Design Failure Modes and Effects Analysis

DFMEA with Suppliers
Design Failure Modes and Effects Analysis

A structured approach that ensures potential product failure modes and their associated causes have been considered and addressed in the product design

– What can go wrong?
– Where will the variation come from?
– How can we prevent or control?
DFMEA Objective

Design and sell products so that in the future the customer returns, **NOT** the product

- Performing DFMEAs on existing or new product designs allows:
  - Early identification of the ways the product design can fail
  - Rational prioritization of potential failures so that corrective/preventive action and/or redesign can be accomplished before risk and cost can escalate
  - Smoother production ramps
  - Enhanced system reliability once countermeasures are implemented
  - Reduced development, production and warranty cost
  - Higher customer and end-user satisfaction
Overview of the DFMEA Process

- People knowledgeable about the product analyze situations where critical customer requirements might not be met.
- A ranking system is used to estimate three factors:
  - how **Severe** the failure would be
  - how frequently the failure would **Occur**,
  - how difficult it would be to **Detect**, and
- These three factors are multiplied and the resulting value is called the Risk Priority Number (RPN).
- The RPN is used to prioritize the failure modes so that corrective actions can be taken to reduce the frequency, and severity and/or improve the detectability of the failure mode.
DFMEA Benefits

- Part of an objective evaluation of design requirements and alternatives
- Helps to identify potential Critical Characteristics and Significant Characteristics
- Identifies potential failure modes ranked according to their effect on the customer; establishes a priority system for design improvement and development testing while still in the design phase
- Provides critical input for the planning of effective design test and development programs
- Provides an open issue format for recommending and tracking risk-reduction actions
- Aids in analyzing field concerns, evaluating design changes and developing advanced designs
Supplier DFMEA Benefits

- Proactive and collaborative; become more than “just a vendor”
- Identify issues which might drive in-process or post-process failures
- Suggest risk-mitigation alternatives for design incorporation
  - Features
  - Dimensions
  - Materials
  - Finishes
  - Validation requirements
- Opportunity to influence through added-value during the design phase
- Expected as part of quote package
DFMEA Prerequisites

- Select proper team and organize members
- Select teams for each product or system
- Create/agree on a ranking system
- Agree on format for DFMEA matrix
- Define the customer and customer needs/expectations
- Design requirements
DFMEA Flow

1. Assemble the team
2. Review the design
3. Assign S/O/D ratings and calculate RPN
4. Create action plan to reduce RPN
5. Drive actions to resolution
6. Implement controls
7. Re-baseline RPNs

**FAILURE MODE:** How a product can fail to meet design specifications or functional intent

**CAUSE:** A deficiency that results in a failure mode ➔ e.g. sources of variation

**EFFECT:** Impact on customer if the failure mode is not prevented or corrected
Typical DFMEA Team Members

- Design Engineer - Generally the Team Leader
- Project Manager
- Manufacturing/Assembly Engineer
- Process Engineer
- Quality Engineer
- Test Engineer
- Reliability Engineer
- Materials Engineer
- Field Service Engineer
- Component Process Engineer
- Others, as required, including Sales, Marketing, QA/QC, Packaging
Reviewing the Design

- Construct a block diagram that fully describes coupling and interfaces at all levels; interfaces include controlled inputs (e.g. design parameters) and uncontrolled inputs (noise factors)
- All design parameter inputs should be associated with a corresponding component or subsystem providing the input
- Functional requirements (FR’s, or outputs) at each block level are defined
- For each FR, the team brainstorms all potential failure modes that would prevent the design from failing to satisfy each FR
- For each failure mode, the team brainstorms causes and effects
  - Design weakness because of axiom violation (meets specs but fails to perform)
  - Manufacturing and/or assembly vulnerability or deficiency
    - Process variation
    - Usage
    - Environmental factors
    - Mistakes/errors
    - Deterioration
- Information is used as the input to the DFMEA template
Organizing Information Using the DFMEA Template

- List each design requirement of concern in each topic area
  - Tolerancing/Materials/Finishes/Test specs/Others
- Describe the potential failure modes for each feature/requirement
- Identify the impact of each potential failure mode on downstream processes, product functionality, system performance or the customer experience
- Identify likely causes in the design or process for these failure modes
- Describe the current design controls—if they exist—that are in place to contain the failure mode causes
- Assign appropriate values to Severity/Occurrence/Detectability to obtain RPN (note: scale descriptions are included in DFMEA template)
  - Severity: Scale 1-10, 1=no impact, 10=catastrophic impact/hazardous
  - Occurrence: Scale 1-10, 1=predicted <3 defects/million, 10=>500K defects/million
  - Detectability: Scale 1-10, 1=always detected by current control plan, 10=unable to detect
- Sort design requirements of concern by RPN number high-to-low to prioritize the action plan for maximum impact
DFMEA Template

FMEA Objective, scope and goal(s):

