
SUCCESS
FAILURE

Improve 6 - Risk Management and FMEA

What are we going to cover in this session;

- What is FME(C)A?
- Why FME(C)A?
- How to perform FME(C)A
- FME(C)A Exercise

Failure Modes Effects (& Criticality) Analysis

- A qualitative approach that is intended to:
  - Recognize and evaluate the potential failures of a product or process and the effects of that failure
  - Identify actions which could eliminate or reduce the chance of the potential failure occurring
  - Document the entire process
- Failure Modes Effects and Criticality Analysis(FMECA)
  - Extends FMEA to include criticality analysis – Quantifies failure effects and severity

Definition

- *"Failure modes effects and criticality analysis (FMECA) is a step-by-step approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product or service."*

Warwick Manufacturing Group (2011)

Why is it important?

- Provides a basis for identifying root failure causes and developing effective corrective actions
- Identifies reliability/safety critical components
- Facilitates investigation of design alternatives at all stages of the design
- Provides a foundation for other maintainability, safety, testability, and logistics analyses

History and some Standards

- The FMEA was originally developed by NASA to improve and verify the reliability of space program hardware.
- Automotive suppliers may use SAE J1739 FMEAs, or they may use the Automotive Industry Action Group (AIAG FMEA)
- TS16949 standard
- IEC 60812 - Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)

What are the benefits?

- Is one of the most important and most widely used tools of reliability analysis.
- Facilitates identification of potential design reliability problems
- It can help removing causes for failures or developing systems that can mitigate the effects of failures.
- Help engineers prioritize and focus on high-risk components/failures
- Systematically identifies cause and effect relationships
- Indicates critical failure modes
- Reduces likelihood of customer complaints

What are the benefits?

- It provides detailed insight into the systems interrelationships and potentials for failure.
- Information and knowledge gained by performing the FME(C)A can also be used as a basis for trouble shooting activities, maintenance manual development and design of effective built-in test techniques.
- Framework for identifying mitigating actions

What are the issues?

- Prioritising may become difficult with competing failure modes
- May not easily deal with time sequences, environmental conditions and maintenance aspects.
- Initiated late in the design process
- Considered a form filling task

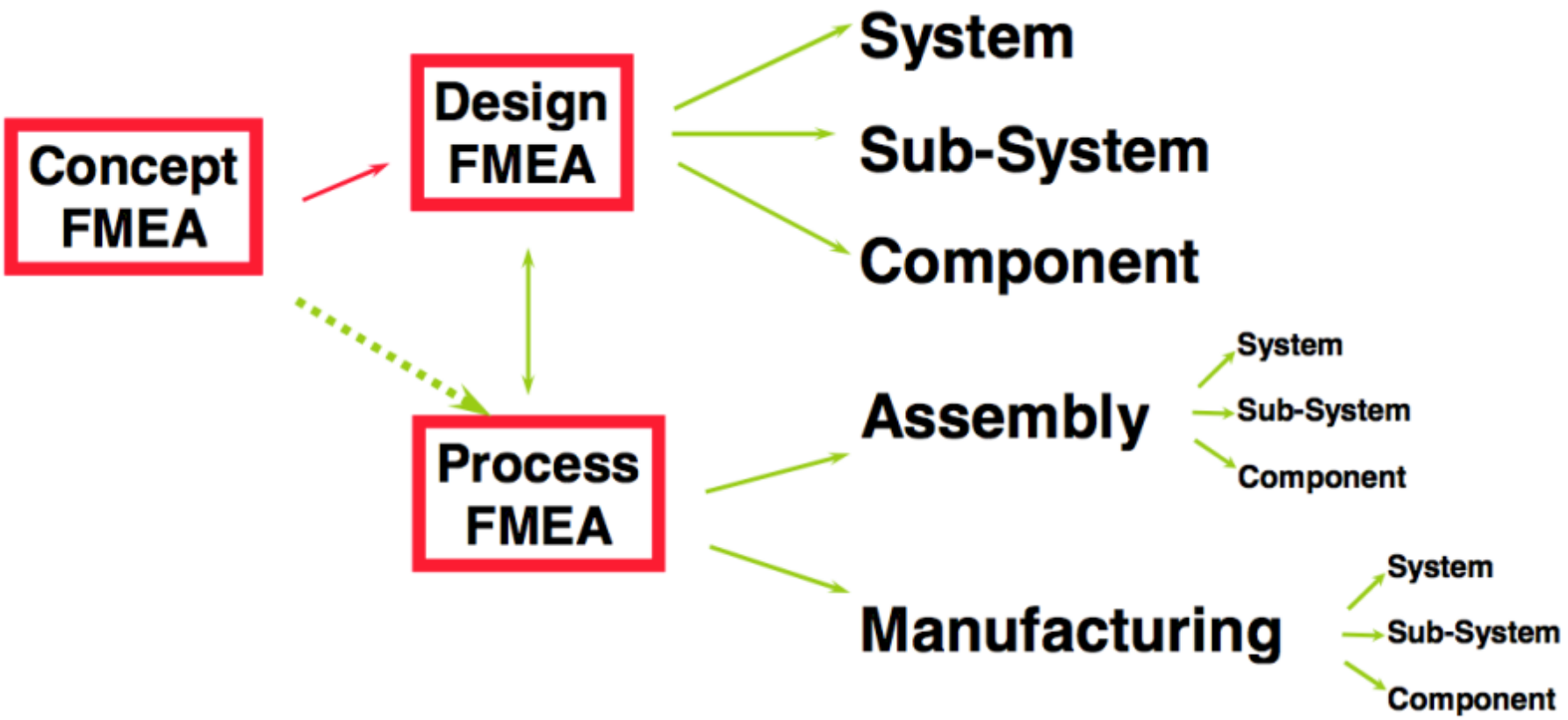
Applications

- To identify failures which, alone or in combination, have undesirable or significant effects; to determine the failure modes which may seriously affect the expected or required quality.
- To identify safety hazard and liability problem areas, or non-compliance with regulations.
- To focus development testing on areas of greatest need.
- To assist the design of Built-in-Test and failure indications.
- To assist the preparation of diagnostic flow charts or fault-finding tables and assist maintenance planning.

