Failure Modes and Effects Analysis

(This material is taken from the FMEA Info Centre, a non-commercial web-based inventory dedicated to the promotion of Failure Mode and Effect Analysis http://www.fmeainfocentre.com/index.htm.)

Summary of Failure Modes and Effects Analysis (FMEA)

FMEA is a qualitative reasoning approach best suited for reviews of mechanical and electrical hardware systems. The FMEA technique (1) considers how the failure modes of each system component can result in system performance problems and (2) ensures that appropriate safeguards against such problems are in place. **FMEA is best used at the design stage, *before* the product is placed into service, to insure maximum reliability.**

Brief summary of characteristics

- A systematic, highly structured assessment relying on evaluation of component failure modes and team experience to generate a comprehensive review and ensure that appropriate safeguards against system performance problems are in place
- Used as a system-level and component-level risk assessment technique
- Applicable to any well-defined system
- Sometimes performed by an individual working with system experts through interviews and field inspections, but also can be performed by an interdisciplinary team with diverse backgrounds and experience participating in group review meetings of system documentation and field inspections
- A technique that generates qualitative descriptions of potential performance problems (failure modes, causes, effects, and safeguards) as well as lists of recommendations for reducing risks
- A technique that can provide quantitative failure frequency or consequence estimates

Most common uses

- Used primarily for reviews of mechanical and electrical systems, such as fire suppression systems and vessel steering and propulsion systems
- Used frequently as the basis for defining and optimizing planned equipment maintenance because the method systematically focuses directly and individually on equipment failure modes
- Effective for collecting the information needed to troubleshoot system problems

Three key questions to be answered by the FMEA process:

- What could fail in each component of my product or design?
- To what extent might it fail and what are the potential hazards produced by the failure?
- What steps should be implemented to prevent failures?

Design FMEA Analysis

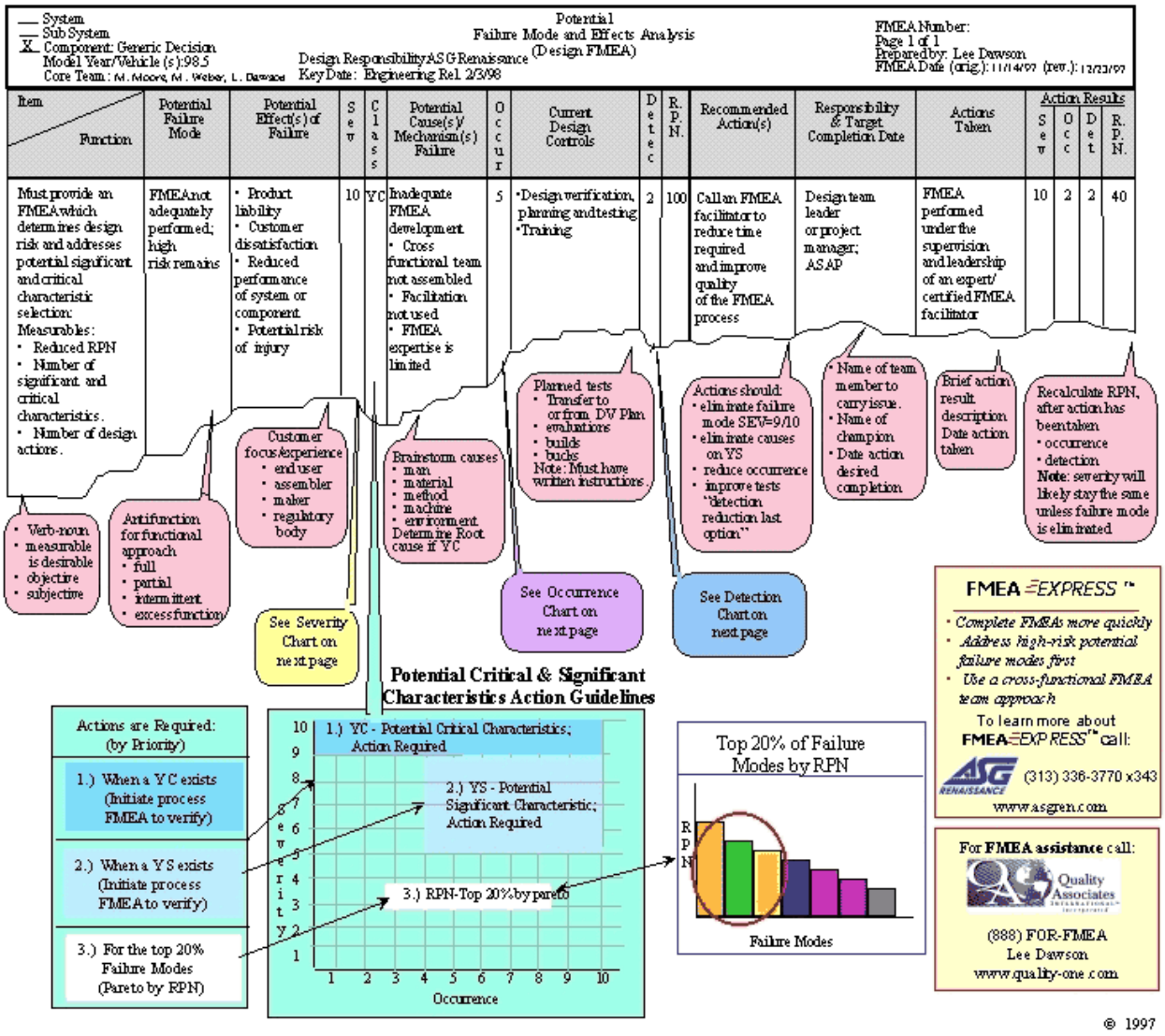
Item and Function	Potential Failure Mode	Potential Effects of Failure	∇	S E V	Potential Cause(s) of Failure	O C C	Detection Method & Quality Controls	D E T	R P N	Recommended Actions
List Part Name, Number and Function	List the possible modes of failure	List the consequences of failure on part function and on the next higher assembly			List those such as: inadequate design, improper materials, etc.		List these measures available to detect failures before they reach the customer			List them for each of the failure modes identified as being significant by the RPN

