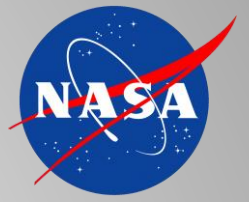


Digital Twin for Quality and Mechanical Systems Assurance

Alejandra Constante
NASA GSFC/MEI
Code 373

Agenda

- Quality Assurance Activities
- Process Definitions
- Digital Twins
- Quality Assurance Informed Decisions
- Taxonomy of Processes

Introduction

- Have you had these kind of problems?
  - Suspect that the supplier is not following a rigorous process control
  - Inspect parts that look good, but you are not completely sure (e.g. bonded or welded parts)
  - Lack of familiarity with failures associated to the process of parts manufactured by an external supplier
  - Absence of technical evidence to approve/reject a requirement waiver
  - Need to find a Subject Matter Expert to understand the root cause of parts issues/failures during I&T

Quality Assurance Activities

- The NPR 8735.2C defines hardware quality assurance program requirements for programs and projects
- NASA Quality Assurance domains were defined using a Model Based construct
- Quality Assurance needs tools to support early lifecycle activities

QA02 Critical Items and Processes Determination

QA05 Supply Chain Risk Management

- QMS Standards and Certifications

QA06 Product Readiness

- Review, approval, control for special processes
- QMS control to ensure external processes/products conform

QA07 Product Quality Assurance

- Generate objective evidence of conformance for each safety-critical product or process attribute
- QCI or NDE performed by government

QA09 NASA Product Acceptance Process and Data

- Parts and materials certifications and traceability data
- Define acceptance requirements for qual or engineering units

Plante J., NASA Quality Assurance Across the Mission Lifecycle via NPR 8735.2C, April 2021

Process Definitions (NPR 8735.2C Appendix A)

Welding, Creative Commons

Special Process

- Results in a condition of conformance that cannot be fully verified by means of non-destructive inspection
- The point of acceptance and the assurance of conformance is attained through adherence to process control specification and verifying compliance incrementally during production

Argonne's tribology lab. Creative Commons

Complex

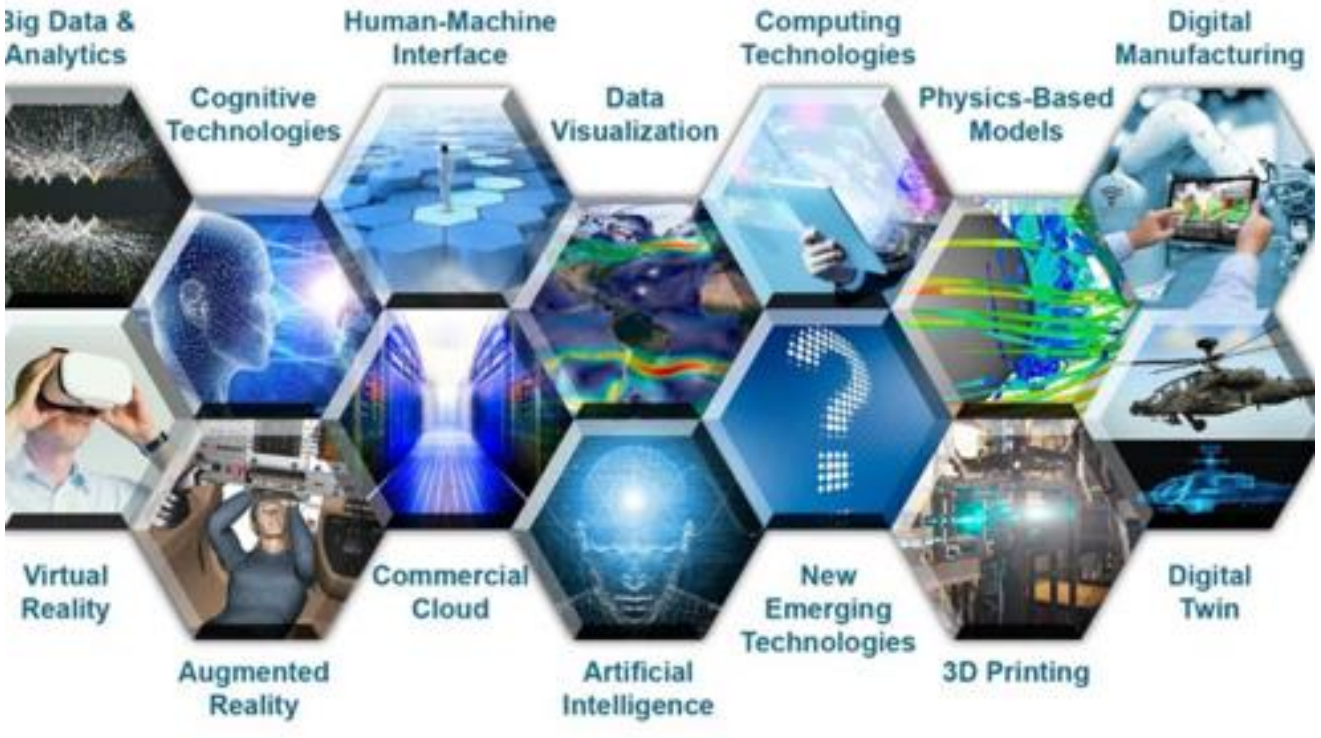
- Items that have quality characteristics, not wholly visible in the end item
- For which contractual conformance must be established progressively through precise measurements, test, and controls applied during purchasing, manufacturing, performance, assembly, and functional operation

