AESQ

PROCESS FAILURE MODE & EFFECTS ANALYSIS

ZERO DEFECTS TOOLKIT

AS13100 / RM13004 PROCESS FMEA WEBINAR

Application of RM13004 in a Complex Assembly Environment

Dr Ian Riggs
Quality Executive
Rolls-Royce

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Rolls-Royce

Steve Roebuck
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February 29th 2024

AESQ CONSORTIUM™
A Program of SAE ITC

Introductions

Dr Ian Riggs

Global Quality & HSE Executive
Assembly & Test Operations

- Worked for Rolls-Royce Aerospace for past 19 years, 16 years experience working in the Automotive Industry,
- Founding member of the AESQ in 2013
  - Led the writing teams for AS13100 and AS13003
  - Team leader for AESQ RM13004 Subject Matter Interest Group

Harj Sanghera

Manufacturing Engineer
Assembly & Test Operations

- Worked for Rolls-Royce Aerospace for past 2 years
- Leads the Community of Practice (CoP) for RM13004 Process FMEAs in Assembly & Test
- BEng Hons Mechanical Engineering (Derby University). Awarded the Rolls-Royce Sir Denning Pearson Award.
- 10 years engineering experience

Steve Roebuck

Head of Certification & Assurance
Assembly & Test Operations

- Worked for Rolls-Royce Aerospace for the past 12 years working in manufacturing and supply chain quality roles
- Current Human Factors Deployment Lead for Assembly & Test Operations
- Previous experience in aerospace supply chain (special processes) and pharmaceutical industry

A Global Attendance

A Total of
486 People Registered from
207 Organisations in
33 Countries

Getting the most out of the Session

Amanda Myers

Aerospace Standards
Committee Manager
SAE

Please note we are recording today's webinar.

This recording will be available for free viewing on the AESQ website subsequent to this event.

An email notification will be issued to attendees when the video is available.

We will be muting all lines at the start of the session

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

Please complete the **Poll & Quiz Questions** when asked (they are anonymous).

AS13100 / RM13004 PROCESS FMEA Webinar

APPLICATION IN A COMPLEX ASSEMBLY ENVIRONMENT

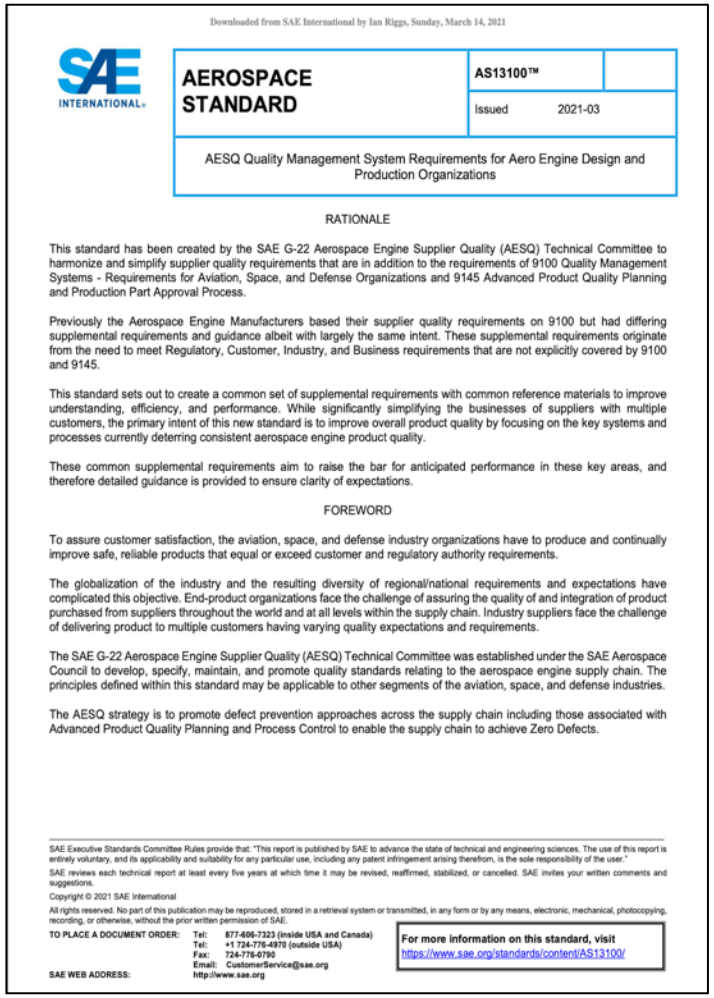
1	AS13100 & RM13004 Process FMEA (short) Recap
2	Process FMEA in an assembly environment – Key Insights
3	**Practical Demonstration**
4	Dealing with Human Error in a Process FMEA
5	Questions & Answers
6	Further Information Sources

AS13100 FMEA Requirements & Guidance

AS13100

Available to purchase from

https://www.sae.org/standards/content/as13100



SAE INTERNATIONAL

AEROSPACE STANDARD	AS13100™	
	Issued 2021-03	

AESQ Quality Management System Requirements for Aero Engine Design and Production Organizations

RATIONALE

This standard has been created by the SAE G-22 Aerospace Engine Supplier Quality (AESQ) Technical Committee to harmonize and simplify supplier quality requirements that are in addition to the requirements of 9100 Quality Management Systems - Requirements for Aviation, Space, and Defense Organizations and 9145 Advanced Product Quality Planning and Production Part Approval Process.

Previously the Aerospace Engine Manufacturers based their supplier quality requirements on 9100 but had differing supplemental requirements and guidance albeit with largely the same intent. These supplemental requirements originate from the need to meet Regulatory, Customer, Industry, and Business requirements that are not explicitly covered by 9100 and 9145.

This standard sets out to create a common set of supplemental requirements with common reference materials to improve understanding, efficiency, and performance. While significantly simplifying the businesses of suppliers with multiple customers, the primary intent of this new standard is to improve overall product quality by focusing on the key systems and processes currently deterring consistent aerospace engine product quality.

These common supplemental requirements aim to raise the bar for anticipated performance in these key areas, and therefore detailed guidance is provided to ensure clarity of expectations.

FOREWORD

To assure customer satisfaction, the aviation, space, and defense industry organizations have to produce and continually improve safe, reliable products that equal or exceed customer and regulatory authority requirements.

The globalization of the industry and the resulting diversity of regional/national requirements and expectations have complicated this objective. End-product organizations face the challenge of assuring the quality of and integration of product purchased from suppliers throughout the world and at all levels within the supply chain. Industry suppliers face the challenge of delivering product to multiple customers having varying quality expectations and requirements.

The SAE G-22 Aerospace Engine Supplier Quality (AESQ) Technical Committee was established under the SAE Aerospace Council to develop, specify, maintain, and promote quality standards relating to the aerospace engine supply chain. The principles defined within this standard may be applicable to other segments of the aviation, space, and defense industries.

