		E
Interface: A4-A5 Wpr Mtr - Wpr Linkage	Actuate linkage by converting motor torque to reciprocating motion	1. Splined joint 2. Nut tightening torque	H		P
Interface: A5-A6 Wpr Linkage - Wpr Arm			L		P
Interface: A6-A7 Wiper Arm - Wiper Blade			L		P

Figure 6 - Item/function matrix example for windshield wiper system

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5.2.5.5 Prioritization of Functions

A final step in FMEA preparation is to identify and prioritize the functions that relate to the item being analyzed. These become candidate functions to be brought into the FMEA. See 5.3.1.

Once basic and interface functions are listed, prioritizing the functions can be done based on company-specific criteria, such as past field problems, changes to the design, and new technology. If the functions are prioritized (high, medium, low), the FMEA team can begin with the high-priority functions and proceed with other priorities based on company or customer guidance. Functions of greatest concern to the team should be discussed first, and in greatest detail. Not all functions need to be included in the DFMEA.

5.2.5.6 Parameter Diagram for select Functions

A parameter (P) diagram is a graphical representation of the environment in which an item exists. Parameters are attributes of the behavior of a function. A P-diagram includes factors which influence the transfer function between inputs and outputs, focusing on design decisions necessary to optimize output. An example of a parameter diagram is shown in Figure 7.

A P-diagram is typically used to characterize the behavior of a system or component in the context of a single function. P-diagrams are not required for all functions. Each P-diagram represents only one function. Teams should focus on a few key functions affected by new conditions and those with history of robustness issues in previous applications. More than one P-diagram may be needed in order to illustrate the function(s) of the system or component that are of concern to the FMEA team.

A P-diagram focuses on achievement of function. It clearly identifies all influences on that function including what can be controlled (control factors), and what cannot reasonably be controlled (noise factors). The P-diagram is a key input for robust DFMEA analysis. It enables teams to understand transformations and how they are influenced. Information gained through developing a P-diagram provides input to the test plan.

The P-diagram, completed for specific ideal functions, assists in the identification of:

- Factors, levels, responses, and signals necessary for system optimization
- Functions which can be inputs to the FMEA
- Control and noise factors which could affect functional performance
- Failure modes and unintended system outputs (diverted outputs)
- Potential effects of failure
- Recommended actions

P-diagrams are a useful way of illustrating system behavior:

- Sources of variation
- Ways of controlling performance
- Links between failure modes and noise factors

As P-diagrams are completed on a specific function, there may be multiple P-diagrams for one DFMEA; in this case, attach all of the P-diagrams to the DFMEA.