Delta = Critical characteristic which may effect safety, compliance with Gov. regulations, or require special controls.
SEV = Severity rating (1 to 10)
OCC = Occurrence frequency (1 to 10)
DET = Detection Rating (1 to 10)
RPN = Risk Priority Number (1 to 1000)

List of Example Failure Modes

Corrosion	Ingress	Delamination
Fracture	Vibrations	Erosion
Material Yield	Whirl	Thermal shock
Electrical Short	Sagging	Thermal relaxation
Open Circuit	Cracking	Bonding failure
Buckling	Stall	Starved for lubrication
Resonance	Creep	Staining
Fatigue	Thermal expansion	Inefficient
Deflections or deformations	Oxidation	Fretting
Seizure	UV deterioration	Thermal fatigue
Burning	Acoustic noise	Sticking
Misalignment	Scratching and hardness	Intermittent system operation
Stripping	Unstable	Egress
Wear	Loose fittings	Surge
Binding	Unbalanced	
Overshooting (Control)	Embrittlement	
Ringing	Loosening	
Loose	Scoring	
Leaking	Radiation damage	

FMEA - Quick Reference Guide



Guidelines For Auditing FMEA'S per QS 9000:
(Source: Potential Failure Mode and Effects Analysis (FMEA) Reference Manual (AIAG): (Feb, 1996))

1. Is there evidence that a cross-functional team was used to develop the FMEA?
2. Is the FMEA header completely filled out with a tracking number, the component or (sub) system name, design responsible activity, preparer's name, model year and vehicle (if known), the initial FMEA due date, the date the original FMEA was compiled, the latest revision date and names/departments of team member?
3. Is the FMEA that is being audited the latest revision level?
4. **Function** – Has the component or (sub) system been identified? Has the nomenclature found on the engineering drawing been used? Has the function of the part been identified?
5. **Potential Failure Mode** – Is there at least one failure mode listed for every function?
6. **Potential Effects of Failure** – Are the effects of the failure defined and are they defined in terms of what the internal or vehicle level external customer might notice?
7. **Severity** – Is the severity (or seriousness) of the potential effect of the failure rated? (See Definitions provided above.)
8. **Classification** – Are the significant and critical characteristics identified in this column? (blanks are allowed) (See Special Characteristics model on other side)
9. **Potential Causes/Mechanisms of Failure** – Is there at least one potential cause of failure listed for every failure mode?
10. **Occurrence** – has an occurrence ranking been assigned to each of the potential causes/mechanisms of failure? (See Definitions provided above.)
11. **Current Design Controls** – Is there listed a prevention, design validation/verification (DV) or other activities which will maximize design adequacy of the failure mode and or cause mechanism?
12. **Detection** – Is there a detection ranking that assesses the ability of the design controls to detect a potential cause/mechanism or the ability of the design controls to detect the subsequent failure mode before the component or (sub) system is released for production. (See Definitions provided above.)
13. **RPN** – Has the RPN been calculated by multiplying S x O x D?
14. **Recommended Actions** – Have actions been identified for potential significant and critical characteristics and to lower the risk of the higher RPN failure modes? Has "none" been entered in the column if no actions are recommended?
15. **Responsibility** – Has an individual, SBU and target completion date been entered in columns where an action has been recommended? (Blanks are OK when no action is recommended)
16. **Actions Taken** – Has a brief description of the actual action and effective date been entered after the action has been taken? (Blanks are OK when no action is recommended)
17. Resulting severity, occurrence, detection and RPN – Have the new severity, occurrence, detection and RPN numbers been entered after an action has been completed and verified?
18. Has the design responsible engineer implemented or adequately addressed the recommended action?

