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# Design Failure Modes and Effects Analysis

## *DFMEA with Suppliers*



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# 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

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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





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# 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

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- 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





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# DFMEA Flow

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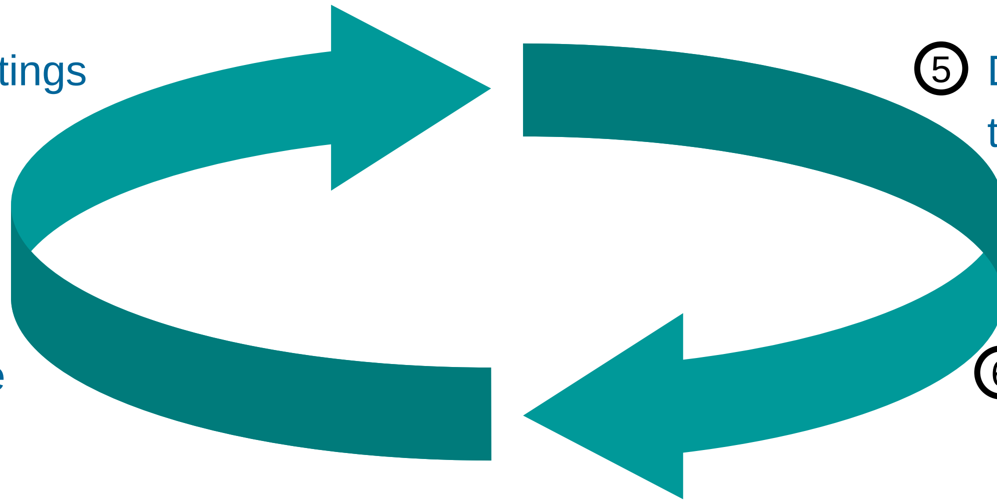



**FAILURE MODE**: How a product can fail to meet design specifications or functional intent

**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





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# Typical DFMEA Team Members

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- 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





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# Reviewing the Design

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- 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





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# Organizing Information Using the DFMEA Template

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- 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 **S**everity/**O**ccurrence/**D**etectability to obtain RPN (note: scale descriptions are included in DFMEA template)
  - **S**everity: Scale 1-10, 1=no impact, 10=catastrophic impact/hazardous
  - **O**ccurrence: Scale 1-10, 1=predicted <3 defects/million, 10=>500K defects/million
  - **D**etectability: 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





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# DFMEA Template

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FMEA Objective, scope and goal(s):

| | | | |
|---|---|---|---|
| Drawing/Spec Number: | | FMEA Type: | |
| System: | | FMEA Number: | |
| Subsystem: | | Prepared By: | |
| Component: | | FMEA Date: | |
| Design Lead: | | Revision Date: | |
| Raytheon Core Team Members: | | | |
| Supplier Core Team Members: | | | |

| | | | | | | | | | | | | Action Results | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Functional Requirement / Design Parameter | Potential Failure Mode(s) | Potential Effect(s) of Failure | SEV | Potential Cause(s)/ Mechanism(s) of Failure | OCC | Current Design/Process Controls | DET | RPN | Recommended Action(s) | Owner | Completion Date | Actions Taken | New SEV | New OCC | New DET | New RPN |
| | | | 0 | | 0 | | 0 | 0 | | | | | | | | 0 |
| | | | 0 | | 0 | | 0 | 0 | | | | | | | | 0 |
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| | | | 0 | | 0 | | 0 | 0 | | | | | | | | 0 |

| Areas to consider in the DFMEA | |
|---|---|
| Dimensions/Tolerancing | |
| Material | |
| Finish | |
| Test specifications | |
| Other Issues | |

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DFMEA Template





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# DFMEA Example

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

| | | | |
|---|---|---|---|
| Drawing/Spec Number: | XXXXXXX | FMEA Type: | Design |
| System: | Central Power Unit | FMEA Number: | DXXX1 |
| Subsystem: | Controller CCA | Prepared By: | Application Engineer |
| Component: | HV Capacitor | FMEA Date: | 9/18/2006 |
| Design Lead: | Supplier Application Engineer | Revision Date: | 12/15/2006 |
| Raytheon Core Team Members: | Design Engineer | | |
| Supplier Core Team Members: | Application Engineer, Design Engineer, Process Engineer, Test Engineer, Materials Engineer | | |

