Failure Modes Effects Analysis in MBSE

Ron Kratzke, Principal Systems Engineer
Vitech Corporation
Introduction

• Failure Modes Effects Analysis is used in a number of industries to conduct an analysis of system, subsystem, and component design

• In some industries an FMEA is required by a regulatory body prior to receiving “authorization” to take a product to market
FMEA Definition and Basics

• Failure Mode and Effects Analysis (FMEA) and Failure Modes, Effects and Criticality Analysis (FMECA) are methodologies designed to identify potential failure modes for a product or process, to assess the risk associated with those failure modes, to rank the issues in terms of importance and to identify corrective actions to address the most serious concerns.

• The purpose, terminology, and other details vary according to industry and type (e.g. Process FMEA, Design FMEA, etc.), the basic methodology is similar for all design efforts.

• Basics:
  ➢ Identify Failure Modes
  ➢ Assess Failure Modes
  ➢ Rank the Failure Modes
  ➢ Identify Corrective Actions
Basic References

Failure Mode Effect Analysis: FMEA from Theory to Execution, 2 ed. by D.H. Stamatis, Quality Press

Procedures for Performing a Failure Mode, Effects and Criticality Analysis, MIL-STD-1629

FMEA and FMECA Webpage on Weibull.com (www.weibull.com/basics/fmea.htm), last accessed May 20, 2017


Elements of a FMEA
Expanding the basic FMEA Model...

Failure Mode Analysis

Failure Mode ➔ Failure Effect* ➔ Failure Cause* ➔ Detection Method*

S – Severity
O – Occurrence
D - Detectability
Severity Rating

Severity (S) – a rating of the seriousness of the effect of a failure mode to the system, assembly, product, customer, or government regulation.

Severity is related to the Failure Effect.

Severity Guidance for system FMEA

<table>
<thead>
<tr>
<th>Effect</th>
<th>Rank</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>1</td>
<td>No Effect</td>
</tr>
<tr>
<td>Very Slight</td>
<td>2</td>
<td>Customer not annoyed. Very slight effect on product or system performance.</td>
</tr>
<tr>
<td>Slight</td>
<td>3</td>
<td>Customer slightly annoyed. Slight effect on product or system performance.</td>
</tr>
<tr>
<td>Minor</td>
<td>4</td>
<td>Customer experiences minor nuisance. Minor effect on product or system performance.</td>
</tr>
<tr>
<td>Moderate</td>
<td>5</td>
<td>Customer experiences some dissatisfaction. Moderate effect on product or system performance.</td>
</tr>
<tr>
<td>Serious</td>
<td>9</td>
<td>Potential hazardous effect. Able to stop product without mishap – time dependent failures. Compliance with government regulation is in jeopardy.</td>
</tr>
</tbody>
</table>

Ref: Failure Mode Effect Analysis: FMEA from Theory to Execution, by D. H. Stamatis
Occurrence Rating

Occurrence (O) – a rating corresponding to the cumulative number of failures that could occur over the design life of a system or component.

Occurrence is related to the Failure Cause

CNF – Cumulative number of failures

<table>
<thead>
<tr>
<th>Effect</th>
<th>Rank</th>
<th>Criteria</th>
<th>CNF/1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost Never</td>
<td>1</td>
<td>Failure unlikely, history shows no failures</td>
<td>&lt; .00058</td>
</tr>
<tr>
<td>Remote</td>
<td>2</td>
<td>Rare number of failures likely</td>
<td>.0068</td>
</tr>
<tr>
<td>Very Slight</td>
<td>3</td>
<td>Very few failures likely</td>
<td>.0063</td>
</tr>
<tr>
<td>Slight</td>
<td>4</td>
<td>Few failures likely</td>
<td>.46</td>
</tr>
<tr>
<td>Low</td>
<td>5</td>
<td>Occasional number of failures likely</td>
<td>2.7</td>
</tr>
<tr>
<td>Medium</td>
<td>6</td>
<td>Medium number of failures likely</td>
<td>12.4</td>
</tr>
<tr>
<td>Moderately High</td>
<td>7</td>
<td>Moderately high number of failures likely</td>
<td>46</td>
</tr>
<tr>
<td>High</td>
<td>8</td>
<td>High number of failures likely</td>
<td>134</td>
</tr>
<tr>
<td>Very High</td>
<td>9</td>
<td>Very High number of failures likely</td>
<td>316</td>
</tr>
<tr>
<td>Almost Certain</td>
<td>10</td>
<td>Failure almost certain. History of failures exists from previous or similar designs.</td>
<td>&gt;315</td>
</tr>
</tbody>
</table>

