AEROSPACE STANDARD

AS6500™	REV. A
Issued 2014-11 Revised 2021-07 Superseding AS6500	

(R) Manufacturing Management Program

RATIONALE

This standard has been published for 5 years and companies that have been implementing it have identified recommended improvements and clarifications.

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1. SCOPE

This standard is applicable to all phases of the system acquisition life cycle. It is intended for use on all programs with manufacturing content. It requires proven manufacturing management practices with the goal of delivering affordable and capable systems to the extent that it is invoked contractually. The term “organization” as used in this document refers to the company or facility that is implementing this standard, such as when imposed contractually by the customer.

1.1 Conformance

The agreement between the customer and the organization shall include the manufacturing management requirements based on the tailoring of the requirements of this standard to address the program situation. The assessment of the organization is based on compliance to the agreement. The customer’s request for proposal may include the intended tailoring of the requirements from this standard. The organization may propose changes or alternatives during the steps to finalize the agreement.

If tailoring of this standard is required to meet program requirements, then there are two ways that an implementation can be claimed to conform to the provisions of AS6500. Any claim of conformance is cited in only one of the two forms below.

Full conformance: Full conformance is achieved by demonstrating that all of the requirements of this standard have been satisfied using the outcomes as evidence.

Tailored conformance: For tailored conformance, the clauses are selected or modified using the tailoring process agreed to between the customer and the organization. Tailored conformance is achieved by demonstrating that requirements for the processes, as tailored, have been satisfied using the outcomes as evidence.

NOTE 1: The term “shall” is used wherever the criterion for conformance with the specific recommendation requires that there be no deviation. The term “should” is used to recommend best practices, however compliance with the specific recommendation is optional.

NOTE 2: Documents cited in “notes” throughout the standard are intended for guidance only.

NOTE 3: Legacy, modification, production, and sustainment programs that are past the design phase may not be able to comply with all of the requirements in this standard without tailoring.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. 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 examption has been obtained.

2.1.1 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.

ARP5580	Recommended Failure Modes and Effects Analysis (FMEA) Practices for Non-Automobile Applications
AS5553	Counterfeit Electrical, Electronic, and Electromechanical (EEE) Parts; Avoidance, Detection, Mitigation, and Disposition
AS6174	Counterfeit Materiel; Assuring Acquisition of Authentic and Conforming Materiel
AS9017	Control of Aviation Critical Safety Items

AS9100 Quality Management Systems - Requirements for Aviation, Space, and Defense Organizations

AS9102 Aerospace First Article Inspection Requirement

AS9103 Aerospace Series - Quality Management Systems - Variation Management of Key Characteristics

AS9145 Aerospace Series - Requirements for Advanced Product Quality Planning and Production Part Approval Process

EIA557 Statistical Process Control Systems

SAE J1739 Potential Failure Mode and Effects Analysis (FMEA) Including Design FMEA, Supplemental FMEA-MSR, and Process FMEA

STD-0016 Standard for Preparing a DMSMS Management Plan

2.1.2 Department of Defense Publications

Copies of these documents are available online at https://quicksearch.dla.mil.

Department of Defense Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs

DoD Manufacturing Readiness Level Deskbook

MIL-HDBK-516 Airworthiness Certification Criteria

MIL-HDBK-727 Design Guidance for Producibility

MIL-HDBK-896 Manufacturing and Quality Program

NAVSO P-3687 Producibility System Guidelines

SD-22 A Guidebook of Best Practices for Implementing a Robust Diminishing Manufacturing Sources and Material Shortages Management Program

2.1.3 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE 15288.2 IEEE Standard for Technical reviews and Audits on Defense Programs

2.1.4 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E2782 Standard Guide for Measurement Systems Analysis

2.2 Definitions

2.2.1 AFFORDABILITY

The degree to which the life cycle cost of an acquisition program is in harmony with the long-range investment plans of the customer.

2.2.2 COST MODEL

A model that estimates, collects, and tracks product costs and incorporates cost drivers and cost data.

NOTE: As development proceeds, additional cost elements should be added, such as: new manufacturing technologies, materials, labor, equipment, tooling, special test equipment, special inspection equipment, set-up, yields, scrap, rework, repair, capability/capacity constraints, design requirements, material specifications, schedules, facilities, simulation results, and prototype or other product or process demonstration data from increasingly realistic environments.

