AESQ

DESIGN FAILURE MODE & EFFECTS ANALYSIS

ZERO DEFECTS TOOLKIT

Key Care Points when Creating

DESIGN FMEAs WEBINAR

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Chief of Mechanical Systems
Rolls-Royce Civil Aerospace

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MTU

June 23rd 2022

AESQ STRATEGY GROUP
A Program of SAE ITC

Webinar Overview

We are **recording** today's webinar and will distribute the video link following the close of the webinar. It will also be posted on the AESQ website for free viewing.

We will take **questions** during today's webinar using the **Chat** feature.

Please remain on Mute during the presentation to prevent background noise. We will also be muting all lines at the start of the session.

RM13004 DESIGN FMEA Webinars

June 22nd & 23rd 2022

AS13100 & RM13004 DESIGN FMEA - Understanding the Requirements

Led by Rob Farndon, these interactive webinars are designed to describe the intent of the AESQ AS13100 requirements for Design FMEAs and how they link to the effective deployment of Advanced Product Quality Planning (APQP) and a Zero Defect Strategy.

These webinars shall explain how AS13100 Design FMEA can be developed, maintained and improved using real examples of best practice from across the industry.

SESSION 1 AS13100 DFMEA Requirements and Overview (June 22nd 14.00 – 16.00 UK Time)	**SESSION 2** Key Care Points when Creating the Design FMEA (June 23rd 14.00 – 16.00 UK Time)
Overview of the requirements for Design FMEA in Chapter C of AS13100 and their link to the APQP / PPAP process	A closer look at some of the key steps when creating Design FMEAs to illustrate the intent of the AS13100 requirements, including; a) Requirements & Potential Failure Modes b) Potential Effects & Severity Rating c) Potential Causes d) Prevention Controls & Occurrence Rating e) Detection Controls & Detection Rating f) Calculating the Risk Priority Number (RPN) g) Prioritizing Improvements
Explanation of the intent of each requirement and what success looks like	
Overview of the Design FMEA approach aligned to the RM13004 Reference Manual	
Links to further help and guidance	
Questions & Answers	**Questions & Answers**

Rob Farndon Introduction

- Worked for Rolls-Royce for 33 years.
- Career including Design Practitioner, Manager and Specialist roles in Civil Aerospace.
- Currently Chief of Mechanical Systems Capability .
- Design Process Specialist, and Subject Matter Expert for APQP/PPAP and Defect Prevention toolset including DFMEA.
- Led creation of design processes as part of RR Civil Aerospace APQP/PPAP transformation.
- Lead Design Coach for Civil Large Engines.
- Led authoring team for RM13004 and AS13100 DFMEA content.
- Deputy Team Leader for RM13004 Subject Matter Interest Group.

Andrea Neumann Introduction

- Worked for MTU Aero Engines AG for 2 years
- Career including Type Inspector for Propulsion Systems at German Military Airworthiness Authority
- Currently Safety- and Certification Engineer at Airworthiness Department MTU
- System Safety Assessment Specialist
- Subject Matter Expert for DFMEA
- Led process definition of interfaces between DFMEA and System Safety Process
- Supported definition of Design Failure Mode and Effect Analysis Process at MTU

How to contribute

Use the **Chat Function** to ask a question, at any time, or to make a comment.

Steven W. Finup
Consulting Engineer
GE Aviation

Stéphan DAUX
APQP Leader & Master
Safran Aircraft Engines

Registration Status (June 20th)

Over 180 people registered from 19 Countries

Overview

1

Items, Functions & Requirements

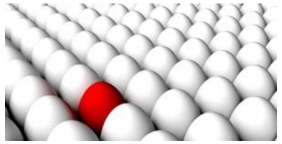
2

Potential Failure Modes, Potential Effects & Severity Rating

3

Potential Causes, Prevention Controls & Occurrence Rating

4



Detection Controls & Detection Rating

5

Calculating the Risk Priority Number (RPN)

6

Improvement Actions

The Design FMEA Template

Section 1			Section 2			Section 3			Section 4		Section 5	Section 6
Item	Function	Requirement	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Potential Causes of Failure	Prevention Controls	OCC	Detection Controls	DET	RPN	Improvement Actions

What is the item that you are focusing on (Item)?

What function does the item have? (Function)

What are you trying to achieve (Product Requirements)?

Defined by Engineering Drawings & Specifications Or Assembly Instructions

DFMEA must include ALL Functions

How could you get the Requirements wrong (Failure Modes)?

What could happen if it did go wrong (Potential Effects)?

How bad would it be if it did go wrong (Severity Score)?

What would need to fail in the design to cause the Failure Mode to occur (Potential Causes)?

How could this be prevented (Prevention Controls)?

How likely is it to go wrong (Occurrence Score)?

How will you check if the Cause and/or Failure Mode occur (Detection Controls)?

How likely are you to detect the Cause or Failure Mode if it was defective (Detection Score)?

Risk Priority Number (RPN)

List of Improvement Actions required to mitigate the key Risks Identified

Function and Requirement Focus | **Design Process Focus** | **Risk Mitigation**

Design FMEA Information Flow

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Item	Function	Requirement	Failure Mode	Potential Effect	Severity	Potential Cause	Prevention Control	Occurrence	Detection Controls	Detection	RPN
Fuel Air Bracket	Prevent excessive lateral motion of fuel tube #XYZ	Fuel Tube lateral motion constrained to < x mm	Fuel Tube lateral motion > x mm	fire, explosion safety hazard (10)	10	Tube locating hole allowable diameter defined as too large	Analysis – tube high cycle fatigue and wear (conducted at nominal dimensions only) (6)	6			480
						Bracket thermal growth defined as > tube thermal growth	Analysis – Components thermal growth (4)	4			320
									Test – Engine XYX Durability testing with post-test hardware inspections (8)	6	

Design FMEA Information Flow

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						Bracket thermal growth defined as > tube thermal growth	Analysis – Components thermal growth (4)	4	Test – Engine XYX Durability testing with post-test hardware inspections (8)	6	320

The description in each column must flow directly from the description in the relevant cell

If the Requirements column is incorrect then everything to the right will be incorrect.

Precision of language is vital

Design FMEA Precision of Language

Potential Cause of Failure Mode
Tube locating hole allowable diameter is larger than > x mm (with respect to …)

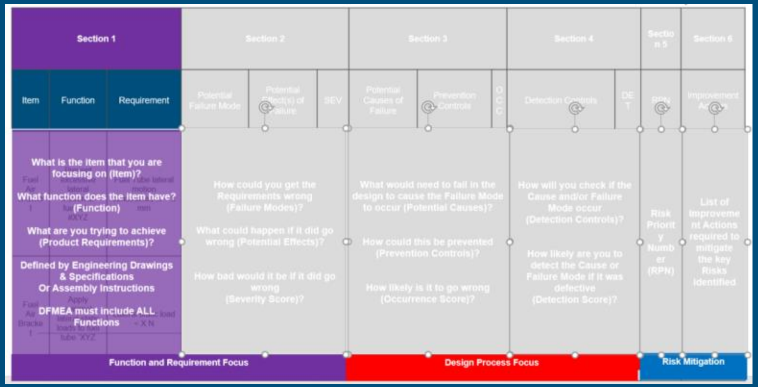
The Design FMEA may be in use for 30 years or more.

It is important that the language used and the level of description will be clear to those reading it in the future and who were not involved in its creation.

For the purposes of this presentation we have not completed each cell to the level of detail that we would expect to see in the real DFMEA.

1
ITEM, FUNCTION & REQUIREMENTS

DEFINING THE SCOPE OF THE DFMEA



Identifying Items

- **ITEM = name or pertinent information (part number, sub system etc.) of the item being analysed**

- **Not every Item will need to be considered**

➔Only those whose credible failure influence the system function

- **Simple parts within BoM may be considered at an aggregated level**

Identifying the Functions

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Item	Function	Requirement	Failure Mode	Potential Effect	Severity
Fuel Air Bracket	Apply minimal lateral static loads to fuel tube #XYZ				
	Prevent excessive lateral motion of fuel tube #XYZ				

1. Function is a description if the design intent of the item
2. Function(s) of each item being analyzed should be written
3. An Item may have more than one function
4. There could exist primary and secondary functions.