The AESQ strategy is to promote defect prevention approaches across the supply chain including those associated with Advanced Product Quality Planning and Process Control to enable the supply chain to achieve Zero Defects.

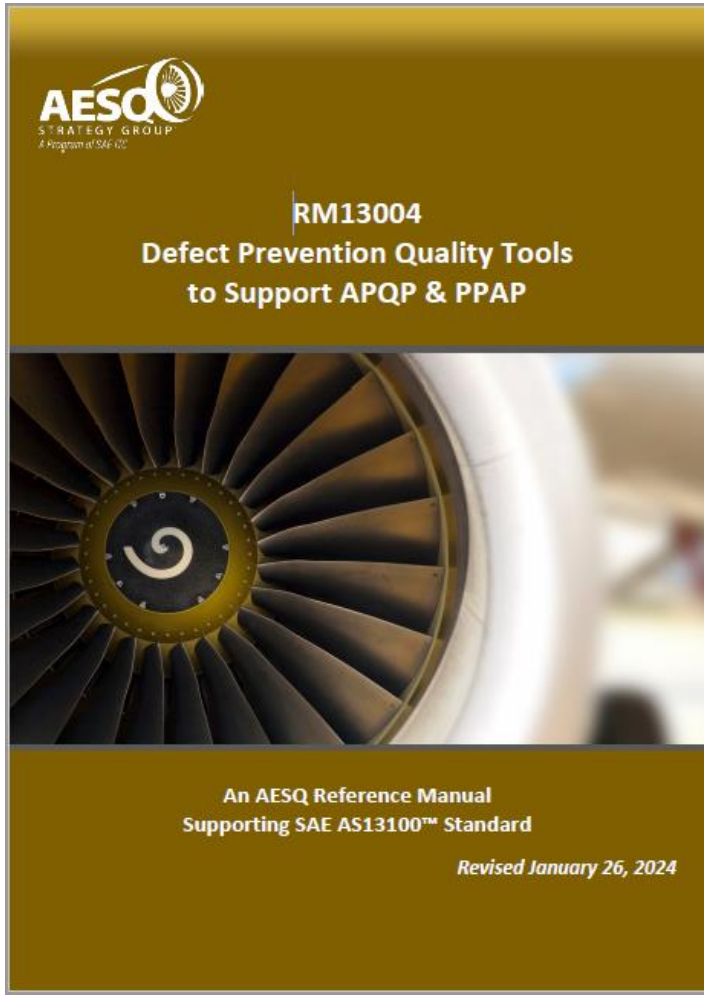
TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada) Tel: +1 724-776-4970 (outside USA) Fax: 724-776-0790 Email: CustomerService@sae.org

SAE WEB ADDRESS: http://www.sae.org

For more information on this standard, visit https://www.sae.org/standards/content/AS13100/

RM13004

Available to Download for FREE at https://aesq.sae-itc.com/supplemental-material



Recently Revised

AS13100 & RM13004

Process FMEA Requirements

AS13100 Process FMEA Key Requirements (Chapter C)

Must be Created & Maintained by a CROSS FUNCTIONAL TEAM (20.1)

EVERY Design Characteristic included in the PFMEA (21.4.1)

PFMEA must be done at the RIGHT TIME in APQP (16.5.10)

PFMEA Failure Modes must describe PRODUCT DEFECTS (21.4.1)

Is **PART NUMBER** Specific (21.4)

PFMEAs must DRIVE ACTIONS to reduce risk (21.4.3)

Include ALL Process Steps (21.4)

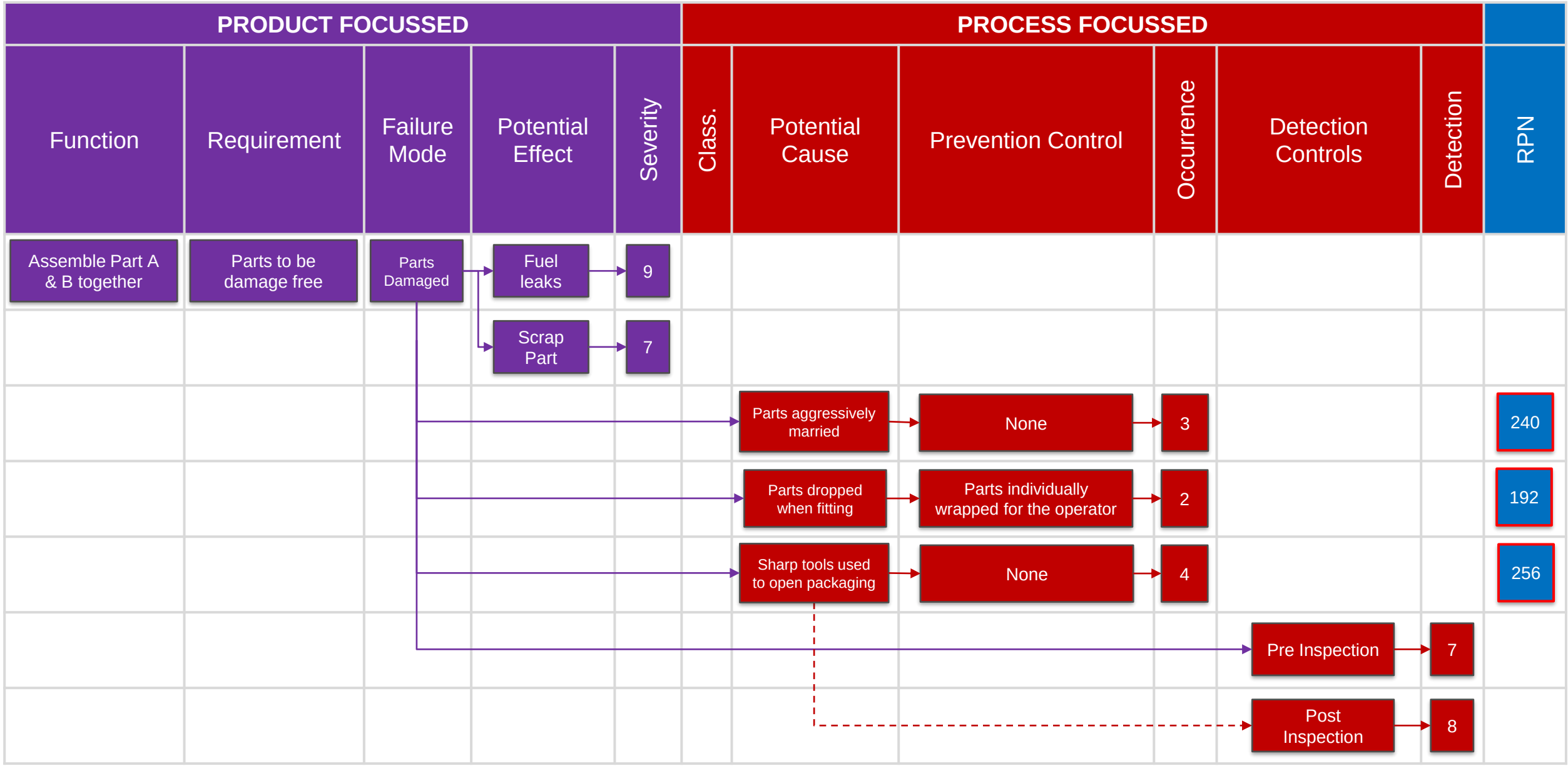
Keep up to date – They are **LIVE** documents (20.1)

