SCOPE:

This PAP clause applies to all DPD products, including FSDA and non-FSDA.

Suppliers, subdivisions, and supplier sub-tiers certified to Boeing D6-51991 shall adhere to the Quality Assurance standard for Digital Product Definition.

Suppliers not certified to D6-51991 should comply with the requirements listed below and with D6-51991**.**

1. Digital Product Definition Quality Assurance Procedures and Documented Processes

1.1. **Documented Processes -** The Supplier, supplier sub division and supplier sub-tiers shall develop and maintain comprehensive documented DPD processes and/or procedures that assure integrity of product and/or tooling configuration is maintained throughout the supplier's QMS from receipt of Boeing data through creation of derivatives to product acceptance and process improvement.

1.1.1. The supplier's documented process shall specifically address the processes and techniques unique to all DPD processes beginning with the receipt of DPD data from Boeing through the product life cycle.

1.1.2. The supplier's documented process shall specify all departmental organizations responsible for performance of CAD/CAM/CAI operations including organizations responsible for the delivery of Boeing data or supplier derived data to sub-tier suppliers.

1.1.3. It is recommended that supplier documented DPD processes describe a single, consistent configuration management and QA process to meet all customer DPD requirements (Boeing, other companies, regulatory agencies, etc.) This documented process shall remain in effect throughout the life of the contract.

1.1.4. Boeing reserves the right to survey and/or review the supplier's QMS to verify effectiveness of the supplier's documented DPD processes and procedures.

1.1.5. Elements of the documented DPD processes shall address, but not be limited to the elements in sections 1.0 thru 10.0. The sections in D6-51991 may be addressed in other supplier documents. If so, reference to the document and sections shall be made in the documented process.

1.1.6. Supplier's documentation shall be available in English in addition to supplier's native language.

1.1.7. Additionally, program specific requirements not provided in this document shall be implemented.

1.2. Flow Diagram - The supplier shall include a flow diagram or equivalent in their documented process including process ownership that graphically depicts the flow of data through the DPD system from receipt of Boeing DPD data through the product life cycle.

1.2.1. The flow diagram shall identify the documented DPD processes, and or work instructions associated with control of the datasets and derivatives.

1.2.2. In lieu of flow diagram, supplier may provide a complete relational diagram of their internal procedures to the requirements of this document. 1.3.

1.3 Responsibilities - The quality organization shall be responsible for the documented DPD processes with procedures for change control and notification to affected organizations. The authority and responsibility for each element of the documented DPD processes shall be defined and documented to assure consistent implementation.

1.3.1. The supplier shall notify their Boeing DPD Rep or update Boeing Supplier Quality (SQ) supplier data system DPD profile within 30 calendar days of implementing any changes to:

a) The Documented DPD Processes
b) CATIA synchronization per D6-56199
c) CAD, CAM (when used for product acceptance), CAI software additions, updates or changes
d) Addition of new coordinate measurement system (CMS) and CNC On-machine probing equipment
e) Quality manager or key personnel.

2. Configuration Management and Media Security

2.1. Media Security - The Supplier shall develop and maintain documented processes used to ensure the integrity and security of Boeing provided datasets or Specification Control Drawing (SCD) data. This may include the use of envelope datasets, supplier created CAD/CAM/CAI datasets, type design and tool designs. Integrity and security of datasets shall include requirements for;

2.1.1. Secure storage and retention of Boeing provided DPD, supplier created DPD derivatives, and digital inspection media used for product acceptance.

2.1.2. The supplier shall assure that datasets found discrepant are suspended from use and originator is contacted for disposition.

2.1.3. Archiving procedures with read/write protection which ensure access control per the time specified per program or contract requirements. This includes authority datasets, derivatives and digital inspection media used for product acceptance.

2.1.4. Encryption protection for sending/receiving of electronically transmitted data.

2.1.5. Establishing and maintaining a secure data backup and storage system whether local or remote, a disaster recovery process for authority datasets, derivatives and digital inspection media used for product acceptance.

2.1.6. Access control with permission and/or password protection shall be established in order to ensure that Boeing provided datasets shall not be inadvertently modified. This process shall include derivative datasets released for manufacturing and inspection.

2.1.7. Supplier will have a process to manage and maintain (addition/removal of) supplier employee access to Boeing technical data systems such as REDARS, Enovia, Team Center, etc.

2.2 Configuration Management and Traceability - The supplier shall develop and maintain documented processes to ensure configuration control of all Boeing provided datasets, supplier created CAD/CAM/CAI datasets, Special Tooling, type design, tool designs and datasets sent to sub-tier suppliers used in the production or inspection of Boeing products. These procedures shall include the following;

2.2.1. Formal release process of DPD data which ensures that only current authorized DPD datasets and derivatives are available for use in production and inspection.

2.2.2. The supplier shall ensure the Boeing authority dataset(s), planning and all derivative DPD data used to manufacture and inspect product is traceable to the authority dataset and retained as part of that products acceptance package.

2.2.3. Supplier shall be able to demonstrate traceability of all product planning and DPD derivatives to the current authority dataset including filename, revision and extension. Additionally derivatives shall have their own revision control system in addition to the product/tool revision.

2.2.4. A documented process for change control and retention for all authority datasets and dataset derivatives including engineering, manufacturing engineering, Bill of Material, SSP's, SPECO's and CAE datasets, Etc.

2.2.5. A documented process that includes segregation, storage and retention of non-current (obsolete) authority datasets and dataset derivatives.

2.2.6. Supplier shall have a documented process to generate digitized manufacturing/inspection data from Boeing provided full scale engineering Mylar plots or from any authority physical representation. This process shall ensure integrity of derived dimensions and include review, release and configuration control.

3. Product Acceptance Software (PAS)

3.1. Commercial Off The Shelf Software - The supplier shall document and maintain documented processes for the control of Product Acceptance Software (PAS). PAS includes software used in the acceptance of special tooling and products.

3.1.1. Supplier must document and maintain PAS procedures and reference applicable documents in their documented DPD processes. Documented results shall provide for identification of software name, software version and validation results when used for QA applications.

3.1.2. Procedures or processes will be maintained to prevent unauthorized changes, to limit personnel access to software files, and to archive masters and duplicates.

3.1.3. Supplier should request objective evidence or certification/accreditation (independent) of the PAS from the software manufacture per ASME B89.4.10 or equivalent. The supplier shall maintain documentation for certification/accreditation as a means of identifying approved PAS, version control and QA management approval. Sample testing of existing product and tool programs following new or revised PAS installation to verify compatibility is considered a best practice.

3.1.4. In the event supplier is unable to obtain objective evidence or certification of the PAS from the software manufacturer, supplier is responsible for verifying PAS prior to product acceptance use. Examples of PAS functionality verification include using calibrated standards, known physical artifacts or embedded software to test feature construction and output accuracy. Examples also should include GD&T functions, temperature compensation, CAD translations and software that controls hardware.

3.2. Computer Aided Manufacturing Software - When used for inspection (i.e. CNC On- machine probing, etc.) the supplier shall develop and maintain documented processes for configuration identification and control of CAM software and must meet the requirements of sections 3.1.1 through 3.1.4.

3.2.1. Supplier must verify numerically controlled software prior to product acceptance and maintain records.

4. Internal Quality Audits

4.1. Internal Audits - Internal Audit procedures shall include provisions for auditing all operations annually affecting DPD data and related documentation to assure compliance with contractual requirements, software and production part quality standards, and the observance of security restrictions.