Ref: Failure Mode Effect Analysis: FMEA from Theory to Execution, by D. H. Stamatis
Detectability Rating

Detectability (D) – a rating of the ability of the proposed design control to detect a potential failure mode or occurrence.

Detectability is related to the Failure Control

Detection Guidance for system FMEA

<table>
<thead>
<tr>
<th>Effect</th>
<th>Rank</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost certain</td>
<td>1</td>
<td>Proven detection methods available while in conceptual design</td>
</tr>
<tr>
<td>Very High</td>
<td>2</td>
<td>Has very high effectiveness</td>
</tr>
<tr>
<td>High</td>
<td>3</td>
<td>Has high effectiveness</td>
</tr>
<tr>
<td>Moderately High</td>
<td>4</td>
<td>Has moderately high effectiveness</td>
</tr>
<tr>
<td>Medium</td>
<td>5</td>
<td>Has medium effectiveness</td>
</tr>
<tr>
<td>Low</td>
<td>6</td>
<td>Has low effectiveness</td>
</tr>
<tr>
<td>Slight</td>
<td>7</td>
<td>Has very low effectiveness</td>
</tr>
<tr>
<td>Very Slight</td>
<td>8</td>
<td>Has lowest effectiveness in each applicable category</td>
</tr>
<tr>
<td>Remote</td>
<td>9</td>
<td>Unproven, or unreliable, or effectiveness is unknown</td>
</tr>
<tr>
<td>Almost Impossible</td>
<td>10</td>
<td>No technique is available or known, and/or none is planned</td>
</tr>
</tbody>
</table>

Ref: Failure Mode Effect Analysis: FMEA from Theory to Execution, by D. H. Stamatis
Criticality of a Failure

Criticality – A relative measure of the combined influence of the consequences or a failure mode (severity or S) and its frequency (occurrence or O). The product of the severity times occurrence provides the relative criticality.

CRITICALITY = S × O

(c) Vitech Corporation 2017
Evaluating the Failure Relative to one another

Risk Priority Number (RPN) – A relative measure used to rank order potential system failures. The RPN defines the priority of the failure. The RPN is the product of the severity, occurrence, and detection ratings.
Recommended Actions…

No FMEA should be done without a recommended action list to improve the system design.

Recommended Actions are taken to reduce severity, occurrence, detection, or all three of them. In essence to eliminate failures and thereby eliminate system deficiencies.

Using Criticality or RPN-
- Rank Order Failures and Causes
- Determine a subset of Failure (generally > RPN value)
- Develop Follow-up, Corrective Actions
FMEA Example
### Automotive Industry Example

#### Potential Failure Mode and Effects Analysis

<table>
<thead>
<tr>
<th>Name / Function Requirements</th>
<th>Potential Failure Mode</th>
<th>Potential Effect(s) of Failure</th>
<th>Severity (S)</th>
<th>Occurrence (O)</th>
<th>Detection (D)</th>
<th>Risk Priority Number (RPN)</th>
<th>Recommended Action(s)</th>
<th>Responsibility &amp; Planned Completion Date</th>
<th>Action Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Op. 70 Manual application of wax inside door/cover inner door, lower surfaces with wax to specification thickness.</td>
<td>Insufficient wax coverage over specified surface</td>
<td>Manually inserted spray head not inserted far enough</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>280</td>
<td>Add positive depth stop to sprayer.</td>
<td>Mfg Engng - 3/10/2003</td>
<td>Stop added, sprayer checked on line.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual check each hour - 1/shift for film thickness (depth meter) and coverage.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Automate spraying.</td>
<td>Mfg Engng - 3/10/2003</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spray head drooped - viscosity too high</td>
<td>Test spray pattern at start-up and after idle periods, and preventive maintenance program to clean heads.</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>175</td>
<td>Use Design of Experiments (DOE) on viscosity vs. temperature vs. pressure.</td>
<td>Mfg Engng - 5/10/2003</td>
<td>Temp and press limits were determined and limit controls have been installed - control charts show process in control Cpk = 1.8.</td>
</tr>
<tr>
<td></td>
<td>Spray head deformed due to impact</td>
<td>Preventive maintenance program to maintain heads.</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>70</td>
<td>Visual check each hour - 1/shift for film thickness (depth meter) and coverage.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1:** Process FMEA (PFMEA) in the Automotive Industry Action Group (AIAG) FMEA-4 format.