The Process FMEA Template Overview

Section 1		Section 2			Section 3			Section 4		Section 5	Section 6
Function	Requirements	Potential Failure Modes	Potential Effects of Failure	Severity Score	Potential Causes of Failure	Prevention Controls	Occ Score	Detection Controls	Detection Score	RPN	Improvement Actions
Assemble Part A & B together	Parts to be damage free	Parts damaged	Fuel Leaks leading to a failure without warning	8	Parts aggressively married	None	3	None	10	240	Improved crane speed control
Parts not protected adequately in packaging	Components are all individually packaged	2	Pre & Post inspection	7	112	N/A
Component dropped when fitting	None	3	Post inspection	168	Implement protective material at assembly	
Sharp tool used to open part packaging		4	Post inspection	256	Decant parts to mitigate risk of damage from sharp tooling	
What is the process that you are focusing on? (Process Step) **What PRODUCT attributes are you trying to achieve? (Product Requirements)** **Defined by Engineering Drawings & Specifications or Assembly Instructions*** **PFMEA must include ALL Design Requirements**		**How could you get the PRODUCT Requirements wrong? (Potential Failure Modes)** **Failure Modes must describe PRODUCT non conformance** **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 process to cause the Potential 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? (Detection Score)**		**Risk Priority Number (RPN)**	**List of Improvement Actions required to mitigate the key Risks Identified**
Product Focused					**Process Focused**					**Risk Mitigation**	

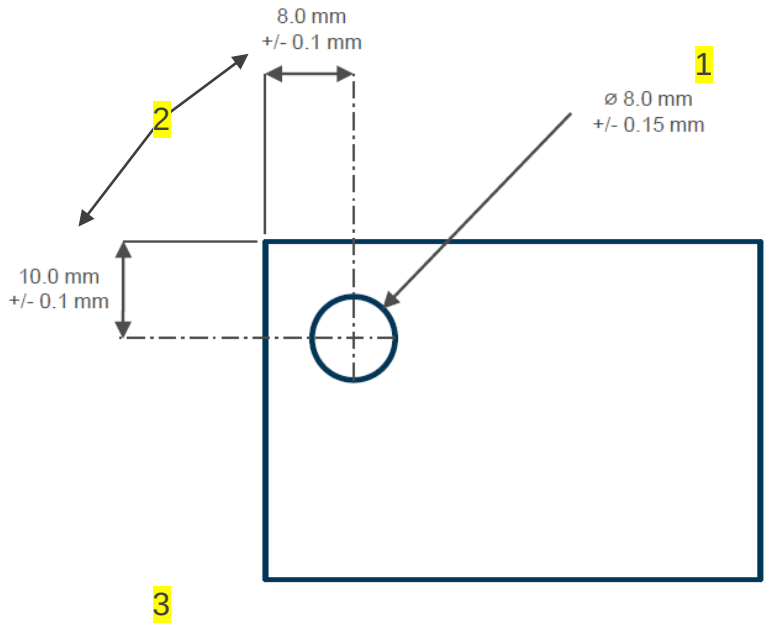
***see section on using Assembly Instruction later in presentation**

Process FMEA Information Flow



Defining the Assembly PFMEA Requirements

Machining PFMEA Requirements Capture



Specification xyz states no burrs / sharp edges on drilled holes are allowed

Function	Requirement	Potential Failure Modes
OP10 CNC Drilling Drill Fuel Hole	1) Ø 8.0mm +/- 0.15mm	Hole diameter too big
		Hole diameter too small
	2) Location 8.00mm +/- 0.1mm (x), 10.0mm +/- 0.1mm (y)	Out of location
	3) No burrs or sharp edges	Burrs / sharp edges present

Machining PFMEA requirements can be derived directly from the Engineering Drawing and Specifications.

Assembly PFMEAs can be more tricky!

Assembly Process FMEA Requirements Capture

Op No.	Operation Text	Who
10	Unpack components from boxes and protective film	Operator
20	Clean components for risk of FOD	Operator
30	Inspect components for damage	Inspector
40	Assemble the inlet & outlet components and align using the bolt holes	Operator
50	Remove bolts from packaging	Operator
60	Apply oil to the bolts before fitting	Operator
70	Fit all 8 bolts and hand tighten	Operator
80	Torque bolts to 100 lbf.in to achieve the correct clamping force	Operator
90	Inspect final assembly	Inspector
100	Signoff and pass the next workstation	Operator

Prior to AS13100 It was common practice to take each line from the Assembly Instruction and transfer it to the REQUIREMENTS column in the PFMEA.

OP / Step	Requirement	Potential Failure Modes
10	Unpack components from boxes and protective film	Components not unpacked
20	Clean components for risk of FOD	Components not cleaned
30	Inspect components for damage	Damage found
40	Assemble the inlet & outlet components	Components not assembled
50	Remove bolts from packaging	Bolts not removed from packaging

Requirements & Failure Modes must describe the **PRODUCT** attributes that need to be achieved

(AS13100 ref 21.4.1)

Assembly Process FMEA Requirements Capture

Op No.	Operation Text	Who
10	Unpack components from boxes and protective film	Operator
20	Clean components for risk of FOD	Operator
30	Inspect components for damage	Inspector
40	Assemble the inlet & outlet components and align using the bolt holes	Operator
50	Remove bolts from packaging	Operator
60	Apply oil to the bolts before fitting	Operator
70	Fit all 8 bolts and hand tighten	Operator
80	Torque bolts to 100 lbf.in to achieve the correct clamping force	Operator
90	Inspect final assembly	Inspector
100	Signoff and pass the next workstation	Operator

OP / Step	Requirement	Potential Failure Modes
40	Assemble the inlet & outlet components in the correct alignment	Incorrect alignment
70	Fit all 8 bolts type xyz into inlet/outlet assembly	Not all bolts fitted
		Wrong bolts fitted
80	Create even clamping force between inlet and outlet by torquing bolts to 100 lbf.in	Clamping force too high
		Clamping force too low
		Clamping force not even