4.1.1. The audit plan shall include provisions for auditing sub-tier suppliers that use DPD data to manufacture or inspect Boeing product or tooling.

4.1.2. The audit plan shall address all requirements of the latest revision of D6-51991 including notification from sub tier to supplier of items listed in section 1.3.1.

4.1.3. Results of all audits shall be documented and maintained for review by an authorized Boeing representative per contract requirements

5. Procurement Control

5.1. Sub-tier Supplier Activity - The supplier shall flow down the requirements of this document (D6-51991 or equivalent supplier document) to sub-tier suppliers and document sub- tier supplier compliance when Boeing authority datasets or dataset derivatives are used for manufacturing or product acceptance. This would include design collaboration when design responsibility is shared with sub-tier suppliers.

5.1.1. The supplier shall be responsible to Boeing for the maintenance, change incorporation, use of DPD and observance of security restrictions by sub-tiers for design, manufacturing and inspection.

5.1.2. The supplier shall establish procedural controls to assure Boeing DPD transferred (authority or derivative) between their company divisions and all levels of sub-tier suppliers shall be in compliance with this document.

5.1.3. The supplier shall determine scope of DPD sub-tier supplier approvals based on their ability to interpret and maintain control, configuration of DPD data and CMS for acceptance of products and/or tools. Criteria for selection, evaluation and re-evaluation shall be established. Records of the results of evaluations and any necessary actions arising from the evaluation shall be maintained.

5.1.4. The supplier shall continue to approve sub-tier suppliers and measurement service providers. It is recommended that suppliers recognize the Nadcap M&I accreditation of sub-tier suppliers. Nadcap accreditation does not relieve suppliers of the responsibility to monitor and measure sub-tier performance.

5.2. Export Control - Flow down to sub-tier suppliers shall include ITAR, MLA, MA, TAA, and EAR requirements.

5.3 Boeing Right of Entry - Boeing reserves the right to survey and/or review the DPD quality assurance and configuration management systems of sub-tiers.

6. Control of Measurement Equipment

6.1. Calibration - The supplier shall implement and maintain a documented process for the calibration and recall of monitoring and measuring equipment. Calibration shall be traceable to NIST or equivalent international standards.

6.1.1. These controls shall provide records of date of acceptance/rejection and next maintenance due date. Measurement equipment shall be physically identified in accordance with certification records. This includes all CMS equipment including CMS sub-components, N/C (CAM) equipment used for inspection, Optical Lay-up Template (OLT's), ply cutters, and plotters used to produce mylars or other inspection or tooling media.

6.2. CMS Procedures - Suppliers using CMS and OLT's for fabrication and/or inspection of Boeing products (parts and tools) must document and control their processes.

6.2.1. Additional CMS requirements are stated below and require capability approval by Boeing.

6.2.2. The supplier and its sub-tier suppliers utilizing CMS and OLT must have documented user level processes or documented procedures that provide adequate asset care, equipment setup, operation, training, and QA procedural methods to perform acceptance of measurements.
Supplier shall determine the applicability and document the criteria to perform the following: (any exclusion shall be approved by the Boeing DPD representative)

a) Purpose / Scope – Overview or statement of specific equipment and its intended use.

b) Calibration – Supplier shall define calibration intervals and maintain a system for periodic maintenance of measurement equipment. The supplier must document inventory of all specific components used for CMS and OLT measurement that could affect the integrity of data collection. This inventory shall include but not be limited to CMM reference sphere and Laser Tracker target accessories (e.g. bushings, adapters, sphere mounts, bar/rod, probing, drift nest, supports, all reflector types, etc.) and weather station equipment.

c) Product Acceptance Software – Supplier shall perform Product Acceptance Software testing per section 3.0.

d) Field Checks / Probe Calibration / Set up – Establish criteria for field checks / probe calibrations / set up to ensure data and system accuracy prior to collecting measurement data.

e) Drift Points / Stability – For all non-fixed (CMM) CMS equipment drift point analysis is required to ensure stability between the equipment and object being measured. Drift points must be attached to the object being measured and a record of drift points measured and acceptance tolerance used, before and after measurements, is required as objective evidence. It is also recommended that Drift Points be measured periodically during the survey as an indication of on-going stability, particularly for long surveys.

f)Temperature Compensation / Scale Factors – The product dimensional characteristics being verified must meet the engineering definition requirements at 68 degrees Fahrenheit as defined in ANSI/ASME Y14.5 and ANSI B89.6.2.

1) When product is measured in a controlled environment the allowable deviation from 68 degrees F shall be documented by the supplier based on product material, size and allowable tolerances. A process, often referred to as soak time, shall be defined, documented and followed to insure product is at the correct temperature at the time of measurement.

2) When products are measured in an uncontrolled environment, or the process often referred to as soak time has not been followed, a documented process to compensate for thermal effects of the objects being measured is required. Objective evidence is required for temperature compensation when using scale bars, artifacts or temperature calculation. Supplier shall document their temperature compensation process which includes planning for pre, post and during measurement survey analysis.

g) Establish Coordinate System – Establish criteria for changing the coordinate system from a CMS coordinate system to a part or tool coordinate system (e.g. tolerances, datum targets, datum features, tooling holes, tool enhanced reference system or best fit). Establishment of coordinate systems shall be in accordance with customer engineering definition and ANSI/ASME Y14.5 as applicable. Best Fit alignment shall not be used for production hardware acceptance unless contractually authorized by Boeing engineering and evidence of authorization shall accompany final inspection reports.

h) Multiple Station Set-up Criteria – When moving CMS equipment or product is moved from one location to another, or combining CMS equipment during a survey, supplier shall document their process and acceptance tolerance. A minimum of seven adequately distributed Common Points used as reference for repositioning/adding the CMS equipment during a survey shall be verified and recorded as objective evidence.

i) Data Collection Parameters – Establish measurement guidelines and specific collection parameters for the CMS equipment prior to collecting measurement data. (E.g. point density, point labels, time/distance separation parameters, apex angles, distance limitations).

j) Data Analysis – Establish guidelines for the evaluation of 3D point data to tool engineering, engineering datasets, point maps or drawings.

k) Reports – Establish standard process for CMS reports shall include job information, coordinate system establishment (alignment verification), object temperature, data analysis, measured results and point maps. When measured in a controlled environment object temperature is only required when the documented process, often referred to as soak time, is not followed. When products are measured in an uncontrolled environment CMS reports shall also include scale bar and drift point measurements. Reports shall be in English and in inches unless directed otherwise by customer contract. Reports shall include feature identification, nominal, actual, tolerance and deviation.

l) Record Retention – Establish standard process for all inspection and test records to be archived and retained per customer contract requirements and provided to the customer upon request.Boeing will recognized a suppliers option to become Nadcap Measurement and Inspection (M&I) approved in lieu of the applicable CMS portion of a Boeing DPD audit for fixed CMM, Laser Tracker or Articulating Arm measurement devices.

7. Inspection Media

7.1. Inspection Planning for Validation - When product or tool engineering definition 2D drawings include digitally defined surfaces/features (3D models), the supplier must ensure inspection of these surfaces/features. Supplier’s QA organizations are responsible, at a minimum, for inspection media, measurement instructions and analysis of data for product acceptance. Inspection planning shall include the following activities, as appropriate, in meeting the specified design requirements;

7.1.1. Description of the method and instructions for validation of each digitally defined product feature for first article inspection and production parts.

7.1.2. To validate digitally defined product features with methods other than CMS inspection the supplier must document the media and/or process used.

