Process Failure Modes and Effects Analysis

PFMEA for Suppliers

Process Failure Modes and Effects Analysis

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

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

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Overview of the PFMEA Process

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- People knowledgeable about the process analyze situations where critical customer requirements might not be met
- A ranking system is used to estimate three factors:
  - how **S**evere the failure would be
  - how frequently the failure would **O**ccur,
  - how difficult it would be to **D**etect, and
- The S/O/D factors are multiplied; 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, severity and/or improve the detectability of the failure mode
- PFMEA output is the starting point for the
  - Process redesign/leaning
  - Control Plan
  - Out-of-Control Action Plan (OCAP)

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PFMEA Benefits

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- Disciplined approach for identifying the ways a process design can fail before impacting the customer or the product function
  - Identifies potential manufacturing and/or assembly process failures
  - Identifies the significant process variables to control to reduce occurrence and improve detection of failure conditions
- Rational prioritization of potential failures for corrective/preventive action and/or redesign
- Helps to identify critical process parameters
- Provides critical input for the process control plan
- Opportunity to collaborate with and influence Raytheon designers to eliminate problems before they occur in your production line
- Smoother production ramps
- Reduced development, production and warranty cost
- Higher customer satisfaction

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PFMEA Prerequisites

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- Select proper team and organize members effectively
- Select teams for each process
- Create/agree on a ranking system
- Agree on format for the PFMEA matrix
- Define the customer and customer needs/expectations
- Define the process requirements
- Map the baseline process with a flow chart

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PFMEA Flow

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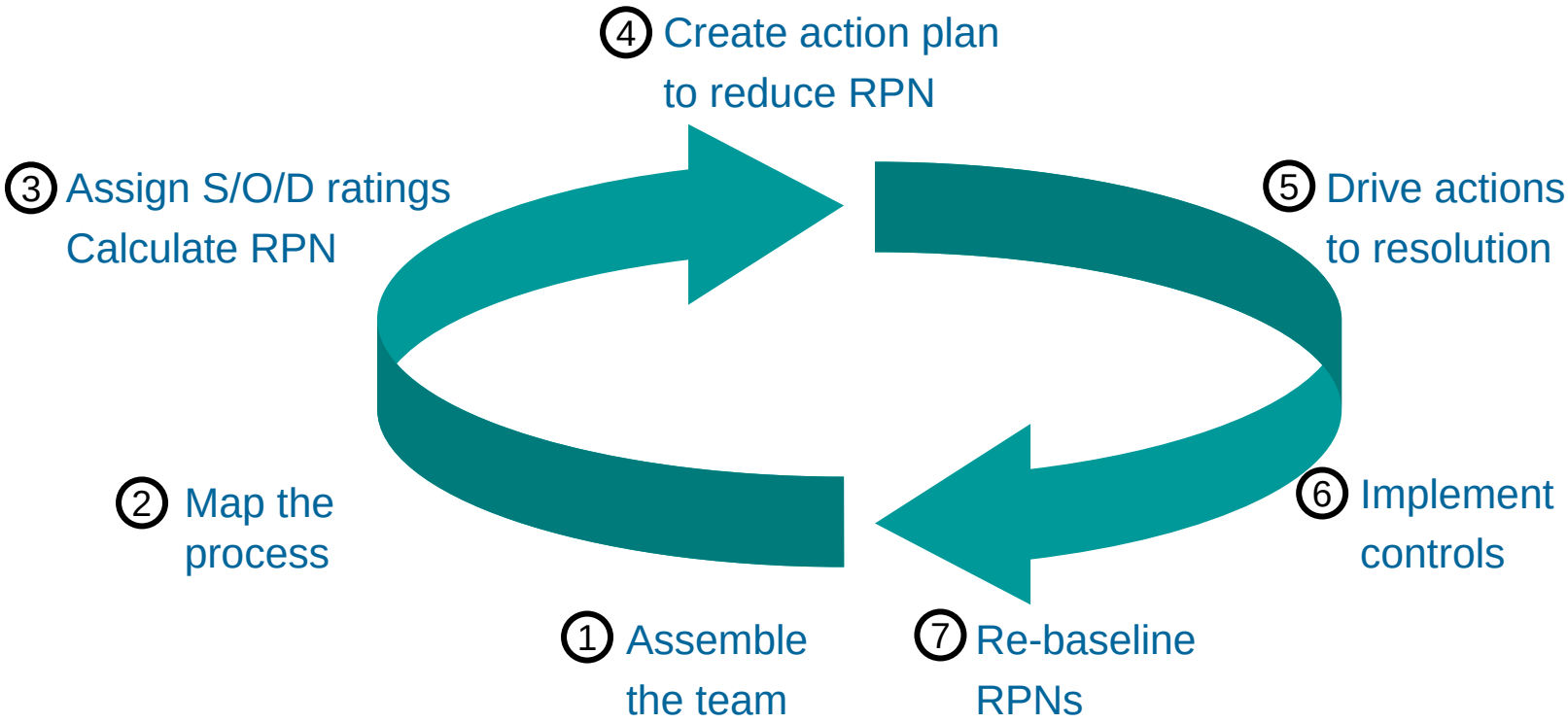