QUICK POLL 1

Use the **Chat Function** to ask a question, at any time, or to make a comment.

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GE Aviation

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APQP Leader & Master
Safran Aircraft Engines

The function definition is one important point of DFMEA

Therefor which function should not be included in the DFMEA? (use poll to select those that apply)

1. Carry aerodynamic load
2. Apply minimal lateral static loads
3. Lateral motion constrained to < x mm
4. Loading
5. Prevent excessive lateral motion of fuel tube #XYZ
6. Withstand environmental condition

Quick Poll Answers

Function Proposal	Yes	No
Carry aerodynamic load	X	
Apply minimal lateral static loads	X	
Lateral motion constrained to < x mm		X
Loading		X
Prevent excessive lateral motion of fuel tube #XYZ	X	
Withstand environmental condition	X	

Good function description

Function
Carry aerodynamic load, which is produced during compression of previous stages. Pressure increase will be increased in downstream stages.

- Functions should be precise
- Minimal functions require: "Verb" + "Noun"
- The function should clearly identify the function of the item

➔ **As much information as necessary**

- But it has to be different to the requirement

➔ **Function should be as short as possible**

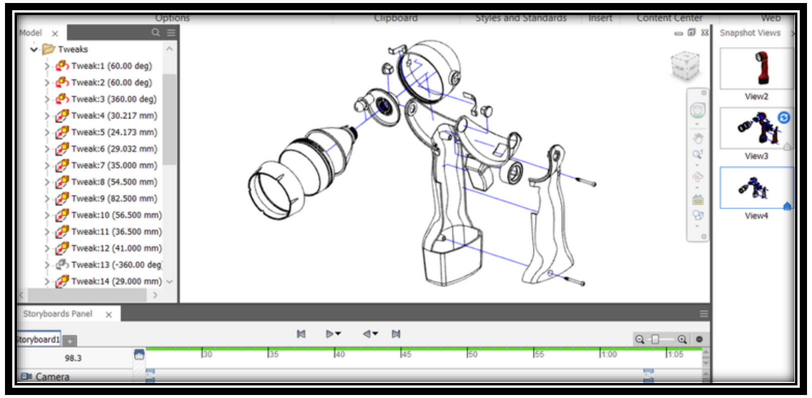
Design FMEA Functions: Other Examples

Primary functions	Secondary functions
Transfer Fuel	
Transform electrical into mechanical energy	Withstand environmental conditions
Provide air	Provide axial clearance
Compress air	

Defining Requirements

Certification requirements

Requirements from customer



Requirements from lessons learned, previous DFMEAs, previous projects

Identifying the Requirements

Item	Function	Requirement	Failure Mode	Potential Effect	Severity
Fuel Air Bracket	Apply minimal lateral static loads to fuel tube #XYZ	Fuel Tube lateral motion constrained to < x mm			
	Prevent excessive lateral motion of fuel tube #XYZ	Lateral static load < X N			

1. Requirement is the quantified measure of an Item function
2. An Item could have multiple requirements

Poor requirements definition

Function : Transfer Fuel

Requirement
1 liter per second @ 50 bar pressure

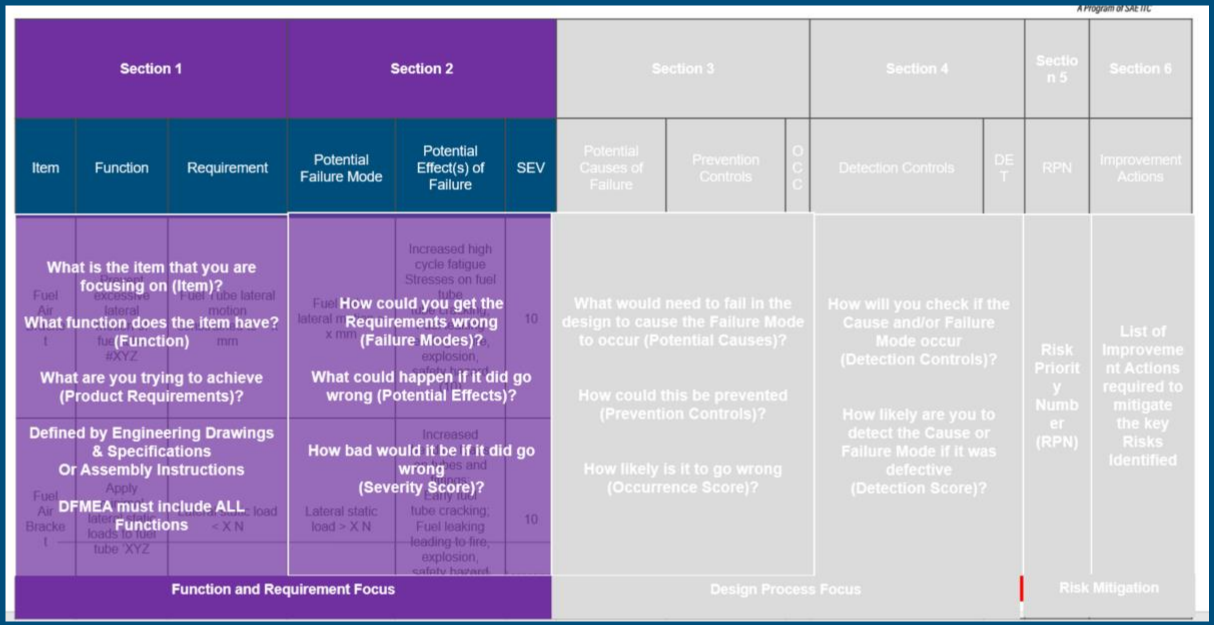
1. Should include functional attributes and non-functional performance attributes
2. Non-functional performance attributes should include the environment in which the item operates
3. Should be **unique, measurable and unambiguous**

Line of sight to requirements

- <u>All relevant requirements</u> for the function should be named

- Requirements which <u>may not</u> be relevant, should be excluded as long there is no necessity

2
POTENTIAL FAILURE MODES, EFFECTS & SEVERITY RATING



Identifying Failure Modes

- The way in which a component, subsystem or system could potentially fail to deliver the intended function

- Each function have several failure modes

- A large number of failure modes may indicate that the requirement is not well defined

- If Failure modes only occur during certain conditions, this should be highlighted.

- *Failure modes which potentially occur together (e.g. multi-point failures) should not be treated by DFMEA*

Identifying Failure Modes

<u>Five different categories</u> of potential failure modes:

- Loss of function (i.e. inoperable etc.)
- Under/over function (i.e. performance loss etc.)
- Intermittent function (i.e. operation starts/stops/starts often as a result of moisture, temperature, etc.)
- Degradation (i.e. performance loss over time, etc.)
- Unintended function (i.e. operation at the wrong time, unintended direction, etc.)

Identifying Failure Modes – Example

Item	Function	Requirements	Potential Failure Mode
Fuel Pipe	Transfer Fuel	1 litre per second @ 50 bar pressure	Too much fuel transferred
			Too little fuel transferred
			No fuel transferred

Identifying Failure Modes

Item	Function	Requirement	Failure Mode	Potential Effect	Severity
Fuel Air Bracket	Apply minimal lateral static loads to fuel tube #XYZ	Lateral static load < X N	Lateral static load > X N		
	Prevent excessive lateral motion of fuel tube #XYZ	Fuel Tube lateral motion constrained to < x mm	Fuel Tube lateral motion > x mm		
			Loss of bracket function	?	

Failure Modes are always connected to functions and requirements

SUMMARY: Failure Modes

1. To ensure that the right Failure Modes are captured the REQUIREMENTS description must be precise.
2. Failure Modes must be connected to Functions.
3. Do not specify different increments of Failure. This will be considered when discussing EFFECTS later.
4. Do not add Failure Modes where there is no Requirement or Function.
5. FAILURE MODES are finite. Once established they can be captured in a Failure Mode Library and reused.