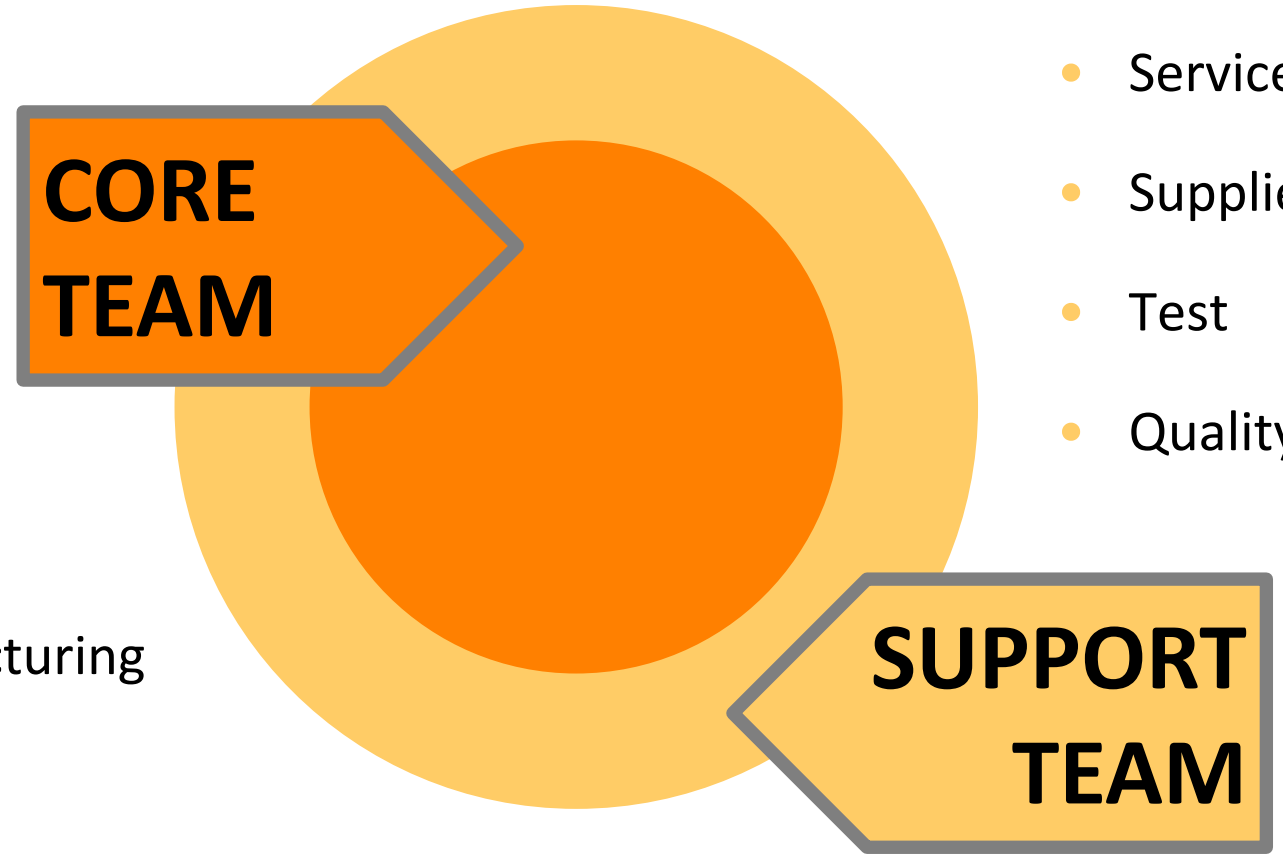
Applications

- To identify key areas in which to concentrate quality control, inspection and manufacturing controls.
- To provide a systematic and rigorous study of the process and its environment.
  - To support the need for standby or alternative processes or improvements to current processes.
  - To identify deficiencies in operator and supervisor training and practices.
- Focus development testing on areas of greatest need.

Types of FMEA



Design FMEA Team



- Design
- Manufacturing
- Process
- Materials

- Operators
- Service
- Suppliers
- Test
- Quality

Procedure

- Identify all potential item failure modes and define their effects on the immediate function or item, on the system, and on the mission to be performed
- Evaluate each failure mode in terms of the worst potential consequence, which may rank severity classification
- Identify failure detection methods and compensating provision for each failure mode
- Identify corrective design or other actions required to eliminate the failure or control the risk
- Document the analysis and identify the problems, which could not be corrected by design

‘5’ Whys

- 5 Whys typically refer to the practice of asking five times, why the failure has occurred in order to get to the root cause(s) of the problem.
- There can be more than one cause to a problem.

Example, on your way home from work your car stops;

- Why did your car stop? *Because it ran out of petrol.*
- Why did it run out of petrol? *Because I didn’t fill it up on way to work.*
- Why didn’t you fill it up on the way to work? *I didn’t have my card.*
- Why didn’t you have your card? *I lost it out in Wind Street last night.*
- *Why did you loose it in Wind St (caught in my phone case, in the same pocket)*

- Numbers of whys aren’t important, it’s more of the philosophy.


“I hear and I forget
I see and I remember
I do and I understand”
Confucius
(551 BC to 479 BC)

Example

- What can go wrong with the bonnet release on your car?