Only the **PRODUCT** focussed instructions are required in the **FMEA REQUIREMENTS** column
This will help to **Reduce the Size** of the Process FMEA and keep it focussed on **Product Conformance**

Assembly Process FMEA Requirements Capture

Operation Number	Operation Text	Where else in the PFMEA could this information be shown?
10	Unpack components from boxes and protective film	**Potential Cause:** Maybe a cause of damage if not done correctly
20	Clean components for risk of FOD	**Potential Cause:** Maybe a cause of FOD if not cleaned properly
30	Inspect components for damages	**Detection Control:** Should be described in the Detection column against a Damage Failure Mode
40	Assemble the inlet & outlet components	**REQUIREMENTS**
50	Remove bolts from packaging	**Potential Cause:** Maybe a cause of damage if not done correctly, also potential to select wrong bolts
60	Apply oil to the bolts before fitting	**Potential Cause:** May cause stress damage to the bolt if oil is not applied
70	Fit all 8 bolts	**REQUIREMENTS**
80	Torque bolts to 100 lbf.in to achieve the correct clamping force	**REQUIREMENTS**
90	Inspect final assembly	**Detection Control:** Should be described in the Detection column against the appropriate Failure Mode
100	Signoff and pass the next workstation	Not Applicable

Using Standard Assembly Failure Modes

When developing an Assembly Process FMEA there are a number of Standard Failure Modes that can be used to prompt the team.

1. Part not fitted
2. Wrong part fitted
3. Part misaligned
4. Incorrect orientation
5. Damaged part
6. FOD present
7. Incorrect clamping force
8. Uneven clamping force

NOTE: There may be some other **Standard Failure Modes** that are specific to your assembly process so customise if necessary.

They can also help to validate the accuracy of the **Requirements Description**.

Using Standard Assembly Failure Modes to Refine the Requirements Description

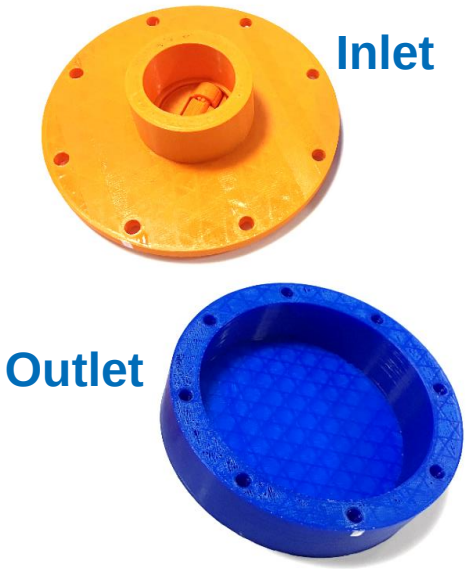
Function	Requirements	Using Standard Assembly Potential Failure Modes	Potential Effects of Failure	Severity Score	Potential Causes of Failure
Assemble Inlet to Outlet	Assemble the **Inlet (part # IN1)** to the **Outlet (part # OU2)** using the alignment marking and bolt holes.	Part not fitted			
		Wrong part fitted			Part mislabeled
		Part misaligned			
	Ensure that the inlet is in the correct orientation	Incorrect orientation			
	No Damage to mating faces	Damaged part	**Review the Assembly Standard Failure Modes & Update Requirements description if necessary**		
	No FOD	FOD present			
	Not Applicable	Clamping Force too high	**No need to include in FMEA if the Standard Failure Mode is not a genuine requirement**		

Practical Demonstration of

RM13004 PFMEA

in an Assembly Environment

Practical Demonstration of an Assembly PFMEA



1

Assemble the Inlet and Outlet components with the inlet facing upwards as shown (orientation).

Ensure that there is no damage or FOD present on the mating faces.

2

Align parts using the white markings and ensure bolt holes are aligned.

3

Fit 8 bolts (type CDE4506) and hand tighten

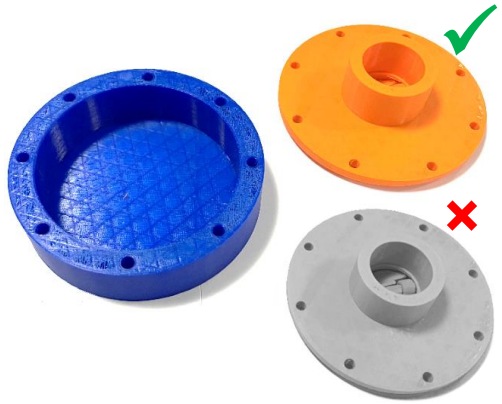
4

Use torque wrench (#213) to tighten bolts to the specified value

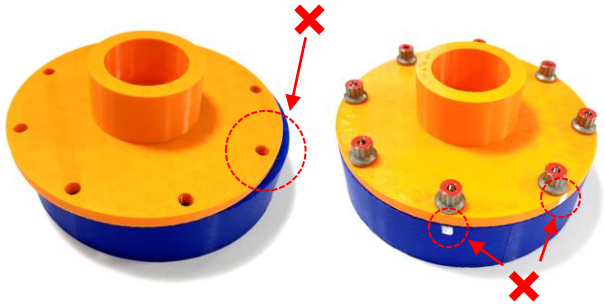
in the correct sequence (see instruction xyz) to create an even clamping force between the inlet and outlet components.