   Keep updated if new knowledge comes to light.

Potential Effect(s) of Failure

- **Effects are consequences or results of each failure mode**

- **Effect(s) should be listed in the DFMEA for each failure mode in the Potential Effects column**

- **Should be considered against the local, next higher system level and the final product**

- **State clearly if the effect of a failure mode could impact safety or non-compliance to regulations**

- **Multiple Effects, the DFMEA should include all reasonable Effect propagations (captured within a single cell)**

Potential Effects of the Failure Mode

Item	Function	Requirement	Failure Mode	Potential Effect	Severity
Fuel Air Bracket	Apply minimal lateral static loads to fuel tube #XYZ	Lateral static load < X N	Lateral static load > X N	Increased bending loads on tubes and fittings; Early fuel tube cracking; Fuel leaking leading to fire, explosion, safety hazard (10)	
	Prevent excessive lateral motion of fuel tube #XYZ	Fuel Tube lateral motion constrained to < x mm	Fuel Tube lateral motion > x mm	Increased high cycle fatigue Stresses on fuel tube tube cracking; Fuel leaking leading to fire, explosion, safety hazard (10)	

Potential Effect(s) of Failure

Pessimist

Optimist

Both sides should be investigated. DFMEA should show the **REALISTIC** effect.

SEVERITY RANKING

Ranking	Severity Category (Product)	Criteria: Severity of Effect Effect on Product – DFMEA
10	Safety and/or Regulatory Compliance	Potentially hazardous failure without warning. Failure potentially affects safe operation of the product or causes regulatory non-compliance.
9		Potentially hazardous failure with warning. Failure potentially affects safe operation of the product, causes regulatory non-compliance or results in a significant reduction in safety margins.
8	Primary Function	Product is not operational; safety not compromised. Failure causes major customer dissatisfaction and severe disruptions.
7		Operability severely affected; primary functions/systems may be degraded. Failure causes high degree of customer dissatisfaction or severe disruptions.
6	Secondary Function	Operability significantly degraded; secondary systems may be inoperable. Failure causes significant customer dissatisfaction or significant disruptions.
5		Moderate effect on operability; secondary systems may be degraded. Product secondary systems do not conform to operational requirements. Failure causes customer dissatisfaction, often resulting in operational disruption.
4	Annoyance	Moderate effect on operability. Non-compliance to functional requirement, although all systems operational. Failure causes some customer dissatisfaction noticed by most customers, often requiring in-service repair.
3		Minor effect on operability. Non-compliance to functional requirement. Failure causes minor customer dissatisfaction noticed by many customers, often requiring action at next overhaul.
2	Awareness	Slight effect on operability. Non-compliance to functional requirement. Failure causes slight customer annoyance noticed by few customers, potentially resulting in additional overhaul cost.
1	No Effect	No discernible effect on product operation.

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Severity is a ranking number associated with the most serious product level effect for a given failure mode for the function being evaluated.

It is determined **without** regard for occurrence or detection

Potential Effects of the Failure Mode (SEV)

Item	Function	Requirement	Failure Mode	Potential Effect	Severity
Fuel Air Bracket	Apply minimal lateral static loads to fuel tube #XYZ	Lateral static load < X N	Lateral static load > X N	Increased bending loads on tubes and fittings; Early fuel tube cracking; Fuel leaking leading to fire, explosion, safety hazard (10)	10
	Prevent excessive lateral motion of fuel tube #XYZ	Fuel Tube lateral motion constrained to < x mm	Fuel Tube lateral motion > x mm	Increased high cycle fatigue Stresses on fuel tube tube cracking; Fuel leaking leading to fire, explosion, safety hazard (10)	10

EFFECTS & SEVERITY SCORE SUMMARY

Ranking	Severity Category (Product)	Criteria: Severity of Effect Effect on Product – DFMEA
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2	Awareness	Slight effect on operability. Non-compliance to functional requirement. Failure causes slight customer annoyance noticed by few customers, potentially resulting in additional overhaul cost.
1	No Effect	No discernible effect on product operation.

1. There could be multiple Effects per Failure Mode
2. The Potential Effects should include the Impact on the Customer including the End User and Subsequent Operations
3. The Effects description must be clear and concise – It will be read by other teams and will need to make sense to them
4. Effects should be described in terms that will help to determine the Severity Score
5. If the **SEVERITY SCORE is 1** then there is not need to do any further analysis for that Failure Mode


QUESTIONS?
CONCERNS?
COMMENTS?

3
POTENTIAL CAUSES, PREVENTION CONTROLS & OCCURRENCE RATING

Identify Potential Causes

Item	Requirement	Failure Mode	Potential Effect	Severity	Potential Cause(s) of Failure Mode
Fuel Air Bracket	Fuel Tube lateral motion constrained to < x mm	Fuel Tube lateral motion > x mm	Increased high cycle fatigue Stresses on fuel tube tube cracking; Fuel leaking leading to fire, explosion, safety hazard (10)	10	Tube locating hole allowable diameter defined as too large
	Fuel Tube lateral motion constrained to < x mm	Fuel Tube lateral motion > x mm	Increased high cycle fatigue Stresses on fuel tube tube cracking; Fuel leaking leading to fire, explosion, safety hazard (10)	10	Bracket thermal growth defined as > tube thermal growth
	Lateral static load < X N	Lateral static load > X N	Increased bending loads on tubes and fittings; Early fuel tube cracking; Fuel leaking leading to fire, explosion, safety hazard (10)	10	Tube locating hole positional variation callout error

Identify Potential Causes

- Cause = an error in the design that leads to the failure mode
- Identify every potential Cause for each failure mode
- One failure mode could have several potential causes
- Causes should be listed as concisely and completely as possible

QUICK POLL 2

Which of the Following are not Potential Causes in an RM13004 DFMEA?

CHAT NOW

Use the **Chat Function** to ask a question, at any time, or to make a comment.

Steven W. Finup
Consulting Engineer
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APQP Leader & Master
Safran Aircraft Engines

1. Hot gas ingress
2. Diameter too small
3. Crack initiation
4. Tolerance too wide
5. Radii too big
6. Surface roughness too rough defined
7. Overloaded area
8. Length too short
9. Length not adequate
10. Flange opening

QUICK POLL 2

Which of the Following are not Potential Causes in an RM13004 DFMEA?

Potential Causes	Mechanisms
Diameter too small	Hot gas ingress
Tolerance too wide	Crack initiation
Radii too big	Overloaded area
Length too short	Flange opening
Surface roughness too rough defined	

Please be aware of the difference between Cause and Effect.

Effect = Consequences and results

Causes = Error in the design

Prevention Controls

Item	Requirement	Failure Mode	Severity	Potential Cause(s) of Failure Mode	Prevention Controls	OCC
Fuel Air Bracket	Fuel Tube lateral motion constrained to < x mm	Fuel Tube lateral motion > x mm	10	Tube locating hole allowable diameter defined as too large	Bracket design Standard work document XYZ (2) Analysis – tube high cycle fatigue and wear (conducted at nominal dimensions only) (6)	
	Fuel Tube lateral motion constrained to < x mm	Fuel Tube lateral motion > x mm	10	Bracket thermal growth defined as > tube thermal growth	Materials thermal expansion property database (Brackets and tube are standard materials) Bracket design standard work document XYZ(2) Analysis – Components thermal growth	
	Lateral static load < X N	Lateral static load > X N	10	Tube locating hole positional variation callout error	Fuel tube system tolerance stack up analysis (2) Bracket design Standard work document XYZ (2)	

Prevention Controls

Prevention Controls	OCC
Bracket design Standard work document XYZ (2) Analysis – tube high cycle fatigue and wear (conducted at nominal dimensions only) (6)	
Materials thermal expansion property database (Brackets and tube are standard materials) Bracket design standard work document XYZ(2) Analysis – Components thermal growth	
Fuel tube system tolerance stack up analysis (2) Bracket de-sign Standard work docu-ment XYZ (2)	

Should include (but are not limited):

- Design standards
- Design guidelines
- Design norms
- Lessons learnt/best practices
- Planned analysis
- Design studies/optimization
- Testing informing the specific solution and forming part of standard design process

Should include all activities planned and committed to be performed such that they influence the solution released at design freeze.

