Supplier PPAP Requirements

BAE Systems, Electronic Systems US Defense

Revision G

September 11 , 2024

BAE SYSTEMS

Date	Author	Rev	Description
5/24/18	P. Trainor	-	Initial release per DCR DRB31135
2/12/19	M. Goderre	A	Updated for closer alignment to AS9145
4/12/21	M. Goderre, L. Dudley	B	Updated to align with AS9145 and associated BAE documents. Updated to reflect associated command media
2/15/22	M. Goderre, L. Bourne	C	Incorporated new test equipment PPAP requirements, MFA requirements, PPAP samples requirements, DFMEA guidelines and rating scales, and a table of figures. Updated PPAP clausing summary, Control Plan requirements, PFMEA detection rating scale guidelines, FAI requirements, and moved all FMEA rating scales to the Appendix.
4/15/22	L. Bourne	D	Updated Definitions, DFMEA section, MSA section, Appendix D, and Figure 1. Added Acronyms section, pre-production requirements in sections 5.5-5.10, Appendix H, and figures 4 & 5. Removed material test results, qualified labs, and checking aids sections.
6/27/22	L. Bourne	E	Removed PPAP submission clausing section and renumbered remaining sections. Added Submission Timing section 6.1.
10/30/23	L. Bourne	F	Re-ordered sections. Added sub-sections to section 5.9, and a reference to PO Packaging Requirements Codes. Added Section 9.2 for Capacity Verification.
9/11/24	L. Bourne S. Mollner R.Ibañez	G	Removed references to clause 099 in section 6 and figure 1. Created sub-section headers for section 5.5 PFMEA (5.5.1-5.5.4 and 5.5.10). Content under sub-sections 5.5.2, 5.5.3, and 5.5.10 is new. Removed ITE requirements. Changed order of contents and renumbered sections. Added Figure 17. Updated Purpose. Compiled all APQP tables. Removed obsolete document B25279. Sections 4.1.1: Added Preliminary Risk Assessment (ARA) requirement for organizations with Design Authority. Added ARA definition

Revision History

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1. Purpose

The purpose of this document is to serve as a guide and define the Production Part Approval Process (PPAP) as part of Advanced Product Quality Planning (APQP) process required on orders with quality clause 199, Scope of Work or other agreements. BAE Systems' requirements are aligned with SAE AS9145.

PPAP activities are measures that ensure high product quality and are achieved through concurrent process and product design and development built into the APQP phases.

There are ten PPAP Elements which are potentially applicable when required. The criteria used to identify the PPAP requirements are described in the subsequent sections of this document. The selected applicable requirements will be defined in the PPAP Submission Electronic Portal per section 5.2 or equivalent form and shall be agreed between BAE Systems and the supplier when establishing scope for the PPAP.

1.1 APQP Process

APQP has five phases (conceptually illustrated in Figure 1) starting with conceptual product needs and extending throughout the product life cycle. The actual duration of each phase will differ depending upon the scope and timing of the specific product and/or production development project.

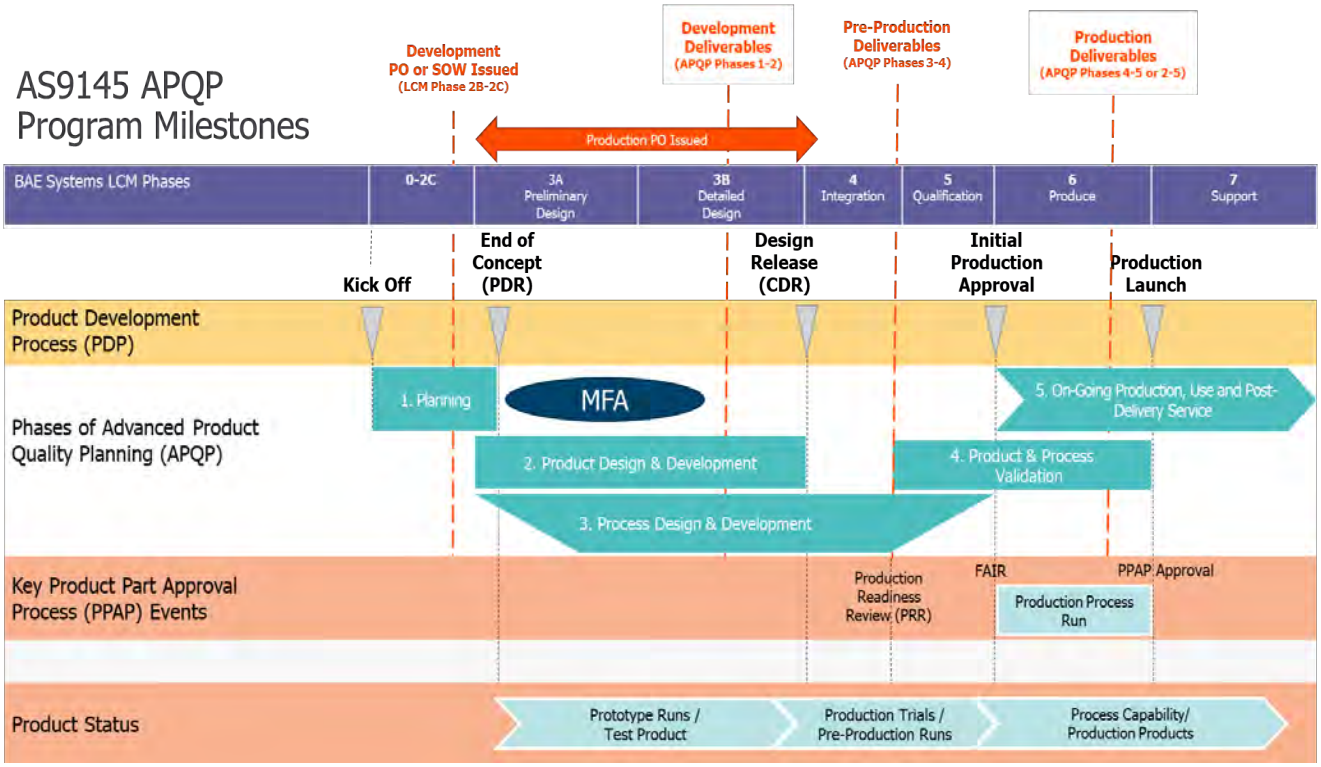


Figure 1. Product development process and advanced product quality planning (conceptual illustration).

1.2 Production Part Approval Process (PPAP)

The purpose of PPAP is:

- To provide the evidence that all engineering, design record and specification requirements are properly understood and fulfilled by the manufacturing organization and their processes.
- To demonstrate that the established manufacturing processes can produce consistently conforming product, which meets all requirements during an actual production run at the quoted production rate.

2. Scope

BAE Systems may require a PPAP submission per purchase order requirements, when any of the following occur:

New parts, processes, or suppliers

- New part or product
- New process or technology
- New supplier
- New Customer Standard

Changes to existing product

- Change to design including material, construction, or component.
- New, additional, or modified tools
- Refurbishment of current tools
- Production or equipment transfer to a different location
- Change of sub supplier or material source
- New source of raw material
- Change in production process or method
- Product when tooling has been inactive for 12 months or greater.
- Major environmental impact affecting fit, form or function of the product.

The requirement may be flowed down by a SOW or by PPAP clausing on the PO. PPAP Clausing is defined by the released Quality Assurance Codes used at the time the BAE Systems PO is issued. All QA Code Requirements are located on the BAE Systems Supplier Center.

3. Ongoing Requirements

BAE Systems reserves the right to request any information you have provided in any data or document in any element of approval, at any time, including after the approval has been granted. PPAP documents are considered “living” documents, and all documents shall be maintained to be IAW the latest revision of this document (B45157). The Process Flow Diagram, PFMEA, and Control Plan are “living” documents and shall be updated as risks are mitigated, new risks are identified, or additional controls are put in place.

4. Element Requirements

BAE Systems PPAP requirements are based on SAE AS9145. The following elements in Table 1 are required (unless otherwise specified by the BAE Systems SQE):

Table 1. APQP Activity & PPAP Submittal List

	Production Part Approval Process (PPAP)Elements	APQP Phase	Preliminary PPAP	EDM PPAP	Production PPAP
1	Design Records *	2	◆	◆	
	1.a. ARA (AS9145 Risk Assessment) *	2	◆	◆	◆
	1.b. Manufacturing Feasibility Assessment (MFA)*	2	◆	◆	◆
2	Design Risk Analysis (e.g., DFMEA) KC and CI identified	2	◆	◆	◆
3	Process Flow Diagram	3		◆	◆
4	Process Failure Mode and Effects Analysis (PFMEA)	3		◆	◆
5	Control Plan (CP)	3		◆	◆
6	Measurement System Analysis (MSA)	4		◆	◆
7	Process Capability Studies	4		◆	◆
8	Packaging, Preservation, and Labeling Approvals	3			◆
9	First Article Inspection Report (FAIR)	4			◆
10	Customer PPAP Requirements	4			◆
11	PPAP Approval Form (Part Submission Warrant, PSW)	4			◆

◆ - Initial Submittal ◆ - Updated

*Supplier is Design Authority

NOTE: BAE Systems provides suggested templates of all forms for the PPAP submittal. However, Supplier generated forms meeting the requirements of SAE INTERNATIONAL AS9145™ and SAE J1739 may also be utilized. Completion and submission of PPAP records conveys no additional data rights to BAE Systems than that defined in the respective Procurement Agreement.

Table 2. Timing of Events Table

Activity	Timing
Development	
Preliminary PPAP	30 days after the supplier's design is completed (suppliers CDR), or as agreed upon with BAE Systems
Complete EDM PPAP	Supplier has completed 50% of their delivery or agreed upon with BAE Systems
Production	
Complete Production PPAP	10 days before the start of BAE's production builds (LRIP and FRP)

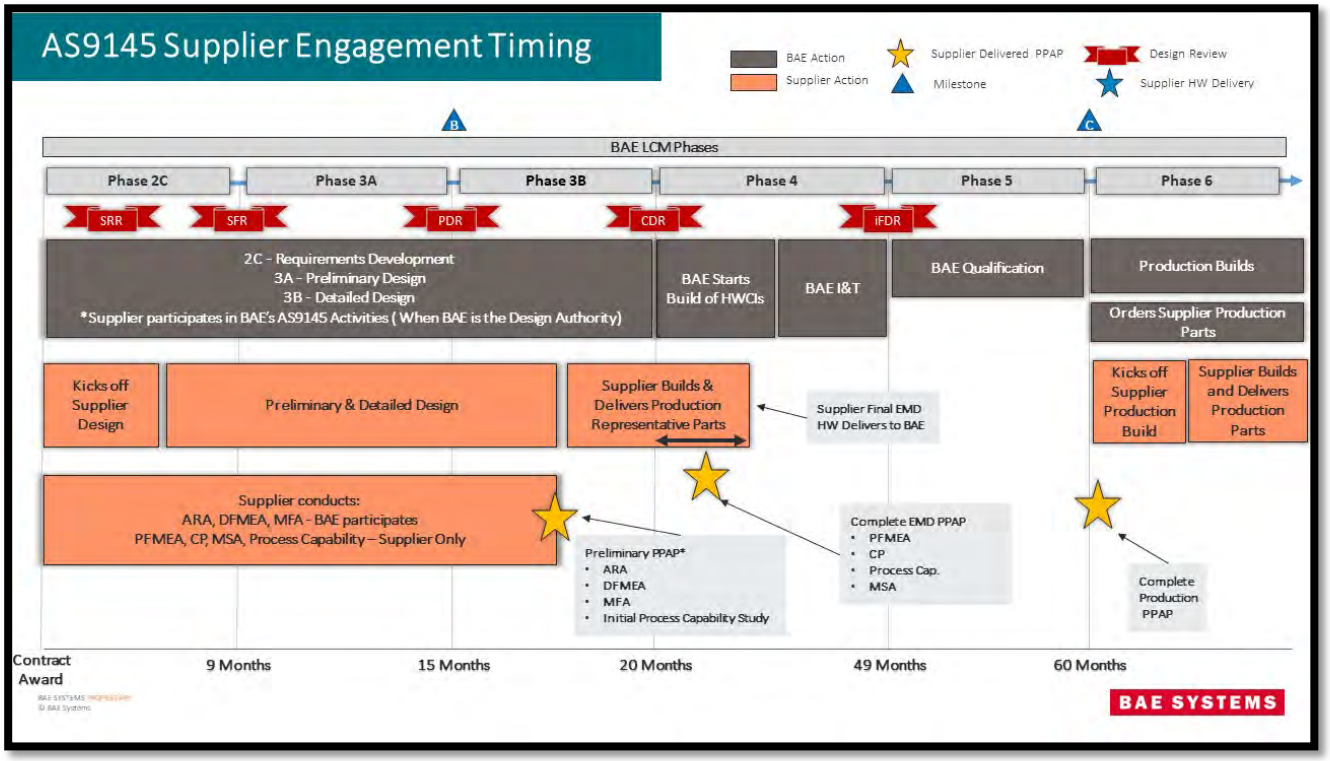


Figure 17. PPAP Delivery Requirements Overview During Development and Production.

4.1 PPAP Elements & Phase Alignment

Element Applicability

Certain PPAP elements in Table 1 may not be applicable to some programs. The BAE Systems SQE will indicate if an element(s) is N/A in the Net-Inspect PPAP System or on a paper PPAP Approval Form. Any substitutions from the standard submission will be noted in the comments.

The following are examples when the BAE Systems SQE may adjust the applicability of elements based on the APQP phase:

4.1.1 APQP Phase 1

- Preliminary Design Records and DFMEAs can begin in phase 1 but aren't deliverables until phase 2.
- The supplier shall perform a Preliminary Risk Assessment (ARA) when the organization has Design Authority.
- The ARA should be conducted:
  - No later than at the beginning of the Product Design and Development Phase and the product introduction cycle.
  - When there is a change to the design of the product
  - When there is a change to the manufacturing process or source of supply.
- The following considerations are needed to assess risk:
  - New Technology, Material, or new/untested designs
  - New or Complex Application/Environment of existing technology
  - New requirements (Technical, Environmental or Regulatory)
  - Is item impacted by Cyber Security?
  - New Supplier(s) and/or Supplier Performance Issues
  - New Manufacturing Requirements
  - Historical quality and/or yield issues with make or buy items
- BAE Systems Form TM389 can be used if supplier does not have a form to capture the results of the Preliminary Risk Assessment

4.1.2 APQP Phase 2

- If the supplier does not have design authority or the program has fully completed the development phase, the Design Records may not be required.

- There should be an assessment of the BOM, including internally assembled and purchased parts, relative to the following;
  - Technology
  - Logistics
  - Lead-time Obsolescence
  - Authenticity
  - Counterfeit Parts Prevention
  - Sole Sourcing
  - Productivity
  - Capability
  - Quality
  - Cost
- These assessments should be carried forward into the APQP Phase III where they can be integrated into the PFMEA and Control Plan as appropriate.
  - A parts list may be used in place of a BOM provided the BAE Systems SQE and Program Engineer agree.
  - An unreleased drawing can be used as part of interim approval, but a released drawing shall be in place before full PPAP approval is granted.

- If the supplier does not have design authority or the part is currently being produced, the DFMEA may not be required.

– A CDR (Critical Design Review) may be used instead provided the BAE Systems SQE & Program Engineer agree.
– Key points from DFMEA's created by BAE may be carried forward for consideration when the Control Plan and PFMEA is being created.

- If the supplier has design authority a DFMEA will be required unless otherwise noted by BAE.
- A revised DFMEA may be required if the Design Change or Reliability triggers noted in Section 6 are in play.

4.1.3 APQP Phase 3

- In cases of Corrective Action, a partial PPAP submission that includes the APQP documentation affected (Process Flow, Control Plan, PFMEA) and a new Approval Sheet, can be allowed.

4.1.4 APQP Phase 5

- The BAE Systems SQE will use his/her discretion to determine which metrics will be tracked and how they will be reported back to the supplier.