NPR 8735.2C, Hardware Quality Assurance Program Requirements for Programs and Projects, March 12, 2021

Welding - Lamar CC, Welding, licensed under a Creative Commons Attribution 4.0 International License, 2020

"Argonne's Tribology Lab: Tensile Test Machine" by Argonne National Laboratory is licensed under CC BY-NC-SA 2.0

Digital twin



Integrated models that consider physics, simulations, and history of a vehicle or system to mirror its performance

Revolution on the traditional manufacturing process

Digital twins are connected to the simulated process to receive “real time” feedback and improve themselves

https://ac.cto.mil/wp-content/uploads/2019/06/2018-Digital-Engineering-Strategy_Approved_PrintVersion.pdf

Glaessgen E. H. and Stargel D.S. The Digital Twin Paradigm for future NASA and U.S. Air Force Vehicles, 53rd Structural Dynamics, and Material Conference: Special Session on the Digital Twin, AIA 2012-1818.

Quality Assurance Informed Decisions

- Informed quality assurance decisions will easily flow from a clear perspective of the minimum requirements through each state of the manufacturing life cycle of a product
  - Understanding complex process parameters contributes to the creation of a road map that facilitates decision making process
  - Evaluate product conformances of special processes
  - Identify process and product deviations using verification and validation techniques earlier in the development life cycle

Taxonomy of Processes

- The Taxonomy of Processes is a tool to organize the technical knowledge required by Quality Assurance during assessment and inspections.
- This taxonomy helps inspections and assessments performed by Quality Assurance:
  - Provides information from NASA and industry approved standards.
  - Identifies process controls and product acceptance criteria.
  - Facilitates multi-disciplinary collaboration between materials, quality, mechanical, and electrical disciplines.

Benefits of using Taxonomy of Processes

- Keep of digital records of validation and inspection assessments which could be used during failure review boards
- Reduce the time spent on extensive surveys of technical standards and documentation
- Provide continuous feedback to the taxonomy based on the findings and lessons learned of failure review dispositions

Taxonomy of Processes

- 9 Process subcategories
  - 50 Processes
    - 13 Elements

Number	Process
PE01	Manufacturing Process
PE01.1	Raw Metals
PE01.1.1	Heat Treatment
PE01.2	Surface Treatment
PE01.2.1	Conversion Coatings
PE01.2.2	Plating and Painting
PE01.3	Composites
PE01.4	Machining
PE01.5	Joining
PE01.6	Electronics
PE01.7	Distribution Systems
PE01.8	Cleaning
PE01.9	Additive Manufacturing