Using Standard Failure Modes

1. Part not fitted

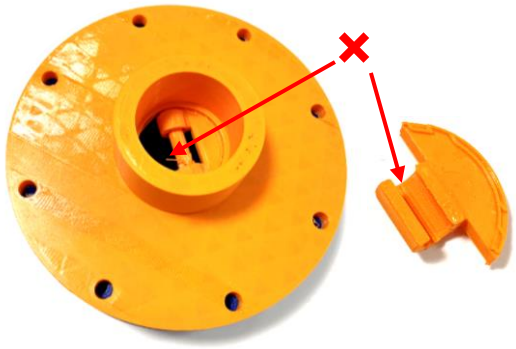


2. Wrong part fitted

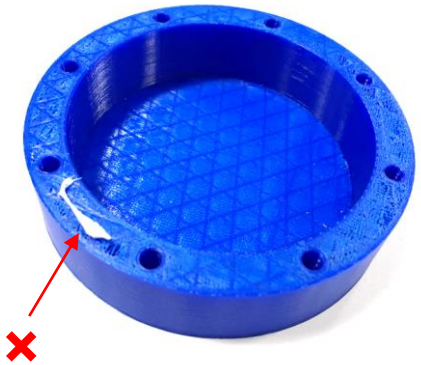


3. Parts misaligned

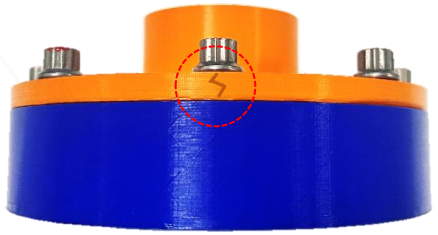
4. Incorrect orientation



5. Damaged part



6. FOD

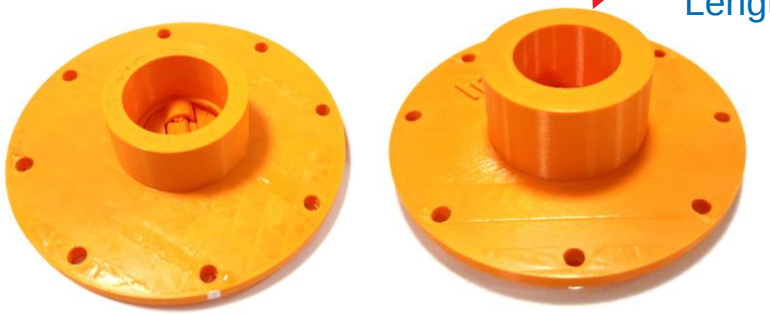


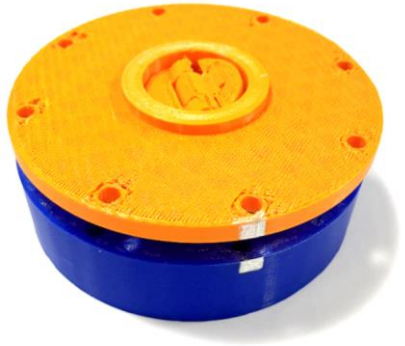
7. Incorrect Clamping Force
(Too High/Too Low)

8. Uneven Clamping Force

Using the PFMEA to Identify Improvements

Orientation
Design Error Proofing





Inlet cannot physically be placed in the incorrect orientation due to thickness/length increase.

Alignment
Design Error Proofing

Both the inlet and the outlet cannot be misaligned due to a new offset hole position.

Intelligent Torque Wrenches
Error Proof the Process

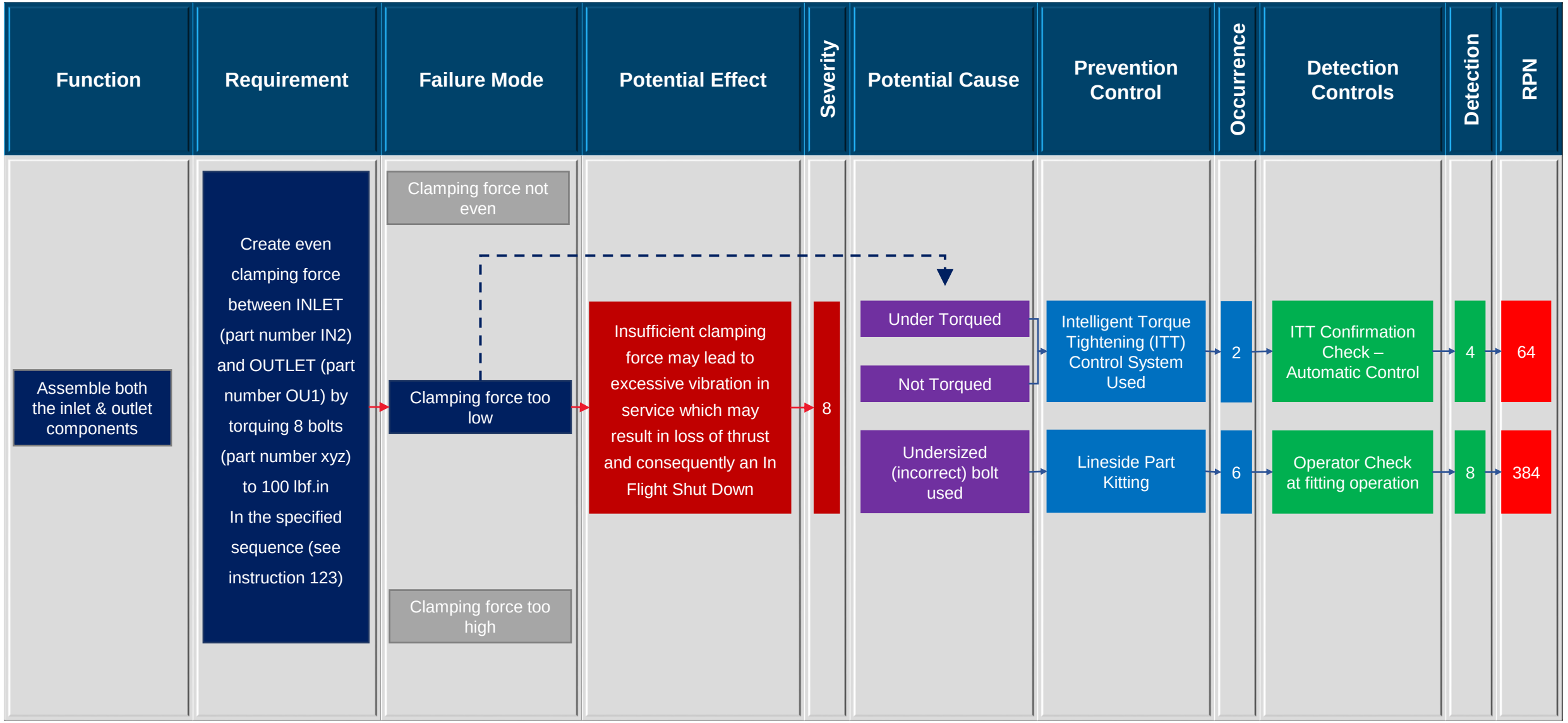
‘Kitting’ C Class Parts
Risk Reduction/Improvement

Only the correct parts are available on the line to select and improved protective packaging

Error Proofing of Parts must be done in the Design Phase

In APQP PFMEA starts at Design Concept Phase so we can influence the design process

Process FMEA Assembly of INLET and OUTLET



Managing
Human Error
in an
Assembly PFMEA

Aero Engine Assembly Operations

30,000

Components

6,000

Manual Operations

HUMAN FACTORS play a critical part in assuring **PRODUCT QUALITY & SAFETY**

Human Factors

The Dirty Dozen

1 Lack of Communication

2 Complacency

3 Lack of Knowledge

4 Distraction

5 Lack of Team Work

6 Fatigue

7 Lack of Resources

8 Pressure

9 Lack of Assertiveness

10 Stress

11 Lack of Awareness

12 Norms

Why don’t you add the Human Factors FMEA into the Part Specific Process FMEA as described in RM13004?