4.2 Design Records

A collection of the design documents, typically including:

- CAD/CAM Math Data
- Part Drawings (ballooned)
- Specifications
- List of all characteristics and requirements

If this PPAP element is required in the scope, the following are the Submission Requirements:

- If BAE Systems is responsible for the design, the Design Records include a copy of the drawing that is sent together with the Purchase Order (PO).
- If supplier is responsible for the Design, this is a released drawing in supplier's release system. A ballooned drawing shall be submitted as part of the PPAP for every submission when dimensional results are required. A ballooned drawing shows the parts or assemblies in a part drawing with numbered "balloons" that point to individual requirements of the part. The numbers on the ballooned drawing correlate with the numbers found on the Dimensional Data Sheet. See Figure 2 for Ballon Drawing Example
- All part requirements on the BAE Systems or Supplier drawing shall be ballooned and numbered for reference and measurement. These may include:
    - Dimensions and tolerance of parts
    - Electrical requirements (performance data, functional tests, etc.)
    - Visual features (color, texture, etc.)
    - Chemical characteristics (cure time, etc.)
    - Physical and mechanical properties (tensile strength, plating thickness, heat treat hardness, etc.)
    - Any other specified requirement that you have the capability to measure or that is described in the drawing notes or reference specifications.
- When dimensions are specified at multiple location on the drawing, the data for each location should be numbered separately.
- Note: This information can be used for the FAIR

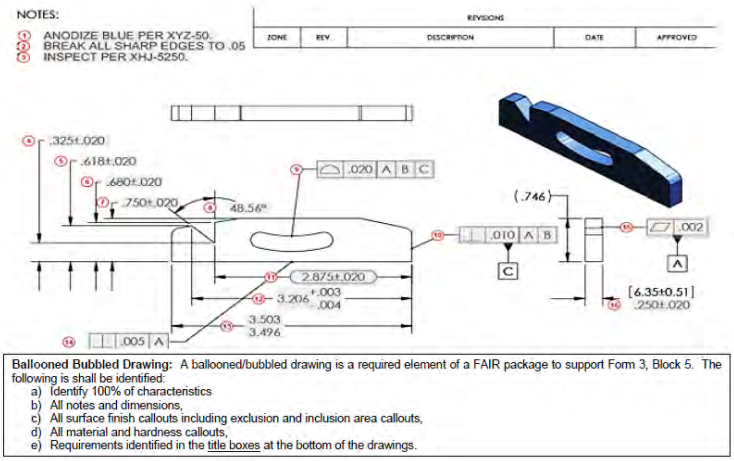


Figure 2: Balloon Drawing Example

4.2.1 Key Characteristics

The purpose of selecting product Key Characteristics is to communicate the risk to manufacturing, assembly and/or other interfacing design disciplines. It is essential that manufacturing engineering is engaged during the technical discussion to understand the impact to manufacturing and assembly when selecting product design.

KCs are essential and should be identified as needed to mitigate risk for both BAE Systems and Supplier designed products. If there are no KCs on the drawing the BAE Systems SQE will work with the supplier to identify potential KCs.

BAE Systems SQE reviews Supplier Manufacturing and Assembly Documentation to confirm they identify, document, and control potential product and process KCs. BAE Systems SQE will ensure suppliers that are design responsible provide Product Producibility and Launch Engineer with their product and process KCs per Supplier PPAP for review and approval.

- Key Product Design Characteristic (KC): is a feature of a product that requires special care because incorrect nominal values/tolerances and corresponding manufacturing/assembly variation may have significant influence on product safety, performance, fit, and service life. [Reference SAE J1739 FMEA Standard].
- Key Control Characteristic (KCC): is a parameter (process characteristic) that requires special care which identifies where variation shall be controlled to ensure process performance remains stable. The purpose of the KCC is to ensure the process is monitored to maintain validated settings and identify variation anomalies requiring attention. These characteristics are measured while the process is running, e.g., machine settings, temperature, pressure, current, fluid level, speed, etc. Process characteristics may be standard or special as shown on a control plan. [Reference SAE J1739 FMEA Standard].

4.2.2 Deviations

When a supplier identifies a drawing or specification issue/error and recommends a change to the BAE Systems drawing. A Supplier Variation Request (SVR) shall be submitted to BAE Systems to review and approve the requested the change. The SVR should be made prior to fabrication or as early in the fabrication process as possible.

Please note the following:

- Material not in compliance with drawing(s) or specification(s) must NOT be shipped without prior BAE Systems Approval.
- The supplier shall receive an approved and closed SVR as authorization to ship product.
- If the SVR disposition requires a drawing change then upon release of the ECO, a PO revision change will be issued to reflect the new part revision Product should not ship until ECO is completed and the SVR closed.
- The supplier must not perform any repair activity before getting BAE Systems approval via a documented repair procedure approved on the SVR by BAE Systems.

A copy of the Supplier Variation Request form and submission instructions can be found on the BAE Systems Supplier Quality Assurance Portal.

4.2.3 Customer Engineering Approvals

The supplier submission is to include BAE Systems Engineering Approval documentation when requested. This will primarily be requested if the supplier has design authority of the parts/products. This will be submitted per direction from BAE System.

4.2.4 Manufacturing Feasibility Assessment (MFA)

If the scope of the PPAP includes development or production trials/pre-production parts or mass production parts to be delivered to BAE Systems, then the supplier will be required to participate in a MFA, unless otherwise specified. The supplier shall assemble a team to work with BAE Systems to complete the MFA.

BAE Systems SQE will hold a kickoff meeting with the MFA team and assign initial actions to be completed.

BAE Systems and the supplier will work together to complete the BAE Systems MFA checklist form. The supplier shall provide appropriate objective evidence to assess each item on the MFA checklist as well as the OPD worksheet, which will map drawing requirements to the manufacturing step responsible for producing the requirements.

It may take multiple sessions during the MFA effort to complete the assessment action items and to provide the necessary objective evidence to make an initial feasibility assessment.

Once the MFA checklist is approved as **Feasible** or **Feasible with Actions,** production purchase orders can be placed with the supplier.

If the assessment is **Feasible with Actions,** then BAE Systems and the supplier will continue to meet as necessary to see all actions to closure before production. No PPAP will be given Full Approval with open actions.

4.3 Design Failure Mode and Effects Analysis (DFMEA)

A Design Failure Mode and Effects Analysis (DFMEA) is a systematic approach used for identifying potential risks introduced in a new or revised design of a hardware-based product.

The primary objective of the DFMEA is to identify potential high risks in a product design and try to keep those high risks from occurring in the end product or if that cannot be accomplished, then to minimize the risk effect(s) to the end product user.

The DFMEA is a systematic group of activities intended to:

1. Identify and understand potential failure modes and their causes, and the effects of failure on the system or end users, for a given product.
2. Assess the risk associated with the identified failure modes, effects and causes, and prioritize issues for corrective action and risk mitigation.
3. Identify and carry out corrective actions and risk mitigation tasks to address the most serious concerns.
4. Document and archive the analysis and distribute the results and lessons learned to other related analysis.

The DFMEA is only required when the supplier has design authority of the hardware. If this PPAP element is required in the scope, the following are important considerations:

Key Characteristics (KCs) are essential and should be identified as needed to mitigate risk for Supplier designed product. KCs are identified on the DFMEA Template in the Potential Key Characteristics column in the DFMEA process and should also be identified on Supplier Hardware Drawings. If no KCs are identified during the DFMEA process, rationale as to why is required and shall be approved by BAE Systems Engineering Stakeholders.

The following is recommended where the propriety of the product allows:

1. BAE Systems should be the DFMEA facilitator in the Supplier DFMEA process.
2. Reciprocal participation is expected from the Suppliers: Subcontractor participation and review of DFMEAs performed by BAE Systems.

BAE Systems has developed a DFMEA form which should be utilized by suppliers. Any template used shall align with the latest revision of SAE J1739.

Severity, Occurrence and Detection ratings are used when performing FMEA activities. These rating scales shall be compliant with the latest revision of SAE J1739. See Appendices A-C.

Any potential failure mode not mitigated in the DFMEA should be included in the PFMEA.

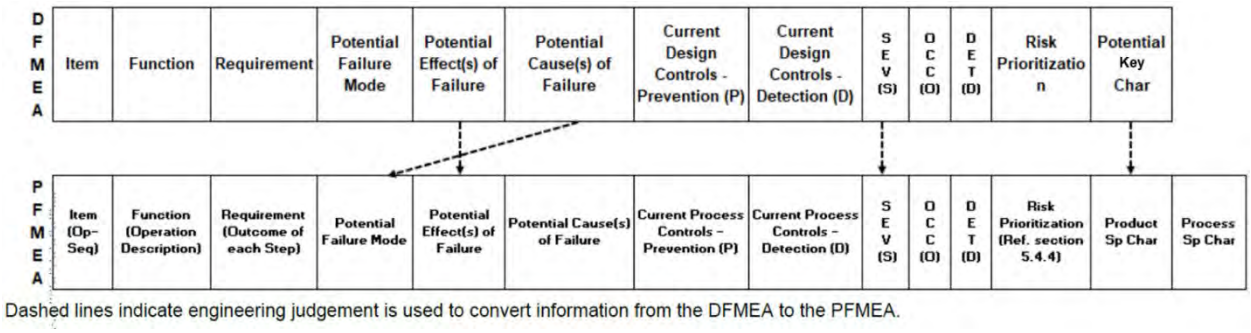


Figure 3: Linkage between a DFMEA and PFMEA

4.3.1 Inputs

Depending on available data, the DFMEA may consider the following inputs:

- Concept / Theory of Operation
- Boundary Diagram
- P-Diagram
- Warranty, recalls and other field history

- Bill of Materials (BOM)
- Technical Solution Baseline
- Reliability Prediction Model (based on the latest BOM with indenture levels)
- List of specific design changes (from the previous versions)
- Requirements
- Operating Conditions and Environments (stresses, de-rating, etc.)
- Interface Control documents
- Test procedures (Preliminary ESS and ATP)
- Prior DFMEAs (Preliminary, Baseline or Product Family)
- Manufacturing Feasibility Assessment (MFA)
- Lessons Learned and Best Practices
- Preliminary Design Verification Plan
- Functional Failure modes identified by systems engineer

4.3.2 Outputs

Depending on contract requirements and analysis objectives, the DFMEA may produce the following outputs:

- Failure Mode Risk Assessment
- Failure Mode Risk Mitigation
- Initial/Updated/Final DFMEA Report
- DFMEA Worksheets
- List of Critical Items (CIs)
- List of potential product KCs
- List of Recommended Actions
- Design Verification Plan and Report (DVP&R)
- Revised Risk Assessment
- Updated test requirements (manufacturability, test solution, testability, etc.)

4.3.3 Process Flow

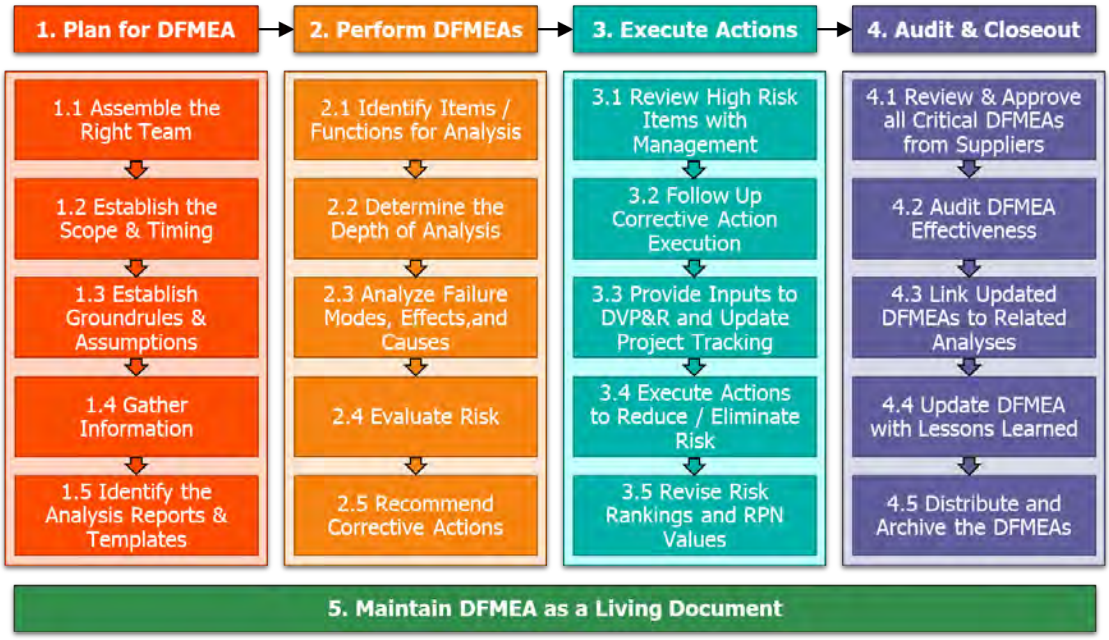


Figure 4: DFMEA Process Flow Diagram

4.3.4 Process Steps

1. Plan for DFMEA Activities (Stage 1)

Step #	Responsible Role(s)	Task
1.1	DFMEA Facilitator	**Assemble the right team**. A team consists of knowledgeable individuals who perform the DFMEA analysis. • DFMEA Facilitator (BAE), Engineering Lead (Supplier) and/or NPI Engineer (Supplier), Reliability Engineer (BAE), Regional SQE (BAE), Business Area SQE (BAE), SCA (BAE), and any other Supplier personnal deemed appropriate by the Supplier's Team. **All the following tasks are performed by the team, but the DFMEA Facilitator is responsible for leading the tasks.**

Step #	Responsible Role(s)	Task
1.2	DFMEA Facilitator	**Establish the scope and timing.** The DFMEA should typically be started after project initiation and completed prior to design release (or design freeze). DFMEAs are performed for three basic cases, each with a different scope or focus. • Case 1: New design or new technology. The scope of the DFMEA is the complete design or technology. • Case 2: Modifications to existing design, which may also include changes due to past failures. The scope of the DFMEA should focus on the modification to design, possible interactions due to the modification, and field history. • Case 3: Use of existing design in a new environment, location, or application, or change in duty cycle (when no physical change made to design). The scope of the DFMEA is the impact of the new environment, location, or application/usage on the existing design. Visualize the scope by creating a boundary diagram.
1.3	DFMEA Facilitator	**Establish ground rules and assumptions and document in DFMEA preparation system.** The ground rules include the definition of failure, coding system used, risk prioritization approach, coordination between different disciplines, and the process for obtaining approvals on the recommended actions and follow-up for execution. The assumptions include details on operational profile, environmental conditions, technical limitations of manufacturing process, possible product abuse.
1.4	DFMEA Facilitator	**Gather information to conduct DFMEA.** Refer to **Section 4.3.1** on DFMEA inputs. DFMEA Facilitator collaborates with Program Reliability & Supplier Engineering Lead, as needed.
1.5	DFMEA Facilitator	**Identify the desired DFMEA reports and their templates.** Refer to **Section 4.3.2** on DFMEA outputs.

2. Perform and Document DFMEAs (Stage 2) - All the following tasks are performed by the team, but the DFMEA Facilitator is responsible for leading the tasks they are responsible for.

Step #	Responsible Role(s)	Task
2.1	DFMEA Facilitator	**Identify Items/functions for analysis** • Identify top-level hardware/functions for analysis, as defined in the program planning documents. • Identify specific changes to the product design, including new items (parts and assemblies) and technologies used, modifications due to past failures, as well as changes in operational environments, locations and/or application/usage profile. • Identify the affected items and functions for further analysis. • Prepare P-diagram when applicable (Optional)
2.2	DFMEA Facilitator	**Determine the depth of analysis** • Determine the focus elements for system, subsystem / module, or component / sub-assembly level DFMEAs considering the risk factors associated with the design as well as the level of details available about the design. • Include subject matter experts who have specific knowledge and experience about the product pedigree and applied technologies where applicable to identify critical areas for analyzing failure modes and recommend preventive controls. • Perform or update preliminary risk to select the areas for more detailed analysis. Critical areas that require detailed analysis could include: o Potential for safety issues o History of significant test, field, and manufacturing issues o Field failure history of similar products and test equipment o Potential for important regulation issues o Mission-critical applications o Supplier capability
2.3	DFMEA Facilitator	**Determine Functions/Requirements, Failure Modes, Causes and Effects for each item under analysis.** • Identify current prevention and detection controls. • Assess rankings for occurrence, severity and detection using Appendices A-C.