Joining Processes

Number	Process	Description
PE01.5	Joining	Joining processes
PE01.5.1	Fusion Welding	Joining processes that rely on the melting of material to join/fuse materials of similar composition and melting point. Encompasses three major types of processes: -Gas Welding - Oxyfuel Welding (OAW)Arc Welding -Shielded Metal Arc Welding (SMAW), -Gas Tungsten Arc Welding (GTAW), -Plasma Arc Welding (PAW), -Gas Metal Arc Welding (GMAW), -High-energy Beam Welding: Electron
PE01.5.2	Solid-State Welding	Coalescence is produced by the application of pressure without melting any of the joint components.
PE01.5.3	Brazing (Torch and Induction)	Joining of two metals using a filler. The filler is melted, flow, and solidified. Torch brazing: The surfaces to be joined are heated using oxy-fuel gas torchches and various fuels. Induction brazing:The joint and the filler are heated to the melting temperature of the filler using a coil that does not contact the parts to be joined.
PE01.5.4	Soldering	Soldering is not available for structural components. See PE01.6.4 Soldering of Electronic Components
PE01.5.5	Adhesive Bonding	Joining of two surface using adhesive polymeric materials
PE01.5.6	Fastening	Metallic system hardware that joins or retains components or structural elements including but not limited to bolts, screws, nuts, nut plates, threaded inserts, rivets, shear pins, set screws, washers, safety wire, and cotter pins.

Taxonomy of Processes - Elements

QA02 Critical Items and Process Determination

QA05 Supply Chain Risk Management

QA09 NASA Product Acceptance Process and Data

Number	Process	Description	Nadcap Audit Criteria	NASA Guidance	Materials	Certification Programs	Industry Standards	Process type	Process Control	Main Variables	Non-Destructive Evaluation (NDE)	Product Acceptance
PE0.1.X.X	QA02	QA02	QA05	QA05	QA05	QA05	QA05	QA06	QA06 QA07	QA06	QA07	QA09

QA06 Product Readiness

QA07 Product Quality Assurance

The NPR 8735.2C defines hardware quality assurance program requirements for programs and projects and quality assurance domains (QA)

Fusion Welding

Number	Process	Description	Nadcap Audit C...	NASA Guidance	Process type	Materials	Main Variables	Product Accept...	Certification Pr...	Non-Destructiv...
PE01.5.1	Fusion Welding	Joining processes that rely on the melting of material to join/fuse materials of similar composition and	AC7110/5 Rev I - Audit Criteria for Fusion Welding	Per NASA-STD-6016B:The processing and quality assurance	Assembly	-Primary: Base metal included in one of the base metal groups shown in	Per AWS D17.1/D17.1M - Electrode: Size, diameter, current type and polarity. - Shielding gas:Type of gas, flow rate, nozzle size. - Lead/lag angle	Per AWS D17.1/D17.1M: - Visual inspection: Welds shall be	Supplier develop qualification programs for AWS Certified Welder and Certified Welder Inspector.	-All nonferromagnetic Class A and B weld shall be penetrant
PE01.5.1.1	Arc Welding									
PE01.5.1.2	High Energy Beam Welding									
PE01.5.1.3	Oxyfuel Gas Welding	The coalescence of workpieces is produced by heating them with an oxyfuel gas flame. The								
PE01.5.1.4	Resistance Welding	Group of processes where faying surfaces are joined by the heat sourced from the workpiece resistance	AC7110/4S Rev. G Supplemental Audit Criteria for Welding for Resistance Welding (Spot, Seam, Projection)	Per NASA-STD-6016B: • Resistance welding for spaceflight hardware that provides mission-critical functions, including resistance spot welding (RSW), shall meet the requirements of AWS D17.2/D17.2M(2013) .	Assembly	Primary: Metals and alloys classified as follows. Group 1: Aluminum and magnesiumGroup 2: Steel, nickel, and cobaltGroup 3: TitaniumSecondary: Electrode	• Current • Welding time • Electrode force • Electrode material	Per AWS D17.2/D17.2M (2013): • Three types of	• AWS Certified Resistance Welding Technician (CRWT)	N/A

Fusion Welding

PE01.5.1

Number

PE01.5.1

Process

Fusion Welding

Description

Joining processes that rely on the melting of material to join/fuse materials of similar composition and melting point. Encompasses three major types of processes: -Gas Welding - Oxyfuel Welding (OAW)Arc Welding - Shielded Metal Arc Welding (SMAW), -Gas Tungsten Arc Welding (GTAW), -Plasma Arc Welding (PAW), -Gas Metal Arc Welding (GMAW), -High-energy Beam Welding: Electron Beam Welding (EBW) and Laser Beam Welding (LBW)