Severity, Occurrence, and Detection Criteria for Design FMEA

Severity Evaluation Criteria

Effect	Criteria: Severity of Effect	Rank
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, with loss of primary function.	8
High	Vehicle/item operable, but at reduced level of performance. Customer dissatisfied.	7
Moderate	Vehicle/item operable, but Comfort/ Convience item(s) inoperable. Customer experiences discomfort.	6
Low	Vehicle/item operable, but Comfort/ Convience item(s) operable at reduced level of performance. Customer experiences some dissatisfaction.	5
Very Low	Fit & finish/Squeak & Rattle item does not conform. Defect noticed by average customers.	4
Minor	Fit & finish/Squeak & Rattle item does not conform. Defect noticed by most customers.	3
Very Minor	Fit & finish/Squeak & Rattle item does not conform. Defect noticed by discriminating customers.	2
None	No effect.	1*

*__Note:__ *Zero (0) rankings for Severity, Occurrence or Detection are not allowed*

Suggested Occurrence Evaluation Criteria

Rank	CPK	Failure Rates	Probability of Failure
10	≥ 0.33	> 1 in 2	**Very High:** Failure almost inevitable
9	≥ 0.33	1 in 3	
8	≥ 0.51	1 in 8	**High:** Repeated failures
7	≥ 0.67	1 in 20	
6	≥ 0.83	1 in 80	**Moderate:** Occasional failures
5	≥ 1.00	1 in 400	
4	≥ 1.17	1 in 2000	
3	≥ 1.33	1 in 15 000	**Low:** Relatively few failures
2	≥ 1.50	1 in 150 000	
1*	≥ 1.67	≤ 1 in 1 500 000	**Remote:** Failure is unlikely

*__Note:__ *Zero (0) rankings for Severity, Occurrence or Detection are not allowed*

Suggested Detection Eval. Criteria

Detection	Criteria	Rank
Absolute Uncertainty	Design Control will not and/or cannot detect a potential cause/ mechanism and subsequent failure mode; or there is no Design Control.	10
Very Remote	Very Remote chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	9
Remote	Remote chance the Design Control will detect a potential cause/ mechanism and subsequent failure mode.	8
Very Low	Very Low chance the Design Control will detect a potential cause/ mechanism and subsequent failure mode.	7
Low	Low chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	6
Moderate	Moderate chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	5
Moderately High	Moderately High chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	4
High	High chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	3
Very High	Very High chance the Design Control will detect a potential cause/mechanism and subsequent failure mode.	2
Almost Certain	Design Controls will almost certainly detect a potential cause/mechanism and subsequent failure mode.	1*

*__Note:__ *Zero (0) rankings for Severity, Occurrence or Detection are not allowed*

Simplified FMEA Example

A simple column-by-column example using a rifle bolt.

Item and Function

Rifle Bolt

- Chambers bullet
- Locks into receiver
- Fires a round
- Sustains firing pressure on lugs
- Provides extraction of spent case

Potential Failure Modes

- Fracture
- Jamming

Potential Effects of Failure		**Delta**	**SEV**
Catastrophic failure with destruction of weapon and injury to personnel------>	yes	10	
Failure of weapon to function---------->		no	1

Likelihood of Occurrence (OCC) - Estimate the potential occurrence of failure

Detection Method & Quality Controls

- Incoming Part Inspection
- Dye penetrate testing
- Measure patterns
- Confirm finished casting dimensions

Calculate the RPN number RPN = (SEV) x (OCC) x (DET)

- A 1000 rating implies a certain failure that is hazardous and harmful
- A 1 rating is a failure that is highly unlikely and unimportant
- Ratings above 100 will occur
- Rating below 30 are reasonable for typical applications

Final Column - Based on your RPN number, develop recommended actions to solve failure modes

- Assign responsibilities
- Outline corrective actions
- Revise test plans, material specifications
- These actions should be specific, not general action items

Part and Function •	Potential Failure Mode	Potential Effects of Failure	**DELT**	SEV	Potential Cause(s) of Failure	OCC	Detection Meth & Quality Controls	DET	**RPN**	**Recommended Actions**
Rifle Bolt §Chambers bulle §Locks into receiver §Fires Round §Sustains firing pressure on lugs §Provides extraction of spen case	Fracture	Catastrophic failure with destruction of weapon and injury to	yes	10	§Shrinkage §Porosity cause by improper fee	6	§Incoming Part Inspection §Dye penetrate testing	5	300	Initiate radiographi testing of all rifle bolts
	Jamming	Failure of weapon to function		8	§Out of spec. Dimension §Change in she refractory	5	§Measure patterns §Confirm finished casting dimensions	3	120	Initiate SPC progra to check and maint bolt dimensions