Step #	Responsible Role(s)	Task
2.4.1	DFMEA Facilitator	Assess Risk and Identify High Risk Items • Determine Action Priority and risk priority number (RPN). Determine High/ Medium / Low risk items using BAE Systems Risk Prioritization Approach in Appendix D. • Identify Critical Items (CIs) as required. • Identify potential Product KCs. May perform Criticality Analysis as desired (Optional). Construct criticality matrix (Optional).
2.4.2	DFMEA Facilitator	Evaluate the risk associated with the design and test equipment • Consider potential safety issues, potential for important regulation issues, history of significant manufacturing or test equipment problems and/or test or field failures, mission-critical applications, and supplier capability
2.5	DFMEA Facilitator	Recommend corrective actions • Mitigate high risk failure modes through Corrective Actions including product re-design, changes to product and test equipment DVP&R, updates to requirements, product drawings / documents to correct error. • Identify specific actions to address potential product KCs including design changes, verification methods, and test plan. • Distribute and save work-in-progress DFMEA worksheet. • Update KC List, as applicable. May perform other activities as required in support of coordinated efforts, such as Testability Assessment and/or support to Maintainability Analysis.

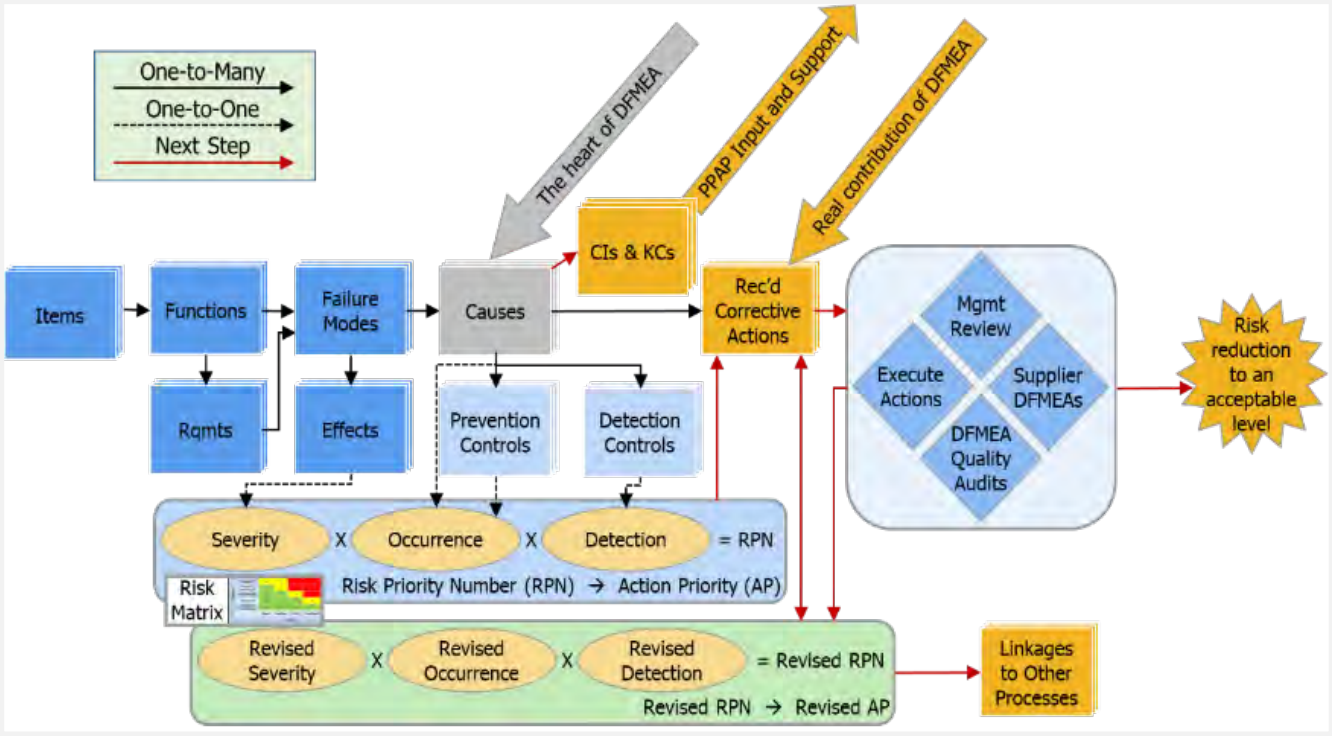


Figure 5: DFMEA Analytical Process and Relationship Between Various Elements

3. Execute Recommended Actions (Stage 3) - The DFMEA Facilitator is responsible for leading the tasks they are responsible for, but they are performed by the team.

Step #	Responsible Role(s)	Task
3.1	DFMEA Facilitator	**Review high risk items with BAE Systems Program Engineering Management.** • Review critical items (CIs) and Product KCs. Incorporate the inputs from Engineering on Product KC specifications and tolerances. • Discuss recommendations and consequences of not completing corrective actions. **Note:** management will determine actions to execute based on risk, and constraints such as budget and schedule. • Identify risks for any corrective actions not selected for program to be implemented using the risk management procedure and document this in the DFMEA (preparation system).
3.2	DFMEA Facilitator	**Follow up corrective action execution.** Document the responsible person/department and target completion date in the DFMEA (preparation system). DFMEA Facilitator collaborates with Program Reliability Lead, as needed.

Step #	Responsible Role(s)	Task
3.3	Reliability Engineer	**Provide inputs (adjudicated recommendations, see step 2.4.2) to DVP&R and KC List** and update DFMEA project tracking. Update KC List in coordination with Engineering.
3.4	Reliability Engineer	**Communicate DFMEA risks to PEM and Execute actions to reduce/eliminate risks as approved by program**.
3.5	DFMEA Facilitator	**Revise risk rankings and RPN values**. See Appendices A-C. May update Criticality Analysis if applicable (Optional).

4. Audit and Closeout (Stage 4) - The DFMEA Facilitator is responsible for leading the tasks they are responsible for, but they are performed by the team.

Step #	Responsible Role(s)	Task
4.1	Supplier	**Review and Approve any 2nd tier supplier DFMEAs associated with mission critical items.** Collaborate with BAE Systems as needed.
4.2	DFMEA Facilitator	**Assess DFMEA effectiveness** in achieving the objectives. Team to provide feedback to improve the effectiveness of the DFMEA process (when applicable).
4.3	Supplier	**Upload DFMEA worksheet and Supporting Documents to the BAE Systems Secure PPAP Management System (when the propriety of the product allows).**
4.3	Reliability Engineer	**Link DFMEAs to other related analysis (when the propriety of the product allows).**
4.4	Supplier	**Update DFMEA with lessons learned (e.g., systemic process, product, and test equipment related)**.
4.5	Supplier	Keep the DFMEA updated throughout product development lifecycle (i.e., update for each Engineering Change Order). Feedback Failure events, corrective actions, and changes to the product design, operating conditions, or regulations, into the DFMEA throughout the lifecycle to maintain compliance to AS9145 and industry best practices. **Resubmit updated DFMEA worksheet within BAE Systems Secure PPAP Management System (when the propriety of the product allows).**

4.4 Process Flow Diagram (PFD)

The purpose of Process Flow Diagrams (PFD) is to document and clarify all the steps required in the manufacturing and assembly of a part. The partitioning of the overall PFD into individual PFDs depends on who is responsible for the manufacturing, assembly, or aftermarket operations. The general rule is whomever has process responsibility should have ownership for the corresponding PFD. The supplier who is responsible for manufacturing individual components should have responsibility for completing the manufacturing PFD.

If this PPAP element is required in the scope, the following are the Submission Requirements:

- The primary process steps shall be linked to both the PFMEA and the Control Plan so that all process steps are addressed for risk and control.
- The final production PFD shall include the entire manufacturing process, receiving through shipping, including operation sequence numbers.
    - NOTE: The initial pre-production PFD may not be all encompassing of the entire production process since it may not be finalized at the time of submission.
- The Process Flow Diagram shall also include key steps in the process and offline activities (such as measurement, inspection, and special processes).
- The flow of the nonconforming material such as scrap parts, non-conforming parts and rework parts should also be included.
    - NOTE, the supplier is not authorized to perform a repair on a part and shall contact BAE Systems for authorization. Inputs and outputs for each process step should be listed.
- The inputs and outputs are extremely useful when creating the PFMEA and Control plan. The SAE J1739 PFD template is recommended as it has direct linkage to the PFMEA template.

PFD templates are located on the BAE Systems Supplier Center.

[Reference SAE J1739 FMEA Standard or SAE AS13004 Process Failure Modes and Effects Analysis (PFMEA) and Control Plans].

NOTE: Suppliers may utilize their own Process Flow Diagram format. In addition to the above requirements, the supplier's template should include a header which includes the Part Number, Description, HDW/DWG Revisions, Original Creation Date, Prepared By (name), PFD Revision, PFD Revision Date, and Revised by Date.

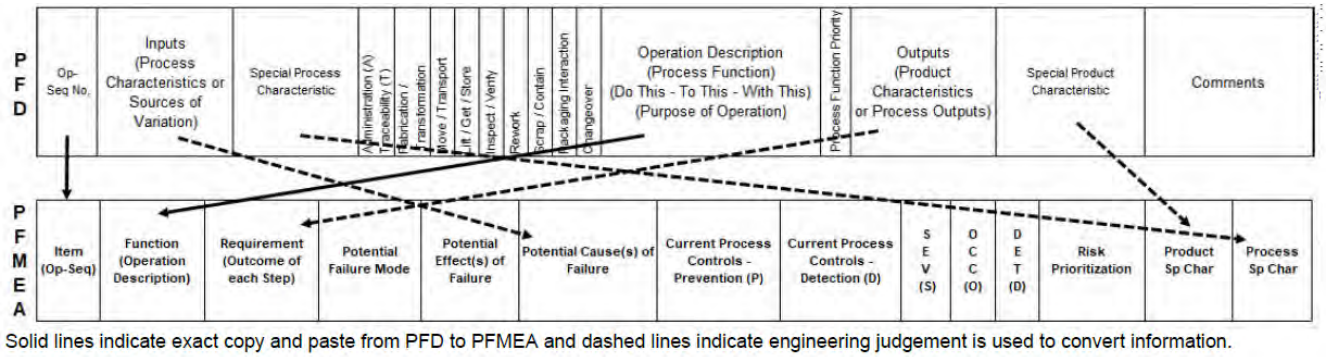


Figure 6: Linkage between the SAE J1739 PFD template to a PFMEA.

BAE PART SPECIFIC PROCESS FLOW DIAGRAM (PFD)

Process Flow Diagrams is to document and clarify all the steps required in the manufacturing of a part.
Process flows must include the entire manufacturing process, receiving through shipping.

Part #:	*800XXXX-1*
Description:	*winshield wiper*
HDW / DWG Rev:	*A/B*
Org. Creation Date:	*1/10/2022*
Prepared by:	*Jane Smith, Derek Brown, Sarah Stone,*
PFD Revision:	*2*
Rev Date:	*2/7/2022*
Revised By:	*Jordan Roberts*

A = AUTOMATIC
M = MANUAL
V = VISUAL
Q = QUALITY AUDIT

Changeover Key
P = PRODUCT
T = TOOLING
S = SOFTWARE
D = DUNNAGE

example text listed below

Op-Seq	Process Characteristics Sources of Variation (Inputs)	Special Process Characteristic	Operation Type: Administration (A) / ceability (T)	Operation Type: ication / Transformation	Operation Type: ve / Transport	Operation Type: / Get / Store	Operation Type: pect / Verify	Operation Type: work	Operation Type: rap / Contain	Operation Type: ckaging Interaction	Operation Type: angeover	Operation Description (Process Function) (Do This - To This - With This) (Purpose of Operation)	ess Function Priority	Product Characteristics (Outputs)	Special Product Characteristic	Comments
10												***Receiving***				
10.1	*1. box cutter 2. barcode reader*		*A / T*	X								*Open Box & Scan paperwork barcode*		*Printed Receiver*		*Traceability*
10.2	*barcode reader*		*T*			X						*Get ESD bag*		*Correct ESD bag*		*Traceability*
10.3	*ESD bag*				X							*Place parts in ESD bag*		*No Damage*		
10.4	*1. Parts 2. Paperwork 3. Bin*				X							*Place parts & paperwork in bin on Incoming Inspection Rack (FIFO)*		*Jobs in order (FIFO)*		

Figure 7: SAE J1739 PFD template example.

BAE PART SPECIFIC PROCESS FLOW DIAGRAM (PFD)

Process Flow Diagrams is to document and clarify all the steps required in the manufacturing of a part.
Process flows must include the entire manufacturing process, receiving through shipping.

Part #:	*800XXXX-1*
Description:	*bus bar*
HDW / DWG Rev:	*A/B*
Org. Creation Date:	*1/10/2022*
Prepared by:	*Jane Smith, Derek Brown, Sarah Stone,*
PFD Revision:	*2*
Rev Date:	*2/7/2022*
Revised By:	*Jordan Roberts*

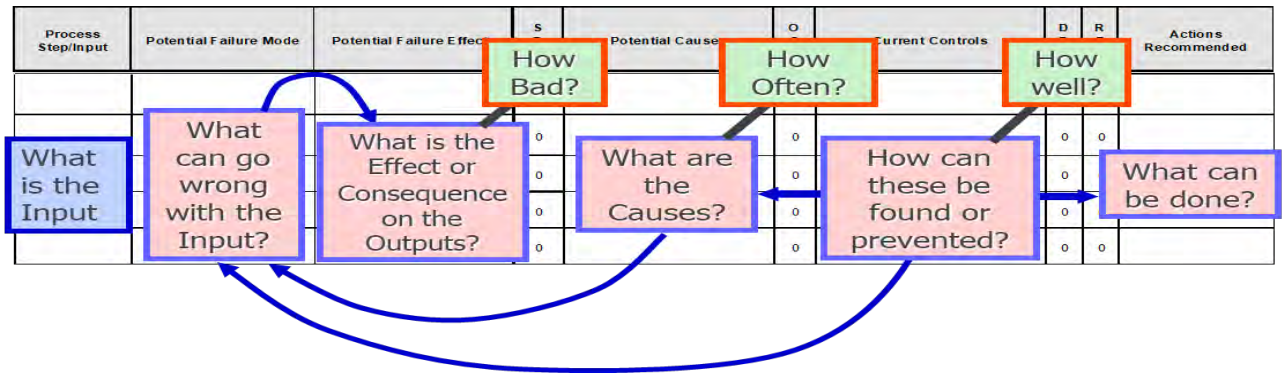
example text listed below

Inputs	Process Step/op #	Outputs
Material arrives, Correct Quantity, Barcode Scanner	Receiving/10	*Parts logged, Sent to Inspection*
Material Pack Slip, Material CofC and Test Reports, Incoming Inspection SOP #1234, Measuring tools	Incoming Inspection & Stock Room/20	*Correct Material, Meets Material Specification, Correct Length, Correct Thickness, Purchased from Authorized Source, Material Sent to Stock*
Correct Bar Stock pulled from Stock, Saw Work Instructions #1235, Correct Saw Blade, PPE	Cut Bar Stock/30	*Cut to correct length and correct width, No burrs or sharp edges*
Correctly Cut Bar Stock, Drill Work Instructions #1236, Correct Drill Bit, PPE	Drill Holes/40	*Correct size holes, No burrs or sharp edges*
Final Part, Final Inspection SOP #1237, Calipers, GO-NOGO Gage, Material CofC	Final Inspection/50	*Verified length, width, thickness and hole size, Verified material CofC, No burrs or sharp edges, QA CofC Created and Signed*
Verified part, QA CofC, Box, Bubble Wrap, Tape, Packaging Work Instructions #1238	Shipping/60	*Pack Slip, Correctly packaged parts, Shipping label*

Figure 8: Example of a Block PFD with inputs and outputs.

4.5 Process Failure Mode Effects Analysis (PFMEA)

A PFMEA project is the entire set of PFMEAs that need to be performed during the process development timeframe to support the quality objectives of the manufacturing/assembly processes and how they relate to the safety, reliability and performance objectives of the product design [reference SAE J1739 FMEA Standard].



If this PPAP element is required in the scope, the following are important considerations:

4.5.1 PFMEA Scope

The scope shall define the process operations required to manufacture and assemble the hardware, electrical, or software for which the team is responsible. The partitioning of the overall project into individual PFMEAs depends on who is responsible for the manufacturing, assembly, or aftermarket operations. The general rule is whomever has process responsibility should have ownership for the corresponding PFMEAs. The supplier who is responsible for manufacturing individual components should have responsibility for completing the manufacturing PFMEAs. PFMEAs shall be in compliance to this document and the latest SAE J1739 standard.