7.2. Inspection Media - The Supplier shall develop and maintain documented processes to create inspection media from DPD datasets. These shall assure:

a) Media is independently derived from and traceable to the authority dataset Media must be under configuration control

b) Media contains graphics, annotations, text, and GD&T to illustrate inspection operations

c) Coordinate system, alignment and datum features are defined Part/Tool set up instructions

d) Media is created by qualified personnel

e) A media review process exists (checker, checklist or peer/team review)

7.2.1. Document the establishment of the coordinate system, datum targets and datum features.

7.2.2. Digitized manufacturing/inspection data generated from Boeing provided full scale engineering Mylar plots must have evidence of QA acceptance.

7.2.3. Data or datasets identified as "Pre-Release" or “REFERENCE ONLY" shall not be used for product acceptance purposes. Any use of this data for manufacturing or design is at the risk of the supplier.

7.2.4. Supplier may use definition of MDD, MDI, MDS, TDI, loft surfaces or other digital definition, including IGES or STEP format, as authority for product acceptance when supplied by Boeing according to a Master Dimensions Request (MDR) process.

7.3 Reduced Content Drawings - Suppliers who receive reduced content drawings with an associated 3D model, must be able to extract information from the 3D model sufficient for manufacturing and inspection in addition to the 2D drawing.

7.3.1. Suppliers must identify and document for manufacturing and inspection, the following requirements at a minimum.

a) All features identified on the 2D drawing

b) Features of the 3D model not defined by the 2D drawing

c) Fabrication & manufacturing process specifications

d) Flag notes, parts list and other specified requirements

e) SSP’s, SPECO’s, and APO’s

7.4. Printed Wire Boards (PWB) - PWB suppliers that have been provided 100% Boeing defined 2D drawings are exempt from the D6-51991 approval.

7.5. Model Based Definition (MBD) - Suppliers who receive Engineering and/or Tooling MBD datasets must extract information from the dataset sufficient for manufacturing and inspection activity for the product. Additionally, utilizing MBD requires a capability assessment by a Boeing Supplier Quality DPD.

7.5.1. Supplier's QA must verify that all design implicit and explicit requirements (e.g., all features defined by GD&T, annotations, specifications, notes and other specified requirements in the authority MBD dataset and associated parts list including dimensional and other properties) are identified and planned for inspection/validation.

Note: 2D drawings, 2D sketches/views or a Low End Viewer (LEV) may be used to convey manufacturing and inspection information as required to fit the supplier's methods of operation.

7.6. First Article Inspection - All explicit and implicit design characteristics within the engineering shall be positively identified within the FAI plan. This shall include all engineering characteristics requiring traceability:

a) All features annotated within the 3D model (explicit)

b) Features of the 3D model not annotated (implicit)

c) All characteristics applicable on the 2D drawings/reduced content drawings

d) All applicable notes and material lists

e) All feature tolerances per the standard / general notes.

7.7. Boeing Provided Plots - Boeing plotted media used for manufacturing and inspection shall be requested through procurement agent.

7.7.1. Boeing Product Definition Template (PDT) - Suppliers using Boeing PDTs shall order, control and perform verification prior to use of Boeing PDTs in accordance with D950-11288-1 Product Definition Template (PDT) Requirements, Validation and Verification Processes, and Handling Instructions for Plot Centers and Supplier Use.

7.8. Supplier Created Plotted Media - Suppliers creating plots for product acceptance must have a documented procedure. These procedures shall include the following, at a minimum, and require capability approval by Boeing Supplier Quality DPD representative:

a) Plotter calibration – Follow OEM process for calibration and adjustment and independent validation to NIST or equivalent.

b) Plotting Environment – Equipment located in temperature and humidity controlled environment to meet product requirements. (Typically 68 degree Fahrenheit (with +/- 2 degree variance) and 50% Humidity (with +/- 5% variance))

c) Verification of engineering definition – Verification of developed flat pattern and plot verification features

d) Plotted media material - should be minimum .005 inches thick polyester film. Paper plots may be approved on a case by case basis for tolerances greater than +/-.10 inches.

e) Part number Identification & revision - Traceability to the Boeing authority dataset

f) Validation of plotted media - Acceptance criteria of plot accuracy prior to stamping and releasing plot to manufacturing or inspection

g) Quality acceptance stamping – Date, Temperature, Humidity, Accuracy and evidence of inspection.

h) Accuracy of plots used for inspection – Plotted media will be verified prior to use in the environment where they are used. (Manufacturing or Inspection, etc.)
Note: The tightest product tolerance that can be reasonably inspected with a Mylar overlay is +/- 0.030 inch after grid check or defined verification features check has been performed.

7.8.1. Verification of plot accuracy - Check plots for accuracy prior to manufacture and inspection of parts. Measure to ensure the accuracy of the grid lines, or defined verification features vertically, horizontally and diagonally to verify plots. Grid lines are usually plotted in 10-inch increments. Check the grid lines from the first to the last grid line or defined verification features. Grid lines shall be within a tolerance of +/-.020 up to 100 inches and within +.030/-.010 over 100 inches.

Note: A calibrated steel scale (Starrett or equivalent) is recommended to check the grid lines for accuracy.

7.8.2. Environmental Controls - Plotting equipment shall be located in a temperature and humidity controlled environment. Development and validation of plots will be done in an environmentally controlled area using a real time monitoring system for temperature and relative humidity.

Note: The tolerance noted in the plot accuracy stamp is the accuracy of the plot at the time it was generated and does not relieve the user of the responsibility to verify the plot at the time of use.

7.8.3 Handling and Storage - To maintain media accuracy and stability, plots are recommended to be handled and stored as followed:

7.8.3.1. Plots should be handled according to the following recommendations. Failure to follow these recommendations may shorten the usable life:

a) Do not roll less than 3 inches inside diameter

b) Do not expose the media to heat generating sources. This may include laser printers, computer monitors, copy machines, air compressors, transformers, batteries, engines and sunlit enclosed places.

c) Do not fold, crease or damage in anyway, as this also effects the dimensional stability.

7.8.3.2. To maintain accuracy and stability, it is recommended that plots be stored in:

a) In a dust free, non-condensing moisture and chemical free area

b) Temperature from 65 to 80 degrees Fahrenheit and relative humidity from 45 to 55 percent.

7.8.4. Destruction of Obsolete/Unusable - All materials and computing media of any kind containing BOEING PROPRIETARY information shall be disposed of by methods that ensure that all Boeing proprietary information is destroyed so that none of it can be reconstructed from the residue or remains. Disposal methods may include recycling, shredding, burning, etc. and are dependent upon the resources at any given company/supplier facility. Recycling may be used only where procedures are in place to assure continuous security controls throughout the recycling process. The methods used for large-scale disposal shall be approved by the Law Department and Security.

8. Data Exchange Methods

8.1. CAD Compatibility Requirements (BCA only – commonly referred to as synchronization) **-** The supplier shall maintain the current level of hardware configuration, software, software revisions and other digital system information required to maintain compatibility with Boeing supplied datasets and/or data exchange formats per applicable Boeing system(s) requirement documents.

8.1.1. For Boeing Commercial Airplanes divisions (BCA) see D6-56199 Hardware and software compatibility requirements for supplier's use of BCA CATIA native datasets as authority for design, manufacturing and inspection. This includes CAD, LEV, data exchange, and other computing equipment that receives authority data and/or is installed/tested by Boeing. Supplier shall comply with and reference applicable synchronization documents in their documented DPD processes.

8.1.2. Supplier must have a documented process that ensures they can translate, receive and validate all authority datasets without change to the data integrity.

