



AEROSPACE STANDARD	AS13004™	REV. A
	Issued 2017-08 Stabilized 2024-09	
	Superseding AS13004	
Process Failure Mode and Effects Analysis (PFMEA) and Control Plans		

RATIONALE

This technical report is being stabilized and will no longer be updated. This technical report will eventually be cancelled and superseded by AS13100 at a future date to be determined.

STABILIZED NOTICE

This document has been declared “STABILIZED” by SAE G-22 Aerospace Engine Supplier Quality (AESQ) Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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FOREWORD

To assure customer satisfaction, the aviation, space, and defense industry organizations have to produce and continually improve safe, reliable products that equal or exceed customer and regulatory authority requirements. The globalization of the industry and the resulting diversity of regional/national requirements and expectations have complicated this objective. End-product organizations face the challenge of assuring the quality of and integration of product purchased from suppliers throughout the world and at all levels within the supply chain. Industry suppliers face the challenge of delivering product to multiple customers having varying quality expectations and requirements.

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

The AESQ strategy is to create a series of related quality standards for use within the aerospace engine supply chain with the intention of exceeding customer expectations through effective application of the full series of interrelated AESQ quality standards (see Appendix A).

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1. SCOPE

This standard defines requirements for the identification, assessment, mitigation, and prevention of risk in the manufacturing process through the application of Process Flow Diagrams (PFDs), Process Failure Mode and Effects Analysis (PFMEA) and Control Plans throughout the life cycle of a product.

This standard aligns and collaborates with the requirements of AS9100, AS9102, AS9103, and AS9145.

The requirements specified in this standard apply in conjunction with and are not alternative to contractual and applicable statutory and regulatory requirements. In case of conflict between the requirements of this standard and applicable statutory or regulatory requirements, the latter shall take precedence.

2. APPLICABLE DOCUMENTS

The following referenced documents are important for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AS13000	Problem Solving Requirements for Suppliers
AS13002	Requirements for Developing and Qualifying Alternate Inspection Frequency Plans
AS13003	Measurement Systems Analysis Requirements for the Aero Engine Supply Chain
AS9100*	Quality Management Systems - Requirements for Aviation, Space, and Defense Organizations
AS9101*	Quality Management Systems - Audit Requirements for Aviation, Space, and Defense Organizations
AS9102*	Aerospace First Article Inspection Requirement
AS9103*	Aerospace Series - Quality Management Systems - Variation Management of Key Characteristics
AS9131*	Aerospace Series - Quality Management Systems - Nonconformance Data Definition and Documentation
AS9145*	Aerospace Series - Requirements for Advanced Product Quality Planning and Production Part Approval Process

NOTE: *Developed under the auspices of the IAQG and listed here as SAE International “AS” publications. Equivalent versions may be published by other standards bodies [e.g., European Committee for Standardization (CEN), Japanese Standards Association/Society of Japanese Aerospace companies (JSA/SJAC)].

2.2 Other Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ISO 9000	Quality Management Systems - Fundamentals and Vocabulary
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3. TERMS AND DEFINITIONS

In this Aerospace Standard, the following verbal forms are used:

- “shall” indicates a requirement;
- “should” indicates a recommendation;
- “may” indicates a permission;
- “can” indicates a possibility or a capability.

Information marked as “NOTE:” is for guidance in understanding or clarifying the associated requirement.

For the purpose of this standard, terms and definitions stated in ISO 9000 and the following definitions apply. An acronym log for this document is detailed within Appendix I.

ALTERNATIVE PROCESSES: Alternative processes are different approved processes used to achieve the same output (e.g., backup equipment, secondary source, alternative approved sequence).

CHARACTERISTICS MATRIX: An analytical technique for displaying the relationship between process parameters and manufacturing stations.

CONTAINMENT PLAN: Action to control and mitigate the impact of a nonconformity and protect the customer's operation (stop the problem from getting worse); includes correction, immediate corrective action, immediate communication, and verification that the nonconforming situation does not further degrade (refer to AS9101).

CONTROL PLAN: A documented description linking manufacturing process steps to key inspection and control activities. The intent of a Control Plan is to control the design characteristics and the process variables to ensure product quality.

CRITICAL ITEMS (CI): Those items (e.g., functions, parts, software, characteristics, processes) having significant effect on the provision and use of the products and services; including safety, performance, form, fit, function, producibility, service life, etc., that require specific actions to ensure they are adequately managed. Examples of critical items include safety critical items, fracture critical items, mission critical items, key characteristics, etc. (refer to AS9100).