4.5.2 PFMEA Team

PFMEA is a cross functional activity and should not be conducted in isolation. The PFMEA team should consist of subject matter experts who represent cross-functional knowledge associated with the manufacturing, assembly, or service operations and are trained in the PFMEA process. The PFMEA team should include a core team, as appropriate, who meet regularly and understand the details and history of the manufacturing or assembly operations to take the analysis from start to finish. The core team should expand based on the needs of the team (e.g., add disciplines, add more experienced people, etc.).

The reason for a cross-functional team is simply because one person cannot know everything. Multiple disciplines minimize the potential for “blind spots” while conducting the analysis. The project leader, who may be a manufacturing engineer, quality engineer, or PFMEA engineer (facilitator/moderator), should develop a team roster that includes resources assigned to the overall project/program along with additional subject matter experts to ensure the proper expertise is applied to the PFMEA. One of the indispensable values of PFMEA is the journey of discovery. The cross talk and synergy between team members allows them to discover things that individuals often miss.

4.5.3 Ground Rules

- The initial pre-production PFMEAs may not be all encompassing of the entire production process since it may not be finalized at the time of submission.
- The Final PFMEA analysis shall be completed at the detailed operation level as defined by the PFD.
- The PFD operation steps shall be updated based on additions and changes during the development of the PFMEA and control plan.
- Stay focused on operator safety and meeting the requirements of the operation.
- There should be one or more special process characteristics (KCC) for each agreed upon special product characteristic (KC).
- Any known past non-conformances shall be considered when completing the PFMEA. This is especially true for legacy components with NC and SCAR history. Similar parts and PFMEAs shall be considered too.
  Note: It is suggested to have separate PFMEA worksheets for each operation step.

4.5.4 Assumptions

The PFMEA should address manufacturing and assembly risks, while assuming that the product will meet the design intent. It is assumed that parts/materials coming into the operation from previous steps will conform to product specifications. Exceptions can be made as experience dictates (e.g., known deficiencies in incoming part quality). These assumptions are used to keep the team focused on what they have control over.

4.5.5 Potential Failure Mode

Potential failure modes are the manner in which the manufacturing and assembly process could potentially fail to meet the defined outputs of the operation step, called “requirements” in the SAE J1739 PFMEA template. It is a description of a product defect as a result of the process failure (product non-conformance) within a specific operation. Potential failure modes can be in-process related, when the process function and requirement are specific to process outcomes, or a potential product defect when the function and requirement is related to a product outcome. Each failure mode shall be listed separately in order to identify specific potential effects. All potential failure modes for each process step from the process flow diagram should be listed on the PFMEA.

There are several categories of potential failure modes, including:

- Does not meet function
- Over-achieving function (i.e., operation output above acceptable threshold)
- Under-achieving function (i.e., operation output under acceptable threshold)
- intermittent function (i.e., operation output randomly in and out of specification)
- Unintended function (i.e., operator safety)

Note: For legacy parts, NC and SCAR history shall be reviewed to include past known failures.

Item (Op-Seq)	Process Function	Requirements	Potential Failure Mode
30.10	Orient and secure wiper linkage to body structure with battery torque tool	Torque within design specification	Torque too high
30.30	Orient and secure wiper motor ground wire to vehicle with battery torque tool	Ground wire alignment to body	Ground wire damaged during torque operation
30.30	Orient and secure wiper motor ground wire to vehicle with battery torque tool	Torque within design specification	Torque too low

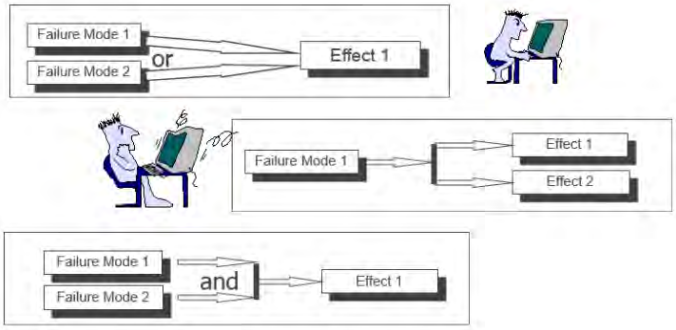
PFMEA Columns Truncated

PFMEA Rows Truncated

Figure 9: Truncated windshield wiper PFMEA failure modes example.

4.5.6 Potential Effects of Failure

Effects are consequences or results of each potential failure mode and will be listed in the PFMEA for each failure mode. Each failure mode can have multiple effects and multiple failure modes may have the same effects.



The effects, for each potential failure mode, can be the effect at the operation, subsequent operations, customer operations, as well as the end customer (operator of the vehicle). If known, the effects of a potential failure mode can include what the customer might notice or experience such as the impact safety or non-compliance to regulations (as applicable). The intent is to forecast the potential effect(s) of failure consistent with the team's level of knowledge.

Item (Op-Seq)	Process Function	Requirements	Potential Failure Mode	Potential Effects of Failure
30.10	Orient and secure wiper linkage to body structure with battery torque tool	Torque within design specification	Torque too high	* In station repair to replace stripped fasteners (4) * Wiper blade angle changes leading to partial loss of visibility (9)
30.30	Orient and secure wiper motor ground wire to vehicle with battery torque tool	Ground wire alignment to body	Ground wire damaged during torque operation	* Major repair out of station station (8) * Intermittent ground leads intermittent loss of visibility (9) * Potential injury to operator fingers (10)
30.30	Orient and secure wiper motor ground wire to vehicle with battery torque tool	Torque within design specification	Torque too low	* In station repair to retorque fasteners (4) * Intermitten ground connection leads to intermittent loss of visiblity (9)

PFMEA Columns Truncated

PFMEA Rows Truncated

Figure 10: Truncated windshield wiper PFMEA potential effects of failure example.

4.5.7 Potential Causes of Failure

All potential causes of each failure mode known shall be listed on the PFMEA. Causes of failure modes shall be listed in actionable terms ("operator error" is not an acceptable cause; instead list actionable causes like "operator selects wrong drill" or "operator release torque tool trigger prior to achieving torque"). There could be multiple causes to a failure mode. Using the 6M typical cause categories may help the PFMEA team determine all the specific causes for a given potential failure mode. Each cause shall be listed separately in order to identify specific prevention/detection controls.

6M typical cause categories:

1. Machine/equipment (machine capability, initial setup adjustment, machine wear over time, inadequate gating/venting, inadequate or no lubrication, tool wear over time, tool breakage, tool-to-tool differences, fixture tolerance, fixture adjustment, fixture wear over time, chip on locator, worn locator, weld current too high or low, weld pressure, heat treat temperature too high or low, conveyor speed too fast or too slow, equipment maintenance including repair, replacement, reassembly, and adjustment, inspection gauging failures including inaccuracies, and ineffectiveness, etc.)
2. Methods/systems (sequence, procedures, layout, off-line rework/repair, off-line inspection, material flow, process control programming, scrap containment, etc.)
3. Material/components (part missing, part mislocated, incoming raw material, purchased parts, previous operations)
4. Manpower/operator (manual over torque, manual under torque, operator skill, ergonomic factors, time, missing or inadequate visual aids, lack of concentration, etc.)
5. Measurements (gauge wear out, gauge out of calibration, etc.)
6. Mother Nature (environment) (e.g., plant temperature, lighting, humidity, dust, noise, etc.)

NOTE: The above examples represent categories. Specific details need to be added to complete the cause description. Only specific errors or malfunctions (e.g., part installed upside down) should be listed; ambiguous phrases (e.g., operator error, machine malfunction) must not be used. The PFMEA team has direct or indirect responsibility towards mitigating the causal risk. Three core risk management tools may be applied to reduce risk. These are: (1) error proof the process or change the design, (2) add a preventative control, (3) add a detective control. Documenting very specific causes makes the analysis more concise and useful.

Item (Op-Seq)	Process Function	Requirements	Potential Failure Mode	Potential Effects of Failure	Potential Cause(s) of Failure
30.10	Orient and secure wiper linkage to body structure with battery torque tool	Torque within design specification	Torque too high	* In station repair to replace stripped fasteners (4) * Wiper blade angle changes leading to partial loss of visibility (9)	Fastener joint degradation due to torque tool out of calibration
30.30	Orient and secure wiper motor ground wire to vehicle with battery torque tool	Ground wire alignment to body	Ground wire damaged during torque operation	* Major repair out of station station (8) * Intermittent ground leads intermittent loss of visibility (9) * Potential injury to operator fingers (10)	Wire damaged during torque operation due to inadequate design to prevent the ground wire connector from twisting during torque operation
30.30	Orient and secure wiper motor ground wire to vehicle with battery torque tool	Torque within design specification	Torque too low	* In station repair to retorque fasteners (4) * Intermitten ground connection leads to intermittent loss of visiblity (9)	Wiper ground wire not torqued to specification due to torque tool trigger released too soon to protect against connector twisting in operator hand (human factors)

PFMEA Columns Truncated

PFMEA Rows Truncated

Figure 11: Truncated windshield wiper PFMEA potential causes example.

4.5.8 Current Product and Process Controls

In PFMEAs, product and process controls are actions or methods that are currently planned or in place to reduce or eliminate the risk associated with each potential failure mode and associated cause. All process controls for each process step-should be listed on the PFMEA. It is recommended to list Prevention Controls in one column and Detection Controls in another column.

Prevention controls describes how a cause, failure mode or effect is prevented based on the current or planned actions but may not be applicable for every cause and/or failure mode. Prevention process controls are based on the application of standards, specifications, process rules, process guides, lessons learned, process norms or best practices, etc., as a means to prevent the occurrence of the cause. Product and process error proofing features and devices and automated process controls are examples of prevention controls.

Detection controls describe how the operation failure mode and/or cause is detected based on automated or manual methods that are currently planned or in place, before the manufacturing or assembly process is released for production. The detection control assumes a failure has occurred and describes how a cause and/or failure mode is detected during the production process. The process control may occur at the subject operation or at subsequent operations and are used as an input to the detection ranking. When not known or not applicable, the detection controls field can be left blank and should be rated according to the detection rating criteria (i.e., detection 10).

A detection control may not be applicable for every cause and/or failure mode. When listing detection controls, it is important to be detailed enough for subsequent reviewer to confirm how well that the process control will, in fact, detect the failure mode and/or cause should it occur.

Details should include the type of automated or mechanical equipment/tooling, operator inspection, and when the detection will occur (in-station or subsequent operation).

Item (Op-Seq)	PFMEA Columns Truncated	Potential Failure Mode	Potential Effects of Failure	Potential Cause(s) of Failure	Current Process Controls - Prevention (P)	Current Process Controls - Detection (D)	PFMEA Columns Truncated
30.10		Torque too high	* In station repair to replace stripped fasteners (4) * Wiper blade angle changes leading to partial loss of visibility (9)	Fastener joint degradation due to torque tool out of calibration	Preventive Maintenance Schedule (PM-2020-R1)	* Visual inspection of calibration Sticker on Torque Tool * First piece verification during torque calibration	
30.30		Ground wire damaged during torque operation	* Major repair out of station station (8) * Intermittent ground leads intermittent loss of visibility (9) * Potential injury to operator fingers (10)	Wire damaged during torque operation due to inadequate design to prevent the ground wire connector from twisiting during torque operation	1) Work Instructions (SAE-2019-TorqueXYZ) 2) Operator training (Form-2019-123xy)	Tactile feel of ground wire twisting during toque operations	
30.30		Torque too low	* In station repair to retorque fasteners (4) * Intermitten ground connection leads to intermittent loss of visiblity (9)	Wiper ground wire not torqued to specification due to torque tool trigger released too soon to protect against connector twisting in operator hand (human factors)	1) Work Instructions (SAE-2019-TorqueXYZ) 2) Operator training (Form-2019-123xy)	Tactile feel torque tool stopped	
PFMEA Rows Truncated							

Figure 12: Truncated windshield wiper PFMEA process controls example.

4.5.9 Severity, Occurrence, & Detection (PFMEA)

The required PFMEA SEVERITY EVALUATION CRITERIA is located in Appendix E. When assigning Severity make sure to prioritize the assignment in to following order of importance:

1. Impact to the End User (When Known)
2. Impact to Ship to Plant (When Known)
3. Impact to your plant

Often times the Impact to the submitting plant is the main or only focus. Doing this overlooks the possibility of undesirable impact to the customer or end user. Two separate columns for severity ratings can be used; one for Internal (impact to plant) and one for External (impact to ship to plant / end user). Following this method would then require two separate RPN columns, one for Internal (impact to plant) and one for External (impact to ship to plant / end user). BAE Systems would then be looking for recommended actions to reduce the high external RPNs. NOTE: Severity scores can only be reduced by a change in design.

The required PFMEA OCCURRENCE EVALUATION CRITERIA is located in Appendix F. This should be used to assess the likelihood that a particular cause will happen and result in the Failure Mode.

The required PFMEA DETECTION EVALUATION CRITERIA is located in Appendix G. This should be used to assess the likelihood that the current controls will detect the cause of the Failure Mode or the Failure Mode itself, PREVENTING the Failure Effect from reaching the customer. The customer in this case could be the next operation, subsequent operations, or the end user.

NOTE: When using the Detection Method Maturity Criteria, objective evidence needs to be submitted to support the system, test or inspection methods are mature (i.e., variable or attribute MSA).

4.5.10 Risk Priority Number (RPN) (PFMEA)

The risk priority number (RPN) is the product of the severity (S), occurrence (O), and detection (D) rating. Within the scope of the individual FMEA, this value is between “1” and “1000”.

The final RPN ratings are relative to a particular analysis and are subjective; therefore, selecting an RPN threshold is not an acceptable practice. Thresholds give the impression that values below the threshold do not need improvement action. In other words, there is no value above which it is mandatory to take a recommended action or below which the team is automatically excused from an action.

This type of behavior avoids addressing the real problem that underlies the cause of the failure mode and merely keeps the RPN below the threshold. It is important to recognize that determining reasonable risk is desirable, it should be based on an analysis of severity, occurrence, and detection, and not through the application of RPN thresholds.

Severity shall be assessed first then occurrence for prevention and then detection to stop the failure mode from getting to the customer. High severity, low RPN can be high risk. The focus of the PFMEA should be to identify opportunities to continually improve the manufacturing and assembly processes.

4.6 Control Plan

The purpose of the control plan is to document control methods imposed on the product and process including for a specific part number: identification of product features and process control settings to be monitored, the measurement methods to be used, and sampling sizes and frequencies along with associated control limits to assure reduced variation and maintain the current quality level.

The control plan details how product quality is controlled and confirmed at each stage of the manufacturing process (from receiving to shipping), including defining the actions to be taken when the process becomes unstable and/or nonconforming product is detected (i.e., reaction plans), when necessary. The control plan should be sufficiently detailed to clearly define who is responsible for completing the specified quality control tasks/activities at each stage of the process. The control plan is agreed to by the supplier’s quality and production departments, and by the customer.

The partitioning of the overall project into individual Control Plans depends on who is responsible for the manufacturing, assembly, or aftermarket operations. The general rule is whomever has process responsibility should have ownership for the corresponding Control Plan. The supplier who is responsible for manufacturing individual components should have responsibility for completing the manufacturing Control Plans.

The Control Plan provides a structure for receiving information from the Process Flow Diagram (PFD) and PFMEA. It also provides the format for capturing the detail on control methods and reaction plans. The Control Plan has 4 major sections of information:

1. Product / Process Information,
2. Characteristics,
3. Methods, and
4. Reaction Plan

The control plan is developed and matured throughout each phase of product development. During the pre-production phase, the number of controls is generally much higher than during serial production since the

producer has not yet identified and removed all sources of variation. The control plan is a living document that is revised and updated throughout the life of the product in response to new quality issues or product/process changes. [Reference SAE AS9145]

The Process Control Plan should place emphasis on pro-active controls at the point of manufacture. Good manufacturing practice should consider: the control of the process inputs to obtain the desired product outputs; employ prevention rather than detection (e.g., use of error-proofing instead of operator dependent work or inspection); and verification of output at the earliest possible operation/step within the process.