Example

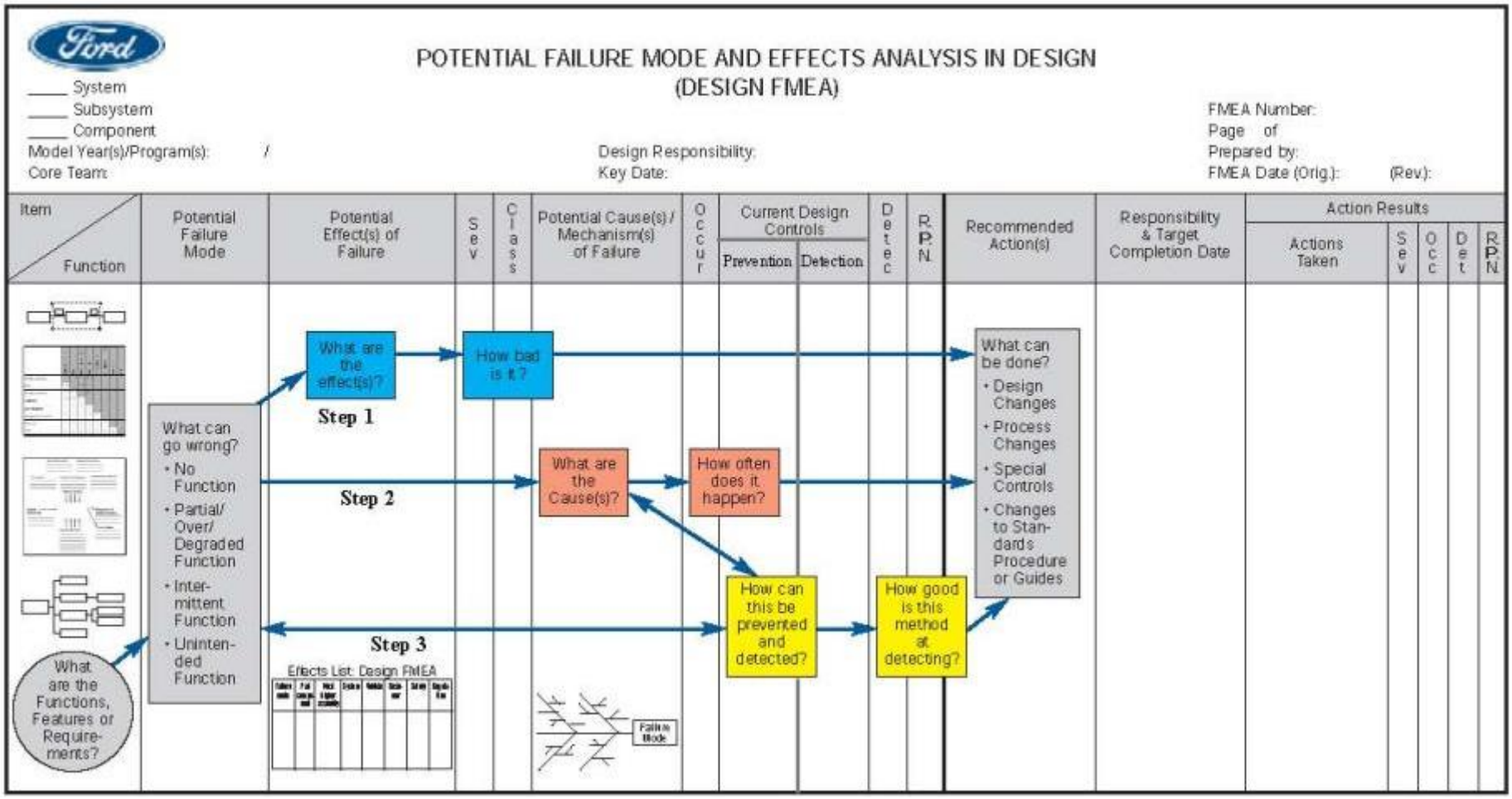
Function	Failure Mode	Cause	Effect
To release Bonnet for opening when required	Cannot release	Cannot operate lever	Customer Annoyance Cancelled Journey Curtailed Journey
		Does not release respective plunger	
		Secondary catch does not operate	
	Difficult to release bonnet.	Difficult to operate lever	Customer Annoyance
		Secondary catch difficult to operate	
To prevent Bonnet releasing or opening when not required to open	Bonnet opens when not required to open	Bonnet liner detaches from bonnet	Safety (accident – loss of vision)
		Primary & secondary catch failure	
	Bonnet releases to safety catch when not required	Primary catch failure	Hazard (reduced safety) Vibration or flexing
		Inadvertent operation of lever	

Techniques

- A layered approach is highly recommended as FMEAs can get complex.
- FMEAs are like ONIONS they are in Layers.
  - Each layer is closer to the root cause
  - Each layer is more detailed
  - The closer to core the more detail
  - Core gets to the root cause
- Do too many and you will cry



FMEA Pocketcard (On Moodle)



Undertaking the FMEA

- When developing a Design FMEA it is assumed that all parts will be manufactured to specification.
- Potential Failure Modes and Causes which could occur during Manufacturing or Assembly should not be included in the DFMEA.
- When developed a Process FMEA it is assumed that the parts are designed correctly!
- DFMEAs should not rely on process controls to overcome potential weaknesses in the design.

Undertaking the FMEA

- DFMEAs should take into consideration the physical limitations of manufacturing or assembly processes. Such as;
  - Necessary moulding draft angles
  - Surface finish limitations
  - Assembly conditions and access for tooling.
  - Limitations in the hardenability of steels.
  - Process Capability

5 Rules of Brainstorming

1. Strict Rotation Rule
2. No such thing as a silly idea
3. Five Second Rule
4. Record what is exactly said
5. Leave the analysis of ideas until the completion of brainstorming.