Should not rely on manufacturing/build controls

Occurrence Scoring

- Ranking number associated with each cause for a given failure mode
- Represents the likelihood of a Cause (design error) being present in the item, based on the prevention controls listed
- Measure of confidence in the design, not the predicted rate of failure in service

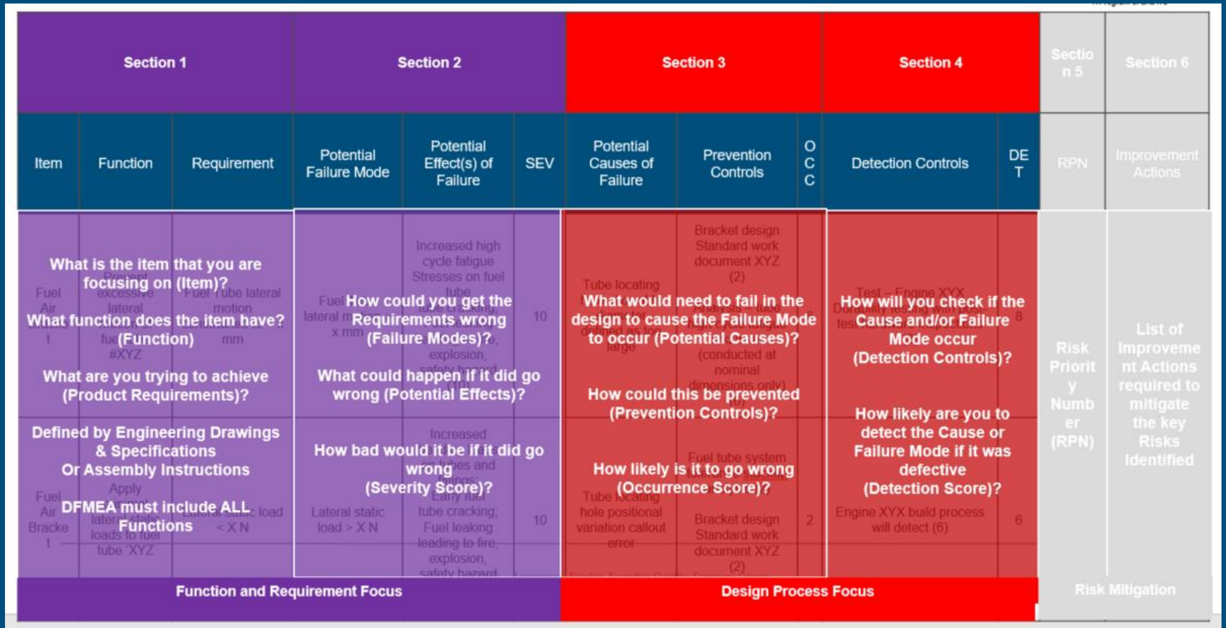
OCCURRENCE RANKING

Ranking	Likelihood of Design Error	Criteria: Occurrence of Cause (DFMEA)
10	Inevitable	No guiding practices upon which to base design are available for this technology - design system will be developed for the first time for this technology in this application. New technology with no history of successful application in any industry. Design process will almost certainly produce a deficient design on first attempt, requiring design iteration(s) after detection activities.
9	Almost Inevitable	Very limited guiding practices for this technology may be available from other industries upon which to base design. New technology with only limited relevance / limited application in other industries. Design process will almost certainly produce a deficient design on first attempt, requiring design iteration(s) after detection activities.
8	Highly Likely	Some standard practices for this technology may be available from other industries upon which to base design. New technology with moderate amount of successful relevant application. Design process is highly likely to produce a deficient design on first attempt, most likely requiring design iteration(s) after detection activities.
7	Likely	Existing standard methods are not applicable to the current design situation. Existing technology, but extremely different duty cycle, operating conditions or application. Past experience base is of limited to no relevance. Design process is likely to produce a deficient design on first attempt, likely requiring design iteration(s) after detection activities.
6	Possible	Existing standard methods are only partly applicable to the current design situation. Existing technology, but highly different duty cycle, operating conditions or application. Past expe partial relevance. Design process could produce a deficient design on first attempt, may require design iteration(s) a activities.
5	Plausible	Existing standard methods are moderately applicable to the current design situation. Existing technology, but moderate differences in duty cycle, operating conditions or application. Past experience base is of moderate relevance. Design process could produce a deficient design on first attempt, may require design iteration(s) after detection activities.
4	Unlikely	Existing standard methods are highly applicable to the current design situation. Existing technology, but slight differences in duty cycle, operating conditions or application. Past experience base is of good relevance. Design process is unlikely to produce a deficient design on first attempt, unlikely to require design iteration(s) after detection activities.
3	Highly Unlikely	Similar successful past experience guiding design practices and choices. Existing technology, but minor differences in duty cycle, operating conditions or application. Past experience base is of good relevance. Design process is highly unlikely to produce a deficient design on first attempt, highly unlikely to require design iteration(s) after detection activities
2	Extremely Unlikely	Probability of design error is significantly minimized through application of prevention controls - identical, highly relevant, & successful past experience guiding design practices. Existing technology, no differences in duty cycle, operating conditions or application. Past experience base is completely relevant, and of moderate extent. Design process is extremely unlikely to produce a deficient design on first attempt, extremely unlikely to require design iteration(s) after detection activities
1	Prevented	Design error is either physically impossible or eliminated through application of prevention controls - extensive, identical, highly relevant, & successful past experience guiding design practices. Existing technology, no differences in duty cycle, operating conditions or application. Past experience base is completely relevant, and of significant extent. Design process will almost certainly not produce a deficient design on first attempt, will not require design iteration(s) after detection activities.

Prevention Controls

Item	Requirement	Failure Mode	Severity	Potential Cause(s) of Failure Mode	Prevention Controls	OCC
Fuel Air Bracket	Fuel Tube lateral motion constrained to < x mm	Fuel Tube lateral motion > x mm	10	Tube locating hole allowable diameter defined as too large	Bracket de-sign Standard work document XYZ (2) Analysis – tube high cycle fatigue and wear (conducted at nominal dimensions only) (6)	2
	Fuel Tube lateral motion constrained to < x mm	Fuel Tube lateral motion > x mm	10	Bracket thermal growth defined as > tube thermal growth	Materials thermal expansion property database (Brackets and tube are standard materials) Bracket design standard work document XYZ(6) Analysis – Components thermal growth (4)	4
	Lateral static load < X N	Lateral static load > X N	10	Tube locating hole positional variation callout error	Fuel tube system tolerance stack up analysis (2) Bracket design Standard work document XYZ (2)	2

4
DETECTION CONTROLS & DETECTION RATING



Detection Controls

- How a design cause and/or failure mode is detected
  - Analytical or physical methods
  - Before the item is released to production i.e. not in-service detection!