| Functional Requirement / Design Parameter | Potential Failure Mode(s) | Potential Effect(s) of Failure | SEV | Potential Cause(s)/ Mechanism(s) of Failure | OCC | Current Design/Process Controls | DET | RPN | Recommended Action(s) | Owner | Completion Date | Action Results: Actions Taken | New SEV | New OCC | New DET | New RPN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dielectric in package size - 4 um film & 17 ga Al | lack of impreg | corona, capacitance | 8 | thickness, tension, can dimension | 8 | none | 10 | 640 | Design Parameter DOE (1) Optimize stress testing methods | DE/AE/TE | | Complete | 8 | 2 | 2 | 32 |
| Dielectric in package size - 4 um film & 17 ga Al | wrinkles | hi-pot, corona, capacitance | 8 | tension, acceleration, speed, material qual | 6 | FAV, material cert, visual | 8 | 384 | Develop in-process spec Process DOE (1) | DE/PE/ME/QE/ Ops | | Complete | 8 | 1 | 2 | 16 |
| terminal brazing | pin holes, voids, dimensions | leaks, dimensional tolerances | 8 | temperature, time, fixtures, setup | 8 | He leak test | 5 | 320 | Process DOE (2) | PE/ME/QE/Ops | | Complete | 8 | 2 | 2 | 32 |
| Corona | dielectric breakdown | early failure | 10 | vaccum, contaminated fluid / film, sharp edges, foreign objects | 6 | oil check, swage fixuture, seal cold, FOE | 3 | 180 | Review/revise material cleanliness requirements | PE/ME/QE | | Complete | 10 | 1 | 2 | 20 |
| Dielectric in package size - 4 um film & 17 ga Al | variation in length | capacitance | 8 | tension, winding controls, thickness | 6 | FAV, capacitance test | 3 | 144 | Design Parameter DOE (1) | DE/AE/PE | | Complete | 8 | 1 | 2 | 16 |
| Brass can welding | pin holes, voids, dimensions | leaks, dimensional tolerances | 8 | contamination, temp, skill | 8 | bubble test, He leak test | 2 | 128 | Operator certification | PE/QE | | Complete | 8 | 1 | 2 | 16 |
| Dielectric in package size - 4 um film & 17 ga Al | stretching | hi-pot, capacitance | 8 | tension, speed | 4 | FAV | 3 | 96 | Design Parameter DOE (1) | DE/AE/PE | | Complete | 8 | 1 | 2 | 16 |
| Dissipation factor | overheat | open, short | 8 | poor swage, contaminated oil | 6 | LCR meter | 2 | 96 | Review/revise material cleanliness requirements | PE/ME/QE | | Complete | 8 | 1 | 2 | 16 |
| Dielectric in package size - 4 um film & 17 ga Al | variation in thickness | capacitance | 8 | supplier capability | 8 | Incoming measurement | 1 | 64 | Design Parameter DOE (1) | DE/AE/PE | | Complete | 8 | 1 | 1 | 8 |
| Dielectric in package size - 4 um film & 17 ga Al | over dimension | doesn't fit | 8 | thickness, tension | 8 | pre / post cure dimension | 1 | 64 | Process DOE (1) | DE/PE/ME/QE/ Ops | | Complete | 8 | 1 | 1 | 8 |
| | | | 0 | | 0 | | 0 | 0 | | | | | | | | 0 |
| | | | 0 | | 0 | | 0 | 0 | | | | | | | | 0 |
| | | | 0 | | 0 | | 0 | 0 | | | | | | | | 0 |

**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

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| AIAG Compiled Ratings | | | |
|---|---|---|---|
| Rating | Severity of effect | Likelihood of Occurrence | Ability to Detect |
| 10 | Hazardous and without warning | Very high; failure is almost inevitable | Cannot detect |
| 9 | Hazardous and with warning | | Very remote chance of detection |
| 8 | Loss of primary function | High; repeated failures | Remote chance of detection |
| 7 | Reduced primary function performance | | Very low chance of detection |
| 6 | Loss of secondary function | Moderate; occasional failures | Low chance of detection |
| 5 | Reduced secondary function performance | | Moderate chance of detection |
| 4 | Minor defect noticed by most customers | | Moderately high chance of detection |
| 3 | Minor defect noticed by some customers | Low; relatively few failures | |
| 2 | Minor defect noticed by discriminating customers | | |
| 1 | No effect | Remote: failure is unlikely | Almost certain detection |