General comments

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) Of Failure	Occur	Current Design Controls		Detec	RPN	Recommended Actions	Response & Target Complete Date	Action Results				
							Prevent	Detect					Action Taken	SEV	OCC	DET	RPN

- Assumptions should be included in the header.
- Product/part names and numbers must be detailed in the header
- All team members must be listed in the header
- Revision date, as appropriate, must be documented in the header

General comments

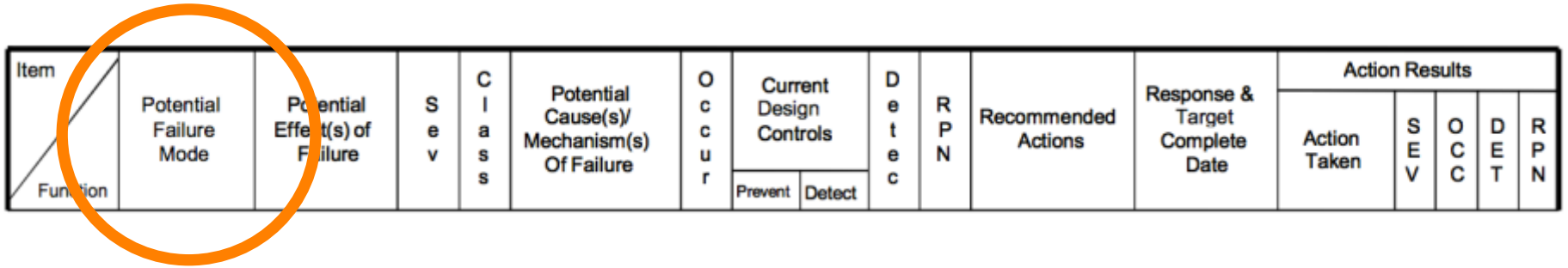
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- Function should be written clearly and must be precise so there is no chance of misinterpretation.
- Each function must have an associated measurable metric.

Example

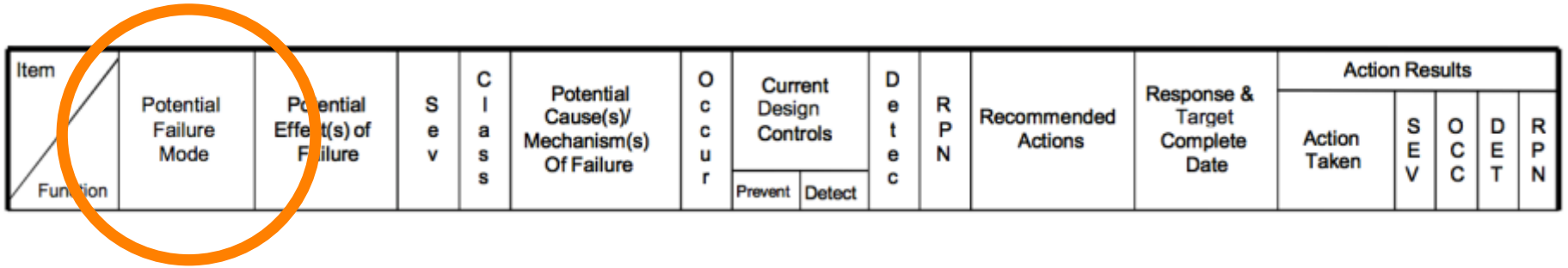
- HVAC system must defog windows and heat or cool cabin to 70 degrees in all operating conditions (-40 degrees to 100 degrees) within 3 to 5 minutes
- As specified in functional spec #_____; rev. date_____

General comments



- Failure modes be written clearly and must be precise so there is no chance of misinterpretation.
- There are 5 types of failure modes:
  - complete failure,
  - partial failure,
  - intermittent failure,
  - function out of specification
  - unintended function

General comments

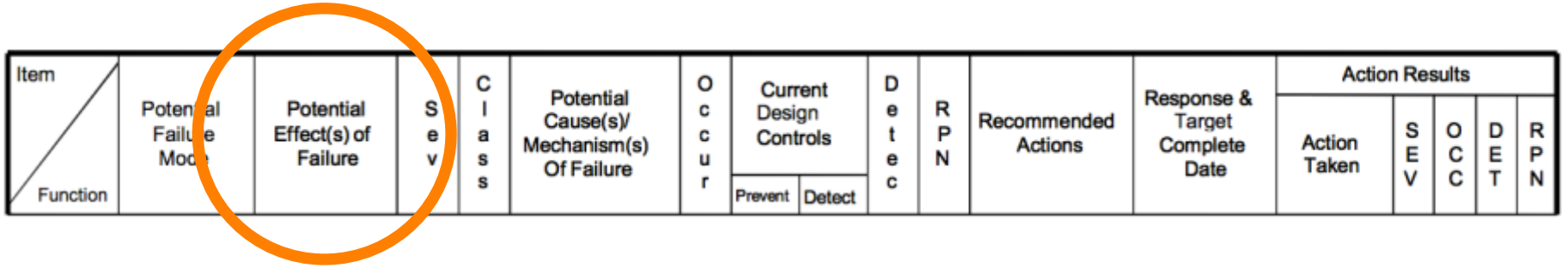


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Examples

- HVAC system does not heat vehicle or defog windows
- HVAC system takes more than 5 minutes to heat vehicle
- HVAC system does heat cabin to 70 degrees in below zero temperatures
- HVAC system cools cabin to 50 degrees

General comments



- Effects must be listed in a manner customer would describe them
- Effects must include (as appropriate) safety / regulatory body, end user, internal customers – manufacturing, assembly, service.

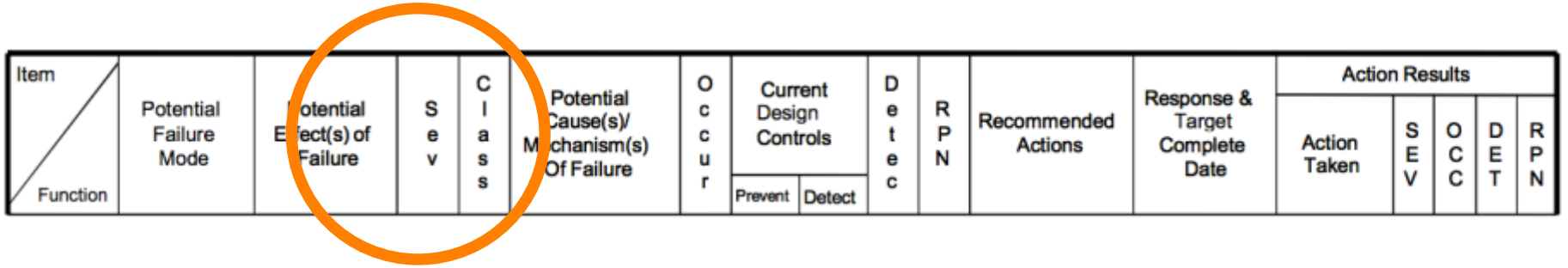
Examples

- Cannot see out of front window
- Air conditioner makes cab too cold
- Does not get warm enough
- Takes too long to heat up

Severity Classification

- A qualitative measure of the worst potential consequences resulting from the item/function failure.
- Rated relatively scaled from 1-10
- Each organisation might have their own basis for classification.