8.1.3. The use of 3D-PDF is for viewing annotation, and shall require authority 3D surface geometry for manufacturing and inspection use.

8.2 Translations - When suppliers with native CAD Software receive their Authority dataset in the same CAD System (native to native) and manage their process which includes manufacturing and inspection software using the same Native system and version, translation verification is not mandatory due to lower risk but recommended as an industry best practice**.** When suppliers translate from Native CAD format to alternate formats including CATIA V4 to CATIA V5 or Native to STEP suppliers are responsible for all dataset translations and must have a clear documented process for each. The documented process must include a method to verify the accuracy of translations. Suppliers must be able to demonstrate the CAD translation process, including verification/interrogation methods used, and the ability to identify known discrepancies.

8.2.1. Acceptance criteria for accuracy of translated surface profile/geometry, (tolerance) must be determined by the supplier, and must ensure the end product will be within engineering tolerance/specification. Objective evidence validating the suppliers' documented translation process must be retained. (Typical allowable deviation is 1/10th of the tightest engineering tolerance)

8.2.2. The verification process for translation of datasets containing 3D annotation (i.e. feature control frames, dimensions, text, and/or surface geometry) must ensure that all intended entities are accounted for in the translated media.

8.2.3. Suppliers receiving Boeing authority STEP format datasets supplemented with a 2D DWG, 3D-PDF or SUPPAR STEP formats throughout their product realization and inspection processes are not required to perform data translation validation. It is strongly recommended data translation validation remain a best practice to mitigate potential errors.

9. Special Tooling

9.1. Tool Design - The supplier shall describe documented processes to ensure release, acceptance, identification, security, access and change control of tool design and tool inspection datasets. Tooling datasets shall have traceability to current authority engineering and derivative tooling dataset sources. The engineering authority dataset(s) shall be identified on the tool design when applicable.

9.1.1. Tool Designs shall be produced using authority data and when required by contract be approved by Boeing authorized personnel.

9.1.2. The supplier shall ensure that when Tool Design responsibility is flowed down to sub tier suppliers, the sub-tier supplier will be approved by the supplier.

9.2. **Traceability -** All digitally defined special tooling and physical inspection media (check fixtures, templates, etc.) will be identified and traceable to the engineering authority dataset, tool design dataset and any tool inspection datasets.

9.3. **Inspection -** These tools and tooling media shall be dimensionally accepted and periodically validated to the authority design at a frequency determined to ensure accuracy and repeatability of the tool before use.

10. Training and Process Performer

10.1. DPD Training - Suppliers shall define training requirements to assure competence and shall maintain employee training records, including on-the-job-training, for all DPD system users (e.g. Quality, IT, planning, purchasing, tooling, contract review and Mfg).

10.1.1. The supplier shall ensure that all personnel having DPD system access have completed training adequate to perform digital product acceptance activities including digital inspection media generation, performance of inspections and 3D data collection.

10.1.2. Syllabus shall include training criteria necessary to ensure proficiency of process performers (e.g. planning, programmers, quality, tooling, CMS etc.) to interpret ASME Y14.5 Dimensioning and Tolerancing (GD&T).

10.1.3. Training shall be updated due to changes driven by new equipment, software or Boeing program requirements.

10.1.4. If Quality activities are performed by individuals other than the supplier’s quality assurance personnel, the supplier shall define the specific tasks and responsibilities that are authorized and the training necessary to perform those tasks.

1. Coordinate Measurement System (CMS)

1.1 CMS Accuracy Limitations - Each CMS has Original Equipment Manufacturers (OEM) limitations on measurement accuracy. Training will include understanding the OEM accuracy statement and will be adhered to when measuring tooling or production hardware. The selection of the specific calibrated measurement device shall be at the discretion of the Quality manager or inspection personnel. The Measurement and Test Equipment performance requirements shall be considered capable if the Test Accuracy Ratio (TAR) is greater than or equal to 4:1. When the TAR is less than 4:1, perform a measurement process evaluation (Gage R&R or Measurement System Analysis) to confirm the capability of the Measurement and Test Equipment. The TAR can be calculated by dividing the engineering by the device or instrument performance specification tolerance.

1.2 Calibration - Periodic certification/calibration of all equipment utilized in the inspection and acceptance of manufactured products, including date of certification, acceptance/limitation, and next certification due date, are maintained, latest revision.

1.3 Targeting Tools & Calibration - CMS data collection devices, targets, and target adapters must be calibrated annually and controlled by the calibration recall system. Because the CMS data collection devices and/or target adapters will cause offset coordinate values to provide the capability to measure unique features, these target offsets must be explicitly defined or graphically shown on set-up records to ensure understanding when performing measurement review/analysis. Ensure the data collection process will validate that all collection devices, targets, and target adapters used on the measurement are correctly indexed to the tooling/production part feature and are certified. All equipment will be calibrated annually, calibration stickers with due dates will be attached to CMS equipment, and the calibration date will be valid before CMS equipment can be set up.

Master calibration spheres shall be calibrated as they are used to validate measurement probes. Individual measurement probes do not need to be on an annual calibration as they are calibrated from the master and will be calibrated before use.

1.4 Tool / Part Level Requirements - Leveling of a tool or part is required for CMS fabrication, rework, or inspection. A rigid tool or part may be measured without leveling as long as the shape/orientation does not affect the accuracy of the CMS measurement (eliminate twist and/or warp); it is approved by the Quality and documented in the inspection records.

1.4.1 Tooling will have a documented leveling plan listing allowable tolerances to ensure the leveling is performed from the exact location and not introduce dimensional stack-up. This will minimize twist/warping and provide the most accurate/repeatable measurement.

1.4.2 Measured Items—Items like production parts or assemblies must be leveled to reduce twisting or warping. Suppose the item must be held in position to ensure the coordinate values for the measurement can be used. In that case, it will be located to mimic its orientation as it would be installed in the next higher assembly/product, approved by Quality, and documented on the inspection record.

1.5 Job Set-up Information - System settings will be:

a) Unit/Length set for Inches unless otherwise contractually specified
b) Decimal place set for 4 places (e.g., 0.0000") unless otherwise noted.
c) Angle set for Degrees, unless otherwise contractually specified
d) Temperature set for Degrees Fahrenheit

1.6 Temperature Compensation / Scale Bar Factor - Thermal Compensation applied to Measurement Equipment when necessary:

1.6.1 The controlled environment shall be monitored using calibrated temperature and humidity devices. The temperature shall be maintained at 68 degrees (+/- 2) and 40-55% for humidity. Soak times can vary depending on material and size. See Section 4.

1.6.2 An uncontrolled environment shall provide objective evidence for temperature compensation when using scale bars or artifacts and temperature calculation see Figure 1. The supplier shall document its temperature compensation process, which includes planning for pre-, post, and during-measurement survey analysis. Scale bars will verify that temperature compensation has been appropriately applied. See Section 5.2

1.6.3 The product dimensional characteristics being verified must meet the engineering definition requirements at 68 (+/—2) degrees Fahrenheit, as defined in ANSI/ASME Y14.5 and ANSI B89.6.2.

1.7 Scale Bars - Scale bars will be used to verify that temperature compensation has been appropriately applied. Scale bars are made from like material or like Coefficient of Thermal Expansion (CTE) of the object being measured. Scale bars shall be proportional to the object being measured but limited to usual industry standards, such as 60–80" on large-scale parts, unless a larger scale bar is required to meet customer requirements. Scale bars can be made in-house if material certification is retained, calibrated, traceable to NIST, and meets the criteria below. Scale bars will be calibrated annually or biannually, and calibration stickers with due dates and actual distances will be identified and attached to them.