See more

Nadcap Audit Criteria

AC7110/5 Rev I - Audit Criteria for Fusion Welding

NASA Guidance

Per NASA-STD-6016B:The processing and quality assurance requirements for manual, automatic, and semiautomatic welding for spaceflight applications that provide mission-critical welds shall meet the requirements of AWS D17.1/D17.1M.Mission-critical structural welds shall comply with AWS D17.1/D17.1M, Class A requirements. Extra low interstitial filler wires shall be used for titanium cryogenic applications and are preferred for general applications. The Welding Procedure Specification (WPS) shall include the following in addition to that required by the AWS D17.1/D17.1M (2010) AMD1 (2012): Prequalified rework welds in accordance with AWS D17.1/D17.1M, testing and documentation of allowable parameter variations for automatic and semi-automatic welds, manual welding parameters, associated Procedure Qualification Record (PQR) with...

See more

Process type

Assembly

Take away

NPR 8735.2C Quality Assurance Domains → Taxonomy of Process → Model-Based Safety and Mission Assurance (MBMA)

- Surveillance Plan
- Internal Audit Plan
- Mandatory Inspection Points (MIPs)
- Training Programs

Summary

- The taxonomy of processes is a tool that facilitates the digital transformation of the NASA Quality Assurance policy
- Process elements in the taxonomy are part of the Quality Assurance domains formulated in the NPR 8735.2C
- Knowledge of process elements earlier in the life cycle will help with supplier assessments and inspections

Taxonomy of Processes

PLEASE CONTACT US IF YOU WANT TO HELP US WITH SPECIAL PROCESS SURVEILLANCE

OR IF YOU WANT TO CONTRIBUTE IN ANY OTHER WAY AT

ANDREW.GLENDENING@NASA.GOV

ALEJANDRA.CONSTANTEPEREZ@NASA.GOV

Backup

Taxonomy elements

- Alias: Additional process names reported in the NASA Standards, Industry Standards, and Nadcap Audit Criteria.
- Certification Programs: Training programs offered by professional associations to increase specific knowledge and skills toward a high-quality product.
- Main Variables: Process parameters that shall be controlled to produce the output expected by the customer.
- Material Types: Primary, secondary, and tertiary
- Process Control: Actions follow to validate/verify the controlled variables
- Product Acceptance: Criteria established to define the minimum performance of the product.

Process Types Categories

- Primary: Shaping process. Casting, molding, powder sintering, forming, and composite lay-up
- Secondary: Bulk heat treatment, material removal processes, and surface treatment
- Assembly: Joining, test-inspection, and assembly.

Types of materials

- Primary: Input material of part that will be modified by the process
- Secondary: Component used to modify the primary material
- Tertiary: Additive or environment used to modify the characteristics of the process

Process Control- Generic Aspects

- Develop, maintain, and adhere to a process control document describing the process and procedures, including all steps in the processing sequence. Process control documents should define requirements for process and procedures as applicable.
- Main process steps should be carried out as defined by shop papers. Shop paper should provide traceable part identification, processing steps, and documentation of rework if done.
- Process parameters should be recorded either manually or by the automatic process equipment.
- Elements of process control that should always/routinely be inspected.
- Preproduction tests are all technical requirements shall be performed prior to or on the initial plated, painted, and surface treated parts to a purchaser, when a change in materials/processing requires approval, and when the cognizant engineer requires confirmatory testing. (Apply to coatings, plating, and painting)

Product Acceptance – General aspects

- Visual inspection is required for most of the processes
- Lot acceptance test should be documented and meet the sampling plan.
- Each lot shall be inspected to ensure that the lot consist of all treated items of the same type, class, form, and method, treated under the same process conditions, and submitted for acceptance at one time.
- Final inspections and test should stamped off or signed off and dated as required.

Validation and Verification

- Validation: Process to demonstrate that the product or process satisfy the user needs. Proof that the product accomplished the intended **purpose** and is ready to use.

- Verification: Process to provide or establish the specification satisfaction on the process or product. Proof that the product complies with the **specification**.