CUSTOMER: Person or organization that could or does receive a product or a service that is intended for or required by this person or organization (refer to ISO 9000).

Example: Consumer, client, end-user, retailer, receiver of product or service from an internal process, beneficiary, and purchaser.

DESIGN CHARACTERISTICS: Those dimensional, visual, functional, mechanical, and material features or properties, which describe and constitute the design of the article, as specified by drawing or Digital Product Definition requirements. These characteristics can be measured, inspected, tested, or verified to determine conformance to the design requirements. Dimensional features include in process locating features (e.g., target-machined or forged/cast dimensions on forgings and castings, weld/braze joint preparation necessary for acceptance of finished joint). Material features or properties may include processing variables and sequences, which are specified by the drawing or Digital Product Definition (e.g., heat treat temperature, fluorescent penetrant class, ultrasonic scans, and sequence of welding and heat treat). These provide assurance of intended characteristics that could not be otherwise defined (refer to AS9102).

NOTE: For the purpose of this standard Design Characteristic is also known as Product Characteristic.

DESIGN RECORDS: The records of the engineering definition/specification, which 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 not yet incorporated into the released engineering definition/specification.

DESIGN RISK ANALYSIS: Analytical techniques 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.

DETECTION CONTROL: Control to detect the cause of the failure mode or the actual failure mode after it has occurred.

FAILURE MODE AND EFFECTS ANALYSIS (FMEA): A structured method for analyzing risk by ranking and documenting potential failure modes in a system, design, or process. The analysis includes:

- Identification of potential failures and their effects
- Ranking of factors (e.g., severity, frequency of occurrence, detectability of the potential failures)
- Identification and results of actions taken to reduce or eliminate risk

The FMEA assists in the identification of CIs as well as Key Characteristics, helps prioritize action plans for mitigating risk, and serves as a repository for lessons learned. These may include: System FMEA, Interface FMEA, Design Failure Mode and Effects Analysis (DFMEA), and Process Failure Mode and Effects Analysis (PFMEA).

INSPECTION PLAN/TEST PLAN: A detailed description of inspection and test activities (e.g., tolerances, methods, gauges) for features or attributes to be performed during specific manufacturing operations.

KEY CHARACTERISTIC (KC): An attribute or feature whose variation has a significant effect on product fit, form, function, performance, service life, or producibility, that requires specific actions for the purpose of controlling variation (refer to AS9100).

This definition is further explained as follows:

- Product or system KCs are those selected geometrical, material properties, functional, and/or cosmetic features; which are measurable, and whose variation control is necessary for fulfilling customer requirements and enhancing customer satisfaction.
- Process KCs are those selected measurable characteristics of a process whose control is essential to manage variation of product or system KCs.
- Substitute KCs may be identified when a customer defined KC is not readily measurable, within the production/maintenance setting, and other characteristics may need to be controlled to ensure conformance.

NOTE: Design output can include identification of CIs that require specific actions to ensure they are adequately managed. Some CIs shall be further classified as KCs because their variation needs to be controlled.

ORGANIZATION: Person or group of people that has its own functions with responsibilities, authorities and relationships to achieve its objectives (refer to ISO 9000).

PREVENTION CONTROL: Prevention control describes how a cause and/or failure mode is prevented or how the rate of occurrence is reduced. It is used as input to the occurrence ranking when integrated as part of the process.

PROCESS: A combination of people, material, machines, tools, environment, and methods that produce a product or service.

PROCESS CHARACTERISTICS: Process variables that have a cause and effect relationship with design characteristics. Process characteristics can only be measured at the time they occur.

PROCESS FLOW DIAGRAM (PFD): A representation of the sequential steps of the process which includes all operations from receipt of the material through to storage, packaging, and shipment.

PRODUCT: Any intended output resulting from the product realization process, which in the context of this standard includes finished detailed parts, sub-assemblies, assemblies, forgings and castings (refer to AS9102).

PRODUCT QUALITY ESCAPE: Any product released by an internal/external supplier or sub-tier supplier that is subsequently determined to be nonconforming to contract and/or product specification requirements (refer to AS9131).

REACTION PLAN: A plan that specifies actions necessary to avoid producing nonconforming product, operating out of control and details containment plans to be invoked when nonconforming product is detected.

RISK PRIORITY NUMBER (RPN): The product of the severity, occurrence, and detection rankings and is calculated for each unique failure mode and cause combination.