2.2.3 COUNTERFEIT PART

An unauthorized copy, imitation, substitute, or modified part (e.g., material, part, component), which is knowingly misrepresented as a specified genuine part of an original or authorized manufacturer; or is knowingly, recklessly, or negligently misrepresented as new without disclosure that it has been previously used. (Sources: AS9100 and AS5553.)

2.2.4 CRITICAL APPLICATION ITEM (CAI)

A part or assembly essential to system performance or operation, or the preservation of life or safety of operating personnel. (Source: Defense Logistics Agency Regulation 3200.3.)

2.2.5 CRITICAL CHARACTERISTIC

A characteristic whose variation has a significant impact on human safety, or could cause a catastrophic failure resulting in loss of life, permanent disability, or major injury to personnel.

2.2.6 CRITICAL MANUFACTURING PROCESS (CMP)

A process that creates or substantially affects a critical characteristic.

2.2.7 CRITICAL PART

Material, part, or assembly whose failure or malfunction could cause a catastrophic or critical failure resulting in loss of life, permanent disability, or major injury to personnel.

NOTE: Critical parts include critical application items and critical safety items.

2.2.8 CRITICAL SAFETY ITEM (CSI)

A part, assembly, installation equipment, launch equipment, recovery equipment, or support equipment for an aircraft or aviation weapon system that contains a characteristic which failure, malfunction, or absence of could cause a catastrophic or critical failure resulting in the loss of or serious damage to the aircraft or weapon system, an unacceptable risk of personal injury or loss of life, or an un-commanded engine shutdown that jeopardizes safety. (Source: AS9017.)

2.2.9 CRITICAL SUPPLIER

A supplier of critical parts.

2.2.10 DESIGN FOR ASSEMBLY (DFA)/DESIGN FOR MANUFACTURING (DFM)

Systematic analyses of the design of product, assembly, or subassembly to reduce product cost by simplifying its design, assembly, and manufacturing without impacting performance. DFA focuses on products designed with ease of assembly in mind, such as reduction in number of parts or inclusion of self-orienting features. DFM focuses on producibility and lowering costs for individual parts.

2.2.11 FIRST ARTICLE INSPECTION (FAI)

A planned, complete, independent, and documented inspection and verification process to ensure that prescribed production processes have produced an item conforming to engineering drawings, digital product definition (DPD), planning, purchase order, engineering specifications, and/or other applicable design documents. (Source: AS9102.)

2.2.12 FIRST ARTICLE TESTING (FAT)

Testing and evaluating the first article for conformance with specified contract requirements before or in the initial stage of production. (Source: Federal Acquisition Regulations, Subpart 2.101.)

2.2.13 KEY CHARACTERISTIC (KC)

An attribute or feature whose variation has a significant influence on product fit, form, function, performance, service life, or producibility that requires specific actions for the purpose of controlling variation. (Source: AS9103.)

2.2.14 KEY MANUFACTURING PROCESS (KMP)

A process that creates or substantially affects a key characteristic.

2.2.15 KEY PART

A material, part, or assembly whose lack, failure, or malfunction will impact cost, schedule, performance, or is a critical part.

NOTE: These include parts that can impact a program due to problems such as availability, long lead-time, manufacturing maturity, quality problems, foreign sources, or diminishing domestic manufacturing sources.

2.2.16 KEY SUPPLIER

A supplier whose performance significantly impacts cost, schedule, technical, or supportability requirements, or is a critical supplier.

NOTE: Includes suppliers that are sole, single, unique, or perform special processes.

2.2.17 LEAN MANUFACTURING

A management practice that uses production tools and principles, such as value stream, waste reduction, and continuous improvement, aimed at reducing costs, improving throughputs, and creating value for the end customer through the elimination of waste along the entire value stream.

2.2.18 LINE OF BALANCE (LOB)

A production control technique that combines features from a critical path scheduling timeline with a required delivery schedule presenting in graphic form information relating to time and accomplishment of production. It shows the delivery objective, sequence and duration of all activities required to produce a product, the current status of production items, and, from this data, an assessment showing the relationship of actual component production to schedule.