4.6.1 Completing the Control Plan

This is a process whereby the Supplier documents all materials and processes involved in the manufacturing process from start to finish. The process flow diagram, ballooned drawing, and PFMEA all provide inputs to the Control Plan. All KCs identified as Process, First-Piece or Safety Related by the supplier or BAE Systems shall be listed on the Control Plan.

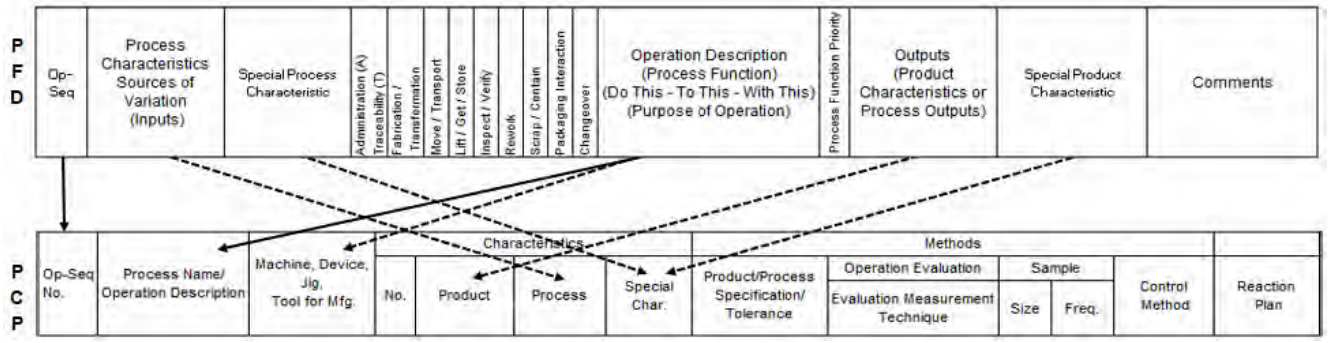


Figure 13: Linkage between the SAE J1739 Process Flow Diagram template and a Control Plan.

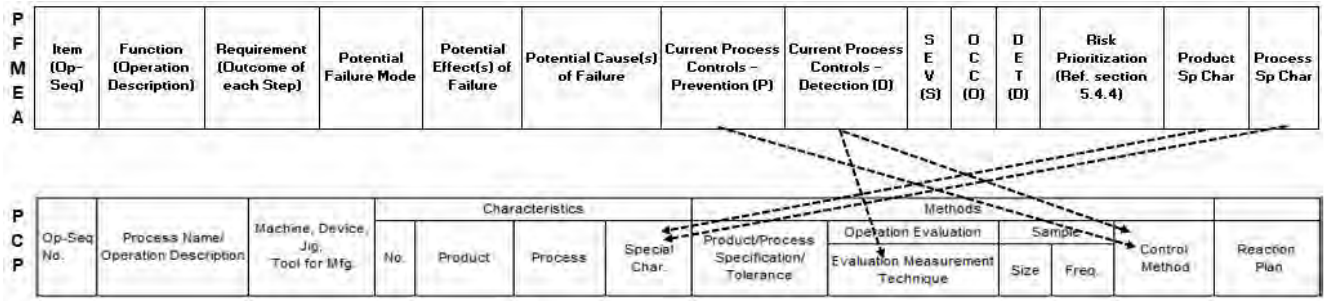


Figure 14: Linkage between a PFMEA and a Control Plan.

All processes should have a control plan that defines all methods used for process control and complies with BAE Systems specified requirements. The control plan should clearly state each step in the process; the specification and all KC characteristics shall be addressed for product and process. The Process Flow Diagram, PFMEA and Control Plan need be aligned. Each major process step in the process flow diagram should correlate with PFMEA steps and there should be documented control plan actions for each of the steps.

If this PPAP element is required in the scope, the following are the Submission Requirements:

The control plan shall contain the following information:

- Organization's name/site designation;
- Key Contact;

- Date of Origination;
- Date of Latest Revision;
- Core Team;
- Part number(s);
- Part name/description;
- Engineering change level (i.e., revision level);
- Phase covered (e.g., pre-production, production);
- Process name/operation description;
  - Shall align with the PFD and PFMEA.
- Machine, Device, Jig, & Tools for Mfg.;
- Characteristic No. (from the FAI balloon drawing);
- Operation/process step number;
  - Shall align with the PFD and PFMEA.
- Product and process characteristics and related Key Characteristics (KCs) and Critical Items (CIs);
  - List Product Characteristics that are important. All features or properties of the part, component or assembly that are listed on engineering drawings. The team should identify the Product Characteristics by referencing: Engineering drawings, customer critical characteristics, key/critical characteristics that affect the product. There may be several for each operation – can be dimensional, performance or visual criteria.
  - List Process Characteristics that are important. A Process characteristic (parameters) is a setting made within a process that effects the variation within the operation. The team should identify process characteristics for which variation shall be controlled to minimize product variation. There could be one or more process characteristics listed for each product characteristic. Examples include: Temperature, Pressure, Speed, Feed, Torque, Flow Rate
- Product or process specification/tolerance;
  - Specifications and tolerances are obtained from engineering specifications or a key process characteristic.
- Evaluation/measurement technique;
  - Identifies how the characteristic is going to be measured. Examples include calipers, attribute gages (go/no-go), fixtures, test equipment, or visual.
- Sample size and frequency;
- Control method, including error-proofing; and
  - This column contains a brief description of how the characteristic will be controlled, including procedure numbers where applicable. Examples include: X-bar/R-chart, Checklist, 1st piece inspection/ 1st piece buyoff, np chart, Log sheet, Lab report, Pre-control chart, Mistake proofing, 100% inspection.
- Reaction plan.
  - The reaction plan specifies what happens when the characteristic or parameter is found to be out of control. Should include: Segregation of nonconforming product, Correction method, and who to contact. Also, may include: Sorting, Rework/Repair, and Customer notification.

The control plan should address all testing requirements, inspection and measurements that are required to verify product quality and conformity. The control plan should not be excessively dependent on visual inspection and should always target prevention techniques wherever possible.

The control plan provides the process monitoring and control methods that will be used to control all product and process characteristics but most importantly the product KCs and process KCCs. All items on Form 3 of the FAI should be accounted for on the Control Plan.

The control plan should be developed in stages, from Prototype to Pre-Production and then into Production. The control plan is a "living" document and shall be updated to reflect any changes to the manufacturing process and its controls throughout product lifecycle. BAE Systems may conduct a Control Plan Audit to verify the execution of the process matches latest revision of the Control Plan.

BAE Systems has developed a Control Plan format which is available for suppliers. The Control Plan template is located on the BAE Systems Supplier Center.

Prototype - Pre-Launch- Production - X					Key Contact / Phone	Quality Engineer			Date (Orig.) 07/24/20xx		Date (Rev.) N/A		
Part Number M21345					Core Team	Operator, Process Engineer, Quality Engineer, Operation MGR			Customer Approval Date 07/24/20xx				
Part Name / Description Fuel- Air Bracket													
Operation	Step	Process Function / Description	Machine, Device, Jig, Tools For Mfg.	Characteristics			Classification	Methods					Reaction Plan
				#	Product	Process		Product/Process Specification/ Tolerance	Evaluation/ Measurement Technique	Sample Size	Sample Freq	Control Method	
Note: Several process steps, and controls are omitted from this example to aid clarity for the standard. A Control Plan will usually cover all process steps and relevant and controls.													
100 - CNC Drill - Drill Holes	4	Drill Holes	CNC Drill			Tool Life		Review tool for wear, dull edges, chips, etc.	Visual Inspection of Tool	100%	Continuous	Life / Usage Control	Inform supervisor if tool life does not produce more than 5 parts before replacement required - stop operation and inform supervisor. If tool life produces 5 or more parts before replacement required - replace tool and re-verify first piece to requirements
100 - CNC Drill - Drill Holes	4	Drill Holes	CNC Drill	4	.375+.002-.000 Fuel Hole Diameter		KC	Control Limit - 0.376+/- 0.0005 Fuel Hole Diameter	CMM	100%	Continuous	Chart results on SPC Run Chart	If results violate run chart rules but is with product specification, adjust process. If results are outside product specification stop operation and launch plant non-conformance process.
100 - CNC Drill - Drill Holes	4	Drill Holes	CNC Drill	5	.375+.002-.000 Fuel Hole Position		KC	True Positon to .002 at Max Material Condition	CMM	100%	Continuous	Chart results on SPC Run Chart	If results violate run chart rules but is with product specification, adjust process. If results are outside product specification stop operation and launch plant non-conformance process.
250 - Cleaning	1	Cleaning; Clean Fuel Holes	Cleaning Station			Cleaning Solution Condition		Cleaning solution must not be in use for more than 1 month	Visual Inspection of Log Book	1	Start of shift	Cleaning station log-book.	If cleaning solution identified as being older than 1 month or has been used for in excess of 100 parts, flush cleaning station and replace cleaning solution.

Figure 15: Example of a Control Plan.

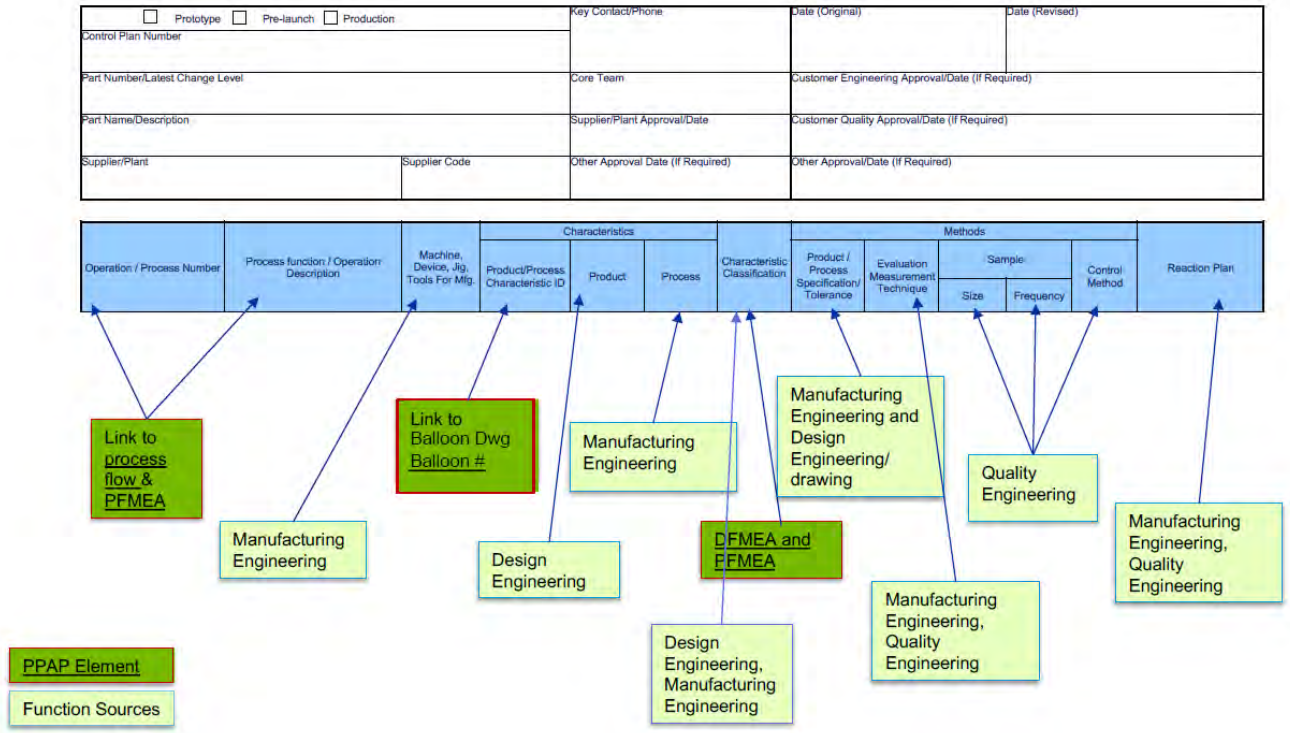


Figure 16: Control Plan Data Sources

4.7 Measurement System Analysis (MSA)

Measurement System Analysis (MSA) is a mathematical method of determining how much variation within the measurement process contributes to overall process variability. MSA is used to ensure the right measurement equipment is used to qualify production parts or processes.

MSA's are conducted on the measurement systems that measure Key Product and Process Characteristics, specifically those which use Statistical Process Control (SPC) to ensure control and conformance.

SPC cannot be implemented until the measurement system is determined to be acceptable.

If this PPAP element is required in the scope, the following are important considerations:

BAE Systems requires an MSA study to be conducted on all measurement equipment that is used to measure and/or accept or fail Product KCs.

If there are no KCs on the drawing the BAE Systems SQE will work with the supplier to identify the Quality Characteristics that are tracked as indicators of the process. These Quality Characteristics could be either Product related KC's or Process related KCC's.

In the pre-production/production trials phase, a MSA Plan for KCs is required. The plan should include:

- How the Appropriate Gage is selected for measuring each KC (ref 4.7.1).
- Type of MSA to be conducted based on data type (variable or attribute).
- Possible environment variation (ref Appendix H).
- Number of operators (ref 4.7.2).
- Operator selection process (ref 4.7.2).
- Number of samples (ref 4.7.2).

- Which manufacturing lot(s) parts for MSA will come from (ref 4.7.2).

A Gauge Repeatability and Reproducibility (GR&R) study is used to ensure that measurements taken in the manufacturing process are reasonably consistent regardless of how many times they are performed or how had performed them. It is important to select a sample size that encompasses the full range of parts.

GR&R studies shall be part specific unless a CMM is used. When measuring with a CMM, a GR&R study from similar components/dimensions can be considered if;

- The basic geometry or type of dimension is similar.
- There are no custom fixtures that would be susceptible to operator loading/set-up variation.
- The data being considered is within the CMM's last calibration period.
- There are no customer requirements for part specific data.

The BAE Systems SQE will use their discretion to determine if individual measurements are required when there is a possibility of using data by similarity.

4.7.1 Gage Selection

- The gage shall be calibrated in accordance with a documented calibration procedure.
- Graduations on the measurement device shall be one-tenth of the tolerance range or smaller (for example a micrometer can measure to the nearest 0.001, it should not be used to measure a feature with a tolerance of less than 0.01).
- Reference Appendix H for additional details.

4.7.2 GR&R Study Design

- Measurements shall be recorded to one decimal place smaller than the tolerance. (For example, if the tolerance is 0.01 the measurements should be reported to a minimum of three decimal places- 0.XXX).
- Typically, variable GR&R has a minimum of 10 parts, 3 operators and 3 trials used for the study. The parts should be chosen randomly from current production and from multiple production lots. There are factors that could impact the number of measurements taken. These could include:
    - KCs may require additional measurements to increase the degree of confidence in the results. Additional parts are preferred, over additional operators or replicates.
    - Large/bulky parts or low volume parts may dictate fewer samples and more trials.
- For KCs, a work instruction should be developed that provides specifics on how set-up the measurement system and how to perform the measurements. These specifics could include orientation of part, pressure applied to measurement device, mastering frequency of measurement device, etc.
- The operators should be selected from those that would normally perform this type of inspection.
- The inspections should be made in random order. The operators should be unaware of which numbered part is being inspected.
- Minitab can be used to create a Gage R&R Study worksheet which will automatically create a random run order. If the supplier does not have access to Minitab, please use the data collection sheet located on the BAE Systems Supplier Center and have the BAE Systems SQE run the GR&R study in Minitab for the supplier.
- Neither operators nor measurement devices should be changed during the duration of the study.
- Reference Appendix H for additional details.

4.7.3 GR&R Study Results

BAE Systems utilizes the following acceptance levels to be used:

$GR\&R_{TOL}\% < 10$	Pass - Gage System is Useable
$10 \leq GR\&R_{TOL}\% \leq 30$	Gage System is useable but marginal
$GR\&R_{TOL}\% > 30$	Fail - Gage System is Unstable

1. %Tolerance of 10% or less is considered to be an acceptable measurement system.
2. %Tolerance between 10% and 30% may be acceptable depending upon the application. An action plan may be necessary to address and improve the method of measurement.
2.1 For KCs, the supplier may be required to submit acceptance justification of a GR&R error percentage between 10% and 30% for BAE Systems review and approval.
3. Gauges with %Tolerance > 30% or more cannot be used for KCs identified on BAE Systems Drawings. Actions to reduce the measurement variation are needed to lower the variation to an acceptable level.