FAILURE MODE: How a product can fail to meet design specifications or functional intent

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 PFMEA Team Members

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- Process Engineer - Generally the Team Leader
- Production Operators
- Industrial Engineer
- Design Engineer
- Quality Engineer
- Reliability Engineer
- Tooling Engineer
- Maintenance Engineer
- Project Manager
- Others including Sales, QA/QC, Operations

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Creating the Process Map

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- Identify the process to map
- Ask the people most familiar with the process to help construct the map
- Agree on the start and end points; defining the scope of the process to be mapped is important, otherwise the task can become unwieldy
- Agree on the level of detail to use; it's better to start out with less detail, increasing detail only as needed to accomplish your purpose
- Identify the sequence and the steps taken to carry out the process; walk the line if necessary
- Construct the process map either from left to right or from top to bottom, using standard flow chart symbols and connecting the steps with arrows
- Identify key process characteristics as potential sources of failure
  - Is the process standardized, or are the people doing the work in different ways?
  - Are steps repeated or out of sequence?
  - Are there steps where errors occur frequently?
  - Are there rework loops?
- Analyze the results and document potential failure modes at each process step

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Process Map Example

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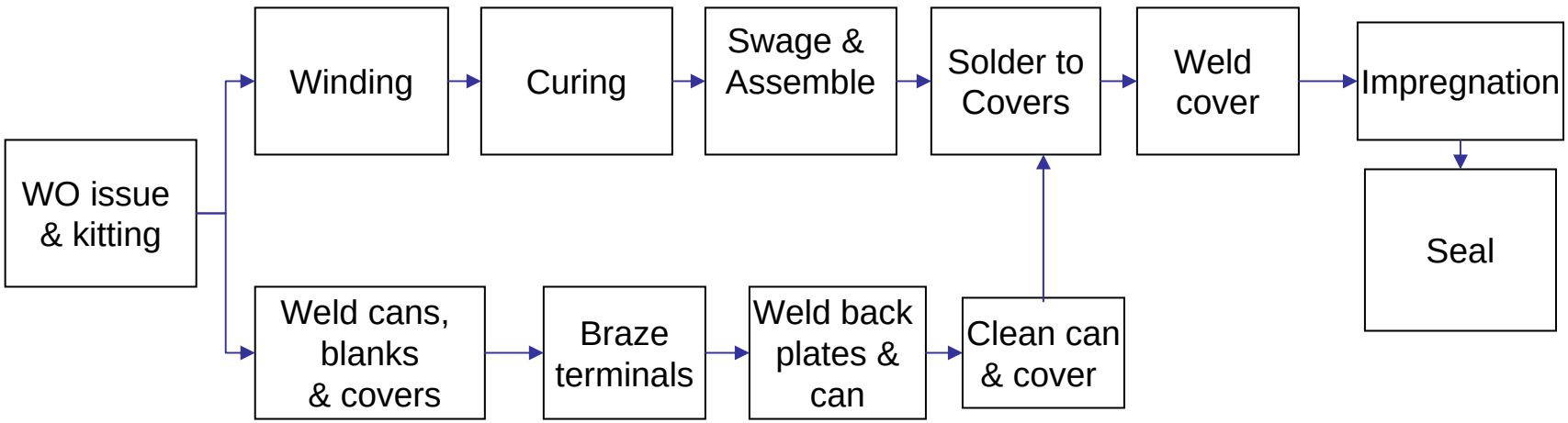
HV Capacitor: High Level Process Map



Note: Test points are at winding, curing, assembly, weld, impregnation and seal

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Organizing Information Using the PFMEA Template

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- List each process step from the process map
- Describe the potential failure modes for each process step
- Identify the impact of each potential failure mode on downstream processes, product functionality or the customer experience
- Identify likely causes in the process for these failure modes
- Describe the current process controls—if they exist—that are in place to contain the causes
- Assign appropriate values to Severity/Occurrence/Detectability to obtain RPN (note: scale descriptions are included in PFMEA 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 process steps by RPN number high-to-low to prioritize the action plan for maximum impact

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PFMEA Template

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PFMEA Objective, scope and goal(s):

Process ID		PFMEA Type:	
		PFMEA Number:	
		Prepared By:	
		PFMEA Date:	
Process Lead		Revision Date:	
Core Team Members:			