2.2.19 MANUFACTURING

The acts, crafts, processes, and methods used to transform tangible inputs such as raw materials, semi-finished goods, and sub-assemblies into goods or services that are suitable for use or have exchange value.

2.2.20 MANUFACTURING MANAGEMENT

The techniques of planning, organizing, directing, coordinating, and controlling the use of people, money, materials, equipment, research and development, methods and processes, and facilities to manufacture products.

2.2.21 MANUFACTURING MANAGEMENT SYSTEM

The integrated collection of the people, processes, policies, information systems, and other tools required to plan, execute, and manage manufacturing operations, including the integration of corresponding supplier activities.

2.2.22 MANUFACTURING MATURATION PLAN (MMP)

A documented risk mitigation plan for an area of manufacturing risk. The plan describes the actions necessary to achieve the target manufacturing readiness level, including required schedule and resources (e.g., personnel, funding, facilities, and equipment).

2.2.23 MANUFACTURING READINESS LEVELS (MRLS)

Manufacturing readiness criteria used to assess manufacturing risk, readiness, and producibility. MRLs provide a common understanding of the relative maturity, identification, and mitigation of manufacturing risks associated with manufacturing technologies, products, and processes. Refer to the DoD MRL Deskbook for additional information.

2.2.24 MATERIAL REVIEW BOARD (MRB)

Representatives of contractor and customer departments necessary to review, evaluate, and determine or recommend disposition of nonconforming material.

2.2.25 MEASUREMENT SYSTEM ANALYSIS

A study of the effects of selected elements of a measurement process (i.e., people, machines, tools, methods, materials, environment) on accuracy, precision, and uncertainty of measurement. (Source: AS9145.)

2.2.26 PILOT LINE ENVIRONMENT

A manufacturing environment that incorporates all of the key production realism elements (equipment, personnel skill levels, facilities, materials, components, work instructions, processes, tooling, temperature, cleanliness, lighting, etc.) required to manufacture production configuration items, subsystems, or systems that meet design requirements in low rate production.

2.2.27 PREDICTIVE INDICATOR

A set of internal process metrics that can provide quality and delivery forecasts, are actionable, and are indicative of the overall “health” of the organization’s and suppliers’ performance.

2.3 PROCESS CAPABILITY INDEX (C_{pk})

A measure of process output centering and spread within specification limits.

2.3.1 PRODUCIBILITY

A design attribute that enables manufacturing to repeatedly fabricate and assemble hardware which satisfies both functional and physical objectives at an optimum cost and within schedule.

2.3.2 PRODUCTION

The processes and methods used to transform raw materials, semi-finished goods, sub-assemblies, ideas, information, and knowledge into goods or services that are suitable for use or have exchange value. Also, a life cycle phase where non-prototype, requirements-compliant products are being manufactured for customer delivery.

2.3.3 PRODUCTION PROCESS VERIFICATION

An analysis conducted to verify that a manufacturing process, including the documentation, tooling, equipment, and test equipment utilized as part of the manufacturing process is capable of producing parts and assemblies that meet requirements.

2.3.4 PRODUCTION READINESS REVIEW (PRR)

A formal examination of a program to determine if the design is ready for production, if manufacturing problems have been resolved, and if the organization has adequately planned for the production phase. PRRs address management, industrial resources, facilities, design/product engineering, materials and purchased parts, manufacturing, production engineering and planning, quality, reliability, test, software, logistics and training, process improvement, schedule, contracts, cost, and funding.

2.3.5 RISK

A potential future event or condition that may have a negative effect on achieving program objectives for cost, schedule, and performance. Risks are defined by (1) the probability (greater than 0, less than 1) of an undesired event or condition; and (2) the consequences, impact, or severity of the undesired event, were it to occur. (Source: Department of Defense Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs.)

2.3.6 RISK MANAGEMENT

The overarching process that encompasses identification, analysis, mitigation planning, mitigation plan implementation, and tracking of program risks.

2.3.7 SIX SIGMA PROCESS

A set of methods, techniques, and tools to improve the quality of processes, with an emphasis on statistical tools.

NOTE 1: For a new product or process, designs utilize a DMADV process (define, measure, analyze, design, verify).

