Design Failure Modes and Effects Analysis

DFMEA with Suppliers

Design Failure Modes and Effects Analysis

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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?

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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

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- 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.

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DFMEA Benefits

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- 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

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Supplier DFMEA Benefits

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- 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

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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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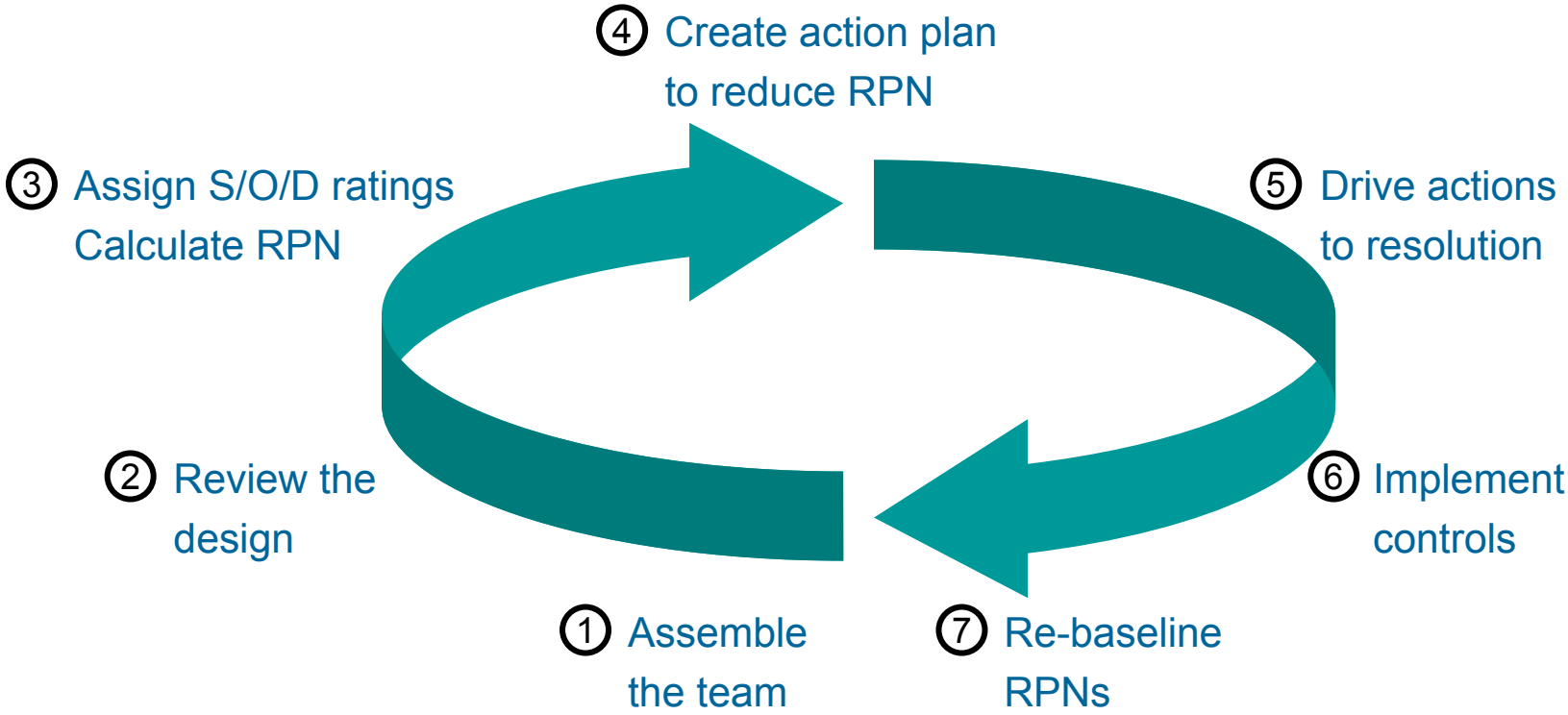

FAILURE MODE: How a product can fail to meet design specifications or functional intent

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:			

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
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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
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Areas to consider in the DFMEA

- Dimensions/Toleranicing
- Material
- Finish
- Test specifications
- Other Issues

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Design Failure Cause Examples