Process Step	Potential Failure Mode(s)	Potential Effect(s) of Failure	SEV	Potential Cause(s)/ Mechanism(s) of Failure	OCC	Current 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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PFMEA Template

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PFMEA Example

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PFMEA Objective, scope and goal(s): Review capacitor assy/test process for potential failure modes and control/risk mitigation strategy

Process ID	Fictional Capacitor Assembly/Test	**PFMEA Type:**	
		PFMEA Number:	XXXX1
		Prepared By:	Anybody
		PFMEA Date:	9/18/2006
Process Lead	Process Engineering Manager	**Revision Date:**	A
Core Team Members:	Swage line operator, Welding line operator, Impregration line operator, Line Supervisor, Process Engineering, Design Engineering, Quality Engineering, Process Engineering Manager		

Process Step	Potential Failure Mode(s)	Potential Effect(s) of Failure	SEV	Potential Cause(s)/ Mechanism(s) of Failure	OCC	Current Process Controls	DET	RPN	Recommended Action(s)	Owner	Completion Date	Action Results: Actions Taken	New SEV	New OCC	New DET	New RPN
Terminal brazing (cover and cap_)	leaks, dimensions	scrap	9	time and temperature	10	Helium leak test, ATP seat test, thermal shock	3.5	315	DOE to optimize parameter settings for robustness	PE/QE		Complete	9	1	2	18
Assembly	low capacitance	scrap	9	operator error, material	4	can size	5	180	Review operator certification requirements, mat'l requirements	PE/QE/Line Spv		Complete	9	2	1	18
Swaging	hi-pot, corona, DF, IR	scrap	9	overheated dielectric, operator skill, workmanship, tooling, swage dimensions	9	visual inspection, tooling, operator quallification, electrical test	2	162	Process capability analysis Review operator certification requirements	PE/QE/Line Spv		Complete	9	1.5	1	14
Welding	leaks, dimensions, hi-pot, corona	scrap	8	fixtures, operator skill, chassis/cover dimension not specified, material type, contamination	8.5	Helium leak test, bubble test, fixtures, QC dimension	2	136	Process capability analysis Review operator certification requirements 6S station review	PE/QE/Line Spv IE		Complete	8	1	2	16
Impregnation	corona	rework	5	machine (time, temp, oil quality), operator	8	gas test, oil quality, water test, PM, low temp seal, electrical test	2	80	Process capability analysis Review operator certification requirements	PE/QE/Line Spv		Complete	5	2	1	10
Impregnation	DF, low capacitance	scrap	9	machine (time, temp, oil quality), operator	3	gas test, oil quality, water test, PM, low temp seal, electrical test	2	54	Process capability analysis Review operator certification requirements	PE/QE/Line Spv		Complete	9	1	2	18
Welding	leaks, dimensions, hi-pot failure, corona	rework	3	fixtures, operator skill, chassis/cover dimension not specified, material type, contamination	8.5	Helium leak test, bubble test, fixtures, QC dimension	2	51	Process capability analysis Review operator certification requirements	PE/QE/Line Spv		Complete	3	3	2	18
Curing	dimensions, soft, cap variation, DF	scrap or rework	3	variable compression time, variable pressure, temp, humidity, time	8	cap measurement, feel, dimension, pressure/load cell, humidity/temp/time	2	48	Process capability analysis	PE/QE		Complete	3	3	2	18
Winding	capacitance, dimension	scrap	2	operator error, winding machine, material (thickness, elongation, damaged, curls)	8	FAV, measure capacitance, dimemsions, hi-pot, PM, incoming and at-station inspection, set-up adjustment	2	32	Process capability analysis	PE/QE		Complete	2	3	2	12
Testing Pads	damage to part	scrap	2	operator error, fixturing, toolling error	3	visual inspection	2	12	None	---		None	2	3	2	12
Testing	false failure	retest	2	operator error, test fixture error	3	software error flag, verification procedure, cal logs	2	12	None	---		None	2	3	2	12
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Potential Process Failure Causes

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- Omitted processing
- Processing errors
- Errors setting up work pieces
- Missing parts
- Wrong parts
- Processing wrong work piece
- Mis-operation
- Adjustment error
- Equipment not set up properly
- Tools and/or fixtures improperly prepared
- Poor control procedures
- Improper equipment maintenance
- Bad recipe
- Fatigue
- Lack of Safety
- Hardware failure
- Failure to enforce controls
- Environment
- Stress connections
- Poor FMEA(s)

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PFMEA 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 control plan for the process step is adequate, no further action required (typically if RPN value is <20)
- If the control plan for the process step is 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 process controls
    - Assess if process steps that don't add value to the output can be eliminated
    - 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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Potential Process Controls