- Should include all activities planned and committed to be performed such that they detect the design error prior to production release

- **A shall not rely on manufacturing/build controls as detection**

Current Design Controls – Detection

Item	Requirement	Failure Mode	Severity	Potential Cause(s) of Failure Mode	Prevention Controls	OCC	Current Design Controls – Detection	DET
Fuel Air Bracket	Fuel Tube lateral motion constrained to < x mm	Fuel Tube lateral motion > x mm	10	Tube locating hole allowable diameter defined as too large	Bracket de-sign Standard w ork document XYZ (2) Analysis – tube high cycle fatigue and w ear (conducted at nominal dimensions only) (6)	2	Test – Engine XYX Durability testing with post-test hardware inspections	
	Fuel Tube lateral motion constrained to < x mm	Fuel Tube lateral motion > x mm	10	Bracket thermal growth defined as > tube thermal growth	Materials thermal expansion property database (Brackets and tube are standard materials) Bracket design standard w ork document XYZ(6) Analysis – Components thermal grow th (4)	4	Test – Engine XYX Durability testing with post-test hardware inspections	
	Lateral static load < X N	Lateral static load > X N	10	Tube locating hole positional variation callout error	Fuel tube system tolerance stack up analysis (2) Bracket design Standard w ork document XYZ (2)	2	Engine XYX build process will detect	

Detection Scoring

- rank associated with the best design control from the list of detection-type design controls

- determined without regard for severity or occurrence

DET vs service detection

- goals of the DFMEA process is to increase the ability to verify and validate a design prior to start of production
- In Service detection would not find the Design failure

DETECTION RANKING

Ranking	Detection Category	Criteria: Likelihood of Detection (Design Verification) - DFMEA
10	Will not detect	No current design control; Design control will not and/or cannot detect a potential failure cause/mechanism
9	Not Likely to Detect or detected post Production Launch	Design analysis/detection controls are not likely to detect a potential failure cause/mechanism; Testing is post Production Launch, virtual analysis is of low fidelity and is not correlated to anticipated actual product operating conditions.
8	Post Design Freeze and Prior to Production Launch	Failure cause/mechanism detected during product verification/validation testing. Detected prior to Production Launch with "pass /fail" testing*or by uncorrelated late detailed analysis.
7		Failure cause/mechanism detected during product verification/validation testing. Detected prior to Production Launch with "test to failure" testing* or by late partially correlated detailed analysis.
6		Failure cause/mechanism detected during product verification/validation testing. Detected prior to Production Launch with "degradation" testing*, or by correlated late detailed analysis.
5	Prior to Design Freeze	Failure cause/mechanism detected prior to Design Freeze using "pass/fail" testing* or by uncorrelated detailed analysis.
4		Failure cause/mechanism detected prior to Design Freeze using "test to failure" testing* or by partially correlated detailed analysis.
3		Failure cause/mechanism detected prior to Design Freeze using degradation testing* or by correlated detailed analysis.
2	Robust Early Detection	Design analysis/detection controls are virtually assured to detect a potential failure cause/mechanism. Virtual analysis is conducted early in the design phase and is highly correlated with actual and/or expected operating conditions.
1	Failure Prevented; Detection not Applicable	Failure cause/mechanism cannot occur because it is fully prevented through preventive design controls (e.g. proven design standard/best practice, proven common material, etc.)

* Pass/fail testing = to performance acceptance criteria (i.e. meets min/max requirements, with no understanding of margin or reserve factor)

Test to failure testing = until yields, leaks, cracks etc. (i.e. meets min/max requirements, with quantified margin or reserve factor)

Degradation testing = e.g. based on extrapolation of data trends (i.e. we will know predictively that the requirements will not be met ahead of any physical failure)

DETECTION RANKING

Ranking	Detection Category	Criteria: Likelihood of Detection (Design Verification) - DFMEA
10	Will not detect	No current design control; Design control will not and/or cannot detect a potential failure cause/mechanism
9	Not Likely to Detect or detected post Production Launch	Design analysis/detection controls are not likely to detect a potential failure cause/mechanism; Testing is post Production Launch, virtual analysis is of low fidelity and is not correlated to anticipated actual product operating conditions.
8	Post Design Freeze and Prior to Production Launch	Failure cause/mechanism detected during product verification/validation testing. Detected prior to Production Launch with "pass /fail" testing*or by uncorrelated late detailed analysis.
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There is no detection method

Detection late in project phase

Detection early in project phase

Detection early during highly correlated analysis

Detection not Required

CHAT FUNCTION: What's the Score? Detection Controls Example

Ranking	Detection Category	Criteria: Likelihood of Detection (Design Verification) - DFMEA
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…tential …se(s) of …re Mode	Prevention Controls	OCC	Current Design Controls – Detection	DET
…ocating hole …le diameter as too large	Bracket de-sign Standard work document XYZ (2) Analysis – tube high cycle fatigue and wear (conducted at nominal dimensions only) (6)	2	Test – Engine XYX Durability testing with post-test hardware inspections	
…ket thermal …defined as > …ermal growth	Materials thermal expansion property database (Brackets and tube are standard materials) Bracket design standard work document XYZ(6) Analysis – Components thermal growth (4)	4	Test – Engine XYX Durability testing with post-test hardware inspections	
…ocating hole …nal variation …out error	Fuel tube system tolerance stack up analysis (2) Bracket design Standard work document XYZ (2)	2	Engine XYX build process will detect	

CHAT FUNCTION: What's the Score? Detection Controls Example

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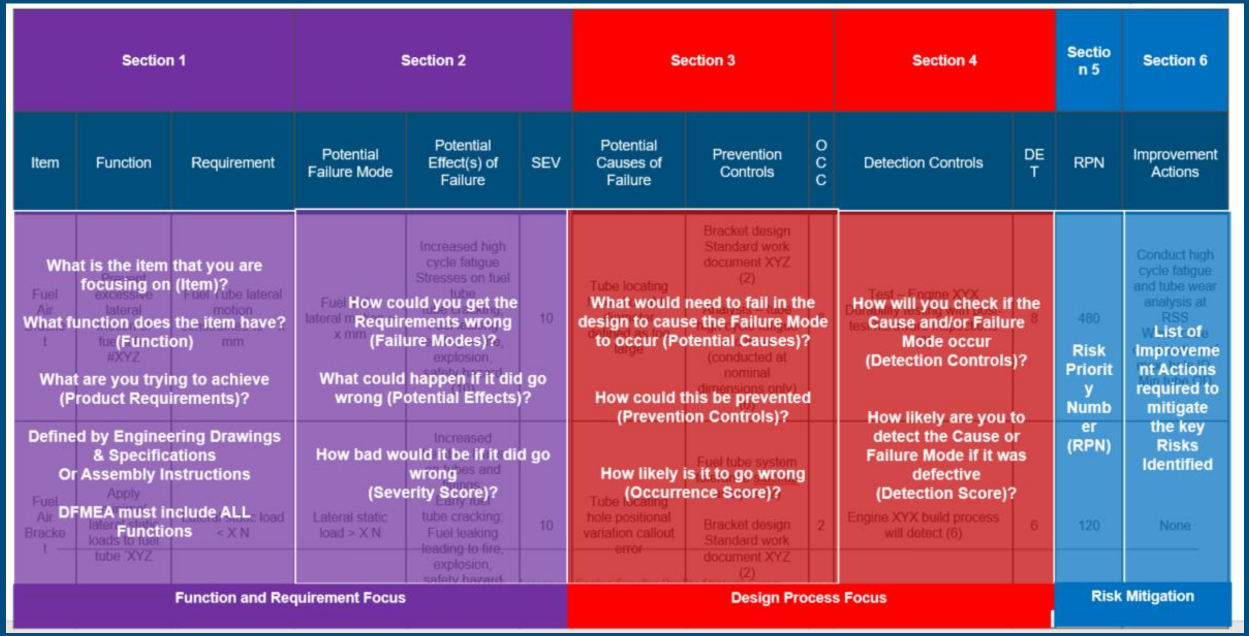
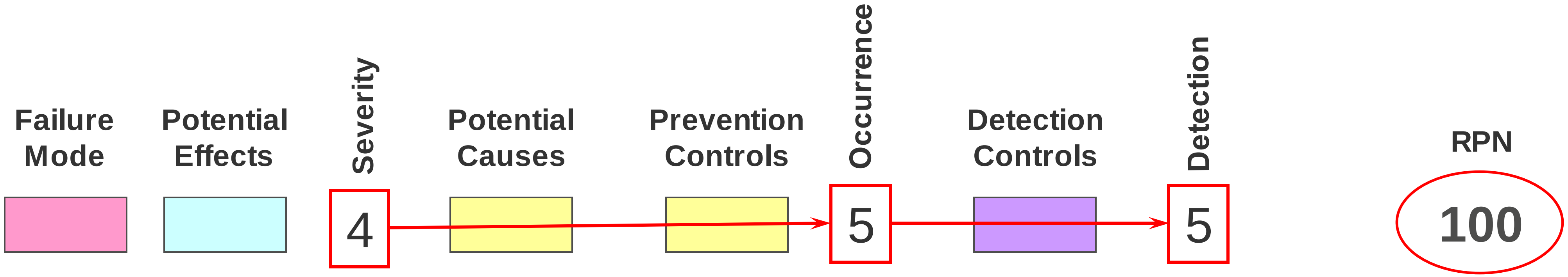
ng hole iameter oo large	Bracket de-sign Standard w ork document XYZ (2) Analysis – tube high cycle fatigue and w ear (conducted at nominal dimensions only) (6)	2	Test – Engine XYX Durability testing with post-test hardware inspections	8
hermal ned as > l growth	Materials thermal expansion property database (Brackets and tube are standard materials) Bracket design standard w ork document XYZ(6) Analysis – Components thermal grow th (4)	4	Test – Engine XYX Durability testing with post-test hardware inspections	8
ng hole ariation error	Fuel tube system tolerance stack up analysis (2) Bracket design Standard w ork document XYZ (2)	2	Engine XYX build process will detect	6