1.8 Scale Bar Report Reporting: Scale Bar measurement data is used to verify the integrity of the measured data and will include the following:

a) The name of the established coordinate system (Used for Alignment of Part/Tool).

b) The serial number or identification of the scale bar, including material and CTE information.

c) The calibrated Nominal distance on the scale bar, Measured (actual) and Deviation.

d) The beginning and ending scale bar analysis (SB1 – SB2, SB3 –SB4) including temperatures.

1.9 Establish a coordinate system:

1.9.1 Coordinate manipulation changes the coordinate system from the CMM to a tool or product coordinate system. It is also known as Transformation or Alignment. Establish criteria for changing the coordinate system from a local coordinate system to a part or tool coordinate system. Considerations include Tolerances, Datum Targets, Datum Features, Tooling Holes, and Enhanced Reference System (ERS). The establishment of coordinate systems shall be per customer engineering definition and ANSI/ASME Y14.5 as applicable.

1.10 Establish Alignment - Alignments shall be performed to correspond to the geometry supplied by the customer for the object coordinate system. The points used in alignment should be agreed upon before any survey is conducted. Contact the lead inspector for specifics, items not covered in this document, or deviations from these guidelines.

1.10.1 The "3-2-1" method utilizes the geometric principle that three points create a plane. The operator determines the origin of the coordinate system, orients an axis of the coordinate system (x, y, or z) through a second point, and establishes a plane of the coordinate system (x-y, y-z, z-x) through a third point.

1.10.2 Axis alignment may not be the preferred method to align into a tool coordinate system for rework or inspection. However, the "Axis Alignment" program is the preferred method for establishing a tool coordinate system, i.e., Enhanced Reference System (ERS). Once the tool has been aligned into the coordinate system and verified/accepted by Tooling QA in subsequent surveys, the Transformation program should be used. The targets to establish the initial coordinate system should be agreed upon by Tool Fabrication, Tool Design, and

1.11 Alignment Tolerances - Establish criteria for changing the coordinate system from a local coordinate system to a part or tool coordinate system. (e.g., tolerances, datum targets, features, tooling holes, tool-enhanced reference system). The establishment of coordinate systems shall be by customer engineering definition and ANSI/ASME Y14.5.

1.11.1 Best Fit or Least Squares Alignments shall not be used for final product acceptance unless explicitly approved by the customer in a formal document such as a purchase order or other command media. Coordinate system measurements such as datum feature locations and applications shall be included in the measured object's dimensional report.

1.12 Data Collection Parameters: Only trained and qualified operators and quality assurance personnel are permitted to use the CMS equipment, target, and target adapters when capturing data to ensure that the measurement data being presented represents the accuracy of the object being measured. If compliance is not controlled, measurements will not be valid for MEC and/or customer use.

CMS operators will follow established measurement guidelines (see Figure 2) and specific collection parameters for the CMS equipment, including point density, point maps, and labels. All required features will be generated in full for downstream reporting, and all other measurements, such as individual points for profile measurements, will be taken per customer specifications. If no customer specifications exist, measurements will be taken per Figure 2.

1.12.1 The inspection checklist for Quality acceptance of measurement data is as follows:

a) Verify that the equipment, scale bars, targets, and target adapters have a current Calibration/Certification sticker showing the date calibrated, the due date, and who performed the calibration

b) Verify the setup stability

c) Verify that the transformation alignment is within acceptable parameters

d) Verify Scale Bar values (as required)

e) Verify multi-station alignments are within tolerance as required

f) Verify that all actual values are within engineering tolerance

g) Document all non-conforming conditions as required

h) Obtain the electronic or printed report and attach to planning or inspection records

i) Signify acceptance by stamping CMS reports and Inspection Record

1.13 Data Analysis: The features 3D point data will be collected per the request for the work statement/order process (e.g., Work Planning, Request for Measurement, etc.). 3D point data, requiring analysis of customer CAD datasets, will be provided to CAD/CAM Quality Assurance by the creation of a copy of the Customer's CAD model (reference D6-51991 section 2.0) derivative containing the "AS MEASURED" (actual) point data in the correct coordinate system. The requesting documentation will explicitly define the requested analysis and provide specific details about the data being provided.

1.13.1 Data analysis printouts supporting acceptance or rejection shall be stamped by the analyzing inspector

1.14 Reports: All reports will be stamped and dated by the organization performing the analysis. All reports must be complete, in English, legible, and understandable with no ambiguities. Reports generated from CMS software shall be traceable, correspond to characteristic numbers or bubbled dimensions or callouts, and correspond to the (First Article Inspection) FAI. QA accepting a measurement will, as a minimum, print, stamp, and retain the following:

1.15 Job Report: The job report will contain all the critical configuration information about the job and will include a printout of the following:

a) Inspection date
b) The operator(s) & inspector(s) employee numbers who performed the measurement.
c) Work order, Planning, Traveler number
d) Part / Tool Number, Revision and Name
e) Serialization and or unique descriptor information for the item being measured
f) Complete Authority Model Number & file extension

g) Specific measurement equipment identification or assets used to make the measurements
h) Part / Tool Temperature recorded and when required before and after
i) Scale factor that was used to compensate for the coefficient of thermal expansion along with the specific temperature used to make the calculation
j) Beginning and ending scale bar analysis (SB1 – SB2, SB3 –SB4) including temperatures
k) Important notes or information such as Restrained/Unrestrained; CMS Set-up Info; Target Offsets; 2D Drawings; 3D Sketches; Characteristic Numbers; Bubbled Sketches; Digital Photos; graphic illustrations for clarification of object and traceability, etc.
l) Graphics and point maps generated by analysis show measured point labels, etc.
m) CMS reports must contain the following:
    1. The alignment results for Datum features A, B, C, and/or Datum Targets (i.e. A1, A2, A3, B1, B2, C1, etc.) Nominal, Measured, and Deviation values shall be reported and compliant with ASME Y14.5 and released to engineering.

    2. The results X, Y, and Z Coordinates of the Nominal & Measured points or features along with reporting deviation and Tolerance (OOT) conditions

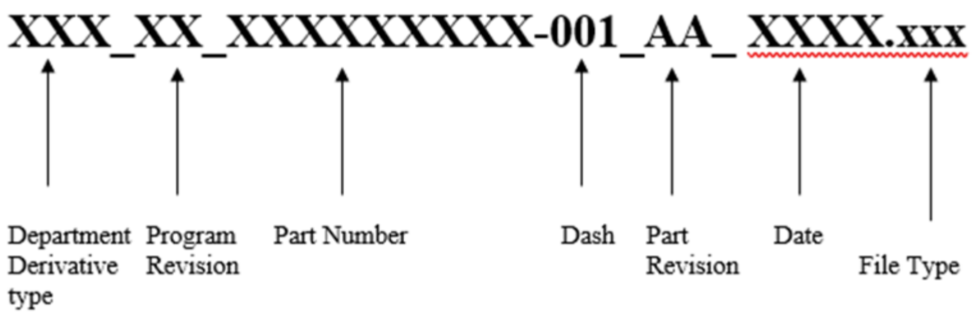
    3. The Point IDs of the points analyzed and traceable (AS9102 traceable to the Characteristic Number)

1.15.1 CMM Data – When a FAI is not required, the Quality Control Inspector (QCI) may attach the complete CMM Report following the sequence of the balloon drawing (instead of manually populating the data from the CMM Report to the supplier's inspection report)

Note: Inspection Report will still need to be filled out referencing the CMM Report or suppliers' report, as applicable.