27

RM13004 Process FMEA & Human Factors

OP / Step	Requirement	Failure Mode	Potential Effect	Severity	Class.	Potential Cause(s) of the Failure Mode	Prevention Control(s) for the Potential Causes	Occurrence	Detection Controls of the Failure Mode and/or the Potential Causes	Detection	RPN
	Avoid Human Error	Fatigue				Night Shift					

This is not a Product Failure Mode

Failure Modes in an RM13004 PFMEA describe Product nonconformance

(RM13004, Chapter 4, (f))

RM13004 Process FMEA & Human Factors

OP / Step	Requirement	Failure Mode	Potential Effect	Severity	Class.	Potential Cause(s) of the Failure Mode	Prevention Control(s) for the Potential Causes	Occurrence	Detection Controls of the Failure Mode and/or the Potential Causes	Detection	RPN
	Assemble Part xyz in correct orientation	Part fitted in incorrect orientation				Distraction					

This is not a Cause & Effect Relationship.

If the Potential Causes occurs, we should expect the part Failure Mode to occur

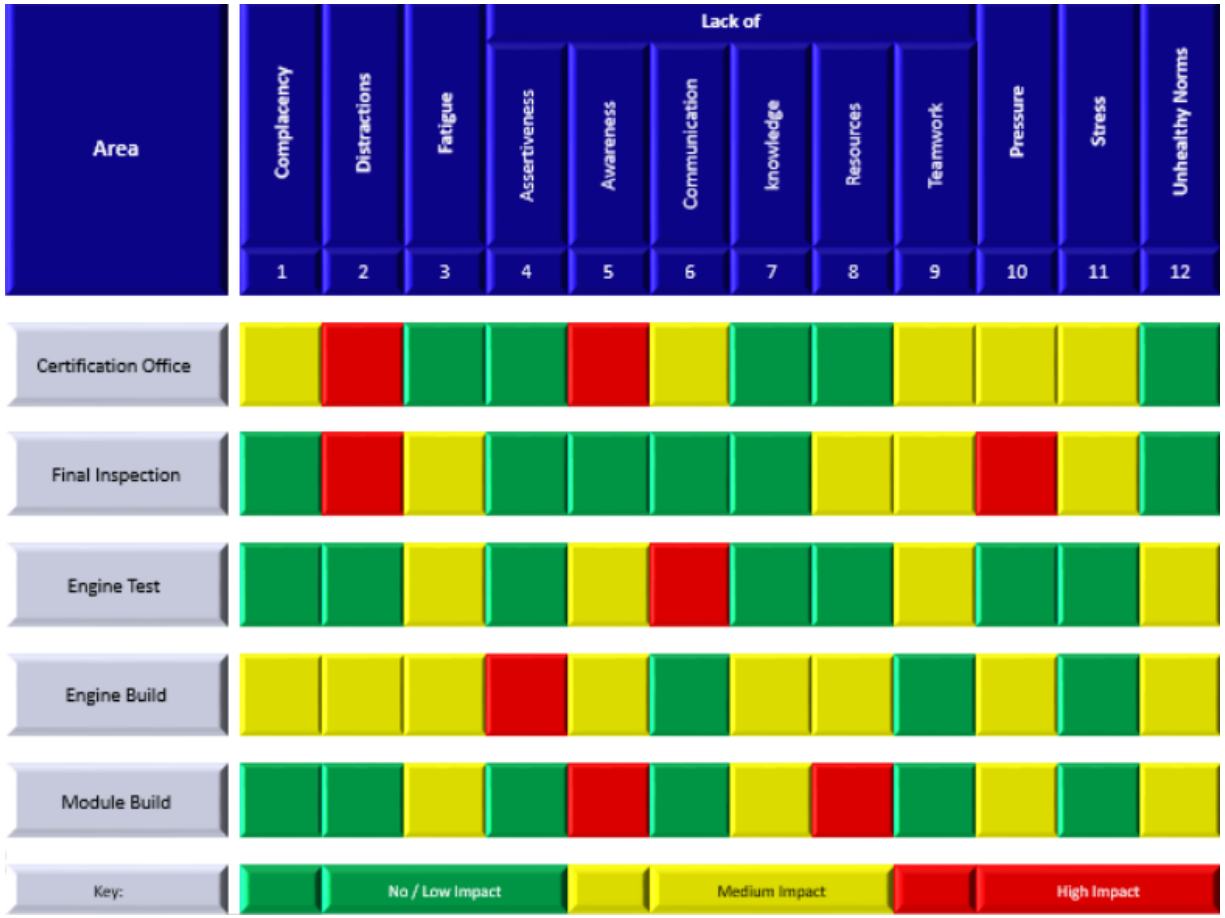
We must avoid simple 'operator error' as a Potential Cause

(RM13004, Chapter 4, (i))

Human Factors are not related to specific part nonconformance.

Instead, they relate to the working environment and can impact any products manufactured in that area.

Human Factors in Process FMEA Key Insights



- Including Human Factor risks into the Product PFMEA creates too much ‘noise’
- The Human Factor FMEA approach is used to create a high-level analysis of a process environment (area)
- In the Human Factors FMEA the Dirty Dozen are used as the failure modes,
- Each area will have a unique ‘signature’ based upon its environment (which can change over time)
- RR have seen significantly increased Human Factors awareness, issue reporting and improvements where deployed

In Summary

RM13004 Assembly PFMEA Summary

1. **The Requirements** must describe the physical product outcome you want to achieve.
   - *Only use the product related descriptions from the assembly instructions.*
   - *This will also help to reduce the size of the PFMEA and keep it focussed*

2. **Failure Modes** must describe a physical property of the product and are derived from the Requirements description.
   - *Use the Standard Failure Mode Checklist (customise if necessary)*
   - *Use it to refine the Requirements Description if needed*

3. **Potential Causes of Failure** should avoid loose descriptions such as “Operator Error”
   - *Use the Human Factors PFMEA Approach*

4. **Potential Causes of Failure**, develop through engagement with the operators/fitters
   - *Observe the actual (or similar*) process*
   - *Capture their insights into known issues and suggested improvements*
   - *Provide Feedback on progress (visual management).*