Severity



- Severity values should correspond with AIAG, SAE, etc.
- If severity is based upon internally defined criteria or is based upon standard with specification modifications, a reference to rating tables with explanation for use must be included in FMEA

Examples

- Cannot see out of front window – severity 9
- Air conditioner makes cab too cold – severity 5
- Does not get warm enough – severity 5
- Takes too long to heat up – severity 4

FMEA Pocketcard (On Moodle)

Suggested DFMEA **Severity** Evaluation Criteria

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

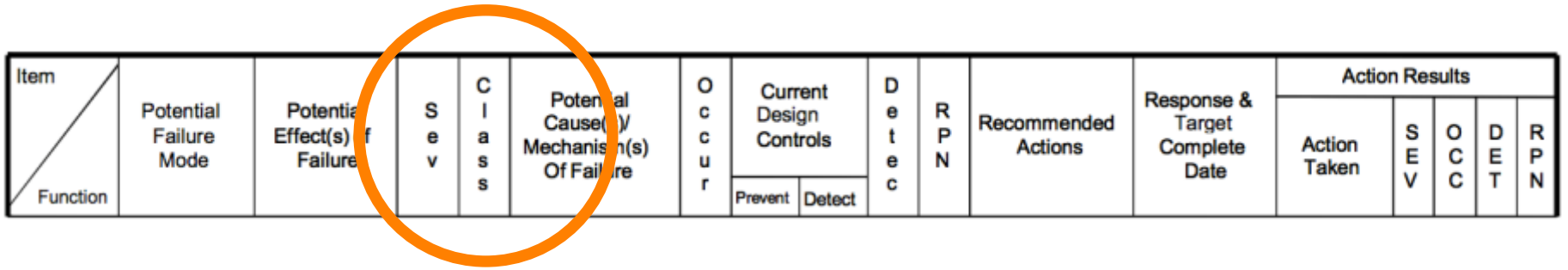
Suggested DFMEA **Occurrence** Evaluation Criteria

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

Suggested DFMEA **Detection** Evaluation Criteria

Detection	Criteria: Likelihood of Detection by Design Control	Ranking
Absolute Uncertainty	Design Control will not and/or can not detect a potential cause/mechanism and subsequent failure mode; or there is no Design Control.	10
Very Remote	Very remote chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	9
Remote	Remote chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	8
Very Low	Very low chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	7
Low	Low chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	6
Moderate	Moderate chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	5
Moderately High	Moderately high chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	4
High	High chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	3
Very High	Very high chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	2
Almost Certain	Design Control will almost certainly detect a potential cause/mechanism and subsequent failure mode.	1

Classification

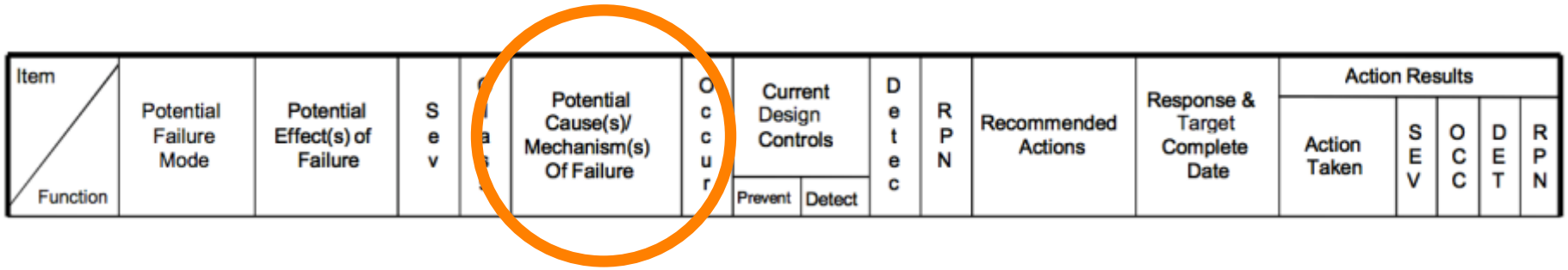


- Classification should be used to define potential critical and significant characteristics

- Critical characteristics (9 or 10 in severity with 2 or more in occurrence suggested) must have associated recommended actions

- Significant characteristics (4 thru 8 in severity with 4 or more in occurrence suggested) should have associated recommended actions