(c) Vitech Corporation 2017
Integrating FMEA into an MBSE environment
Objective

- Expand the “standard” MBSE schema used in Model Based System Engineering (MBSE) to provide for traceability to the FMEA
- Provide for the ability to produce a standard FMEA table
- Provide for Traceability from the system design to the FMEA
Common Elements of any FMEA …

<table>
<thead>
<tr>
<th>Function</th>
<th>Potential Failure Mode</th>
<th>Potential Effects(s) of Failure</th>
<th>Severity (S)</th>
<th>Potential Cause(s) of Failure</th>
<th>O</th>
<th>Current Process Controls</th>
<th>D</th>
<th>RPN</th>
<th>CRI</th>
<th>Recommended Action(s)</th>
<th>Responsibility and Target Completion Date</th>
<th>Action Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispense amount of cash requested by customer</td>
<td>Does not dispense cash</td>
<td>Customer very dissatisfied, Incorrect entry to demand deposit system, Discrepancy in cash balancing</td>
<td>6</td>
<td>Out of cash</td>
<td>5</td>
<td>Internal low-cash alert</td>
<td>5</td>
<td>200</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dispenses too much cash</td>
<td>Bank loses money, Discrepancy in cash balancing</td>
<td>6</td>
<td>Bills stuck together, Denominations in wrong trays</td>
<td>2</td>
<td>Loading procedure (little ends of stack)</td>
<td>7</td>
<td>64</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Takes too long to dispense cash</td>
<td>Customer somewhat annoyed</td>
<td>3</td>
<td>Heavy computer network traffic, Power interruption during transaction</td>
<td>7</td>
<td>None</td>
<td>10</td>
<td>210</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(c) Vitech Corporation 2017
Failure Mode Class

Need a Class to capture the Failure Mode and the relation to the system entities

This arrangement allows for capturing a failure mode for any item in the system design.
Failure Mode Entity Attributes

**Failure Mode:**
- Name
- Number
- Description (Effect)
- Severity

**Failure Cause:**
- Name
- Number
- Description (Cause)
- Occurrence
- Control
- Detection

**FMEA Analysis Features:**
- One Failure Mode can have multiple causes
- Severity is associated with Failure Mode
- Probability of Occurrence associated with each Cause
- Detection associated with each Cause

---

### FMEA Analysis Features:

<table>
<thead>
<tr>
<th>Function</th>
<th>Potential Failure Mode</th>
<th>Potential Effect(s) of Failure</th>
<th>S</th>
<th>Potential Cause(s) of Failure</th>
<th>O</th>
<th>Current Process Controls</th>
<th>D R P N</th>
<th>CR I T</th>
<th>Recommended Action(s)</th>
<th>Responsibility and Target Completion Date</th>
<th>Action Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispense amount of cash requested by customer</td>
<td>Does not dispense cash</td>
<td>Customer very dissatisfied</td>
<td>6</td>
<td>Out of cash</td>
<td>5</td>
<td>Internal low-cash alert</td>
<td>5</td>
<td>200</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dispensed too much cash</td>
<td>Bank loses money</td>
<td>Discrepancy in cash balancing</td>
<td>6</td>
<td>Bills stuck together</td>
<td>2</td>
<td>Loading procedure (off the end of stack)</td>
<td>7</td>
<td>64</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Takes too long to dispense cash</td>
<td>Customer somewhat annoyed</td>
<td></td>
<td>3</td>
<td>Heavy network traffic</td>
<td>7</td>
<td>None</td>
<td>10</td>
<td>210</td>
<td>21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Calculated Values
Schema Extension