Example: Calculating RPN: Severity 7 X Occurrence 3 X Detection 5 = RPN 105

STANDARD REWORK: Documented preapproved detailed actions to fix nonconforming product for a reoccurring condition(s) to make it conform to the design records.

SUPPLIER: Organization that provides a product or service (refer to ISO 9000).

Example: Producer, distributor, retailer, or vendor of a product or a service.

WORK INSTRUCTION: Description of how to carry out the operations of a particular process.

Work instruction information can include "Operation Sequence List", "Router", "Traveler", or "Shop Order".

4. REQUIREMENTS

4.1 Process Risk Identification, Assessment, Mitigation, and Prevention Overview

4.1.1 The methodology defined in this standard shall be accomplished using a cross-functional team, which may include but is not limited to, Manufacturing Engineers (including technical experts), Process Planners, Quality Engineers, Process Operators, Inspectors, Design Engineers, and Equipment Maintenance Staff. The organization shall define roles and responsibilities for accomplishing the requirements of this standard.

Figure 1 illustrates the scope of this standard and the relationship between the key elements. The scope of this standard is indicated by the dashed line.

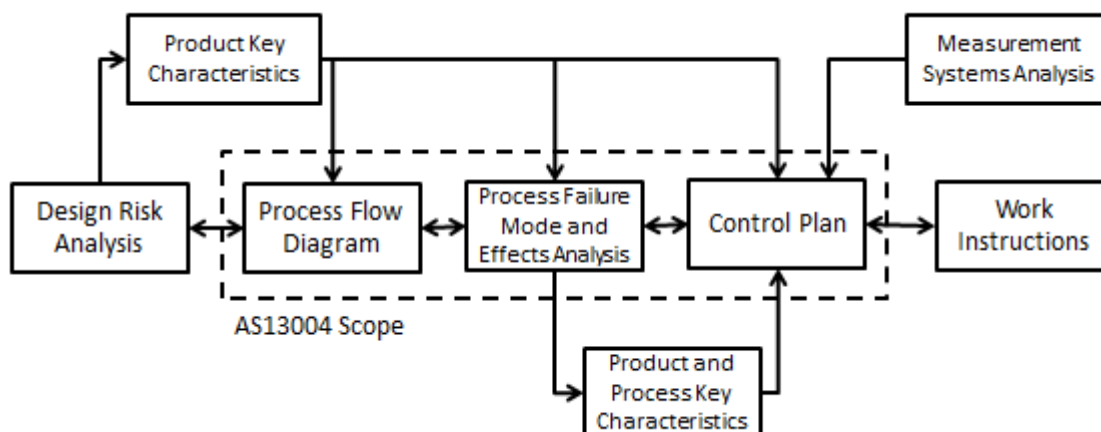


Figure 1 - AS13004 requirements, scope, and relationships

4.1.2 The cross-functional team shall develop PFD, PFMEA, and Control Plans with input from the Design Risk Analysis.

NOTE 1: Design Risk Analysis identifies Product KCs that serve as critical inputs to the risk mitigation process.

NOTE 2: Alternative methods for PFD, PFMEA, and Control Plans that are demonstrated to be equivalently effective are acceptable with prior customer approval.

4.2 Applicability

4.2.1 Process risk identification, assessment, mitigation and prevention shall be conducted as part of New Product Introduction to reduce risks in manufacturing.

4.2.2 This standard shall apply, when directed by the customer, to products currently in production when the manufacturing processes are changed or transferred to a new location or being addressed for improvement, e.g., due to a root cause investigation.

Table 1 provides guidance for the application of this standard to products currently in production.

Table 1 - Application guidance for AS13004 to products currently in production

Event	Clarification
Changes resulting from root cause investigation	Discovery of an unknown failure mode following an inservice issue, product quality escape, major quality issue or manufacturing issue
Process change	A change in material, method and/or measurement technique that can potentially affect form, fit or function
Design change	Design record modification including the addition of new KCs
Standard Parts / Commercial-off-the-Shelf	This standard is not applied to manufacture of standard parts and/or Commercial-off-the-Shelf items unless requested by the customer

4.2.3 When this standard is invoked it shall continue to apply throughout the lifecycle of the product.

4.2.4 The organization shall be responsible for the flow down of this standard to any supplier that manufactures and/or supplies products and services.

4.3 Training and Competency

4.3.1 Competent use of tools and methodologies defined within this standard is essential to ensure effective process risk identification, assessment, mitigation, and prevention. The organization shall determine and document specific competency and training requirements relevant to its ability to comply with this standard.