5
CALCULATING THE RISK PRIORITY NUMBER (RPN)



FMEA Risk Priority Number Scoring



Severity x Occurrence x Detection = RPN

4 x 5 x 5 = 100

FMEA Risk Priority Number Scoring

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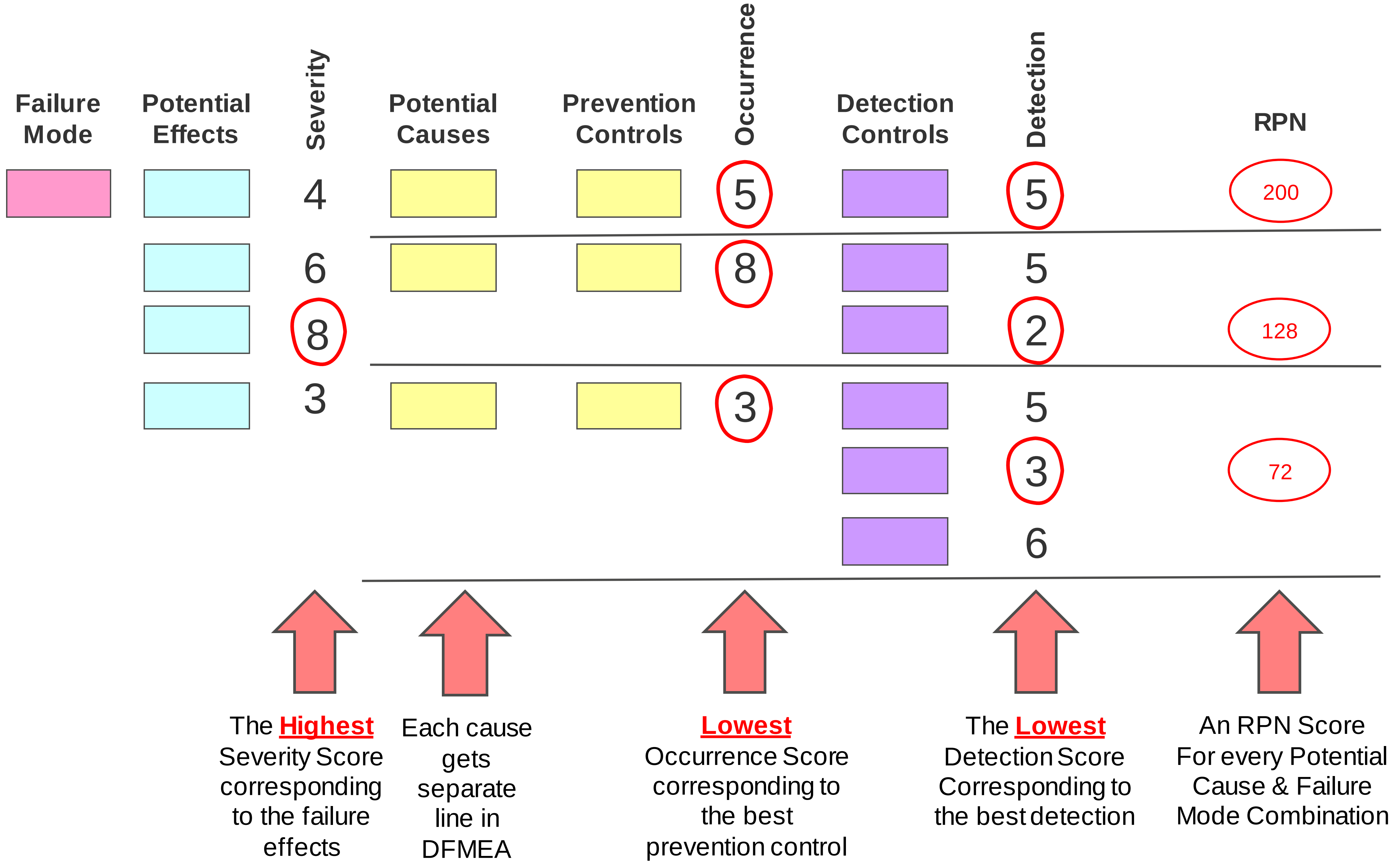
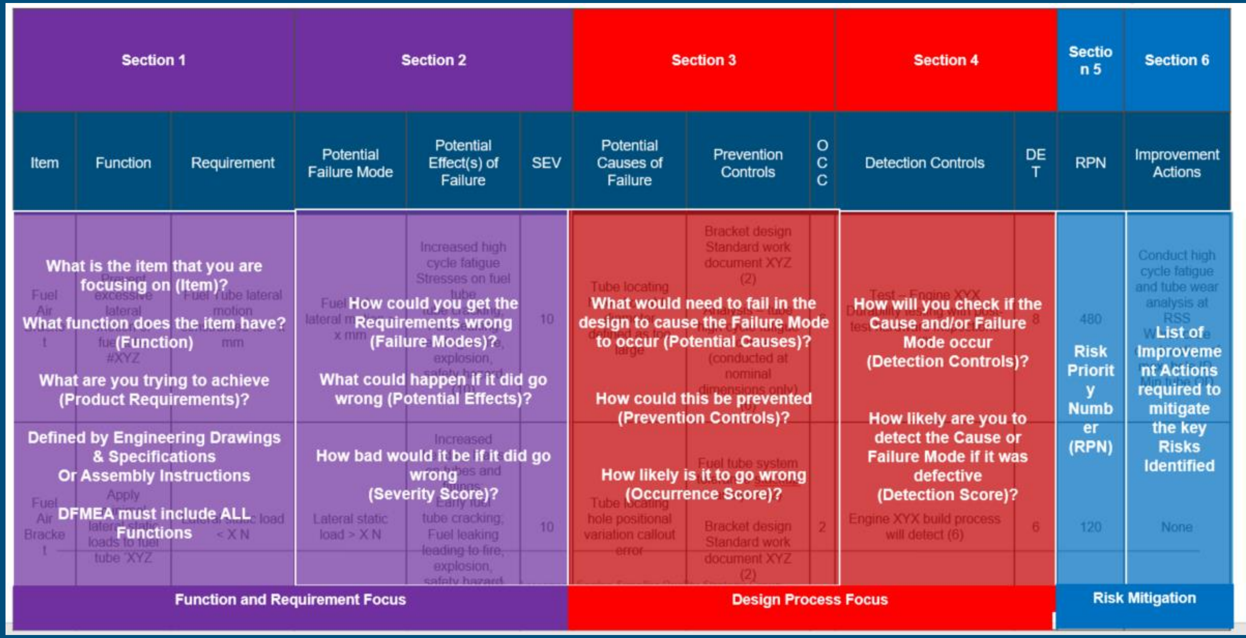
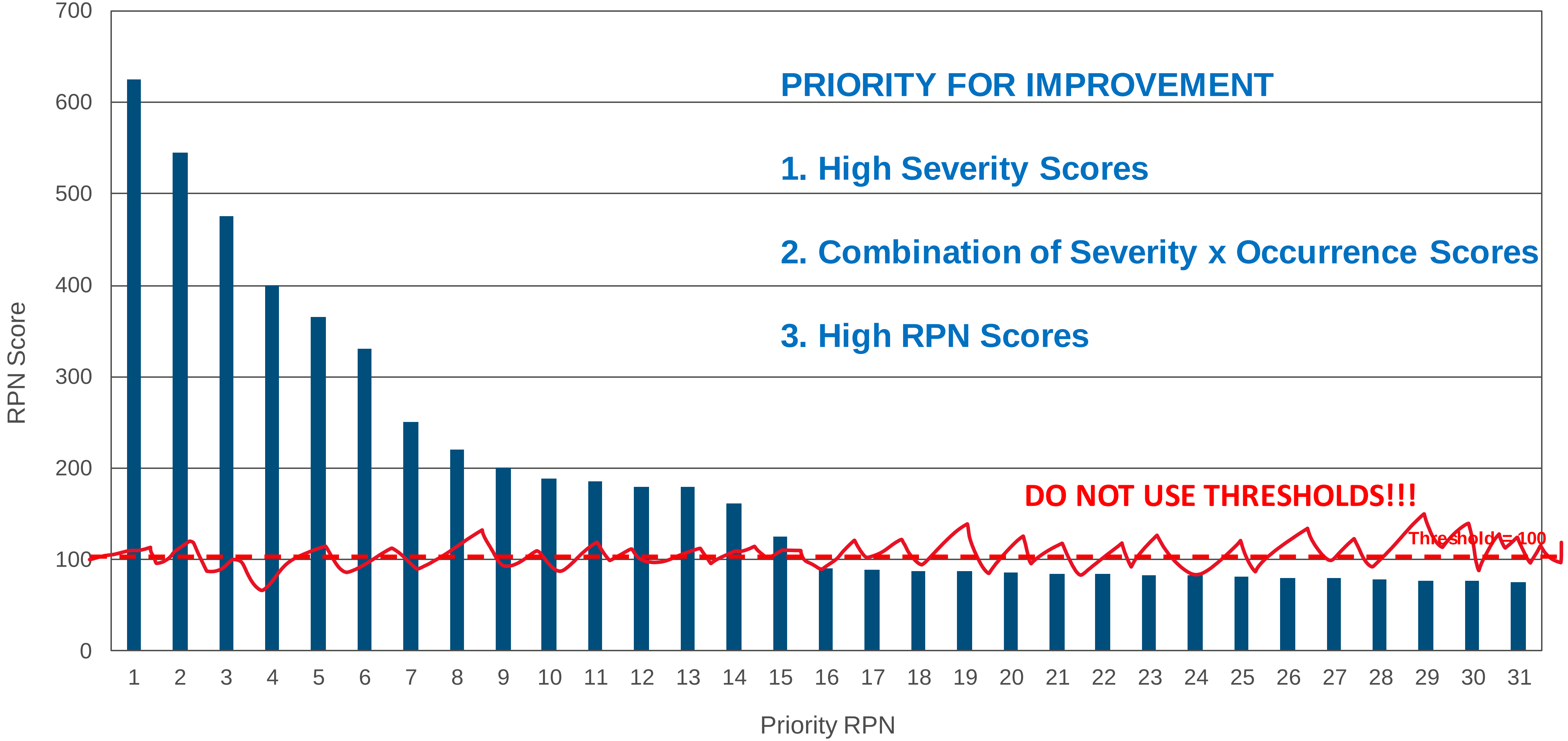