Component, Function, Interface, Link, Requirement

“associated with/ introduced by”

Failure Mode
- Name
- Number
- Description
- Severity

“created by / creates”

Relation attributes:
- Hazard
- RPN

Failure Cause
- Name
- Number
- Description
- Occurrence
- Detection Method
- Detectability

“mitigated by / mitigates”

Nexus
------------
(Concern / Change Request)

“generates”

Risk

“causes”

Component, Function, Interface, Link, Requirement

“results in”

or “impacts”

Failure Reduction
- Name
- Number
- Description
- Recommended Action
- Responsibility
- Due Date
- Updated Occurrence
- Updated Detectability

(c) Vitech Corporation 2017
Reporting on the FMEA
Example Generic FMEA Form

Generally, the results of an FMEA are captured in a table similar to this.

![FMEA Form](image)

Ref: Failure Mode Effect Analysis: FMEA from Theory to Execution, Appendix A, Figure E-10, D. H. Stamatis

(c) Vitech Corporation 2017
<table>
<thead>
<tr>
<th>System Element</th>
<th>Failure</th>
<th>Failure Description</th>
<th>Severity</th>
<th>Cause of Failure</th>
<th>Detection</th>
<th>Detection Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Motor and Fan</td>
<td>Fan Vibration and Interference</td>
<td>Audible Noise, vibration; increased motor wear.</td>
<td></td>
<td>Fan Center of Gravity off axis of rotation causing unbalance.</td>
<td>5</td>
<td>Designed for easy assembly and alignment.</td>
</tr>
<tr>
<td>Assembly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Design calls for lightweight fan with minimum band mass, port thickness.</td>
</tr>
<tr>
<td>Cooling Motor and Fan</td>
<td>Misalignment of Fan and Shroud</td>
<td>Fan and shroud mis-aligned cause reduction of cooling</td>
<td>7</td>
<td>Fan contacts shroud, noise or motor burnout.</td>
<td>2</td>
<td>Designed for easy assembly and alignment.</td>
</tr>
<tr>
<td>Assembly</td>
<td></td>
<td>to the system.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Motor and Fan</td>
<td>Motor Burnout</td>
<td>Motor Burnout causes loss of cooling to the system.</td>
<td></td>
<td>Overheating of motor assembly due to lack of air circulation</td>
<td>2</td>
<td>Vent holes in motor casing, fins in fan hub pull air through motor body.</td>
</tr>
<tr>
<td>Assembly</td>
<td></td>
<td></td>
<td></td>
<td>around motor.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Motor and Fan</td>
<td>Reduced Fan Efficiency</td>
<td>Fan motor is assembled 120 degrees off nominal angle</td>
<td>6</td>
<td>Symmetrical spacing of screw holes allows for non-unique</td>
<td>7</td>
<td>Current design requires visual verification of assembly.</td>
</tr>
<tr>
<td>Assembly</td>
<td></td>
<td>causes reduction of cooling effectiveness.</td>
<td></td>
<td>mounting of fan motor.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Misassembly of Fan and Motor causes pinched wire.</td>
<td>7</td>
<td>Visual Inspection of Fan and Motor assembly.</td>
</tr>
</tbody>
</table>
FMEA with Criticality and RPN Calculations