1.15.2 If a CMS inspection finds feature(s) to be out of Tolerance (OOT), the feature(s) shall be verified using Standard Inspection Methods (SIMs). SIMs are considered the gold standard and are the definitive value of the inspected dimension.

1.16 Record Retention: All CMS files, measurement data, and reports must be archived and retained within customer contract retention requirements and provided to the customer upon request. Suppliers and sub tier suppliers shall electronically store data on a secure server. Programming traceability and control - CMS programs will be configured and traceable to authority datasets. The naming convention is as follows:



Department / Derivative type: ENG = Engineering, NC = NC Programming, CI = Inspection/CMM Programming
Program Revision: Revision of program derivative document
Part Number : Customer Part Number
Dash Number : Customer Dash Number
Part Revision: Customer Part Revision
Date: Date in year/month/day format
File Type : File type Extension

For example:
NC_A_22MEEU12345-001_AA_20250320.prt
CI_B_2ZAH12345-001_E_20240212.stp

1.16.1 All CMS programing will be stored in a secured location with only Quality personnel.

1.16.2 The updated program will supersede the version in WIP. Additionally, a copy of the older version will be stored in an obsolete folder.

1.17 Training:

1.17.1 OEM Equipment Training - All CMS equipment operators will be trained on the OEM start-up & operation manuals along with this procedure.

1.17.2 DPD Training—Suppliers shall define training requirements to assure competence and maintain employee training records for all DPD system users in Quality, including on-the-job training.

1.17.3 Suppliers shall ensure that all DPD system access personnel have completed adequate training to perform digital product acceptance activities, including digital inspection media generation, inspection performance, 3D data collection, and interpreting ASME Y14.5 Dimensioning and Tolerancing (GD&T).

1.17.4 Training shall be updated due to changes driven by new equipment, software, or customer program requirements.

1.17.5 Suppose Quality activities are performed by individuals other than Supplier's quality assurance personnel. In that case, the supplier shall define the specific tasks and responsibilities that are authorized and the training necessary to perform those tasks.

1.18 CMS Preventative Maintenance: All CMMs should have preventive maintenance. The CMS operator completes the maintenance checklist as applicable.

Figure 1

Use the following to "Calculate Scale" for tools or parts that do not have an adequate coordinate reference system, or the CMS cannot calculate the CTE scale.

MATERIAL TYPE	EXPANSION RATE
Aluminum	0.00001310
Steel	0.00000650
Invar	0.00000080
Nickel	0.00000695
Fiberglass Epoxy Prepeg	0.00000790
Graphite Epoxy	0.00000200
Plaster	0.00000940
Concrete	0.00000800

List of most common Material Type and their Expansion Rates

The following is an example of applying CTE when the average temperature is above 68*.

Note: The tool material is aluminum, which expands at 0.0000131" per degree over 68*.

A.) Take temperatures throughout the survey envelope, at each end and in the middle. Then average them by adding all temperatures together and dividing by the total amount of readings taken.

Temperature Equation:

(temp#1 + temp#2 + temp#3) / 3 (number of readings)

(73* + 74* + 73*) = 220*

220 * /3 = 73.33* (average temperature reading)

B.) Subtract 68* from the average temperature reading (in this case 73.33*) 73.33* - 68* = 5.33* (temperature difference)

C.) Multiply the "Temperature Difference" times the "Expansion Factor" of the material being shot (5.33* x 0.0000131") = 0.0000698" (compensation factor)

D.) Subtract the "Compensation Factor" from 1.000" to determine the correct "Scale Factor" (1 - .0000698) = .9999302" (scale factor)

E.) Apply the new scale factor to the coordinate system by typing "Scale" and entering in the adjusted numeric value (.9999302) and click on OK.

F.) Another example is when the temperature is less than 68*. The following equation will assist in the output of data when this occurs.

G.) Follow steps a, b, c (in section 13.1). The difference between this example and the one above is the tool temperature is under 68*.

Temp1= 62* Temp2=63* Temp3=62*

Average Temperature = 62.33*

62.33* - 68* = -5.67*

(-5.67* x 0.0000131) = -0.0000743

(1 - -0.0000743) = 1.0000743 will be the "Scale Factor"

Once the proper scale adjustment has been made the operator may want to transform or axis align to establish the final coordinate system. If it is not necessary to create another coordinate system, then analyze a certified scale bar target points to ensure that the proper scale factor was entered.

Note: When the temperature of the object is greater than 68* the "Scale Factor will be less than 1.000, and when the temperature of the object is less than 68* the "Scale Factor" will be more than 1.000.

Figure 2

Coordinate Measurement System Feature Creation

In all cases, when any feature is out-of-tolerance, additional inspection points need to be created around the discrepant area to determine the full extent of the out-of-tolerance condition on the feature.

Inspection Point Grids

Use of an inspection point grid is favorable for First Article Inspection or for first part tryout of N/C machining programs and corresponding CMM inspection programs. Use of the grid will ensure good inspection point coverage of machined features for the first parts created and assist in process feedback and improvement until the N/C production stage begins.

When feature types have surface areas of greater than 4 X 4 inches, but under 8 feet in length or width, an inspection point grid of approximately 1 point every 4 sq. inches should be placed on the feature. For features greater than 8 feet in length or width, an inspection point grid of 1 point for every 6 sq. inches should be placed on the feature.

In addition, inspectors will consider product manufacturing processes and add inspection points as needed to verify conformance to the design. For example, planes with perpendicular or flatness tolerances will require additional points for a complete analysis of the design feature.

Feature Type	Minimum Number of Points
Line	3 Points (Add pts. per Point Grid criteria above)
Plane	4 Points (Add pts. per Point Grid criteria above)
Surface (+/-.010 to .021)	5 Points (Add pts. per Point Grid criteria above)
Surface (greater than 5 sq. in.)	5 See Inspection Point Grids above
Surface (Under 2 sq. in.)	3 Points
Surface (>10 degrees contour)	5 Points + points spaced at every 10 degrees of contour change
Tangent Surfaces	Add points per Insp.
Curves (less than 5 inches)	4 Points minimum or 1 pt per inch
Curves (greater than 5 inches)	5 Points minimum or 1 pt. per 6 in. (see Point Grid above)
Radius	3 Points or 1 point if defined by profile.
Circle	4 Points
Cylinder	8 Points
Sphere	5 Points

Additional Considerations

Curves - There will be a minimum of one point per inch (or any fraction) of curve for curves shorter than (5) inches. (Three (3) points minimum)

If the curve is longer that five (5) inches a minimum of five points are to be verified. Point spacing on the curve is not to exceed ten (10) inches.

Points will have a maximum of ten (10) degrees of angular separation on curves or surfaces that are of a cylindrical nature. (This requirement is in addition to the requirements based on the length of the curve or the size of the surface).

Surfaces - Select a minimum of four (4) points per surface unless the surface area is less than two (2) square inches in which case three (3) points are adequate.

Points will be measured at a distance from edge breaks and radii (i.e. 0.050”, 0.100”, etc.) of the individual surfaces (this includes tangencies between surfaces).

Points will be measured at inflections of surface tangency and at approximately one inch on either side of these inflections.

A minimum of five points are to be verified if the surface is larger than five (5) inches by five (5) or twenty-five (25) square inches. Point spacing on the surface is not to exceed ten (10) inches.