6
IMPROVEMENT ACTIONS

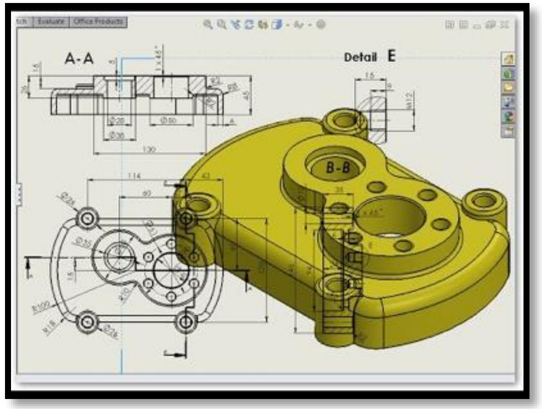


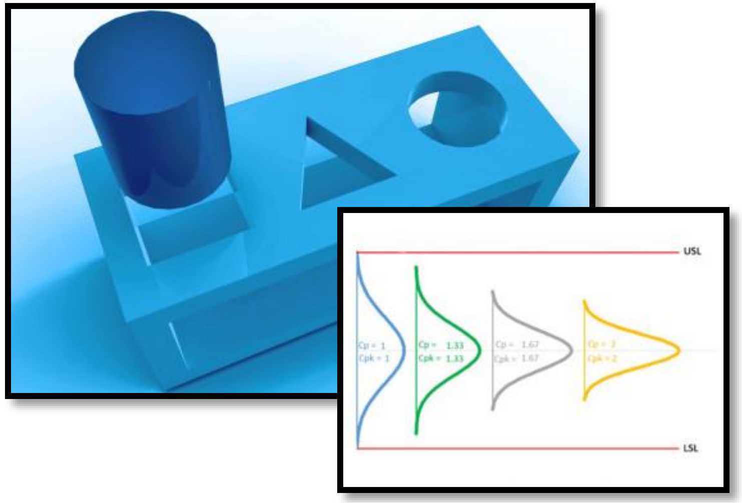
FMEA Action Prioritization

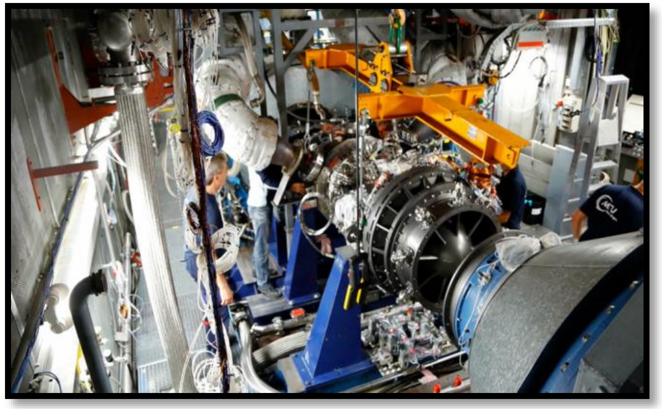
RPN PARETO



Notes on Risk Mitigation







Severity Scores

Can only be reduced through Product Redesign e.g. removing the need for a function or providing a 'fail safe' solution.

Occurrence Scores

Can be reduced through generating more experience with analysis and/or testing

Detection Scores

Can be reduced through enhanced and/or earlier testing

DFMEA FMEA Improvement Actions

Hole Diameter Too Big				
Sev	Potential Cause	Occ	Det	Risk Priority Number
10	Tube locating hole allowable diameter defined as too large	6	8	480

IMPROVEMENT ACTIONS							
Recommended Actions	Responsibility	Target Date	Action Taken	Sev	Occc	Det	RPN
Conduct accelerated stress test to determine limits of max. hole ID, min tube OD configuration *(Improved DETECTION Score)*	Sarah Cracknell	June 1st	Introduced May 29th	10	6	4	240
Conduct high cycle fatigue and tube wear analysis at RSS Worst-case combination of max. hole ID. Min tube OD *(Improved OCCURRENCE Score)*	Daryl Jackman	July 7th	Introduced June 25th	10	2	8	160

Improved Detection Score from 8 to 6 by changing verification schedule

Improved Occurrence Score from 6 to 2 by gain more experience with design

Rob Farndon
Rolls-Royce

Steven W. Finup
GE Aviation

Andrea Neumann
MTU

Stéphan DAUX
Safran Aircraft Engines

DFMEA FMEA SUMMARY & FURTHER INFORMATION

Evaluating Your Design FMEA

Are all relevant Items identified? Is there any Item which can have credible failures to the system function?