Statistical software such as Mini-tab, SPC Excel or equivalent may be utilized to conduct the measurement study. **BAE Systems prefers Minitab is used.** If the supplier does not have access to Minitab, please use the data collection sheet located on the BAE Systems Supplier Center and have the BAE Systems SQE run the GR&R study in Minitab for the supplier. Be sure to include gage information (gage name, gauge number, calibration date, gage tolerance) and the Date of Study.

4.8 Process Capability Study

The purpose of initial process studies (Cp, Cpk, Pp, Ppk) is to determine if the production process is likely to manufacture product that will meet BAE Systems requirements. Initial process studies (capability) are required for all KCs.

If there are no KCs on the drawing the BAE Systems SQE will work with the supplier to identify the Quality Characteristics that are tracked as indicators of the process. These Quality Characteristics could be either Product related KC's or Process related KCC's.

There are two primary indexes used in determining process capability.

- Cpk predicts future capability and should be used when developing new parts or revising specifications on a part. Cpk should also be used when materials, processes, manufacturing location, or equipment have changed, or Material suppliers have changed.
- Ppk indicates past performance. Use Ppk when you are a new supplier to BAE Systems but have already been manufacturing the part which BAE Systems will purchase.

If this PPAP element is required in the scope, the following are the Submission Requirements:

- The capability study is to be performed on samples taken from an actual production run at the quoted production rates.
- The minimum acceptance capability for all KCs is 1.33 and 1.67 for all safety related KC's. In some cases, it may be impossible or prohibitively expensive to meet the stability and capability requirements.

- These exceptions shall be documented by the producer and may require customer approval. An alternative control method (such as 100% gauging) may be required.
- The supplier can submit the Capability data on the format of their choice, i.e., Mini tab (preferred), Excel or equivalent.

NOTE: An initial process study may be required for pre-production/production trials. The BAE Systems SQE will notify the supplier when this is required.

4.9 Material Handling, Packaging, Labelling and Part Marking

4.9.1 Material Handling

Establishing proper material handling methods ensure that products are adequately protected from damage, corrosion, or contamination during manufacturing processes, movement between operations, transit to external operations, and during storage. It is best practice for the supplier to take into account controls specific to Foreign Object Damage (FOD) and Electrostatic Discharge (ESD) and document the determined material handling methods.

4.9.2 Packaging, Labelling, and Part Marking

Planned packaging ensures that the product or material is not physically damaged, nor will the packaging degrade in performance through the normal course of transportation, delivery, and storage. Consider both primary and secondary packaging, as well as use and recycling of packaging materials as applicable. **The supplier shall review the supplier packaging code on their PO against the Packaging Requirements Codes** here before submitting their plan.

Labelling and part marking are typically specified by the on the BAE Systems drawings and specifications. The supplier shall confirm the labelling and part marking requirements are understood and can be executed as planned.

If this PPAP element is required in the scope, the following are the Submission Requirements:

A Packaging, Labelling, and Part Marking plan shall at a minimum define:

- Packaging process & pictures
  - Part Number, Name, and Revision.
  - The forms Revision and supplier name should also be included.
  - Identify if the material is HAZMAT.
  - Supplier shall submit images for the part in packaging position, the container with label shown (label content (part number, SN, barcodes, etc.), label material, and label location(s)), and dunnage.
- Internal packaging material (including identification if it is ESD safe)
  - Supplier shall provide a list of packaging materials including, description, manufacturer, and lead time.
- Packaging reusability (as applicable)
- Labeling requirement, including label content (part number, SN, barcodes, etc.), label material, and label location(s)
- Qty. per box, (as applicable) boxes per pallet, and per layer
- Box size & weight for the part, container, pallet, and unit load. Supplier shall provide the staking rules for the pallet and unit load.

NOTE: The Pre-Production Packaging Plan may not include all of the above requirements if they are not known at the time of submission. The Plan shall be updated once finalized for production parts. BAE Systems created a packaging form that includes all of the required items above which should be utilized by suppliers. The form is located on the BAE Systems Supplier Center.

4.10 First Article Inspection Report (FAIR)

The primary purpose of FAI is to validate that product realization processes are capable of producing parts and assemblies that meet engineering and design requirements.

An FAI will:

- Provide confidence that the product realization processes are capable of producing conforming product.
- Demonstrate that the manufacturers and processors of the product have an understanding of the associated requirements.
- Provide objective evidence of process capability.
- Reduce potential risks associated with production startup and/or process changes.
- Provide assurance of product conformance at the start of production and after changes outlined in this standard.

An FAI is intended to:

- Reduce future escapes, risks, and total costs.
- Help ensure safety of flight.
- Improve quality, delivery, and customer satisfaction.
- Reduce costs and production delays associated with product non-conformances.
- Identify product realization processes that are not capable of producing conforming product and initiate and/or validate corrective actions.

If this PPAP element is required in the scope, the following are important considerations:

4.10.1 Full FAIR

A full FAI is required when an X14 QA code is listed on BAE Systems PO and for the following:

- New production part introduction
- New supplier or location of manufacture
- Lapse in production greater than 24 months, unless otherwise specified within procurement documentation.

NOTE: An initial FAI may be required for pre-production/production trials. The BAE Systems SQE will notify the supplier when this is required. This FAI shall be marked as incomplete since it is not a production FAI.

4.10.2 Partial FAIR

A partial FAIR is submitted for affected characteristics when any of the following CHANGE(S) occur:

- Design characteristics affecting form, fit or function of the part (revision level change).
- If no change to form, fit, or function, only Form 1 is required to identify clerical changes.
- Source(s) supply for product or service.
- Manufacturing source
- Special Process source

- Inspection method(s): When the difference between the two methods reduces the accuracy of inspection results.
- Location of manufacture, tooling, material or raw materials, or Special Processing suppliers that can potentially affect Form, fit, or function.
- Numerical control program or translation to another media that can potentially affect form, fit, or function. Including changes to ATP, ATE, and associated Software programs affecting product.
- A natural or man-made event, which may adversely affect the manufacturing process.
- A lapse in production as defined on the Purchase Order requires a full FAI/FAIR.

NOTE: An initial FAI may be required for pre-production/production trials. The BAE Systems SQE will notify the supplier when this is required. This FAI shall be marked as incomplete since it is not a production FAI.

4.10.3 FAIR Submission

All production FAI activity shall be accomplished in accordance with the requirements of AS9102 (latest revision).

4.11 Customer Specific Requirements

This item is to address BAE Systems specific requirements during PPAP submission. BAE Systems will advise during the PPAP process on specific requirements as there may vary depending on the scope of the project / product being supplied. This item is also utilized to flow down requirements of BAE Systems customers to ensure these elements are captured during PPAP submission.

4.12 Sample Parts

BAE Systems SQE will determine and communicate to supplier if FAI or PPAP Samples will be required as part of the PPAP Package submission. In order to ensure consistency of Digital Samples to BAE requirements, the Supplier shall use the FAI / PPAP Sample Template created by BAE Systems and include it in the PPAP Package submission. This document is located on the BAE Systems Supplier Center.

4.12.1 FAI Samples

The FAI Sample Retain is defined as a physical and/or digital part the supplier used to record the FAI data that will be submitted to BAE Systems for approval. Based on part value, it will be up to the discretion of BAE Systems SQE to determine whether a digital sample should be created instead of a physical one.

When requested, the supplier will maintain, and store physical FAI Sample Retains at their facility to be available upon request by BAE Systems. The digital FAI Sample Retain will be submitted to BAE Systems for approval along with the relevant FAI and both will be approved by BAE Systems.

If a new FAI is required or requested from BAE Systems as part of the PPAP Package, the FAI Sample Retain may be presented as part of the PPAP Package submission. If a FAI has already been submitted and approved prior to the PPAP Package submission for the current Part Number and Revision, BAE Systems SQE may request a PPAP Sample (see 4.12.2).

The physical FAI Sample Retain will be stored at the supplier facility and should include the following information to physically identify the sample:

- Part Number
- Part Description
- Part Revisions (Hardware & Drawing)

- FAI Reference Number

Segregation of the sample parts is needed to avoid them being inadvertently misplaced or mixed up with production parts.

4.12.2 PPAP Samples

A PPAP Sample is defined as a sample part representative of the group of parts used to collect data for one or several artifacts submitted as part of the PPAP Package. Based on part value, it will be up to the discretion of BAE Systems SQE to determine whether a digital sample should be created instead of a physical one.

When required, the supplier will maintain and store physical PPAP Sample Retains at their facility to be available upon request by BAE Systems. When requested, the digital PPAP Sample Retain will be submitted to BAE Systems for approval along with the PPAP submission.

The physical PPAP Sample Retain will be stored at the supplier facility and should include the following information to physically identify the sample:

- Part Number
- Part Description
- Part Revisions (Hardware & Drawing)
- PPAP Reference Number

Segregation of the sample parts is needed to avoid them being inadvertently misplaced or mixed up with production parts.

Disposal of PPAP Samples shall be conducted in accordance with BAE Systems requirements.

5. PPAP Submission

5.1 Submission Method

All PPAPs shall be submitted through the system Net-Inspect. No exceptions will be granted unless the end user restricts the use of cloud-based systems. The BAE Systems SQE initiates a PPAP Package and assigns it to the supplier for all new full PPAPs. The supplier is responsible for initiating delta PPAPs when changes occur.

User Access Set-up Instructions and an APQP module training guide are available within Net-Inspect under Implementation Guide. If your organization doesn't have an account, all supplier licenses are covered by BAE Systems. To request an account visit Submit a request – Net-Inspect (zendesk.com)

For Classified technical data, it shall be specially handled as specified in the Purchase Order or Subcontract. Contact your BAE Systems procurement representative to confirm the approved transmittal method.

5.2 Statuses

The PPAP approval process will be carried out by BAE Systems. The PPAP submission will be reviewed and dispositioned one of the following ways:

- Full Approval

  - The product and/or associated documentation meets all customer requirements
  - The supplier may supply product as required

- Interim Approval
  - The product and/or associated documentation does not meet all customer requirements
  - Root cause defined with interim action plan that is approved by the customer
  - Product may be supplied for a specified period of time or piece quantity
  - Re-submission is required within allotted time frame based on customer feedback comments

- Rejected
  - The product and/or associated documentation does not meet customer requirements
  - Product is not to be shipped
  - Re-submission is required based on customer feedback comments

6. PPAP Changes / Revisions

In order to minimize risks associated with changes, BAE Systems will require PPAP revisions and submittal ahead of such changes. These changes can originate at the supplier (new risks identified and mitigated, equipment or facility moves, etc.) or at BAE Systems (Engineering Changes). Changes are normal and part of the continuous improvement process.

Changes per AS9102 include;

- Change in Design (Hardware Part or Drawing)
- Change in Manufacturing Source(s)
- Change in Location of Manufacture
- Change in Tooling incl. Designed or Qualified Tool
- Change to Source of Supply
- Change in Manufacturing Process(es)
- Lapse in Production ≥ 2 years
- Reliability Improvement
- High Defective Rate

If a change is identified, the supplier should contact the assigned BAE Systems SQE & Supply Chain Lead to request a PPAP Approval Form indicating the requirements for approval of the change. The BAE Systems SQE & Supply Chain Lead will assess the nature of the change relative to the APQP documents and the balance of the PPAP elements. This risk review will also include the complexity and criticality of the part or assembly. Once completed the supplier will be presented with the requirements indicated for interim or full approval.
BAE Systems to be able to receive material after the change. If a change is discovered without proper PPAP approval, BAE Systems may render the previous PPAP as invalid and therefore, new material receipts may not be able to be processed.

7. Post Submission Activities

7.1 Control Plan Audits

If required, Control Plan audits will be scheduled to verify execution against the APQP documents and to ensure the documents are updated, when appropriate, as related to Changes and Corrective Actions. Audits can be conducted either virtually or onsite. In either case, the auditor will work collaboratively with the supplier to verify adherence to the documentation.

- Pre-work
  - The BAE Systems SQE will require to obtain the most current versions of the following documents;
- Purchase Order
- Shop Traveler
- FAI
- Balloon Drawing
- Flow
- Control Plan
- PFMEA
  - The documents will be assessed to see if they are in alignment with each other relative to part, drawing revision, and sequence of operations.
- GEMBA Walk
  - If required, a walk of the process will be conducted onsite with the supplier using the Control Plan as the guiding document. The review shall start at Receiving Inspection and continue through Shipping. The following items will be verified;
- Each Process Operation Name and Number identified.
- All machines, devices, and jigs listed.
- The balloon number on the drawing corresponds with the product characteristic listed on the plan.
- Process and Product characteristics are clearly identified.
- All special or Key characteristics are listed.
- The requirement is defined.
- The measurement technique with frequency and sample size is listed.
- The measurement system for Key characteristics is approved.
- There is a reaction plan for each operation.
- Quality System Assessment
  - The suppliers Quality System will be assessed for the following areas;
- PPAP Overview
- Personnel and Training
- Calibration and Maintenance
- Process Flow Diagram
- PFMEA
- Control Plan
- Measurement System Analysis (MSA)
- Notification of Changes

  - Supplier shall notify of any changes to their process, special processes, or materials prior to any changes.
  - Any changes in drawing revision will require a partial PPAP submission.
- Reference Section # 6 for a list of triggers that require the review of the PPAP submission to determine if customer notification and a re-submission is needed.

7.2 Capacity Verification

The purpose of capacity verification is to verify the supplier's manufacturing process is capable of producing components that meet BAE's on-going quality requirements at the quoted demand.

7.2.1 Selection Process

All new parts with a QA Code 199 on the PO are subject to a capacity verification upon request by the program.

Factors for consideration will include but are not limited to:

- Part Volumes
- Part History
- New Supplier Facilities
- Tooling Changes

7.2.2 General Info

Duration & Timing: The number of components to be produced during the Capacity Verification should be sufficient to demonstrate manufacturing process capability and be performed on a production intent process. These should be predetermined by the supplier, Category SQE, and program team.

Inventory: If parts are produced ahead of production schedules, the supplier will hold all parts produced until authorized to ship.

The supplier shall complete the Capacity Planning Cover Page & Product Line Capacity Planning (for each Part#) after the pre-assessment and before the official Capacity Verification is conducted on-site by the BAE Systems SQE.

7.2.3 Capacity Verification Review & Summary

The Capacity Verification will verify that the results of the supplier's actual manufacturing process meet customer requirements for on-going quality and quoted demand rate. Also, it will verify that the supplier's actual process is to plan, as documented in PPAP.

- Verification Review: Verification of process readiness relative to Documentation, Manufacturing Process, and Capacity will be conducted by completing the Capacity Verification Worksheet. (Appendix I)
- Verification Summary: Verification of process readiness relative to Documentation, Manufacturing Process, and Capacity will be conducted by completing the Capacity Verification Worksheet. (Appendix J)

7.2.4 Capacity Verification Status

Upon completion of the Capacity Verification, the worksheets should be reviewed for completeness and a decision made whether or not to approve the review. The Capacity Verification can have one of three results: pass; open or fail. (See ratings below.)

- **Pass:** all Capacity Verification requirements were met. The supplier demonstrated the capability to produce parts that meet BAE's on-going quality requirements at quoted capacity (net output).
- **Open:** indicates that some minor non-conformances to the requirements were found that need to be corrected. Corrective Action and its verification is required.
- **Fail:** indicates a serious non-conformance exists that requires significant action by the supplier to correct. An additional Capacity Verification will be required.

8. References

The following documents are additional references on the subject of this document.