Severity Occurrence Detectability





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# 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

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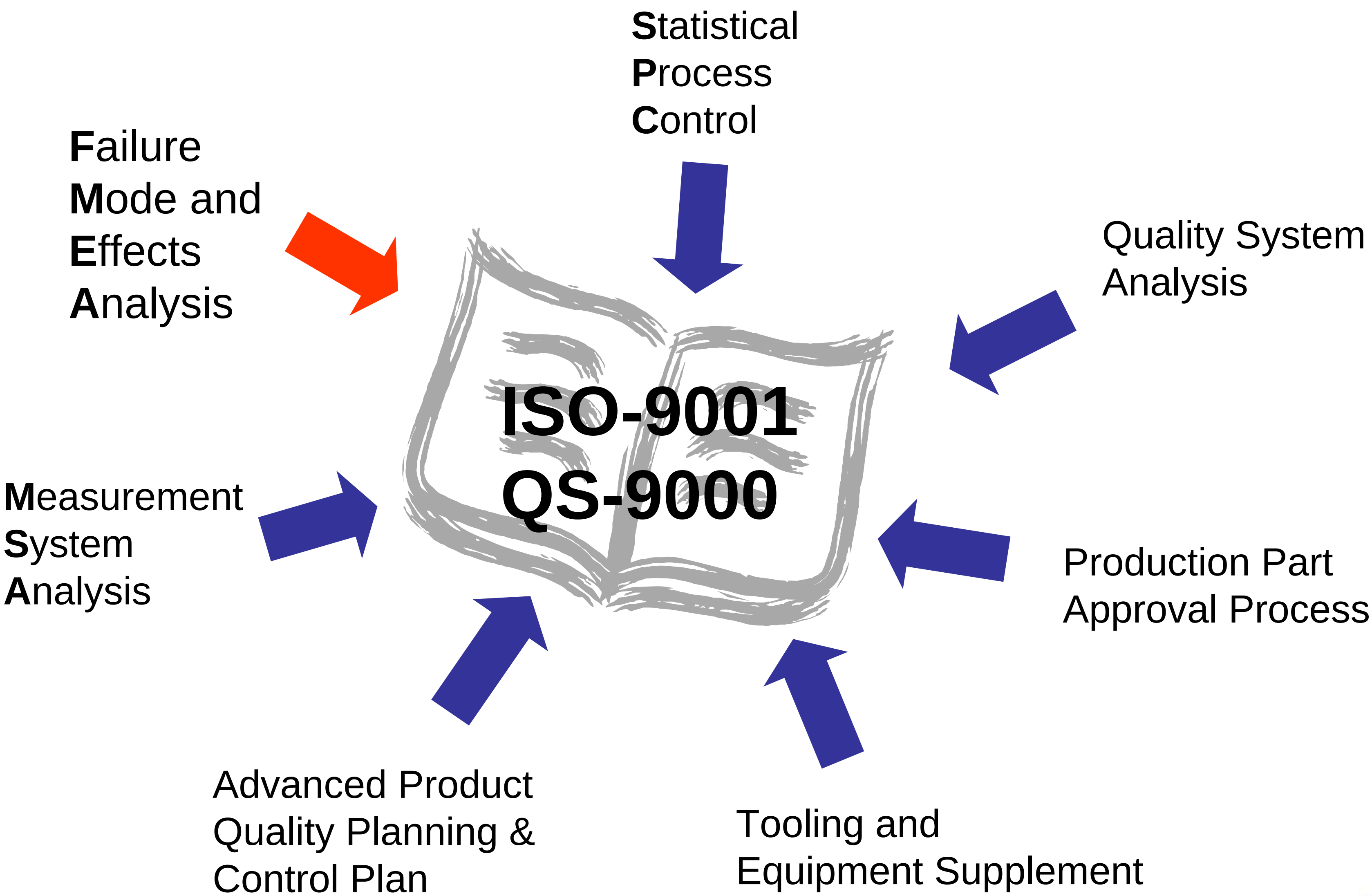






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# Linkage to Raytheon



- 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

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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/
  - http://www.fmeainfocentre.com/examples.htm
- http://www.isixsigma.com/tt/fmea/
- http://www.asq.org/learn-about-quality/process-analysis-tools/overview/fmea.html





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# End