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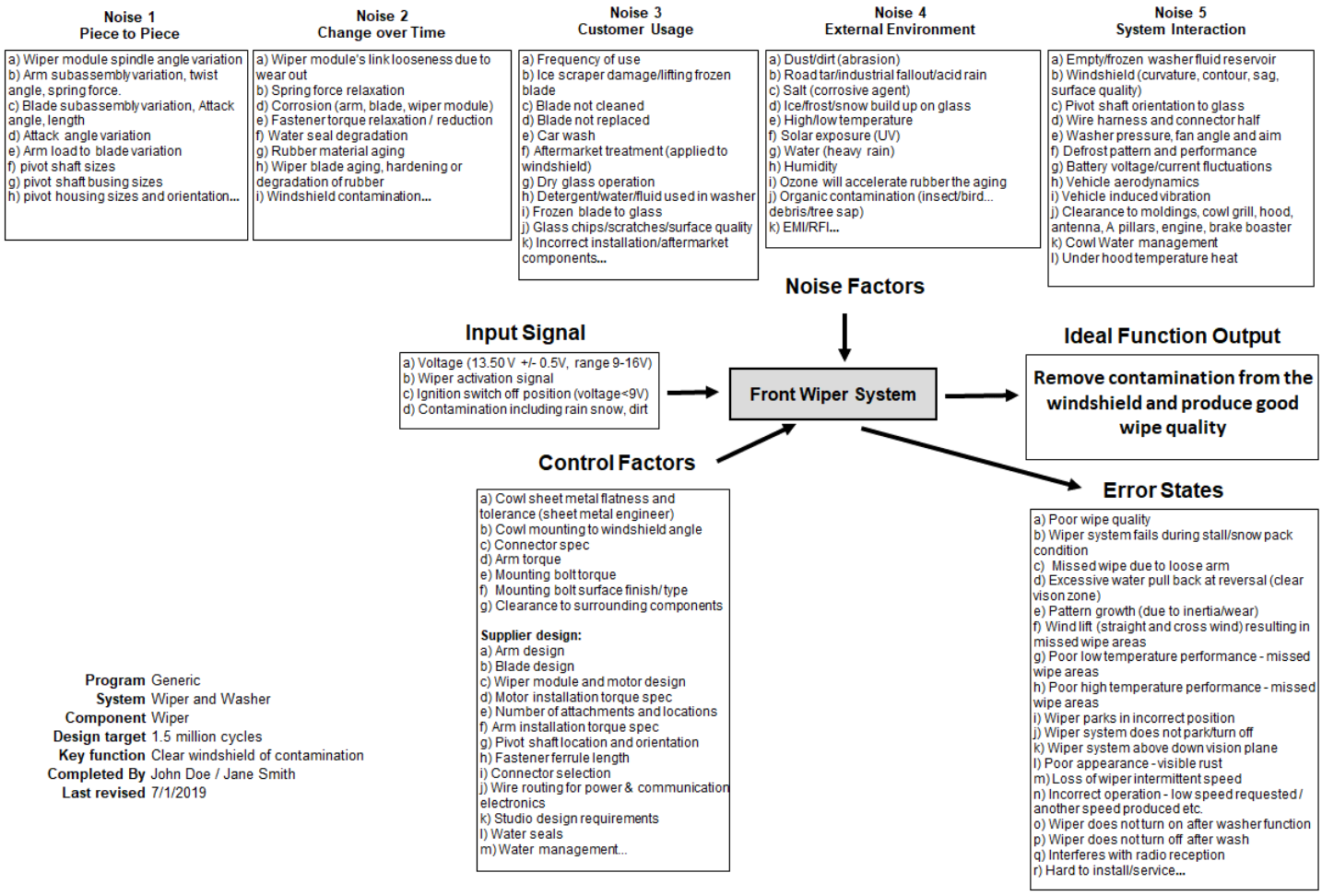


Figure 7 - Parameter diagram example on windshield wiper system

5.3 Technical Risk Analysis (Step 3)



Figure 1C - Step 3 of the FMEA six-step process map

Deliverables: The DFMEA procedure has identified the technical risks for the selected DFMEA.

5.3.1 Transfer Prioritized Functions and Requirements into Analysis

The team can begin the technical risk analysis once the item, functions, and requirements have been selected and transferred to the DFMEA.

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5.3.2 Determine Potential Failure Modes

A potential failure mode is the manner in which an item could potentially fail to meet or deliver the intended function. Each potential failure mode is considered separately from other failure modes allowing the team to address the unique reasons (causes) for that failure mode. List each potential failure mode separately in the DFMEA worksheet. Examples for the windshield wiper DFMEA are shown in Figure 8.

There are several categories (thought starters) of potential failure modes, including:

- Loss of function (i.e., inoperable, etc.)
- Partial function (i.e., performance loss, etc.)
- Degradation of function (i.e., performance loss over time, etc.)
- Over-achieving function (i.e., operation above acceptable threshold, etc.)
- Intermittent function (i.e., operation randomly starts/stops/starts, etc.)
- Unintended function (i.e., operation at the wrong time, unintended direction, etc.)
- Delayed function (i.e., operation after unintended time interval, etc.)

NOTE: Not all categories will always result in failure modes.