<table>
<thead>
<tr>
<th>System Element</th>
<th>Failure</th>
<th>Failure Description</th>
<th>Severity</th>
<th>Cause of Failure</th>
<th>Occurrence</th>
<th>Detection Method</th>
<th>Detectability</th>
<th>Criticality</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Motor and Fan Assembly</td>
<td>Fan Vibration and Interference</td>
<td>Audible Noise, vibration, increased motor wear.</td>
<td>5</td>
<td>Fan Center of Gravity off axis of rotation causing 2-plan imbalance.</td>
<td>5</td>
<td>Design calls for lightweight fan with minimum bend mass, part thickness.</td>
<td>4</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Cooling Motor and Fan Assembly</td>
<td>Misalignment of Fan and Shroud</td>
<td>Fan and shroud mis-aligned cause reduction or complete loss of cooling</td>
<td>7</td>
<td>Fan contacts shroud, noise or motor burnout.</td>
<td>2</td>
<td>Designed for easy assembly and alignment.</td>
<td>3</td>
<td>14</td>
<td>42</td>
</tr>
<tr>
<td>Cooling Motor and Fan Assembly</td>
<td>Motor Burnout</td>
<td>Motor Burnout causes loss of cooling to the system.</td>
<td>5</td>
<td>Overheating of motor assembly due to lack of air circulation around motor.</td>
<td>2</td>
<td>Vent holes in motor casing, fins in fan hub pull air through motor body.</td>
<td>5</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Cooling Motor and Fan Assembly</td>
<td>Reduced Fan Efficiency</td>
<td>Fan motor is assembled 120 degrees off nominal angle causes reduction of cooling effectiveness.</td>
<td>6</td>
<td>Symmetrical spacing of screw holes allows for non-unique mounting of fan motor.</td>
<td>7</td>
<td>Current design requires visual verification of assembly.</td>
<td>7</td>
<td>42</td>
<td>294</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Misassembly of Fan and Motor causes pinched wire.</td>
<td></td>
<td>Visual Inspection of Fan and Motor assembly.</td>
<td>6</td>
<td>42</td>
<td>252</td>
</tr>
</tbody>
</table>
## High RPN Values

<table>
<thead>
<tr>
<th>System Element</th>
<th>Failure Description</th>
<th>Severity</th>
<th>Cause of Failure</th>
<th>Detection Method</th>
<th>Detectability</th>
<th>Criticality</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Motor and Fan Assembly</td>
<td>Fan Vibration and Interference</td>
<td>5</td>
<td>Fan Center of Gravity off axis of rotation causing 2-plan imbalance.</td>
<td>Design calls for lightweight fan with minimum bend mass, part thickness.</td>
<td>5</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Cooling Motor and Fan Assembly</td>
<td>Misalignment of Fan and Shroud</td>
<td>7</td>
<td>Fan contacts shroud, noise or motor burnout.</td>
<td>Designed for easy assembly and alignment.</td>
<td>2</td>
<td>14</td>
<td>42</td>
</tr>
<tr>
<td>Cooling Motor and Fan Assembly</td>
<td>Motor Burnout</td>
<td>5</td>
<td>Overheating of motor assembly due to lack of air circulation around motor.</td>
<td>Vent holes in motor casing, fins in fan hub pull air through motor body.</td>
<td>2</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Reduced Fan Efficiency</td>
<td>Fan motor is assembled 120 degrees off nominal angle causes reduction of cooling effectiveness.</td>
<td>6</td>
<td>Symmetrical spacing of screw holes allows for non-unique mounting of fan motor.</td>
<td>Current design requires visual verification of assembly.</td>
<td>7</td>
<td>42</td>
<td>294</td>
</tr>
<tr>
<td>Reduced Fan Efficiency</td>
<td>Misassembly of Fan and Motor causes pinched wire.</td>
<td>7</td>
<td>Visual Inspection of Fan and Motor assembly.</td>
<td></td>
<td>6</td>
<td>42</td>
<td>251</td>
</tr>
</tbody>
</table>

Values above a threshold require mitigation. Threshold Value varies based on project and industry.
Failure Reduction…

Component, Function, Interface, Link, Requirement

Failure Mode
- Name
- Number
- Description
- Severity

Failure Cause
- Name
- Number
- Description
- Occurrence
- Detection Method
- Detectability

Relation attributes:
- Hazard
- RPN

Fail Reduction
- Name
- Number
- Description
- Recommended Action
- Responsibility
- Due Date
- Updated Occurrence
- Updated Detectability

Component, Function, Interface, Link, Requirement

Nexus
(Concern / Change)

Risk

“associated with/ introduced by”

“created by / creates”

“mitigated by / mitigates”

“results in”

“results in” or “impacts”

“generates”

“causes”