NOTE 2: For an existing product or process, utilize a DMAIC process (define, measure, analyze, improve, control).

2.3.8 STATISTICAL PROCESS CONTROL

A methodology utilizing statistical and graphical tools to achieve process stability and improve capability by reducing variability.

2.3.9 STRATEGIC AND CRITICAL MATERIALS

Materials not found or produced in the domestic industrial base in sufficient quantities to meet program manufacturing needs. “Domestic industrial base” refers to the North American industrial base for DoD applications; for commercial applications, the term is defined by the organization. Strategic and critical materials include any raw material in short supply, limited domestic production, or otherwise posing a risk to a production program.

2.3.10 SUPPLY CHAIN (MANUFACTURING OR PRODUCTION)

The linked network of all organizations, resources, activities, and technology associated with the production of finished products, encompassing the tiers of subcontractors contributing their individual stages of manufacturing processing and manufactured components or subassemblies to the final product as assembled and delivered to the customer.

2.3.11 TECHNICAL DATA PACKAGE (TDP)

For commercial applications, the following definition applies: The collection of data enabling design, production, delivery, and/or maintenance that communicates a customer’s product definition, performance criteria, and method of verification to the source(s) of the deliverable. (Source: AIA/NAS3500.)

For DoD applications, the following definition applies: A technical description of an item adequate for supporting an acquisition, production, engineering, and logistics support (e.g., engineering data for provisioning, training, and technical manuals). The description defines the required design configuration or performance requirements, and procedures required to ensure adequacy of item performance. It consists of applicable technical data such as models, drawings, associated lists, specifications, standards, performance requirements, quality assurance provisions, software documentation, and packaging details. (Source: MIL-STD-31000.)

2.3.12 TRADE STUDY

Evaluation of proposed designs against documented producibility criteria or by use of generally accepted techniques for producibility analysis.

2.3.13 VARIABILITY

Natural and induced deviations from a target specification caused by controllable and uncontrollable influences.

2.3.14 VARIABILITY REDUCTION

A systematic approach to reducing product and process variability in order to improve cost, schedule, and performance.

3. OBJECTIVES

The objectives of the manufacturing management system include:

a. Establishing and maintaining a documented manufacturing system which provides efficient and effective production of quality products.

b. Identifying and reducing manufacturing risk, including risks at key and critical suppliers.

c. Increasing productivity and reducing production unit cost.

d. Identifying and reducing the impact of issues related to strategic and critical materials on the program.

e. Integrating manufacturing and producibility into the design and development process.

f. Timely and effective transition to production.

The organization, at any level of the production supply chain, should seek to accomplish the objectives of the manufacturing management program through the use of industry leading practices as described in Section 4. Further, the organization should enable the appropriate visibility and accountability throughout the supply chain by collecting, recording, and communicating technical and programmatic data to both higher and lower levels of the supply chain network in accordance with the manufacturing management program.

4. REQUIREMENTS

4.1 Manufacturing Management System

The organization shall establish, document, and maintain a manufacturing management system which complies with the requirements of this standard. The organization shall document how, when, and by what function each requirement of this standard is to be accomplished. The organization shall define the authority and responsibility for each element of the manufacturing management system and include all updates and changes. The organization shall apply the requirements of this standard through all life cycle phases as specified in the contract and as tailored contractually.

Figure 1 depicts the relationship between key and critical suppliers, parts, characteristics, and processes; the sections of this standard that have requirements related to the control of those key and critical suppliers, parts, characteristics, and processes. Note that there may be instances of parts with key characteristics that are not key parts.