Item	Function(s)	Requirement(s)	Potential Failure Mode(s)
Wiper System	Clear windshield of debris and water on all wiper speed settings	1. Wipe quality is defined in document #XYZ 2. Blades must not contact windshield or body moldings at any time. 3. Reference FMVSS 104	Windshield is not clear of debris and water
Wiper arm	Transfer angular motion from wiper pivot to wiper blade	1. Blade-glass pressure X 2. Wiper arm length Y 3. Wiper arm bending stiffness Z [Reference wiper arm specification #abc]	Wiper arm bends
Low washer fluid-level warning software	Communicate low fluid level to instrument display	Send 5 volt signal to the instrument display when the fluid level goes below 25% of its reservoir capacity	Does not send low-fluid level indication to display when below threshold
Wiper Motor (includes motor grounding)	Provides operational power to operate the wiper system.	1. Minimum output torque "X" Nm 2. maximum current (Amps) 3. minimum rotational RPM Y	Insufficient power to overcome static friction in system

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Figure 8 - Potential failure mode examples for windshield wiper DFMEA

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5.3.3 Determine Potential Effects of Failure

The effects of failure are consequences or results of each failure mode. The effect(s) are listed in the DFMEA for each failure mode. The effects of the failure mode should be considered against the next level up assembly, the final product, and the end user/customer (product operator). End effects should state what the user might notice or experience. They should clearly state if the effect of a failure mode could impact safety or non-compliance to regulations, when applicable. The intent is to forecast the potential effect(s) of failure consistent with the team's level of knowledge. In some cases, the team conducting the analysis may not know the end user effect (e.g., commodity parts such as catalogue parts or off-the-shelf parts). When this information is not known, the effects should be defined in terms of the part function and specification. The system integrator has the responsibility to ensure the commodity item addresses integration risks. Examples for the windshield wiper DFMEA are shown in Figure 9.

Item	Function(s)	Requirement(s)	Potential Failure Mode(s)	Potential Effect(s) of Failure
Wiper System	Clear windshield of debris and water on all wiper speed settings	1. Wipe quality is defined in document #XYZ 2. Blades must not contact windshield or body moldings at any time. 3. Reference FMVSS 104	Windshield is not clear of debris and water	Possible reduction of driver visibility and potential violation of FMVSS 104
Wiper arm	Transfer angular motion from wiper pivot to wiper blade	1. Blade-glass pressure X 2. Wiper arm length Y 3. Wiper arm bending stiffness Z [Reference wiper arm specification #abc]	Wiper arm bends	Wiper blade angle changes resulting in blade chatter; glass not fully cleared but partially degraded visibilty, without safety implications (no violation of FMVSS 104)
Low washer fluid-level warning software	Communicate low fluid level to instrument display	Send 5 volt signal to the instrument display when the fluid level goes below 25% of its reservoir capacity	Does not send low-fluid level indication to display when below threshold	Empty washer fluid container leading to insufficient clearing of windshield with potential reduced forward visibility
Wiper Motor (includes motor grounding)	Provides operational power to operate the wiper system.	1. Minimum output torque "X" Nm 2. maximum current (Amps) 3. minimum rotational RPM Y	Insufficient power to overcome static friction in system	Wiper arm stops (thermal overload interrupts circuit); loss of wiping with potential non-compliance with FMVSS 104

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DFMEA rows truncated

Figure 9 - Potential effects of failure examples for windshield wiper DFMEA

NOTE: Some words may be part of the description of a failure mode, effect, or cause depending on the function and requirements of a system, subsystem, or component (e.g., leaks).

5.3.4 Determine Potential Cause(s) of Failure

For each failure mode, the FMEA team identifies the causes. A "cause" is the specific reason for the failure, preferably found by asking "why" until the root cause is determined. For DFMEAs, the cause is the design deficiency that results in the failure mode. For process FMEAs, the cause is the manufacturing or assembly deficiency (or source of variation) that results in the failure mode. If a cause occurs, the corresponding failure mode occurs. There can be many causes for each failure mode. The cause should be described in actionable terms; i.e., something that can be corrected or controlled. Examples for the windshield wiper DFMEA are shown in Figure 10.

Where possible the FMEA team should continue asking "why" until identifying the "root" cause. The only exception to this is for higher levels of analysis, such as system FMEAs, in which the cause may remain at a higher level, such as a component failure, and not carried all the way down to the reason for the component failure, which the subsequent DFMEA would analyze for the component. It is often useful to use the phrase "due to" to help get the root cause. For example, in the case of the projector lamp shattering, a possible cause could be "over pressure due to wrong gas."