(c) Vitech Corporation 2017
# FMEA Report with Failure Reduction

<table>
<thead>
<tr>
<th>System Element</th>
<th>Failure</th>
<th>Failure Description</th>
<th>Severity</th>
<th>Cause of Failure</th>
<th>Prevalence</th>
<th>Detection Method</th>
<th>Detractability</th>
<th>Likelihood</th>
<th>Impact</th>
<th>Recommended Action</th>
<th>Responsibility</th>
<th>Due Date</th>
<th>Updated Frequency</th>
<th>Updated Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Motor and Fan Assembly</td>
<td>Fan Vibration and Interference</td>
<td>Audible Noise, vibration, increased motor wear.</td>
<td>5</td>
<td>Fan Center of Gravity off axis of rotation causing 2-plan</td>
<td>5</td>
<td>Design calls for lightweight fan with minimum bend mass.</td>
<td>4</td>
<td>25</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Motor and Fan Assembly</td>
<td>Misalignment of Fan and Shroud</td>
<td>Fan and shroud mis-aligned cause reduction or complete</td>
<td>7</td>
<td>Fan contacts shroud, noise or motor burnout.</td>
<td>2</td>
<td>Designed for easy assembly and alignment</td>
<td>3</td>
<td>14</td>
<td>42</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Motor and Fan Assembly</td>
<td>Motor Burnout</td>
<td>Motor Burnout causes loss of cooling to the system.</td>
<td>5</td>
<td>Overheating of motor assembly due to lack of air.</td>
<td>2</td>
<td>Vent holes in motor casing, fins in fan hub pull air.</td>
<td>5</td>
<td>10</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Motor and Fan Assembly</td>
<td>Reduced Fan Efficiency</td>
<td>Fan motor is assembled 120 degrees off nominal angle causes reduction of cooling effectiveness.</td>
<td>6</td>
<td>Symmetrical spacing of screw holes allows for non-unique mounting of fan motor.</td>
<td>7</td>
<td>Current design requires visual verification of assembly.</td>
<td>7</td>
<td>42</td>
<td>294</td>
<td>Develop a unique, non-symmetrical bolt pattern for the motor / fan</td>
<td>Joe Engineer</td>
<td>31-Aug-17</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Missassembly of Fan and Motor causes pinched wire.</td>
<td>7</td>
<td>Visual Inspection of Fan and Motor assembly.</td>
<td>6</td>
<td>42</td>
</tr>
</tbody>
</table>
Capture Design Changes based on FMEA

- Component, Function, Interface, Link, Requirement
  - "associated with/ introduced by"

- Failure Mode
  - Name
  - Number
  - Description
  - Severity
  - "created by / creates"

- Failure Cause
  - Name
  - Number
  - Description
  - Occurrence
  - Detection Method
  - Detectability
  - Relation attributes:
    - Hazard
    - RPN
  - "mitigated by / mitigates"

- Component, Function, Interface, Link, Requirement
  - "results in"
  - "results in"
  - "impacts"

- System Design Change
  - "generates"

- Risk
  - "causes"

- Failure Reduction
  - Name
  - Number
  - Description
  - Recommended Action
  - Responsibility
  - Due Date
  - Updated Occurrence
  - Updated Detectability

(c) Vitech Corporation 2017
Failure Reduction Hierarchy

Using the Schema diagram, determine what relations need to be included in the custom hierarchy...

To create the diagram on the left...
Organizing FMEA Analyses

Over the lifecycle you may have several different FMEA Analyses. How can we organize these?

Option 1 – Create individual folders within the Failure Mode Class

Option 2 – Create a Category for a particular analysis, then have the Category “categorize” a set of Failure Modes

Option 3 – Create a Package and have the package include the Failure Modes, Causes, and Reduction Methods
Summary / Conclusion

- Provided an examination of how to do a basic FMEA
- Looked at what we needed in an MBSE environment
- Examined a series of reports need to be produced from the MBSE environment
- Used a hierarchy to trace from the FMEA to the design model
Questions?

2270 Kraft Drive
Suite 1600
Blacksburg, VA 24060
USA
+1.703.883.2270 x306

Ron Kratzke
Principal Systems Engineer

www.vitechcorp.com
rkratzke@vitechcorp.com

(c) Vitech Corporation 2017