If the surface has a profile tolerance of 0.010 inch or less, a minimum of one point will be defined for each five (5) square inches. A minimum of five (5) points per surface are to be verified. Point spacing on the surface is not to exceed five (5) inches.

If the surface has a profile tolerance of greater than 0.010 inch but less than 0.021 inch, a minimum of one point will be defined for each ten (10) square inches. A minimum of five (5) points per surface are to be verified. Point spacing on the surface is not to exceed seven (7) inches.

If the surface has a secondary profile tolerance controlling the smoothness of the surface, points shall be taken in a one (1) inch grid across the entire surface. Point spacing on the surface is not to exceed one (1) inch.

Individual Surfaces - Points added 0.250 to 0.500 from the nominal edges of the individual surfaces

Surfaces – (faces, patches, tangent surfaces/planes, etc.) – Inspection Points are added at approximately one inch on either side of surface inflections and at the tangency between surfaces.

Radius - When a radius is inspected by only one point, it is assumed that the plane or surface in contact with the radius has been inspected and is in tolerance. Also, the design should indicate there is more tolerance allowed (usually double) than the contacting surface. In most cases, radius features are quickly and adequately inspected using a physical radius gauge and are not included in CMM inspection programs. However, inspections of radius features can be added to a CMM program using the one-point scenario to ensure the correct cord height radius has been created on the product. One point will also identify if the location of the radius is within tolerance.

Inspection points are required for the center of tooling holes, scribe lines (trim, crosshair, etc.), datum planes, and tooling surfaces (planes). In all cases, the CMM inspection should begin with inspecting each setup sketch datum to document that the setup is valid without searching through the CMM printout for those datum features.

2.0 Computer Measurement Machine (CMM) Stationary

2.1 Set Up / Environment - Fixed Coordinate Measurement Machines (CMMs) are designed and intended for continued use in a controlled environment to achieve the high degree of accuracy specified by the manufacturer. The location of a CMM outside of a controlled environment will directly impact the accuracy of the measurements.

2.1.1 Environmental stability always needs to be considered before measuring to ensure that the measurement activity is located in an area where the stability of the CMM and object being measured will not be changed due to floor structures, vibration caused by other machinery, or significant temperature changes caused by open doors, windows, or direct influence by climate control units.

2.1.2 The CMM shall be powered on or brought online per the device manufacturer’s process and in conjunction with CMS software requirements. This process shall be performed every time the CMM is powered on. Ensure the CMM probe has an unobstructed path. Verification of the probe shall be performed before any measurements and whenever there is a change in probe requirements.

2.1.3 When environmental conditions, vibration, or the product's stability could affect measurement data, the CMM operator shall take action to minimize variation. Use toe clamps, CMM fixture plates, standoffs, shims, spring clamps, hot glue, sandbags, tape, etc., to ensure the measured part's stability. Use of the aforementioned items must not impede or interfere with the customer’s specifications or cause damage to the object being measured. Set-up or fixturing conditions of the object being measured on the CMM shall mimic datum conditions according to the engineering design of the said object.

2.1.4 The CMM operator must ensure that all object surfaces, holes, targets, target adapters, etc., are debris-free and not damaged before capturing measurements. All measurements must be compliant with this procedure before CMS QA verification.

2.2 Probe Change Requirements - If it becomes necessary to change probes during a survey, ensure that the new probe is seated properly, not damaged, the probe tip is cleaned thoroughly, and the probe tip is identified in the respective CMM software.

a) Probe calibration is required whenever the probe is changed or damaged.

b) The Probe diameter must be specified before performing a probe calibration.

c) Follow the manufacturer's procedure for recalibrating the probe before the measurement session.

2.3 CMM Environment Factors: - If it becomes necessary to change probes during a survey, ensure that the new probe is seated properly, not damaged, the probe tip is cleaned thoroughly, and the probe tip is identified in the respective CMM software.

2.3.1 Controlled Environment - CMMs shall be located in a controlled environment. The CMM room and measured items will be maintained at 68° F, +/-(2)° Fahrenheit, and monitored with a calibrated temperature gauge. CMM operators will verify the inspection room temperature before performing a measurement. Relative humidity shall be maintained within 40-55% range and recorded/tracked by a calibrated hygrometer. CMM operators shall verify that products have sufficient soak time in the CMM room to allow for thermal expansion stability of the part/product/tool temperature. Any product or tool not having sufficient soak time must be compensated for the Coefficient of Thermal Expansion (CTE) as defined in Figure 1 below. The size of the object and material compensation will dictate soak time, and temperature measurements will be taken at various locations on the object to determine the overall object temperature. Multiple temperature measurements are not required if an object has been allowed to soak for 24 hours. However, thermal compensation may still be necessary according to the tolerances imposed on the measurements.

2.3.2 Uncontrolled Environment - If, for any reason, it is deemed necessary to use a CMM outside the above prescribed controlled environment temperature and humidity conditions, the following shall apply:

2.3.3 For CMMs that have temperature sensors/compensation capability that are used in an uncontrolled environment, compensation for thermal effects on the CMM and the objects being measured must be verified by the CMM operator by using a scale bar or artifact of sufficient size, accuracy, and like (product) material before and after product measurement. A record of scale bars or artifacts measured, and acceptance tolerance used is required as objective evidence of proper temperature compensation application.

2.3.4 For CMMs without temperature sensors for both the CMM and product being measured, compensation for thermal expansion must be applied to measurements by the CMM operator. Correct temperature compensation shall be verified by using a scale bar or artifact of sufficient size, accuracy, and like (product) material before and after product measurement. A record of scale bars or artifacts measured, and acceptance tolerance used is required as objective evidence of proper temperature compensation application.

2.3.5 The accuracy of CMM measurements in an uncontrolled environment is verified using calibrated length items, such as scale bars. The scale bar should be the same material as the item being measured; if the object being measured is a combination of materials, the controlling material will dictate the material of the scale bar to be used. The controlling material is steel if a measured object has a steel structure with aluminum contour boards. The following applies to validate the accuracy of CMM setup, stability, multiple station setup, errors, and measurements:

a) Scale bars should be within ± 1 degree [F] of the object being measured, and temperature shall be verified using a calibrated instrument.
b) Clamping or restraining the scale bar by any mechanical means may cause inaccurate distance analysis, so care must be taken not to over-constrain or damage the scale bar.
c) Scale bars must be certified and NIST traceable.
d) All data files used to accept or reject tooling and manufacturing hardware will have a minimum of one set of point pairs used to verify scale accuracy.
e) All scale bar evaluations will be performed in the final, verified coordinate system.
f) Scale bars will be measured during any survey used as inspection media for product acceptance or rejection.
g) Scale bar measurements must be compared to the certified length on the Calibration or Certification sticker, and tolerance shall be determined by the device manufacturer’s volumetric specifications. Tolerance shall not exceed +/- 0.0020” inches to ensure measurement validity.
h) Scale bar measurements shall be compensated using the appropriate Coefficient of Thermal Expansion (CTE) value for the material from which the scale bar is made.
i) The dimensional report for the object being measured shall include Scale bar identification, measurements, CTE, and temperatures. See Section 10.

2.3.5.1 The product dimensional characteristics being verified must meet the engineering definition requirements at 68 +/—2 degrees Fahrenheit, as defined in ANSI/ASME Y14.5 and ANSI B89.6.2.

2.3.6 Multiple CMS Station: When the object being measured on the CMM must be moved within the same survey, common points are used as a reference for repeatability checks and to help maintain a consistent axis system.