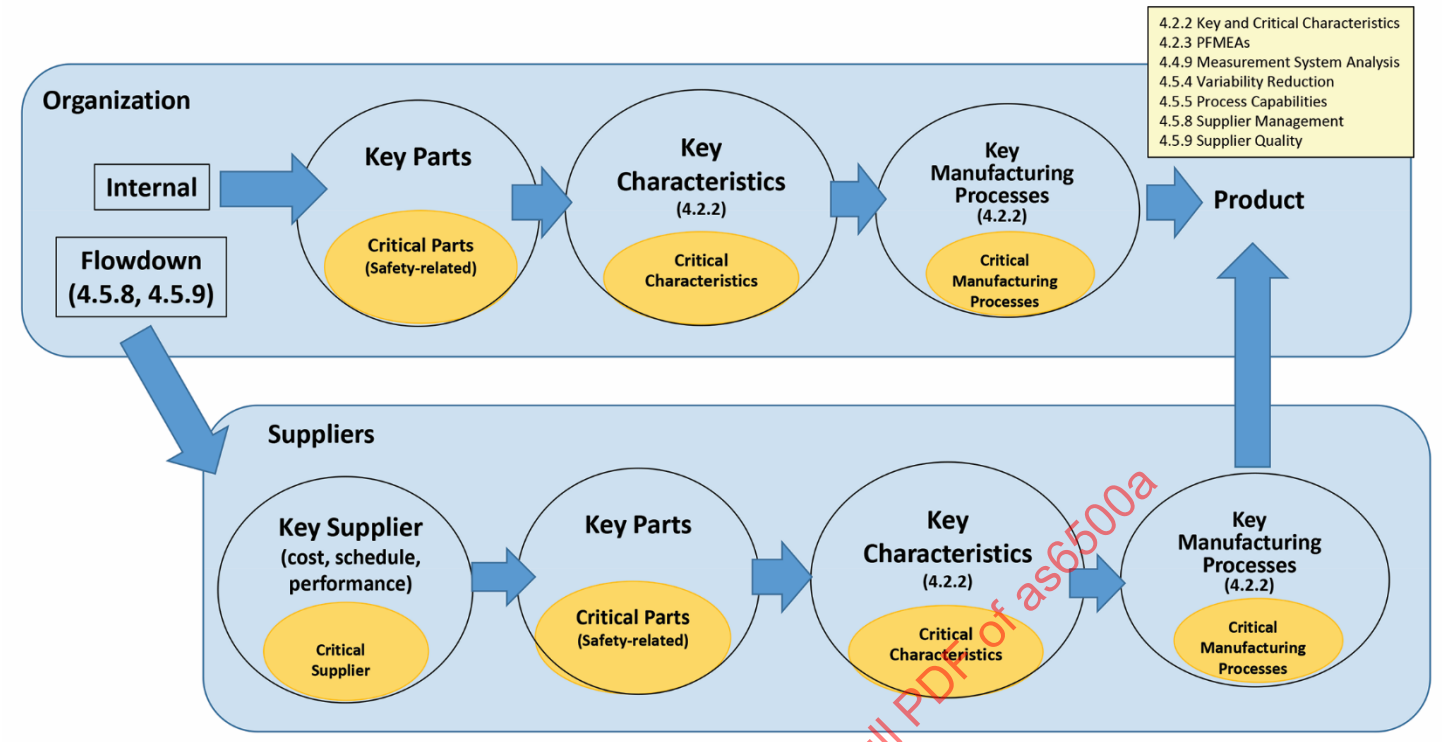

Figure 1 - Key and critical relationships

4.2 Design Analysis for Manufacturing

The organization shall integrate manufacturing into the product design and development process and shall engage manufacturing expertise in this process. In support of this, the organization shall conduct analyses of producibility, design, key and critical characteristics, and failure modes.

4.2.1 Producibility Analysis

The organization shall perform producibility analysis as part of the design and development process. Producibility constraints shall be considered during cost and trade studies.

The producibility process shall include, as a minimum:

a. Selection: Procedures and criteria for selecting candidate items for producibility analysis.

b. Analysis: Identification of the producibility drivers and potential initiatives for improving producibility.

c. Trade study: The organization's design trade studies shall include:

   1. Manufacturing process capabilities, alternative production processes, capacity, manufacturing costs, special tooling, and special test equipment.

   2. Participation by key and critical suppliers within their scope of responsibility.

d. Decision criteria: Implementation of a documented process to evaluate the cost/benefits of potential producibility projects; review, prioritize, and approve potential projects; and monitor the implementation of approved projects.

e. Reporting: Process for reporting producibility status, analysis, and issues during trade studies, preliminary design reviews, and critical design reviews.

The organization should strive for robust product designs tolerant to variation in the intended manufacturing, assembly, test, and usage environments. The producibility process should use a DFA/DFM process, including maximizing the use of common parts, safety and ergonomics; minimizing the number of parts; and minimizing the use of hazardous material. The design trade studies should also include other manufacturing issues such as long lead material, special training, and schedule impacts.