8.1 SAE Publications

- SAE International AS9145™ – Requirements for Advanced Product Quality Planning and Production Part Approval Process
- SAE J1739™ - Potential Failure Mode and Effects Analysis (FMEA) Including Design FMEA, Supplemental FMEA-MSR, and Process FMEA
- SAE International AS9103 – Variation Management of Key Characteristics
- SAE AS13003 Measurement Systems Analysis Requirements for the Aero Engine Supply Chain
- SAE AS9102 Aerospace First Article Inspection Requirement
- SAE AS13004 Process Failure Modes and Effects Analysis (PFMEA) and Control Plans

8.2 BAE Systems, Electronic Systems, Publications

- B25279: Supplier Requirements for FAI Reports
- BAE Systems Supplier Variation Request (SVR)

8.3 AIAG Publications

- AIAG FMEA Manual
- AIAG APQP Manual
- AIAG PPAP Manual
- AIAG SPC Manual
- AIAG MSA Manual
- AIAG SPC Manual
- AIAG MSA Manual

8.4 Other Publications

- IEEE 1490:2011 Adoption of the Project Management Institute (PMI(R)) Standard; A Guide to the Project Management Body of Knowledge
- MIL-HDBK-896 Department of Defense Handbook – Manufacturing Management Program Guide

9. Definitions, Acronyms

9.1 Definitions

Term	Definition
ARA	The ARA is a collaborative, cross functional risk assessment used to assess an assembly, sub-system, or component to determine if they would benefit from having AS9145 applied to mitigate risks earlier in the product realization lifecycle.
Baseline FMEA:	An existing FMEA from a functionally similar product without program specific details. It is used as a starting point to leverage past experience and knowledge. Its use is optional. Common names for a baseline FMEA also include Generic, Best Practice, and Gold Standard FMEA.
Block Diagram:	The Block or Boundary Diagram is a pictorial tool to facilitate analysis of system interfaces usually used in Design FMEAs. It defines the analysis scope and responsibility and it provides guidelines for structured brainstorming.
Boundary Diagram:	A graphical representation of the system/product, sub-system, or sub-assembly that shows what is being analyzed (e.g. parts list and/or layout), what its interfaces are (e.g. other parts, sub-systems, products), and what its inputs and outputs are.
Bill of Material (BOM):	Total list of all components and materials contained in the design record of a product required to manufacture the product.
Containment:	Recognition, identification and where possible, the segregation of the entire population affected by the condition of nonconformance. Containment includes raw material, stock inventory, kits, work-in-process, product in sell-off, finished goods inventory, goods in transit, and goods at BAE Systems.
Control Plan:	A written description of the systems for controlling production parts, materials and processes. Control plans identify the important characteristics and engineering specifications of the product and how they are controlled to assure quality of the product. The control plan should be linked to the process flow diagram and the process failures modes and effects analysis.
Critical Item (CI):	An item (e.g., function, part, software, characteristic, process) having significant effect on the product realization and use of the product; including safety, performance, form, fit, function, producibility, service life, etc.; that require specific actions to ensure it is adequately managed. Examples include: safety CIs, fracture CIs, mission CIs, Key Characteristics (KCs), and maintenance tasks critical for safety.
Correction:	Action taken to eliminate a detected nonconformity.
Customer:	The recipient of the supplier's or organizations products or service.
Deliverables:	Outputs completed as part of the APQP/PPAP process.
Design Records:	The records of the engineering definition/specification, that fully define the product (system, part, component, or assembly), including physical or electronic/digital drawings, electronic/digital models, software, or other associated information. This includes records of authorized engineering changes (Approved via SVR) not yet incorporated into the released engineering definition/specification.
Design Risk Analysis:	Analytical techniques (e.g., Design Failure Modes and Effects Analysis – DFMEA) used by the design responsible organization to identify, to the extent possible, potential failure modes related to product

	performance (i.e., fit, form, and function), durability, manufacturability, and cost. [Reference SAE J1739 FMEA Standard].
Design Validation:	The assurance that a product, service, or system fulfills the needs of the customer and other identified stakeholders. It often involves acceptance with external customers (defined in IEEE 1490:2011). Relevant types of validation include: – Confirmation through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled. Testing and/or analysis to ensure the product design conforms to defined user needs and/or requirements. Design validation follows successful design verification and may involve preproduction product (e.g., development, prototype) [Reference SAE AS9145 Aerospace Series – Requirements for Advanced Product Quality Planning (APQP) and Production Part Approval Process (PPAP)].
Design Verification:	Testing to assure that all design outputs meet the requirements of the design inputs with objective evidence that the specified product requirements have been fulfilled. Testing and/or analysis to ensure that all design outputs satisfy requirements may include activities such as: design review, performing alternate calculations, understanding tests and demonstrations, and review of design stage documents before release [Reference SAE AS9145 Aerospace Series – Requirements for Advanced Product Quality Planning (APQP) and Production Part Approval Process (PPAP)].
Failure Mode and Effects Analysis (FMEA):	An organized methodology used to assure that potential design and manufacturing risks are mitigated through mistake proofing and design/process enhancements. Potential risks are ranked and prioritized for improvement. [Reference SAE J1739 FMEA Standard].
Functional Block Diagram:	A graphical representation of the functional relationships within a system, product, sub-system, or sub-assembly. Each block represents one element, along with its inputs, outputs, and transfer function.
Key Characteristic (KC):	An attribute or feature whose variation has a significant influence on product fit, performance, service life, or produceability; that requires specific action for the purpose of controlling variation (reference AS9103, AS9145, SAE J1739 standards).
Key Control Characteristic (KCC):	Measurable characteristics of a process whose control is essential to manage variation of part, subsystem, or system KCs. Key Control Characteristic (sometimes called Special Process Characteristic or process KC) is a parameter that requires special care. Key Control Characteristics are monitored during manufacturing/assembly. The purpose of the KCC is to ensure the process is monitored to maintain validated settings and identify variation anomalies requiring attention. Monitoring process characteristics is preferred over measuring the correlated product characteristics. (SAE J1739)
Measurement Systems Analysis (MSA):	A study of the effects of selected elements (repeatability and reproducibility) of a measurement process on accuracy, precision, and uncertainty of measurement. [Reference SAE AS13003 Measurement Systems Analysis Requirements].
Nonconformance:	The failure or potential failure of a characteristic to conform to the requirements specified in a contract, purchase order, drawing, specification or other approved product description. Potential/suspect non-conformances include improper handling, storage, transport, and exposure to out-of-tolerance environmental, test or process conditions.
Nonconforming Material:	Any item, part, or product containing one or more nonconformance
Preliminary Capacity Assessment:	An assessment performed early in the process planning and development phase to determine resources (e.g., people, equipment, facilities) necessary to produce product at the customer demand rate.

P-Diagram:	A diagram that shows the inputs, control factors, error states, ideal functions, and noise factors for a system, product, sub-assembly, or sub-system. Noise factors are categorized as: piece-to-piece variation; deterioration or degradation over time; other systems; customer usage or duty cycle; and the environment.
Preventive Action:	Action to eliminate the cause of a potential nonconformity or other undesirable condition. If a nonconformance has not occurred, but an action is taken to proactively reduce the risk of a nonconformance, the action is preventive. [Reference SAE J1739 FMEA Standard].
Process Capability:	Comparing actual process performance with process specification limits using measure e.g.: Cpk, CP, Sigma Level and parts defective parts per million.
Process Validation:	Confirmation through physical demonstration that a process consistently produces a result or product fulfilling its predetermined specifications, including key product or process characteristics which are stable and capable at the desired level. [Reference SAE J1739 FMEA Standard].
Production Process Verification (PPV):	A review of the manufacturing process (e.g., equipment, operator training, manufacturing documentation, control plan, associated measurement tools) by a multi-disciplinary team to verify that the production processes are appropriately defined, documented, and ready for production.
Recommended Action:	Any action intended to mitigate risk by reducing the severity, occurrence, detection, or all three ratings.
Repair:	A procedure that reduces but does not eliminate a nonconformance and is approved by the Customer when required by contract.
Rework:	A procedure applied to a nonconformance that will completely eliminate the nonconformance, and result in a characteristic that conforms completely to the drawing, specification or contractual requirement.
Risk Priority Number (RPN):	A measure of risk that is the product of the severity, occurrence, and detection ratings.
Scrap:	Nonconforming material that is not usable for its intended purpose that cannot be economically reworked.
Severity Occurrence Number (S.O.N.):	A measure of risk that is the product of the severity and occurrence rankings.
Supplier:	The entity or party that supplies product or services to a customer in accordance with contract requirements.

9.2 Acronyms

ARA	AS9145 Risk Assessment
ATP	Acceptance Test Plan
BOM	Bill of Materials
CI	Critical Item
DFMEA	Design Failure Modes and Effects Analysis

DVP&R	Design Verification Plan and Report
EMD	Engineering Manufacturing and Development (Type of project)
ESS	Environmental Stress Screening
FMEA	Failure Modes and Effects Analysis
GR&R	Gage R&R or Gage Repeatability and Reproducibility
KC	Key Characteristic
KCC	Key Control Characteristic
MFA	Manufacturing Feasibility Assessment
MSA	Measurement System Analysis
PEM	Program Engineering Manager
PFD	Process Flow Diagram
PFMEA	Process Failure Modes and Effects Analysis
PPV	Production Process Verification
RPN	Risk Priority Number
SCAR	Supplier Corrective Action Request
SON	Severity Occurrence Number
SOW	Statement of Work

10. Appendix

10.1 Appendix A: Severity (DFMEA)

SEVERITY EVALUATION CRITERIA		
S	**Effect**	**Severity Criteria**
10	Very High	Affects safe operation of the vehicle and/or other vehicles (system or products), the health of driver or passenger(s) or road users or pedestrians (users or operators)
9		Noncompliance with regulations
8	High	**Loss of primary** vehicle function necessary for normal driving during expected service life
7		**Degradation of primary** vehicle function necessary for normal driving during expected service life
6	Moderate	**Loss of secondary** vehicle function
5		**Degradation of secondary** vehicle function
4		**Very objectionable** appearance, sound, vibration, harshness, or haptics.
3	Low	Moderately objectionable appearance, sound, vibration, harshness, or haptics.
2		Slightly objectionable appearance, sound, vibration, harshness, or haptics.
1	Very Low	No discernible effect

Note: "Vehicle" can be replaced with a generic term "product/system". Driver can be replaced with Operator.

10.2 Appendix B: Occurrence (DFMEA)

OCCURRENCE EVALUATION CRITERIA		
O	**Prediction of Failure Cause Occurring**	**Occurrence Criteria - DFMEA**
10	Extremely High	First application of **new technology anywhere without operating experience** and/or **under uncontrolled operating conditions**. No product verification and/or validation experience. Re-use of design which is **expected to fail** during intended service life. **Standards do not exist,** and best practices have not yet been determined. Prevention controls **not able to predict field performance** or do not exist.
9	Very High	First use of design with technical innovations or materials **within the company**. New application or change in duty cycle/operating conditions. No product verification and/or validation experience. Re-use of design which is expected to fail during intended service life. Prevention controls not targeted to identify performance to specific requirements.
8		**First use of design with technical innovations or materials on a new application.** New application or change in duty cycle/operating conditions. No product verification and/or validation experience. Re-use of design which is expected to fail during intended service life. Few existing standards and best practices, not directly applicable for this design. **Prevention controls not a reliable indicator of field performance.**
7	High	**New design based on similar technology and materials.** New application or change in duty cycle/operating conditions. No product verification and/or validation experience. Re-use of design which is expected to fail during intended service life. Standards, best practices, and design rules apply to the baseline design, but not the innovations. **Prevention controls provide limited indication of performa**nce.
6		Similar to previous designs, using existing technology and materials. Similar application, with changes in duty cycle or operating conditions. Previous testing or field experience. Standards and design rules exist but are insufficient to ensure that the failure cause will not occur. Prevention controls provide some ability to prevent a failure cause.
5	Moderate	Detail changes to previous design, using proven technology and materials. Similar application, duty cycle or operating conditions. Previous testing or field experience, or new design with some test experience related to the failure. Design addresses lessons learned from previous designs. Best practices re-evaluated for this design but have not yet been proven. Prevention controls capable of finding deficiencies in the product related to the failure cause and provide some indication of performance.
4		Almost identical design with short-term field exposure. Similar application, with minor change in duty cycle or operating conditions. Previous testing or field experience. Predecessor design and changes for new design conform to best practices, standards, and specifications. Prevention controls capable of finding deficiencies in the product related to the failure cause and indicate likely design conformance.
3	Low	Detail changes to known design (same application, with minor change in duty cycle or operating conditions) and testing or field experience under comparable operating conditions, or new design with successfully completed test procedure. Design expected to conform to standards and best practices, considering lessons learned from previous designs. Prevention controls capable of finding deficiencies in the product related to the failure cause and predict conformance of production design.
2	Very Low	Almost identical mature design with long term field exposure. Same application, with comparable duty cycle and operating conditions. Testing or field experience under comparable operating conditions. Design expected to conform to standards and best practices, considering lessons learned from previous designs, with significant margin of confidence. Prevention controls capable of finding deficiencies in the product related to the failure cause and indicate confidence in design conformance.
1	Extremely Low	Failure eliminated through preventive controls and failure cause is not possible by design.

Product Experience: History of product usage within the company (novelty of design, application, or use cause). Results of already completed detection controls provide experience with the design.

Prevention Controls: Use of best practices for product design, design rules, company standards, lessons learned, industry standards, material specifications, government regulations, and effectiveness of prevention-oriented analytical tools including computer aided engineering, math modelling, simulation studies, tolerance stacks, and design safety margins

Note: The occurrence rating (O = 10, 9, 8, or 7 for example) can drop based on product validation activities.

10.3 Appendix C: Detection (DFMEA)

DETECTION EVALUATION CRITERIA			
D	**Ability to Detect**	**Detection Method Maturity**	**Opportunity for Detection**
10	Very Low	Test procedure yet to be developed	Test method not defined
9		Test method not designed specifically to detect failure mode or cause	Pass-Fail, Test-to-Fail, Degradation Testing
8	Low	New test method; not proven; planned timing is later in the product development cycle.	Pass-Fail, Test-to-Fail, Degradation Testing
7		New test method; not proven; planned timing is sufficient to modify production tools before release for production.	
6	Moderate	Proven test method for verification of functionality or validation of performance, quality, reliability, and durability; planned timing is latest in the product development cycle such that test failure may result in production delays for re-design and/or re-tooling.	Pass-fail testing
5			Test-to-Fail, Degradation Testing
4	High	Proven test method for verification of functionality or validation of performance, quality, reliability, and durability; planned timing is sufficient to modify production tools before release for production.	Pass-Fail Testing
3			Test-to-Failure
2			Degradation Testing
1	Very High	Prior testing confirmed that failure mode or cause cannot occur, or detection methods proven to **always** detect the failure mode or failure cause	

10.4 Appendix D: Action Priority (DFMEA)

This Action Priority table is used to prioritize actions for risk reduction when DFMEA is performed as per AIAG-VDA Handbook Methodology. The Action Priority is based on combinations of Severity (S), Occurrence (O), and Detection (D) rating.

BAE Systems Risk Prioritization Method:

1. Determine AP as per the table (below)
2. Determine RPN: S * O * D
3. For Failure modes with S ≥ 4 and RPN ≥ 201 , update the action priorty as High (H)
   a. This may add some additional failure modes to High Risk group (from Medium-AP group). These are the failure modes that are in the boarder of High-AP and Medium-AP region.
   b. Rank them using AP > SO > RPN order.

c. Update the AP column in the DFMEA worksheet for the affected rows / failure modes (change AP from Medium to High due to this additional OR condition).

4. Address all High Risk failure modes (High-AP + High RPN and S) determined in the previous step (step #4).
    a. The DFMEA team needs to either identify an appropriate action to improve prevention and/or detection controls or justify and document why current controls are adequate.
5. Address remaining failure modes (Medium/Low AP) that are not determined as High Risk failure modes as per AIAG-VDA.
    a. Give priority to high ranked failure modes in mitigating the risks.
    b. Medium Risk (AP) failure modes: The DFMEA team should identify an appropriate action to improve prevention and/or detection controls, or, at the discretion of the company (management), justify and document why controls are adequate.
    c. Low Risk (AP) failure modes: The DFMEA team could identify actions to improve prevention and/or detection controls (no justification or documentation is needed even if no action is identified).
6. Demonstrate the effectiveness of risk mitigation actions using the following approaches:
    a. Number failure modes reduced from High Risk (AP) to Medium/Low Risk (AP)
    b. Initial and revised RPN and SO values
    c. List all High Risk failure modes (includes all high AP items) that are not addressed along with the justification.
7. Once the mitigation actions are implemented, update the worksheet with revised AP and RPN values.