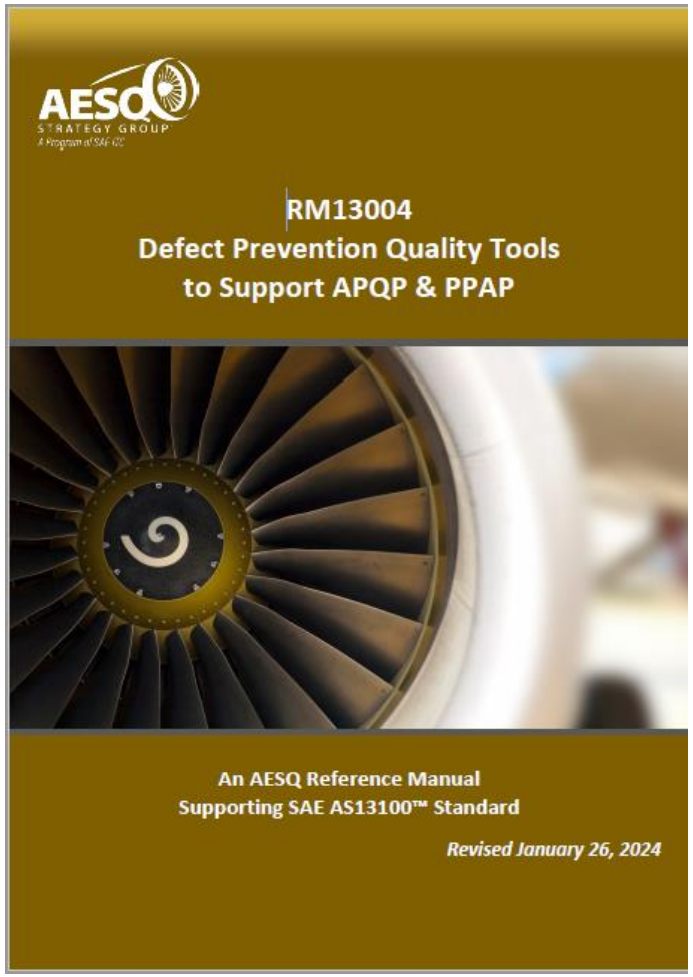
*necessary when the process is not yet in place e.g. still in design & development phase

Where to Get

Further Information

on RM13004

RM13004 Sources of Further Information & Guidance



https://aesq.sae-itc.com

1. **Reference Manual RM13004** is available free of charge from the AESQ website
2. **Subject Matter Interest Group** to support RM13004 Deployment established and contactable through AESQ Website
3. **RM13004 LinkedIn Community of Practice** established to answer questions and share best practice (https://www.linkedin.com/groups/9044623/)

Other Reference Manuals and Subject Matter Interest Groups exist for;