NOTE: Additional information on producibility analysis can be found in MIL-HDBK-727 and NAVSO P-3687.

4.2.2 Key and Critical Characteristics

The organization shall identify KCs, which shall include CCs for critical parts. KCs and CCs shall be included in the technical data package. The organization shall manage KCs and CCs as described below:

a. Add or delete KCs and CCs as a result of design changes.

b. Identify the KMPs for each KC and CMPs for each CC.

c. Develop process control plans for the KMPs and CMPs.

d. Flow-down KCs and CCs to the appropriate level, including to suppliers, i.e., assembly KCs should flow-down to detailed part fabrication KCs.

e. Require suppliers with design authority to identify KCs and CCs for their designs and any corresponding KMPs and CMPs.

NOTE: Additional information on key characteristics can be found in AS9102. Additional information on the control of CCs and critical safety items can be found in AS9017.

4.2.3 Process Failure Modes Effects Analyses (PFMEA)

The organization shall perform PFMEA as part of the design and development process to identify potential failure modes in KMPs and CMPs, as a minimum, to identify actions to prevent or mitigate the failures, and opportunities for mistake proofing. PFMEAs shall be performed prior to the critical design review (CDR). PFMEA shall be updated after CDR when either significant process changes or design changes impacting form, fit, or function occur. Where the design process has progressed sufficiently to allow, PFMEAs should be performed prior to the preliminary design review.

NOTE: Additional information on PFMEA can be found in ARP5580 and SAE J1739.

4.3 Manufacturing Risk Identification

Manufacturing risk management activities shall be integrated into the program risk management process throughout the entire program life cycle. Manufacturing risk areas shall be identified and mitigation plans established and tracked to completion.

NOTE: Additional information on government program risk management can be found in Department of Defense Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs.

4.3.1 Manufacturing Feasibility Assessments

The organization shall conduct and document manufacturing feasibility assessments for competing design alternatives under consideration before selection of the preferred concept. The assessments should use the manufacturing readiness level matrix (or equivalent) as a guide in determining the elements to be evaluated. The feasibility assessments shall include the identification of required production processes and manufacturing technologies not sufficiently mature (e.g., not at the appropriate MRL) and the risks associated with the development of those processes and technologies.

4.3.2 Manufacturing Readiness Level (MRL) Assessments

The organization shall conduct assessments of manufacturing risk and maturity using the MRL criteria and metrics. The organization shall identify the appropriate manufacturing maturity level as a target based on guidance in the MRL Deskbook. As a minimum, the organization shall conduct MRL assessments prior to major milestone and technical reviews (e.g., preliminary design review, critical design review, PRR, etc.) to assess risk against the appropriate MRL. The organization shall present the results of MRL assessments at those reviews. MRL assessments shall include key and critical suppliers. Suppliers should be reviewed for impact to the program. For threads that are not at the appropriate maturity, the organization shall develop and implement manufacturing maturation plans and risk reduction plans to achieve the target MRL.

NOTE: Additional information on MRLs can be found in the DoD MRL Deskbook and MIL-HDBK-896.

4.3.3 Production Readiness Reviews (PRRs)

The organization shall conduct PRRs prior to the production decision. The PRR results shall be an input to the production decision. PRRs should include all internal and external stakeholders and be conducted incrementally throughout the development phase. MRL assessments shall be used to support the manufacturing related elements of PRRs.

NOTE: Additional information on PRRs can be found in IEEE 15288.2 and the DoD MRL Deskbook.

4.4 Manufacturing Planning

The organization shall conduct manufacturing planning.

4.4.1 Manufacturing Plan

The organization shall establish and maintain a manufacturing plan. The plan shall address how the requirements of this standard will be met.