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When a system FMEA is being performed, and a supplier has responsibility for a subassembly or component, the system FMEA team may need to request access to appropriate FMEA information, in order to be certain risk has been identified, and high-risk issues are properly addressed.

In DFMEAs, root causes are often described in terms of product characteristics, such as dimensions, weight, orientation, hardness, strength, etc., where the design deficiency is associated with a product characteristic.

Causes should be listed as concisely and completely as possible, so that remedial efforts (controls and actions) can be aimed at appropriate causes.

When identifying causes, it is useful to review the assumptions for the DFMEA, such as the following:

1. The DFMEA team may assume the part is manufactured or assembled within engineering specifications. Based on this assumption, failure modes may be caused by potential deficiencies in design.

2. The DFMEA team may assume the part design may include a deficiency that could cause unacceptable variation in the manufacturing or assembly process. Based on this assumption, failure modes may be a result of manufacturing or assembly mis-builds, but the mis-builds are due to potential design deficiencies.

In the SAE J1739 DFMEA worksheet, the cause column can also include the underlying failure mechanism. Failure mechanisms are the physical, chemical, electrical, thermal, or other processes that result in failure. For a system, the failure mechanism is the process of error propagation following a component failure that leads to a system failure. Including failure mechanisms in the cause description of FMEAs leads to a more thorough understanding of the physics of failure, resulting in effective resolution of potential design deficiencies.

It is helpful to emphasize the difference between failure mode, cause, and failure mechanism. A failure mode is the manner in which the item or assembly could fail to meet the intended function and its requirements. A cause is the specific reason for the failure, expressed as a potential design deficiency. A failure mechanism is the actual physical phenomenon behind the failure mode or the process of degradation or chain of events leading to and resulting in a particular failure mode.

Wherever possible, for high-risk issues the FMEA team should define the cause at the failure mechanism level. This means for system FMEAs or subsystem FMEAs, the FMEA team should either proceed with a component FMEA that can drill down to the precise root cause and failure mechanism that explains the failure mode and place it in the cause column or continue with the “five whys” until isolating the cause at the mechanism level. No matter how the FMEA team chooses to proceed, wherever possible the FMEA team should properly define the cause at the failure mechanism level for high-risk issues.

It is important that engineers consider foreseeable misuse when evaluating factors that can lead to potential failure modes and causes, especially when there is a direct interface between the customer/user/operator and the system, sub-system, or component being reviewed. Although potential misuse is not a cause by itself, a design can potentially be made robust to misuse that is reasonably foreseen. Potential misuse should be considered in the context of defining requirements.

Incorrect cause wording (not actionable): Using wiper system to clear ice or deep snow from windshield.

Correct cause wording (actionable): Insufficient robustness to wiper blade blockage specified.

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Item	Function(s)	Requirement(s)	Potential Failure Mode(s)	Potential Effect(s) of Failure	Potential Cause(s) of Failure
Wiper System	Clear windshield of debris and water on all wiper speed settings	1. Wipe quality is defined in document #XYZ 2. Blades must not contact windshield or body moldings at any time. 3. Reference FMVSS 104	Windshield is not clear of debris and water	Possible reduction of driver visibility and potential violation of FMVSS 104	Wiper linkage assembly clearance to windshield molding is reduced over time as linkage isolators degrade
Wiper arm	Transfer angular motion from wiper pivot to wiper blade	1. Blade-glass pressure X 2. Wiper arm length Y 3. Wiper arm bending stiffness Z [Reference wiper arm specification #abc]	Wiper arm bends	Wiper blade angle changes resulting in blade chatter; glass not fully cleared but partially degraded visibilty, without safety implications (no violation of FMVSS 104)	Wiper arm has insufficient stiffness due to wrong arm material
Low washer fluid-level warning software	Communicate low fluid level to instrument display	Send 5 volt signal to the instrument display when the fluid level goes below 25% of its reservoir capacity	Does not send low-fluid level indication to display when below threshold	Empty washer fluid container leading to insufficient clearing of windshield with potential reduced forward visibility	Algorithm does not recognize faulty signal from fluid-level sensor due to missing fault-detection capability
Wiper Motor (includes motor grounding)	Provides operational power to operate the wiper system.	1. Minimum output torque "X" Nm 2. Maximum current (Amps) 3. Minimum rotational RPM Y	Insufficient power to overcome static friction in system	Wiper arm stops (thermal overload interrupts circuit); loss of wiping with potential non-compliance with FMVSS 104	Insufficient current due to weak ground path resulting from insufficient ground tightening torque specified