RM13000 Problem Solving

RM13001 DPRV Training

RM13002 Inspection Planning

RM13003 MSA

RM13005 Quality Audit

RM13006 Process Control

RM13007 Sub Tier Management

RM13008 Design Work

RM13009 Compliance Assessment

RM13010 Human Factors

RM13011 Rework & Repair

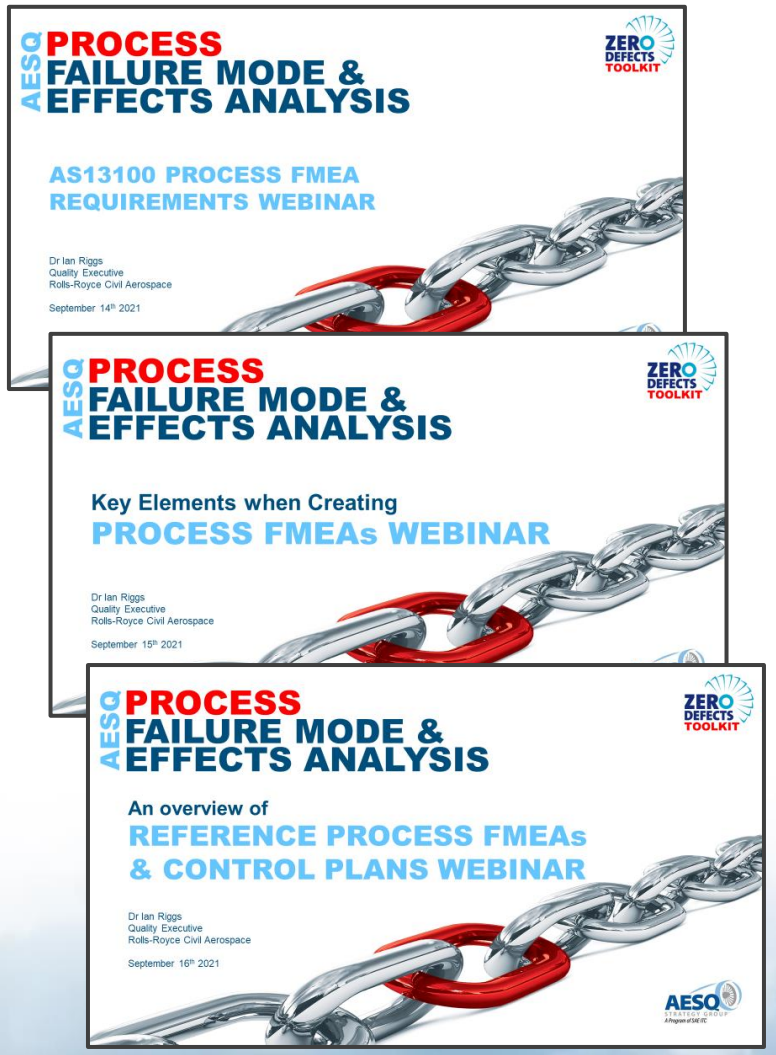
RM13102 First Article Inspection

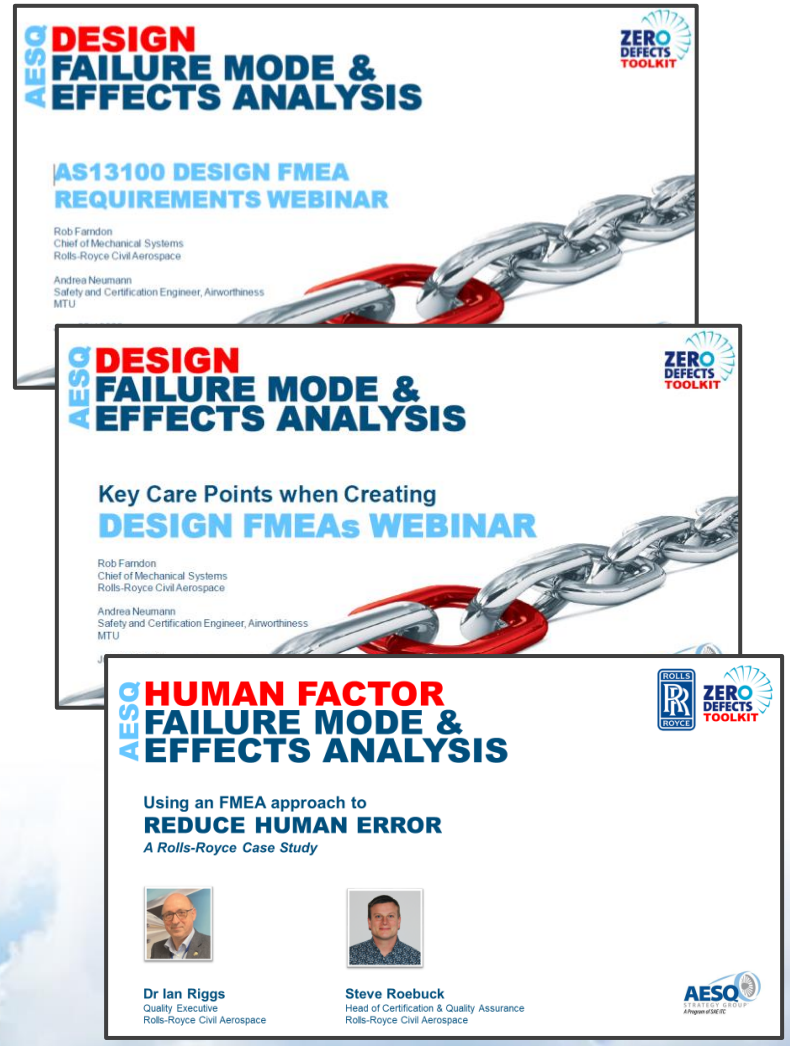
RM13145 APQP / PPAP

AESQ RM13004 Available Webinars

SCAN ME

Video recordings and presentation materials of other RM13004 FMEA Webinars are available to download from https://aesq.sae-itc.com/defect-prevention





SCAN ME

Check the AESQ Website Future Events page for updates.

AESQ PROCESS FAILURE MODE & EFFECTS ANALYSIS

ZERO DEFECTS TOOLKIT

RM13004 FMEA Software User Insights

FREE Webinar

Ebru Cetin
MTU Aerospace

Jonas Nickel
Rolls-Royce

Date To Be Confirmed in 2024

COMING SOON

What other subjects would you like the RM13004 SMIG Group to cover? Contact the LinkedIn CoP to let us know

SCAN ME

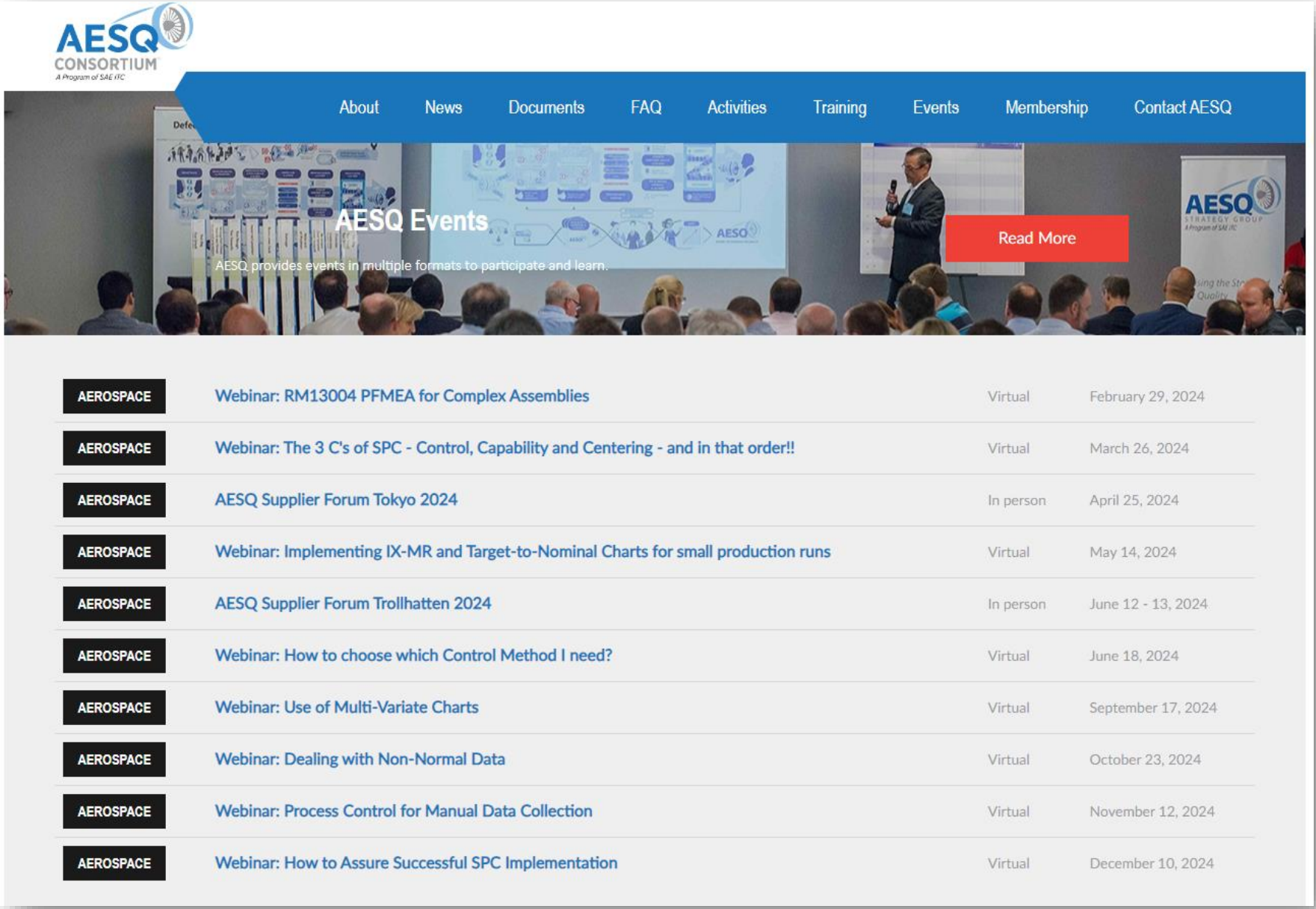
LinkedIn RM13004 Community of Practice (CoP)

AESQ 2024 Webinar Schedule

More will be added throughout the year.

SCAN ME

Check the AESQ Website Future Events page for updates.



AEROSPACE	Webinar: RM13004 PFMEA for Complex Assemblies	Virtual	February 29, 2024
AEROSPACE	Webinar: The 3 C's of SPC - Control, Capability and Centering - and in that order!!	Virtual	March 26, 2024
AEROSPACE	AESQ Supplier Forum Tokyo 2024	In person	April 25, 2024
AEROSPACE	Webinar: Implementing IX-MR and Target-to-Nominal Charts for small production runs	Virtual	May 14, 2024
AEROSPACE	AESQ Supplier Forum Trollhatten 2024	In person	June 12 - 13, 2024
AEROSPACE	Webinar: How to choose which Control Method I need?	Virtual	June 18, 2024
AEROSPACE	Webinar: Use of Multi-Variate Charts	Virtual	September 17, 2024
AEROSPACE	Webinar: Dealing with Non-Normal Data	Virtual	October 23, 2024
AEROSPACE	Webinar: Process Control for Manual Data Collection	Virtual	November 12, 2024
AEROSPACE	Webinar: How to Assure Successful SPC Implementation	Virtual	December 10, 2024

Thank You for Attending This Webinar – We Hope You Found it Interesting