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- Standardized work instructions/procedures
- Fixtures and jigs
- Mistake-proofing tooling and/or product design
- Mechanical interference interfaces
- Mechanical counters
- Mechanical sensors
- Electrical/Electronic sensors
- Job sheets or Process packages
- Bar coding with software integration and control
- Marking
- Training and related educational safeguards
- Visual checks
- Post process inspection/testing
- Gage/MSA studies
- Statistical Process Control
- Design of experiments on the process/Robust process design
- Preventive maintenance
- Automation & Real Time Control

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PFMEA as Part of ISO9001

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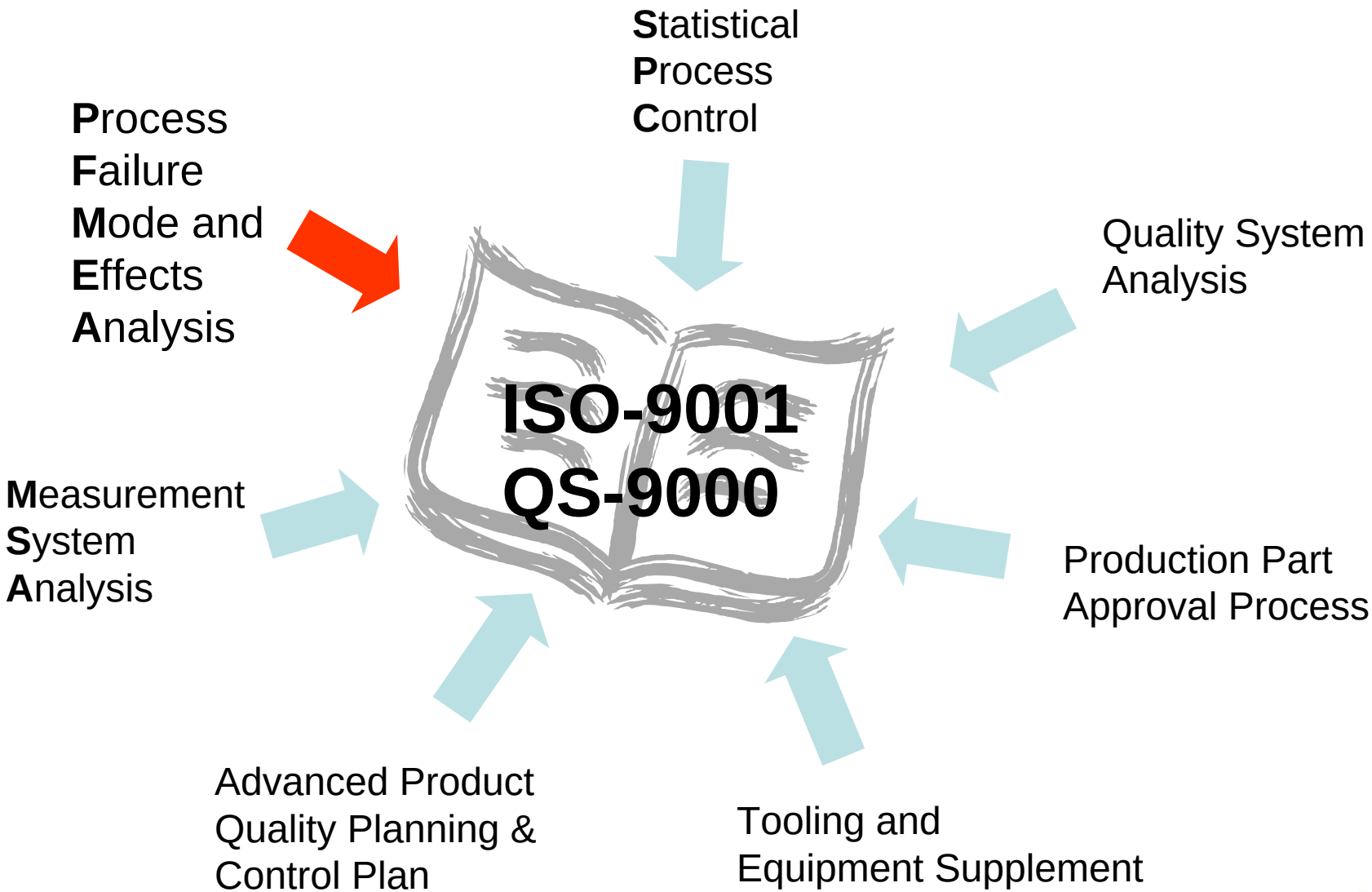

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Linkage to Raytheon

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- PFMEA is a team effort
- Promotes actionable input to the design phase
  - Designs can and do impact ability to execute processes, and vice versa
- 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
  - Non value-added steps
  - Material or finish selection
  - Design requirements
  - Material flows
  - Rework flows
  - Test and/or detection strategies and capabilities
- Mitigation action plans could include:
  - Supplier actions
  - Joint Raytheon/supplier actions

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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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