Action Priority Table (Condensed Version)

Severity (S)	Occurrence (O)	Detection (D)	ACTION PRIORITY (AP)
9-10	6-10	*Any	H
9-10	4-5	2-10	H
9-10	4-5	1	M
9-10	2-3	7-10	H
9-10	2-3	5-6	M
9-10	2-3	1-4	L
9-10	1	*Any	L
7-8	8-10	*Any	H
7-8	6-7	2-10	H
7-8	6-7	1	M
7-8	4-5	7-10	H
7-8	4-5	1-6	M
7-8	2-3	5-10	M
7-8	2-3	1-4	L
7-8	1	*Any	L
4-6	8-10	5-10	H
4-6	8-10	1-4	M
4-6	6-7	2-10	M
4-6	6-7	1	L
4-6	4-5	7-10	M
4-6	4-5	1-6	L
4-6	1-3	*Any	L
2-3	8-10	5-10	M
2-3	8-10	1-4	L
2-3	1-7	*Any	L
1	*Any	*Any	NA/L

*Any = 1-10 (any value of the score)

H = High, M = Medium, L = Low

10.5 Appendix E: Severity (PFMEA)

Severity of Effect on Process and Product				
Potential effect(s) of failure rated according to the criteria below.				
S	**Effect**	**Impact to Your Plant**	**Impact to Ship-to-Plant (when known)**	**Impact to End User (when known)**
10	**High**	Failure may result in healthand/or safety risk for the manufacturing or assemblyworker.	Failure may result in healthand/or safety risk for the manufacturing or assemblyworker.	Affects safe operation of the vehicle and/or other vehicles, the health of driver or passenger(s) or road users or pedestrians.
9		Failure may result in in-plant regulatory noncompliance.	Failure may result in in-plant regulatory noncompliance.	Noncompliance with regulations.
8	**Moderately high**	100% of production run affected may have to bescrapped.	Line shutdown greater than full production shift; stop shipment possible; field repairor replacement required (assembly to end user) other than for regulatory noncompliance.	Loss of primary vehicle function necessary for normal driving during expected service life.
7		Product may have to be sorted and a portion (less than100%) scrapped; deviation from primary process; decreased line speed or added manpower.	Line shutdown from 1 hour upto full production shift; stop shipment possible; field repairor replacement required (assembly to end user) other than for regulatory noncompliance.	Degradation of primary vehicle function necessary for normal driving during expected service life.
6	**Moderately low**	100% of production run mayhave to be reworked off-lineand accepted.	Line shutdown up to 1 hour.	Loss of secondary vehicle function.
5		A portion of the production runmay have to be reworked off- line and accepted.	Less than 100% of product affected; strong possibility foradditional defective product; sort required; no lineshutdown.	Degradation of secondary vehicle function.
4		100% of production run may have to be reworked in stationbefore it is processed.	Defective product triggers significant reaction plan; additional defective productsnot likely; sort not required.	Very objectionable appearance, sound, vibration, harshness, or haptics.
3	**Low**	A portion of the production runmay have to be reworked in- station before it is processed.	Defective product triggers minor reaction plan; additional defective products not likely;sort not required.	Moderately objectionable appearance, sound, vibration, harshness, or haptics.
2		Slight inconvenience toprocess, operation, or operator.	Defective product triggers no reaction plan; additional defective products not likely; sort not required; requiresfeedback to supplier.	Slightly objectionable appearance, sound, vibration, harshness, or haptics.
1	**Very low**	No discernible effect.	No discernible effect or noeffect.	No discernible effect.

10.6 Appendix F: Occurrence (PFMEA)

Occurrence of the Cause
Assessment of “likelihood of failure cause occurring” for PFMEA is accomplished by assessing that the current prevention-type process controls will reduce the likelihood of occurrence of the failure cause, considering guidance from “time-based failure cause prediction.” One of two methods are used: Method One considers the capabilities of thecurrent prevention-type process controls and plant floor experience; Method Two considers the current prevention-typeprocess controls and knowledge of the process, equipment, tools, fixtures, etc. Both methods produce a qualitative (subjective) rating. Occurrence is a predictive qualitative rating made at the time of evaluation and may not reflect the actual occurrence. The occurrence rating number is a relative rating within the scope of the FMEA (process being evaluated). Estimated occurrence of the cause is an assessment of occurrence during manufacturing and is not an assessment of product defect rates or reliability.

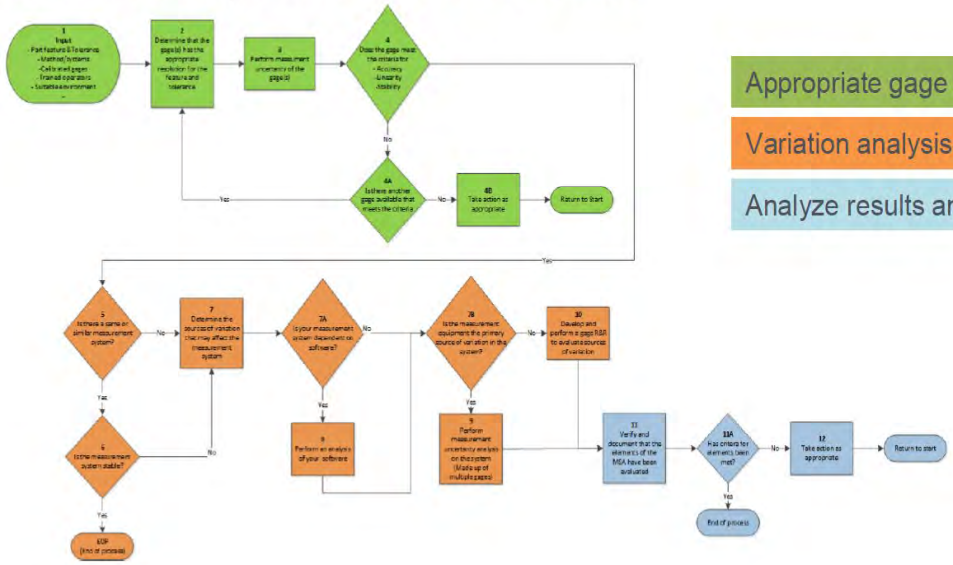
O	Likelihood of Failure Cause Occurring	Influence of Prevention Controlson Occurrence	Time Based FailureCause Prediction	Process Performance Based Failure Cause Prediction
10	**Extremely high**	No prevention controls.	Every time	≥ 100 per thousand ≥ 1 in 10
9	**Very high**	Prevention controls will have littleeffect in preventing failure cause.	Almost every time	50 per thousand 1 in 20
8			More than once per shift	20 per thousand 1 in 50
7	**High**	Prevention controls somewhat effective in preventing failure cause.	More than once per day	10 per thousand 1 in 100
6			More than once per week	2 per thousand 1 in 500
5	**Moderate**	Prevention controls are effective in preventing failure cause.	More than once per month	0.5 per thousand1 in 2000
4			More than once per year	0.1 per thousand1 in 10000
3	**Low**	Prevention controls are highly effective in preventing failure cause.	Once per year	0.01 per thousand1 in 100000
2	**Very low**		Less than once per year	≤ 0.001 perthousand 1 in 1000000
1	**Extremely low**	Prevention controls are extremely effective in preventing failure cause from occurring due to design (e.g., part geometry) or process (e.g., fixture or tooling design).	Never	Failure is eliminated throughpreventative control

10.7 Appendix G: Detection (PFMEA)

Likelihood of Detection by Process Control			
Assessment of “ability to detect” for PFMEA is accomplished by assessing the likelihood that the current detection-type process controls will be able to detect the failure mode or associated cause, considering guidance from detection maturity method and opportunity for detection. One of two methods are used: Method One considers the capabilities of all the current detection-type process controls (together); Method Two assesses the “ability to detect” for each of the current detection-type process controls separately (using lowest rating). **Note: When using the Detection Method Maturity Criteria, objective evidence shall be submitted to support the system, test or inspection methods are mature (i.e., variable or attribute MSA).**			
D	**Ability to Detect**	**Detection Method Maturity**	**Opportunity for Detection**
10	**Very low**	No testing or inspection method hasbeen established or is known.	The failure mode will not or cannot bedetected.
9		It is unlikely that the testing or inspection method will detect thefailure mode.	The failure mode is not easily detectedthrough random or sporadic audits.
8	**Low**	Test or inspection method has not been proven to be effective and reliable (e.g., plant has little or no experience with method, marginal MSA results on comparable process orthis application, etc.).	Human inspection (visual, tactile, audible), or use of manual gauging(attribute or variable) that should detect the failure mode or failurecause.
7			Machine-based detection (automated or semi-automated with notification by light, buzzer, etc.), or use of inspection equipment such as a coordinate measuring machine that should detectfailure mode or failure cause.
6	**Moderate**	Test or inspection method has been proven to be effective and reliable (e.g., plant has experience with method; MSA results are acceptableon comparable process or this application, etc.).	Human inspection (visual, tactile, audible), or use of manual gauging (attribute or variable) that will detect the failure mode or failure cause (including product sample checks).
5			Machine-based detection (semi- automated with notification by light, buzzer, etc.), or use of inspection equipment such as a coordinate measuring machine that will detect failure mode or failure cause (including product sample checks).
4	**High**	System has been proven to be effective and reliable (e.g., plant hasexperience with method on identicalprocess or this application), MSA results are acceptable, etc.	Machine-based automated detection method that will detect the failure mode downstream, prevent further processing or system will identify the product as discrepant and allow it to automatically move forward in the process until the designated reject unload area. Discrepant product will be controlled by a robust system that will prevent outflow of the product from thefacility.
3			Machine-based automated detection method that will detect the failure mode in-station, prevent further processing or system will identify the product as discrepant and allow it to automatically move forward in the process until the designated reject unload area. Discrepant product will be controlled by a robust system that will prevent outflow of the product from thefacility.
2		Detection method has been proven tobe effective and reliable (e.g., plant has experience with method, error- proofing verifications, etc.).	Machine-based detection method thatwill detect the cause and prevent the failure mode (discrepant part) from being produced.
1	**Very high**	Failure mode cannot be physically produced as designed or processed, or detection methods proven to always detect the failure mode or failure cause.	

10.8 Appendix H: MSA Process Flow

Measurement System Analysis which includes:



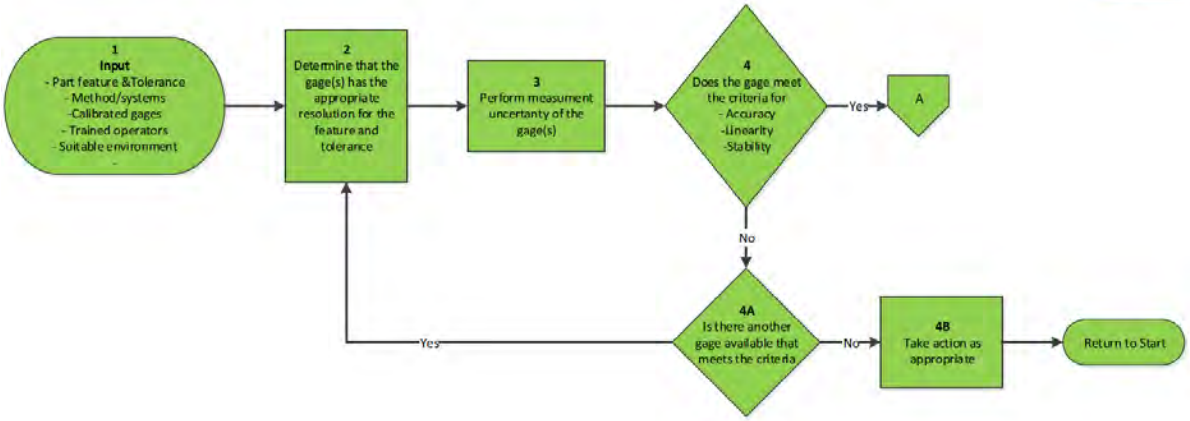
Appropriate gage selection

Variation analysis

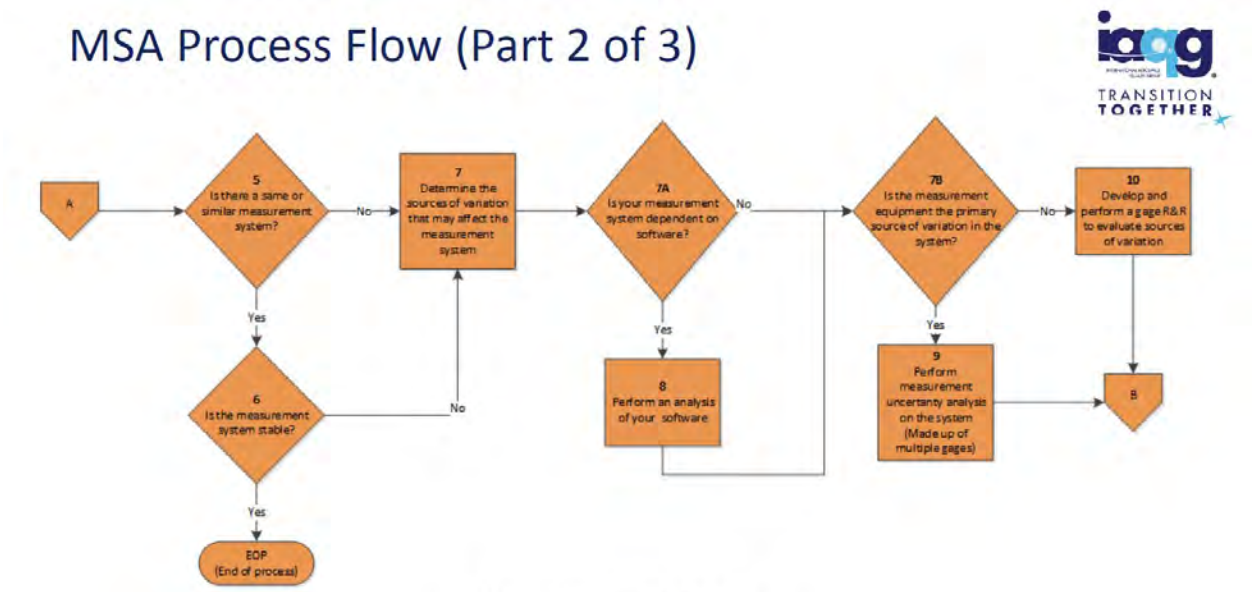
Analyze results and take action

2

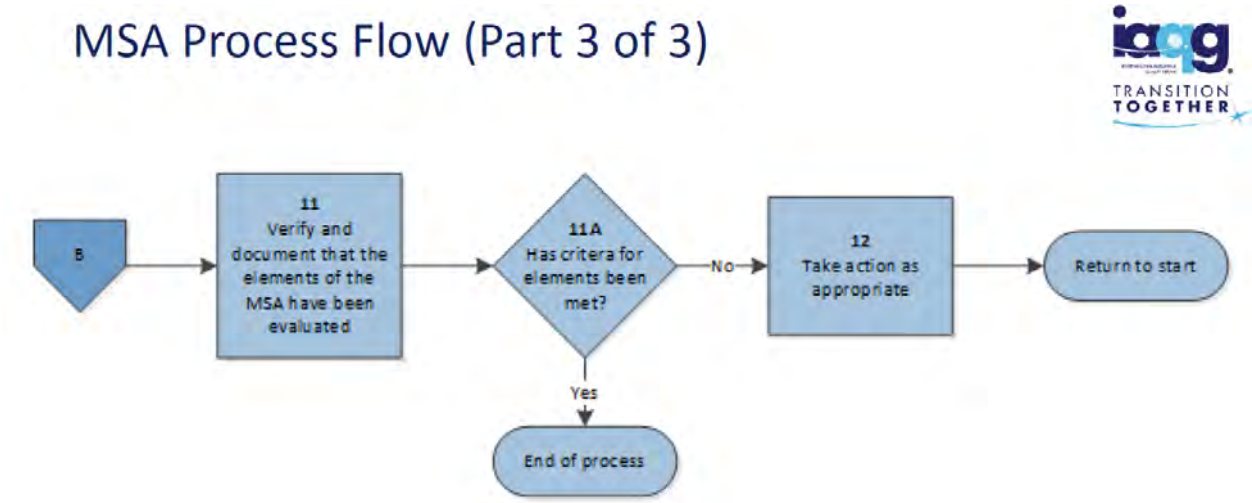
MSA Process Flow (Part 1 of 3)



Appropriate Gage Selection



Variation Analysis



Analyze Results and Take Action

Further details of each process flow step can be found here:

SCMH-3.11.3-Measurement-Systems-Ar

10.9 Appendix I & J: Capacity Verification

Appendix I & J.xlsx