4.4 Organizational Quality System Requirements

4.4.1 The organization shall have a documented process within its own quality system which meets the requirements of this standard. The process shall be fully implemented and subject to a periodic assessment (see Appendix B).

4.5 General Requirements

4.5.1 Unless otherwise agreed by the customer, the PFD, PFMEA, and Control Plan shall be part number specific.

4.5.2 PFDs, PFMEAs, and Control Plans shall be reviewed and updated to capture process and inspection changes and new knowledge gained during production, e.g., lessons learned from production stops or delays, nonconformance, product quality escapes, inspection data, root cause corrective action investigations on current or similar products, and scrap data.

NOTE: There is a close link between the PFMEA and the Design Risk Analysis. The Design Risk Analysis identifies potential failure modes and effects, and with their severity, should be used as an input to the PFMEA. Updates to either may impact the other and should be taken into account.

4.5.3 The PFD, PFMEA, and Control Plan shall be linked to provide an easy read-across from process operations through to risk reduction through to process control (see Appendix D).

4.5.4 Operation numbering and sequencing detailed on the PFD shall be consistent throughout all documents produced to this standard by an organization.

4.6 Process Flow Diagram (PFD)

4.6.1 Inputs to developing a PFD shall include the following (when available):

- Design Risk Analysis [e.g., Design Failure Mode and Effects Analysis (DFMEA)]
- Design Records
- Bill of Material
- Product and Process KCs
- Tooling and equipment
- Handling equipment and packaging
- Subcontracted process steps
- PFD from similar products
- Quality history on similar products and processes (e.g., defect data, material review board history, quality notifications, product quality escapes)

4.6.2 Outputs from the development of a PFD shall include:

- PFD including details of all operations in sequential order from receipt of materials through storage and shipment of finished product. This encompasses alternative processes, standard rework and movement of product from operation to operation as well as to and from external operations.

NOTE: Information from the PFD may be used to establish processing sequence documents, as defined in work instructions.

4.6.3 The PFD shall be sufficiently detailed in order to clearly and completely describe the process required to receive material, manufacture, inspect, test, protect, store, and ship conforming product.

NOTE: The PFD need not include processes for procured materials, components, and assemblies.

4.6.4 The organization shall use one of the PFD templates as defined within this standard, or one with equivalent content (see Appendix H). Any deviation to this shall be approved by the customer.

Typical worked examples of PFDs have been included within this standard for reference (see Appendix C, Figures C3 and C4).

4.7 Process Failure Mode and Effects Analysis (PFMEA)

4.7.1 Inputs to developing a PFMEA shall include the following (when available):

- PFD
- Identification of all steps within each operation
- Nonconformance data for similar products and processes, including lessons learned
- Characteristics Matrix
- Design Risk Analysis (e.g., DFMEA)
- Existing PFMEA on similar products and processes
- Product KCs (including customer defined KCs)
- Process KCs (potential or as defined in the design records)
- Control Plan from similar processes

4.7.2 Outputs from the development of a PFMEA shall include:

- PFMEA with action plans to mitigate risks where necessary
- Product and process KCs identified through the PFMEA

4.7.3 The organization shall use the PFMEA methodology to identify additional product KCs and/or relevant process KCs, in addition to those defined in the design records.

4.7.4 The PFMEA shall include all operations identified in the PFD. Details of steps within each operation shall be considered and included based on the potential risk (see Appendix C, Figure C3 and C4).

4.7.5 The PFMEA severity, occurrence and detection rankings shall be reviewed and actions considered for reprioritization when changes are made to the process or product, when rate of failure occurrence is not reflective of actual frequency, nonconformance has occurred that was not previously listed or when new controls are implemented or existing controls modified.

4.7.6 PFMEA Template and Ranking Criteria

4.7.6.1 The organization shall use the PFMEA template defined within this standard, or one with equivalent content (see Appendix F). Any deviation to this shall be approved by the customer.

4.7.6.2 The organization shall use the severity, occurrence, and detection ranking criteria defined within this standard (see Appendix E). Use of alternative ranking criteria is acceptable with prior customer approval.

4.7.7 Identification of Potential Failure Modes

4.7.7.1 The PFMEA shall identify potential failure mode(s). Any potential manner in which the product could fail to meet requirements or fail to deliver the intended function shall be considered as a potential failure mode.

NOTE: Experiences based on similar products can be a valuable input. To aid failure mode identification, the team should also refer to previous product history, similar product history, lessons learned, customer feedback, etc.