4.4.2 Materials Management

The orginization shall assess the capability of the suppliers to support program requirements. Anticipated sources (including single, sole, and foreign sources) shall be identified, their stability determined, and their risks identified and managed. Materials management includes the following areas.

a. Key and critical parts: The organization shall identify all key and critical parts used, or planned to be used, in the system and develop plans and procedures for securing adequate supplies for anticipated customer demand increases.

b. Strategic and critical materials: For Department of Defense purposes, the organization shall identify all strategic and critical materials used, or planned to be used, in the system, develop plans and procedures to conserve them, minimize waste and scrap, and employ reclamation procedures.

c. Diminishing manufacturing sources and material shortages (DMSMS) and obsolescence management: The organization shall develop and implement a DMSMS Management Plan. The DMSMS plan shall encompass the entire program, including support equipment, for which the organization has design responsibility. The organization will establish a risk-based DMSMS monitoring system using the appropriate tools (e.g., GIDEP). The organization shall identify all diminishing manufacturing sources and obsolete materials used or planned to be used in the program and develop plans and procedures to mitigate their risk.

d. Counterfeit parts: The organization shall implement a counterfeit parts prevention program to prevent the acquisition and incorporation of counterfeit parts or parts embedded with malicious logic into factory and test equipment and delivered products. The program shall include procedures for prevention, detection, tracking, and reporting of counterfeit parts.

NOTE: Additional information on DMSMS can be found in ANSI/TechAmerica STD-0016 and SD-22. Additional information on counterfeit parts can be found in AS5553 and AS6174.

4.4.3 Manufacturing Technology Development

The organization shall determine if new or unproven manufacturing technologies are required to meet program requirements. The manufacturing plans will identify the necessary resources to develop, mature, and implement manufacturing technologies to meet requirements.

4.4.4 Cost

The organization shall develop and maintain a cost model for manufacturing and production costs for the program. The model shall be updated with the most recent design, manufacturing and quality plans, program requirements, and relevant actual manufacturing costs. The organization shall perform cost analysis as an input to the development process, including design trades, cost reduction strategies and initiatives, and manufacturing management. Budgets for manufacturing development and risk reduction projects shall be developed and executed. Cost models should be the basis for estimating production costs.

4.4.5 Manufacturing Modeling and Simulation

The organization shall analyze the manufacturing processes using modeling and simulation (M&S) techniques to identify potential bottlenecks or constraints, confirm the achievability of planned cycle times, evaluate impacts of process variabilities, and estimate required quantities of tooling, personnel, and inventory. The organization shall evaluate the proposed design and manufacturing concepts using M&S techniques before the product and process designs are implemented in the actual production environment. M&S techniques should match the level of complexity of the product manufactured. Levels may range from spreadsheet analysis of manufacturing characteristics, to basic methods of modeling and simulation of selective manufacturing processes, up to virtual factory simulations.

4.4.6 Manufacturing System Verification

The organization shall verify that the proposed production processes, tooling, and test equipment (including special tooling and special test equipment) meet program requirements. Verification methods shall include an evaluation of both direct and indirect infrastructure. Verification may be accomplished through the use of line proofing (manufacturing processes demonstrated in a pilot line environment), virtual simulations, production process verifications, or a combination of methods, based on risk assessments and the cost of each approach.

4.4.7 Manufacturing Workforce

The organization shall identify workforce requirements, including special skills, certifications, and training requirements, and develop a plan to acquire and maintain those skills and certifications that meet program requirements.

4.4.8 Tooling/Test Equipment/Facilities

The organization shall identify tooling, test equipment, and facility requirements including capability and capacity constraints, and capacity for any anticipated short or long term surge requirements. The organization shall identify capital investments for tooling, test equipment, and facilities needed for successful execution of the program. The organization shall implement actions necessary for the timely identification, design, fabrication, and proofing of tooling and test equipment. Plant layout should incorporate principles of lean manufacturing to the greatest extent possible to make effective and efficient use of the contractor's facilities to store, move, manufacture, test, and support production.

4.4.9 Measurement System Analysis (MSA)

The organization shall perform MSA, as a minimum, on the measurement methods for KCs and CCs using common techniques (e.g., calibration studies, bias studies, gage repeatability and reproducibility, measurement uncertainty analysis, attribute gage study, etc.). The organization shall establish and implement corrective action plans when MSA results do not satisfy the internal and/or customer acceptance criteria. The organization should demonstrate that all measurement methods and checking aids for KCs and CCs are suitable, capable, and support the full production rate.

NOTE: Additional information on MSA can be found in ASTM E2782.