2.3.6.1 Unless the CMS OEM or customer requires additional common points, a minimum of 7 common points is required to bring in additional stations. More points are recommended and preferred for superior accuracy. These points shall be spread over the object as far as possible and are to include key features.

2.3.6.2 The result for the station orientation must be within +/-0.0010” (or device manufacturer’s specifications) for surveys that are 100 inches or less in length. For surveys larger than 100 inches, 0.0005” will be added to the orientation transformation tolerance for each additional 100 inches.

3.0 Computer Measurement Machine (CMM) Articulating Arm Portable

3.1 Set-up / Field Checks - When setting up the PCMM, consideration should be given to the stability of the equipment and the object being measured. Environmental stability always needs to be considered before measuring to ensure the measurement activity is located in an area where the stability of PCMM and object being measured will not be changed due to floor structures, vibration caused by other machinery, or significant temperature changes caused by open doors, windows, or direct influence by climate control units.

3.1.1The PCMM shall be powered on or brought online per the device manufacturer’s process and in conjunction with CMS software requirements. This process shall be performed every time the PCMM is powered on. Ensure the PCMM probe is seated correctly and shows no sign of damage. Verification of the probe shall be performed before any measurements and whenever there is a change in probe requirements.

3.1.2 When possible, PCMM equipment and the measured object shall be located on the same table or work bench area to minimize external influences that influence drift. When PCMM and object are not located on the same surface, proper drift checks will be performed and reported.

3.1.3 PCMM operators must ensure that all object surfaces, holes, targets, target adapters, etc., are debris-free and not damaged before capturing measurements. All measurements are compliant with this procedure before CMS QA verification.

3.2 Field Checks

3.2.1 PCMM field checks are required prior to collecting measurement data or when the equipment is moved over 25 feet.

3.2.2 The CMS/PCMM operators will maintain records documenting the field check performed. If the equipment fails the field check, another field check, up to a maximum of three (3) totals, can be performed to prove stability. If after the third field check, the CMS equipment is still failing, then it must be sent to Calibration for investigation and correction.

3.2.3 The PCMM operator will perform the “validation” or “calibration” process within the measurement software to validate the PCMM's accuracy and repeatability. Prior to the measurement session, follow the manufacturer’s procedure for calibrating the probe. This check will be performed each day the device is used.

NOTE: During the daily field checks, ensure that you move the joints of the PCMM while measuring the points, do not digitize a point if any of the encoders reach their end stop, and avoid a position where a degree of freedom is lost. Field checks will be retained for objective evidence.

3.3 Accuracy Verification

3.3.1 The accuracy of PCMM measurements is verified using calibrated length items, such as scale bars. The scale bar should be the same material as the item being measured; if the object being measured is a combination of materials, the controlling material will dictate the material of the scale bar to be used. The controlling material is steel if a measured object has a steel structure with aluminum contour boards. The following applies to validate the accuracy of PCMM setup, stability, multiple station setup, errors, and measurements:

a) Scale bars should be within ± 1 degree [F] of object being measured and temperature shall be verified using a calibrated instrument.

b) Clamping or restraining the scale bar by any mechanical means may cause inaccurate distance analysis so care must be taken not to over-constrain or damage the scale bar.

c) Scale bars must be certified and NIST traceable.

d) All data files used to accept or reject tooling and manufacturing hardware will have a minimum of one set of point pairs used to verify scale accuracy.

e) All scale bar evaluations will be performed in the final, verified coordinate system.

f) Scale bars will be measured during any survey that is used as inspection media for product acceptance or rejection.

g) Scale bar measurements must be compared to the certified length on the Calibration or Certification sticker, and tolerance shall be determined by the device manufacturer’s volumetric specifications. To ensure measurement validity, tolerance shall not exceed +/—0.0020” inches.

h) Scale bar measurements shall be compensated using the appropriate Coefficient of Thermal Expansion (CTE) value for the material from which the scale bar is made. See section 5.

i) The dimensional report for the object being measured shall include Scale bar identification, measurements, CTE, and temperatures. See Section 10.3.4

3.4 Probe Change Requirements: If it becomes necessary to change probes during a survey, ensure that the new probe is seated properly, not damaged, the probe tip is cleaned thoroughly, and the probe tip is identified in the respective PCMM software.

a) Probe calibration is required anytime the probe is changed or the probe is damaged, as applicable

b) The Probe diameter must be specified before performing a probe calibration

c) Follow the manufacturer’s procedure for recalibrating the probe before the measurement session. (Single Point; Plane; or Sphere Method)

d) For probes not requiring recalibration: Verify the probe accuracy by measuring the common features, such as known straight-length scale bar features, and examining the maximum range. The maximum range should be within the limits established by the PCMM OEM certification requirements. The points from the new probe must also reside within 0.0015” of the previous points or the probe will be calibrated, and the measurement of the common features shall be repeated. This process can be performed up to 3 times. After 3 failures the probe shall be recalibrated and re-evaluated for ability to perform within manufacturer’s specifications. If the probe fails the field check after calibration, then the set-up of the PCMM will need to be confirmed with another known probe to prove stability. If the set-up is stable then, the probe that failed the field check must be sent to Calibration for investigation and correction.

3.5 Using PCMM Equipped with Laser Scanner: PCMMs equipped with internal or external laser scanners must be treated as an additional accessory or piece of equipment used for measurement. Laser scanners rely on the accuracy of the PCMM Articulating Arm and must be calibrated similarly to the way a probe is calibrated. Follow the Articulating Arm manufacturer’s procedures for laser calibration/validation. The laser scanner must also be treated as an accessory to the PCMM that requires calibration on the same cycle as the PCMM device. This laser scanner will have its own calibration sticker showing such activity.

3.5.1 When a PCMM equipped with a laser scanner is used common features, such as spheres on a known scale bar must be used to validate probed data vs scanned data. Probed data compared to scanned data must not deviate by more than 0.0015” (or manufacturer’s specifications) and the measurements can be taken a total of 3 times. If scan data fails on the 3rd attempt the PCMM equipment must be sent to Calibration for investigation and correction.

3.6 DRIFT POINTS / STABILITY

3.6.1 Many factors may influence the stability of a measurement, e.g., the precision of the surface of the feature being measured, stability of the setup, vibration due to various processes, or operator technique. To verify the stability of the survey, drift points must be measured as follows when applicable.

3.6.2 Prior to performing measurements, a minimum of two Drift Points (DP) must be measured and identified (i.e. DP1, DP2, etc.) using a stationary point (i.e. reference system, tooling hole, coordination hole, etc.).

3.6.3 At the conclusion of the survey, during temperature variation, or before the PCMM is moved, these Drift Points must be re-measured to validate the PCMM's accuracy.

3.6.4 The 3D difference between the two measured drift points should be less than or equal to 0.002”. If the range exceeds the limits, stability may be problematic between the CMS and the object being measured. Examine the physical stability of the setup and correct as necessary.

3.6.5 Any time an unplanned disruption occurs, e.g. the PCMM equipment is bumped, dropped, etc., or the setup was left alone for any reason, it is required that the Drift Points be re-measured to verify the set-up has not moved and is still valid.

APPROVAL SIGNATURES

Hector Yescas
Vote Approval via Email 03/04/2026
Hector Yescas, Director Quality Control

Robert Wright
Vote Approval via Email 03/04/2026
Robert Wright, Director Supply Chian

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Benjamin Gapasin, Manager Quality Systems

Benjamin Gapasin for Lynne Kunster
Vote Approval via Email 03/03/2026
Lynne Kunster, Vice President Quality

DOCUMENT HISTORY RECORD

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