Cause(s) of Failure

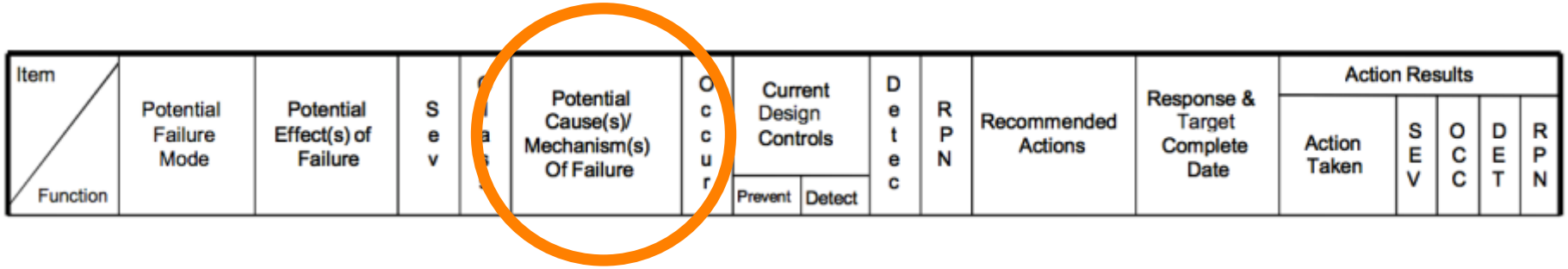


- Causes should be limited to design concerns
- Analysis must stay within the defined scope (applicable system and interfaces to adjacent systems)
- Causes at component level analysis should be identified as part or system characteristic (a feature that can be controlled at process)
- There is usually more than one cause of failure for each failure mode.
- Causes must be identified for a failure mode, not an individual effect.

Examples of Failure Modes

Corrosion	Ringing	Embrittlement
Fracture	Loose	Loosening
Material Yield	Ingress	Scoring
Electrical Short	Vibrations	Radiation damage
Open Circuit	Sagging	Delamination
Buckling	Cracking	Erosion
Fatigue	Stalling	Thermal Shock
Deflections	Creep	Thermal Relaxation
Deformations	Thermal Expansion	Bonding Failure
Seizure	Oxidation	Starved of Lubrication
Burning	UV Deterioration	Staining
Misalignment	Acoustic Noise	Inefficient
Stripping	Unstable	Fretting
Wear	Loose Fittings	Thermal Fatigue
Binding	Unbalanced	Sticking

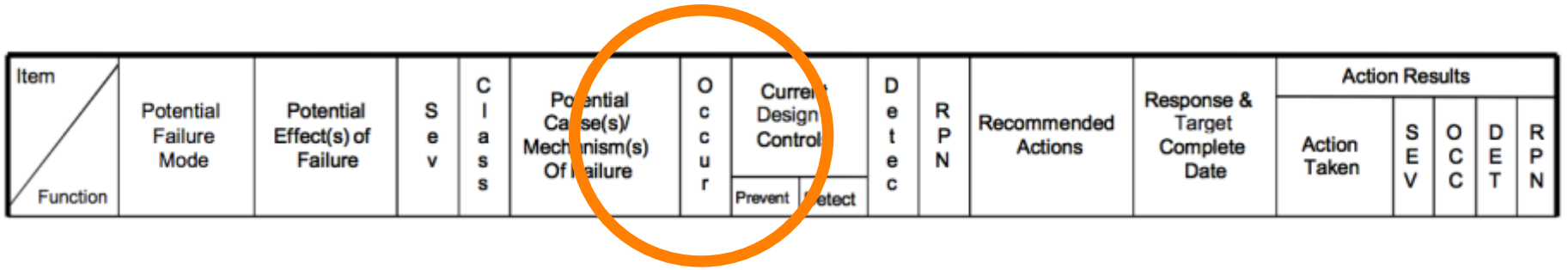
Cause(s) of Failure



Examples

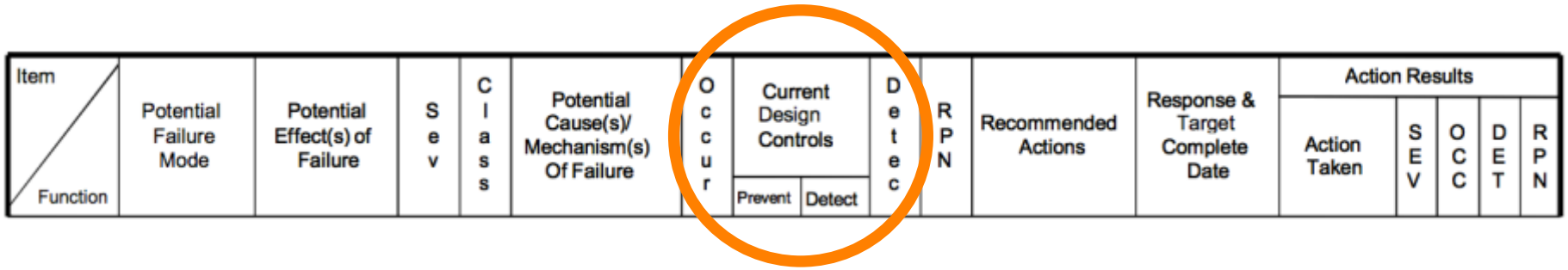
- Incorrect location of vents
- Incorrect routing of vent hoses (too close to heat source)
- Inadequate coolant capacity for application

Occurrence



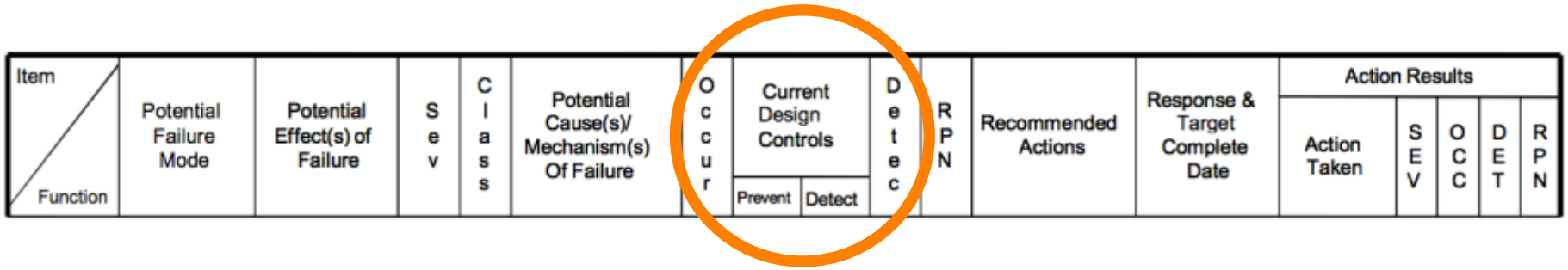
- Occurrence values should correspond with AIAG, SAE
- If occurrence values are based upon internally defined criteria, a reference must be included in FMEA to rating table with explanation
- Occurrence ratings for design FMEA are based upon the likelihood that a cause may occur, based upon past failures, performance of similar systems in similar applications, or percent new content
- Occurrence values of 1 must have objective data to provide justification, data or source of data must be identified in Recommended Actions column