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- Improper tolerancing
- Incorrect stress calculations
- Wrong assumptions
- Wrong material callout
- Lower grade component
- Lack of design standards
- Improper heat treatment
- Improper torque callout

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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

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- 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**

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Typical Design Controls

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- 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

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FMEA as Part of ISO9001

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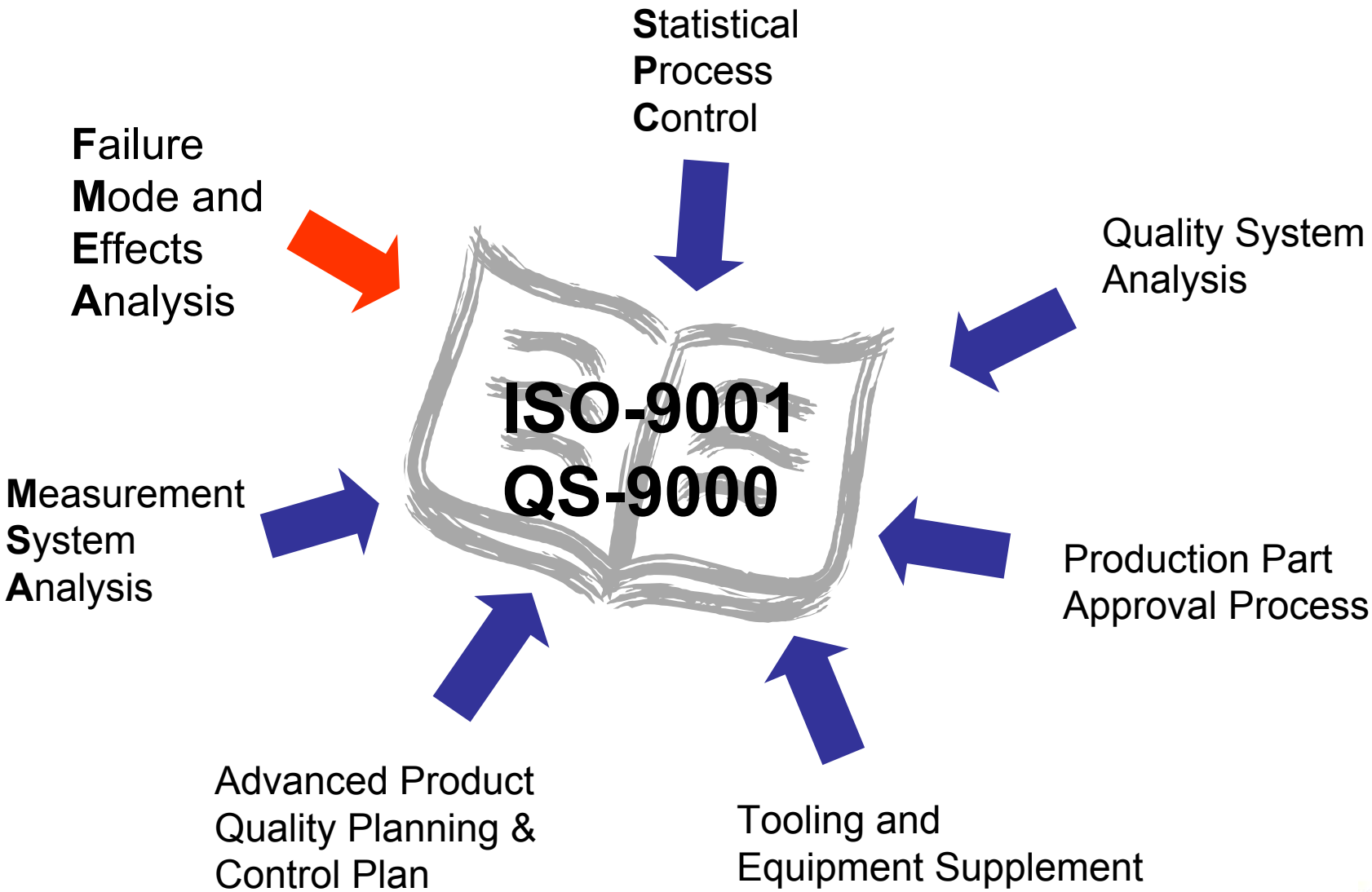

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Linkage to Raytheon

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- 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

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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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