Are all Requirements identified, unique, measurable and unambiguous ?

Do the Effects include a description of how it impacts the customer / user as well as the internal impacts?

Are the Prevention Controls truly preventative to stop the Potential Cause from Occurring?

Item	Function	Requirements	Potential Failure Modes	Potential Effects of Failure	Severity Score	Potential Causes of Failure	Prevention Controls	Occ Score	Detection Controls	Detection Score	RPN
					Does the Severity Score align to the RM13004 Guide?			Does the Occ Score align to the RM13004 Guide?		Does the detection Score align to the RM13004 Guide?	Has the RPN ben scored properly?

Are all Functions (primary, secondary) of the Item identified?

Are the Failure Modes in line with corresponding functions and requirements?

Are the list of Potential Causes clear on how they could cause the Failure Mode? Do they all correspond to the design specification?

Do the Detection Controls include how the Failure Mode could be found as well as the Potential Cause?

SOURCES OF FURTHER INFORMATION & GUIDANCE

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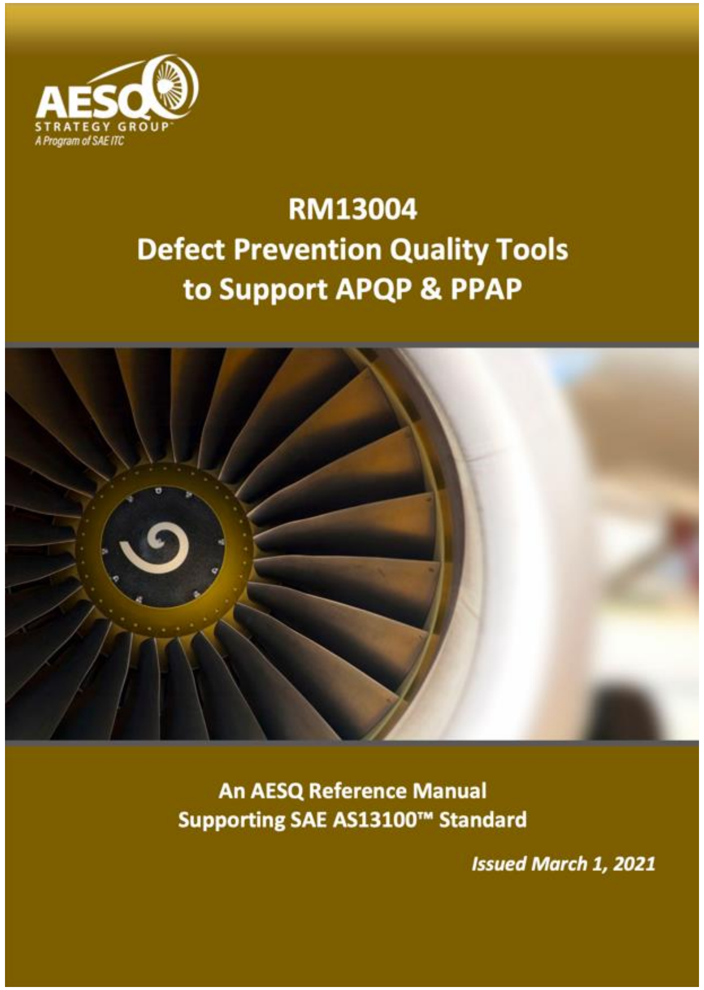


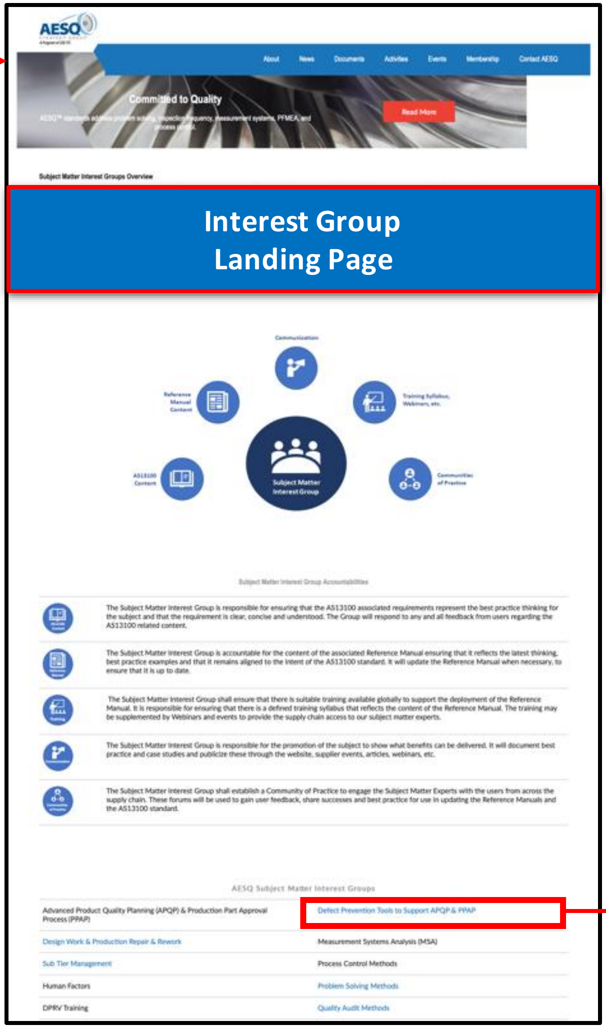
1. **Reference Manual RM13004 is available free of charge from the AESQ website**

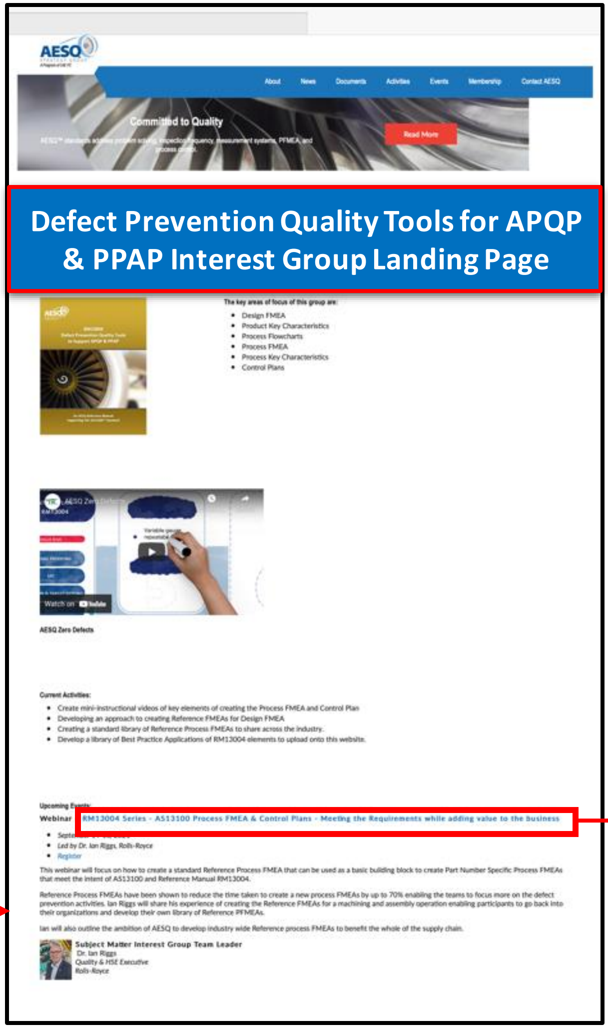
2. **Global FMEA training is available to support this approach through the SAE.**

3. **Subject Matter Interest Group to support RM13004 Deployment established and contactable through AESQ Website**

https://aesq.sae-itc.com

Subject Matter Interest Groups on the AESQ Website





Further links to support materials, events, social media pages, etc.

Resources

All resources will be available on the AESQ website within a few days.

An email will be sent to all registrants with a link to these resources.

Thank You
For Attending!

AESQ

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