Current Design Controls



- **Preventive** controls are those that help reduce the likelihood that a failure mode or cause will occur – affects occurrence value
- **Detective** controls are those that find problems that have been designed into the product – assigned detection value
- If detective and preventive controls are not listed in separate columns, they must include an indication of the type of control

Current Design Controls



Examples

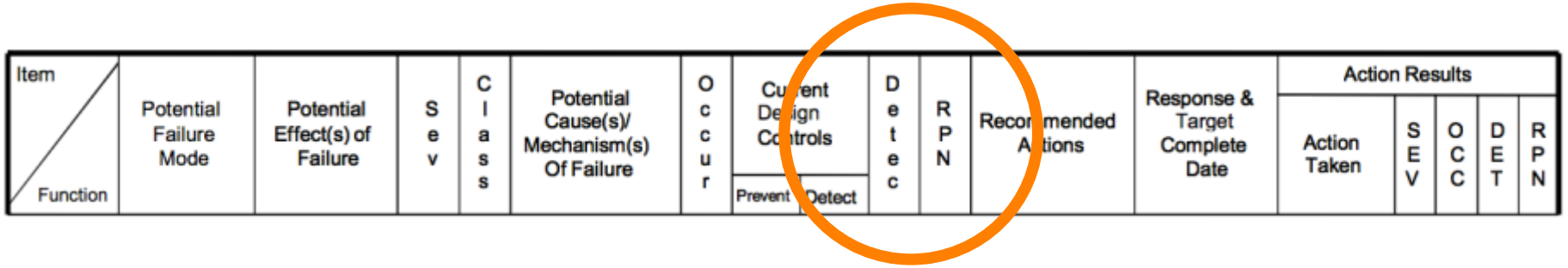
- Engineering specifications (P) – preventive control
- Historical data (P) – preventive control
- Functional testing (D) – detective control
- General vehicle durability (D) – detective control

Detection

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) Of Failure	Occur	Current Design Controls		Detec	RPN	Recommended Actions	Response & Target Complete Date	Action Results				
							Prevent	Detect					Action Taken	SEV	OCC	DET	RPN

- A numerical ranking based on an assessment of
- the probability that the failure mode will be
- detected given the controls that are in place.
- It is rated relatively scaled from 1-10.

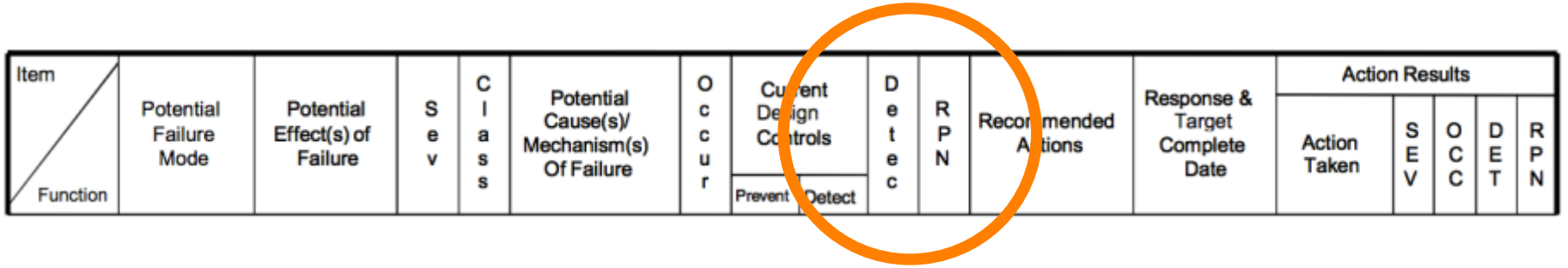
Detection



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							Prevent	Detect					Action Taken	SEV	OCC	DET	RPN	

- Detection values should correspond with AIAG, SAE
- If detection values are based upon internally defined criteria, a reference must be included to rating table with explanation for use
- Detection is the value assigned to each of the detective controls
- Detection values of 1 must eliminate the potential for failures due to design deficiency

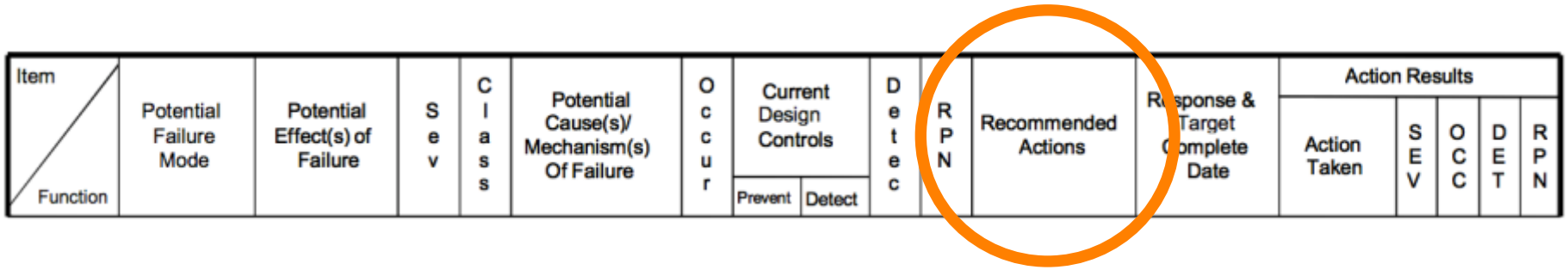
Risk Priority Number (RPN)



Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) Of Failure	Occur	Current Design Controls		Detec	RPN	Recommended Actions	Response & Target Complete Date	Action Results				
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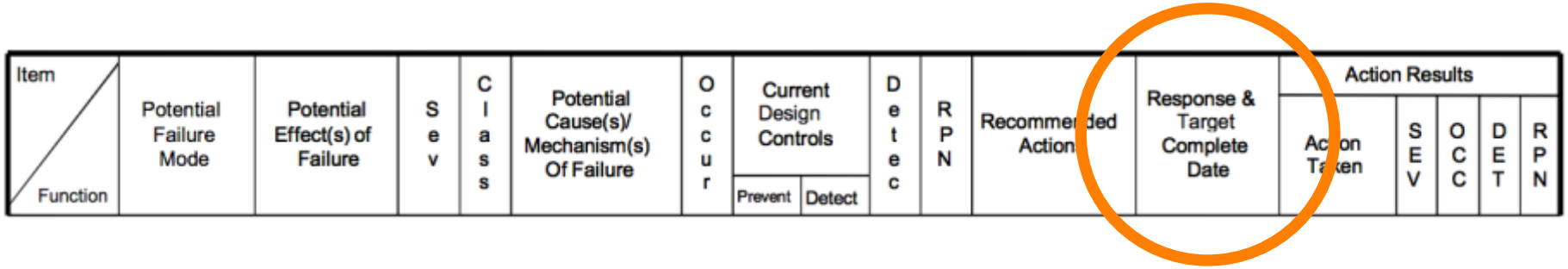
- Risk Priority Number is a multiplication of the severity, occurrence and detection ratings
- A systematic methodology is used to rate the risks relative to each other. The RPN is the critical indicator for each failure mode. The RPN is a function of three factors: The Severity of the effect, the frequency of Occurrence of the cause of the failure, and the ability to Detect (or prevent) the failure or effect.
- RPN = Severity rating X Occurrence rating X Detection rating

Recommended Actions



- All critical or significant characteristics must have recommended actions associated with them
- Recommended actions should be focused on design, and directed toward mitigating the cause of failure, or eliminating the failure mode
- If recommended actions cannot mitigate or eliminate the potential for failure, recommended actions must force characteristics to be forwarded to process FMEA for process mitigation

Responsibility & Target Completion Date



- All recommended actions must have a person assigned responsibility for completion of the action
- Responsibility should be a name, not a title
- Person listed as responsible for an action must also be listed as a team member
- There must be a completion date accompanying each recommended action.

Action Results

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) Of Failure	Occur	Current Design Controls		Detec	RPN	Recommended Actions	Response / Target Complet Date	Action Results				
							Prevent	Detect					Action Taken	SEV	OCC	DET	RPN

- Action taken must detail actions occurred, and results of those actions
- Actions must be completed by the target completion date
- Unless the failure mode is eliminated, severity should not change
- Occurrence may or may not be lowered based on the results of actions
- Detection may or may not be lowered based on the results of actions
- If severity, occurrence or detection ratings are not improved, additional recommended actions must to be defined

FME(C)A Checklist

- System description/specification
- Ground rules
- Identify failure modes
- Failure effect analysis
- Worksheet (RPN ranking)
- Recommendations (Corrective action)
- Reporting



FMECA Facts and Tips

- Highlight single point failures requiring corrective action
- Rank each failure mode.
- Identify reliability, safety critical components
- FMECA is a living document
- FMECAs should begin as early as possible
  - This allows the analyst to affect the design before it is set in stone.
  - If you start early (as you should) expect to have to redo portions as the design is modified.
- FMECAs take a lot of time to complete.
- FMECAs require considerable knowledge of system operation necessitating extensive discussions with software/hardware Design Engineering and System Engineering.

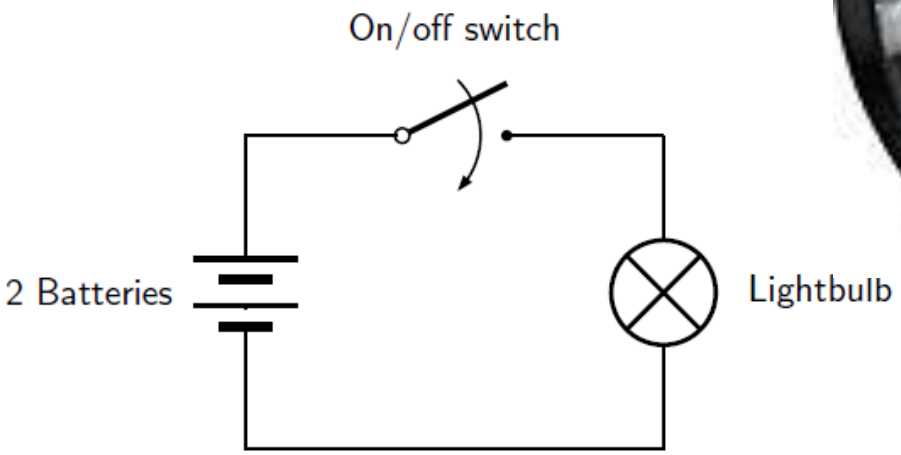
Task


“I hear and I forget
I see and I remember
I do and I understand”
Confucius
(551 BC to 479 BC)

Exercise - Flashlight

- This flashlight is for use by fire and rescue operative involved in emergency operation to rescue people from fires, floods and other disasters.
- Perform an FMECA on the torch.





Exercise - Flashlight

Item	Failure Mode		Effect	Sev.	Cause	Occur.	Design Control		Detect.	RPN
							Prevent	Detect		
Bulb	Dim light		Flashlight output dim							
	No Light		No Flashlight output							
Switch	Stuck Closed									
	Stuck Open									
	Intermittent									
Contact	Poor Contact									
	No Contact									
	Intermittent									
Battery	Low Power									