<table>
<thead>
<tr>
<th>Drawing/Spec Number</th>
<th>FMEA Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td></td>
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<tr>
<td>Subsystem</td>
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<tr>
<td>Component</td>
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<tr>
<td>Design Level</td>
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<tr>
<td>Raytheon Core Team</td>
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<tr>
<td>Supplier Core Team</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Functional Requirement / Design Parameter</th>
<th>Potential Failure Mode(s)</th>
<th>Potential Effect(s) of Failure</th>
<th>Severity</th>
<th>Risk Priority Number</th>
<th>Current Design/Process Controls</th>
<th>Recommended Action(s)</th>
<th>Owner</th>
<th>Completion Date</th>
<th>Action Taken</th>
<th>Rev 0.1</th>
<th>Rev 0.2</th>
<th>Rev 0.3</th>
<th>Rev 0.4</th>
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</tbody>
</table>

Areas to consider in the DFMEA:

- Dimensions/Functional tolerances
- Material
- Finish
- Test specifications
- Other factors

Customer Success Is Our Mission

DFMEA Template
### DFMEA Example

**FMEA Objective, scope and goal(s):** Review customer design for potential failure modes and recommend actions for risk mitigation

<table>
<thead>
<tr>
<th>Functional Requirement / Design Parameter</th>
<th>Potential Failure Mode(s)</th>
<th>Potential Effect(s) of Failure</th>
<th>Severity</th>
<th>Potential Cause(s) / Mechanism(s) of Failure</th>
<th>SWI</th>
<th>Current Design / Process Controls</th>
<th>RCT</th>
<th>SWI</th>
<th>Recommended Action(s)</th>
<th>Owners</th>
<th>Completion Date</th>
<th>Action Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected in package size - 4 g/mil to 17 mils</td>
<td>not described</td>
<td>corona, capacitance</td>
<td>E</td>
<td>thickness, tension, can dimension</td>
<td>E</td>
<td>none</td>
<td>50</td>
<td>688</td>
<td>Design Parameter COE (C)</td>
<td>GSME/EW</td>
<td>GSME/EW</td>
<td>Complete</td>
</tr>
<tr>
<td>Corrected in package size - 4 g/mil to 17 mils</td>
<td>not described</td>
<td>tear, corona, capacitance</td>
<td>E</td>
<td>thickness, tearing, speed, material</td>
<td>E</td>
<td>FAW, material tear, visual</td>
<td>5</td>
<td>180</td>
<td>Design / Process (C)</td>
<td>GSME/EW</td>
<td>GSME/EW</td>
<td>Complete</td>
</tr>
<tr>
<td>Metallurgical</td>
<td>partial voids, voids, dimensions</td>
<td>leaks, dimensional tolerances</td>
<td>E</td>
<td>temperature, time, moisture, setup</td>
<td>E</td>
<td>FAW, material tear, visual</td>
<td>5</td>
<td>309</td>
<td>Design / Process CO</td>
<td>PEFME/EW</td>
<td>PEFME/EW</td>
<td>Complete</td>
</tr>
<tr>
<td>Corona</td>
<td>corrugation breakout</td>
<td>early failure</td>
<td>E</td>
<td>vacuum, contaminated film, stress, sharp edge, foreign objects</td>
<td>E</td>
<td>FAW, material tear, visual</td>
<td>5</td>
<td>188</td>
<td>Design Parameter COE (C)</td>
<td>GSME/EW</td>
<td>GSME/EW</td>
<td>Complete</td>
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<tr>
<td>Corrected in package size - 4 g/mil to 17 mils</td>
<td>not described</td>
<td>capacitance</td>
<td>E</td>
<td>tension, bending, stress, thickness</td>
<td>E</td>
<td>FAW, capacitance test</td>
<td>5</td>
<td>184</td>
<td>Design Parameter COE (C)</td>
<td>GSME/EW</td>
<td>GSME/EW</td>
<td>Complete</td>
</tr>
<tr>
<td>Brassman welding</td>
<td>partial voids, voids, dimensions</td>
<td>leaks, dimensional tolerances</td>
<td>E</td>
<td>contamination, tensile, stress</td>
<td>E</td>
<td>SWI, visual test</td>
<td>5</td>
<td>180</td>
<td>Design Parameter (C)</td>
<td>GSME/EW</td>
<td>GSME/EW</td>
<td>Complete</td>
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<td>Corrected in package size - 4 g/mil to 17 mils</td>
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<td>wrinkling</td>
<td>E</td>
<td>tension, speed</td>
<td>E</td>
<td>FAW, Design Parameter COE (C)</td>
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<td>180</td>
<td>Design Parameter (C)</td>
<td>GSME/EW</td>
<td>GSME/EW</td>
<td>Complete</td>
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<tr>
<td>Objection notes</td>
<td>partial voids, voids, dimensions</td>
<td>leaks, dimensional tolerances</td>
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<td>contamination, tensile, stress</td>
<td>E</td>
<td>FAW, Design Parameter COE (C)</td>
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<td>Design Parameter (C)</td>
<td>GSME/EW</td>
<td>GSME/EW</td>
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<td>partial voids, voids, dimensions</td>
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<td>leaks, dimensional tolerances</td>
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<td>SWI, visual test</td>
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<td>5</td>
<td>180</td>
<td>Design Parameter COE (C)</td>
<td>GSME/EW</td>
<td>GSME/EW</td>
<td>Complete</td>
</tr>
</tbody>
</table>