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DFMEA rows truncated

Figure 10 - Potential causes of failure examples for windshield wiper DFMEA

Failure causes in the DFMEA may, or may not, relate to failure modes in the PFMEA. A failure cause such as Part A to Part B misaligned may be a failure mode in the PFMEA such as Part A to Part B misoriented. The DFMEA would consider the reason for misalignment from a design perspective and the PFMEA would consider the reason for misalignment from a process perspective. In both cases, the FMEA teams discuss what is within their own control (i.e., the design or the process).

5.3.5 Identify Current Prevention and Detection Controls

In DFMEAs, design controls are actions or methods that are currently planned or in place to reduce or eliminate the risk associated with each potential failure mode and cause. Examples for the windshield wiper DFMEA are shown in Figure 11.

5.3.5.1 Prevention Design Controls

Prevention-type design controls describe how a failure mode, cause, or effect is prevented, based on actions or methods currently planned or in place. Prevention controls may not be applicable for every failure mode, cause, or effect; but they are part of the basis for determining the occurrence rating. Table 1 provides examples of types of prevention controls that have an influence on the reduction of field failure.

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Table 1 - Prevention control examples for DFMEA

Standards and Best Practices	Analysis Activities Used for Design Decisions	Design Intent
Company design standards that have been previously validated and used (bill-of-design, template drawings, heat treat standards, established best practices, etc.)	Finite element analysis Tolerance stack analysis Margin of safety analysis that ensures robustness regardless of manufacturing method Design of experiments	Protection against environmental conditions (cold, hot, humidity), driving conditions (water, sand, rocks), etc., in mechanical systems
Catalog specifications (use cases, recommended applications, load limits, temperature ranges, etc.)	Worst case circuit analysis methods (extreme value analysis, root-sum-squared, Monte Carlo analysis)	Protection against electro-magnetic interference, etc., in electrical systems
External design standards (ISO, SAE, etc.)	Virtual analysis methods	Protection against undefined states, malicious code, corrupted code/data (e.g., dual core processing or secondary sensing), hardware design errors, etc., in software

NOTE: FMEA teams should use caution when describing a prevention control as “carryover design.” The use of “carryover design” can be a prevention-control strategy to the degree that the following criteria are in place: (1) the previous design has a proven field history, (2) the new design is similar in content to the previous design, (3) the new design is similar in conditions of use to the previous design, and (4) the new design has no new technology. Deviations to any of these criteria can lessen the value of “carryover design” as a valid prevention control.

Document numbers, when used, are for reference only as pointers to the associated documents at the time the analysis is created. Company policy may determine whether these document numbers must be kept up to date as they may change during the life of the program.

5.3.5.2 Detection Design Controls

Detection-type design controls describe how the item’s failure mode and/or associated cause is detected based on analytical or physical methods that are currently planned or in place, before the product is released for production. Detection-type design controls are used as input to the detection rating and are intended to increase the likelihood that the problem will be detected and/or prove design intent is confirmed, before it is released for production.

A detection control may not be applicable for every cause and/or failure mode. When listing detection controls, it is important to be detailed enough for subsequent reviewer to confirm how well that the design control will, in fact, detect the failure should it occur. Details should include test name, test number, and the paragraph or procedural step that will be used to detect the failure. Table 2 provides examples of types of detection controls.

Table 2 - Detection control types for DFMEA

Analytical Methods	Physical Methods
Use of correlated models to determine if system or component requirements are met Use of simulations to determine if system or component requirements are met Use of analytical methods to determine if system or component requirements are met	Use of physical system/component testing to determine if reliability requirements are met Use of physical system/component testing to determine if performance requirements are met Use of design of experiments to determine if requirements are met Use of functionality testing to determine if functional requirements are met

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