**Areas to consider in the DFMEA:**

- Dimensions / Tolerancing
- Material
- Finish
- Test specifications
- Other issues

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Design Failure Cause Examples

- Improper tolerancing
- Incorrect stress calculations
- Wrong assumptions
- Wrong material callout
- Lower grade component
- Lack of design standards
- Improper heat treatment
- Improper torque callout
### DFMEA S/O/D Ratings

<table>
<thead>
<tr>
<th>Rating</th>
<th>Severity of Effect</th>
<th>Likelihood of Occurrence</th>
<th>Ability to Detect</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Hazardous and without warning</td>
<td>Very high; failure is almost inevitable</td>
<td>Cannot detect</td>
</tr>
<tr>
<td>9</td>
<td>Hazardous and with warning</td>
<td>Very high; failure is inevitable</td>
<td>Very remote chance of detection</td>
</tr>
<tr>
<td>8</td>
<td>Loss of primary function</td>
<td>High, repeated failures</td>
<td>Remote chance of detection</td>
</tr>
<tr>
<td>7</td>
<td>Reduced primary function performance</td>
<td>Moderate; occasional failures</td>
<td>Very low chance of detection</td>
</tr>
<tr>
<td>6</td>
<td>Loss of secondary function</td>
<td>Moderate; occasional failures</td>
<td>Low chance of detection</td>
</tr>
<tr>
<td>5</td>
<td>Reduced secondary function performance</td>
<td>Moderate; occasional failures</td>
<td>Moderate chance of detection</td>
</tr>
<tr>
<td>4</td>
<td>Minor defect noticed by most customers</td>
<td>Low, relatively few failures</td>
<td>Moderately high chance of detection</td>
</tr>
<tr>
<td>3</td>
<td>Minor defect noticed by some customers</td>
<td>High, repeated failures</td>
<td>Remote chance of detection</td>
</tr>
<tr>
<td>2</td>
<td>Minor defect noticed by discriminating customers</td>
<td>High, repeated failures</td>
<td>Very low chance of detection</td>
</tr>
<tr>
<td>1</td>
<td>No effect</td>
<td>Remote; failure is unlikely</td>
<td>Almost certain detection</td>
</tr>
</tbody>
</table>

**Severity** | **Occurrence** | **Detectability**
Defining the Action Plan

- If the design control in place for the design characteristic are adequate, no further action is required (typically if RPN value is <20)
- If the design controls for the characteristic are inadequate:
  - Identify differences between the current and the desired situation
  - Determine how the failure can be better contained and/or eliminated
    - Consider implementation of new or more effective design controls
    - Determine if design modification is effective at eliminating or reducing occurrence or detectability of the failure mode, and if it can be accommodated
- Document plan and reassess S/O/D and RPN values; is it enough?
- Separate between
  - Supplier actions
  - Raytheon actions
  - Joint actions
- Publish result and include in quote/feedback to Raytheon Engineering and Procurement teams
- **Manage to the plan**
Typical Design Controls

- Specifying a requirement as a “critical characteristic”
- Reliability tests/design verification tests
- Design reviews
- Worst case stress analysis
- Robust/parameter design
- Environmental stress testing
- Designed experiments
- Finite element analysis
- Variation simulation and statistical tolerance analysis
- Fault Tree Analysis
- Component de-rating
FMEA as Part of ISO9001

- Failure Mode and Effects Analysis
- Measurement System Analysis
- Advanced Product Quality Planning & Control Plan
- Statistical Process Control
- Quality System Analysis
- Production Part Approval Process
- Tooling and Equipment Supplement

ISO-9001
QS-9000

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Linkage to Raytheon

- DFMEA is a team effort
- DFMEA process promotes actionable input to the design phase
- Enables suppliers to add value and influence designs by highlighting functional concerns earlier in the design/development process
- The risk of some failure modes will be associated with:
  - Supplier process capabilities
  - Material or finish selection
  - Design requirements
  - Design features (or lack of)
  - Test and/or detection capabilities
- Mitigation action plan includes:
  - Supplier actions
  - Raytheon actions
  - Joint actions
- DFMEA result should be included as part of your quote activity with Raytheon
Resources

Textbooks:

- **Failure Mode and Effect Analysis: FMEA from Theory to Execution; Author: D.H. Stamatis**
- **The Basics of FMEA; Authors: Robin E. McDermott, Raymond J. Mikulak, Michael R. Beauregard**

On the Web:

  - [http://www.fmeainfocentre.com/examples.htm](http://www.fmeainfocentre.com/examples.htm)
End