



Common Performance-Based Additive Qualification to Accelerate the Expansion of the AM Industrial Base

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►► Regulators

- FAA
- NASA
- DoD: OSD, USAF, Army, NAVAIR, NAVSEA, etc.

►► Standards Development Organizations

- SAE
- ASTM
- AWS
- DoD

►► Cognizant Engineering Organizations

- LSI's
- System and part designers
- DoD

►► Part Manufacturers

- AM Industrial-base
- DoD

All stakeholders are being included

PAQCS: Performance-based Additive Qualification

Consolidated Strategy

NIAR[®]

WICHITA STATE UNIVERSITY

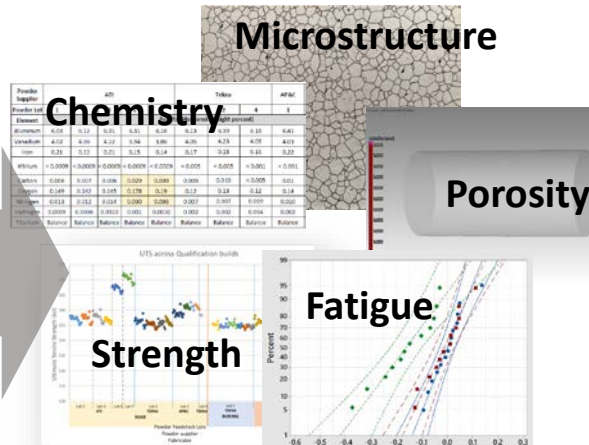
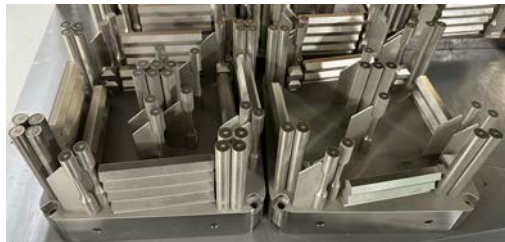


PERFORMANCE-BASED

Qualification performed by validating the **output** of the manufacturing process (*relies on specification control*)

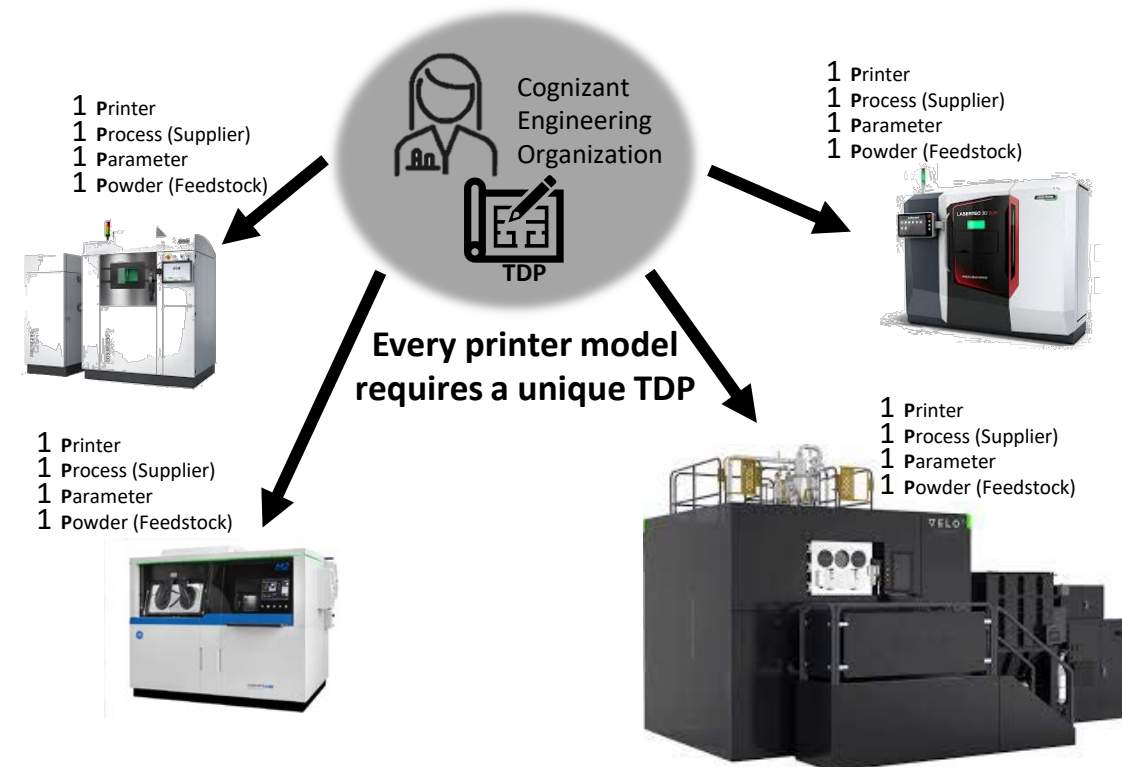
- ✓ Printer Agnostic
- ✓ Process (Supplier) Agnostic
- ✓ Parameter Agnostic
- ✓ Powder (Feedstock) Agnostic

Material Performance Validation



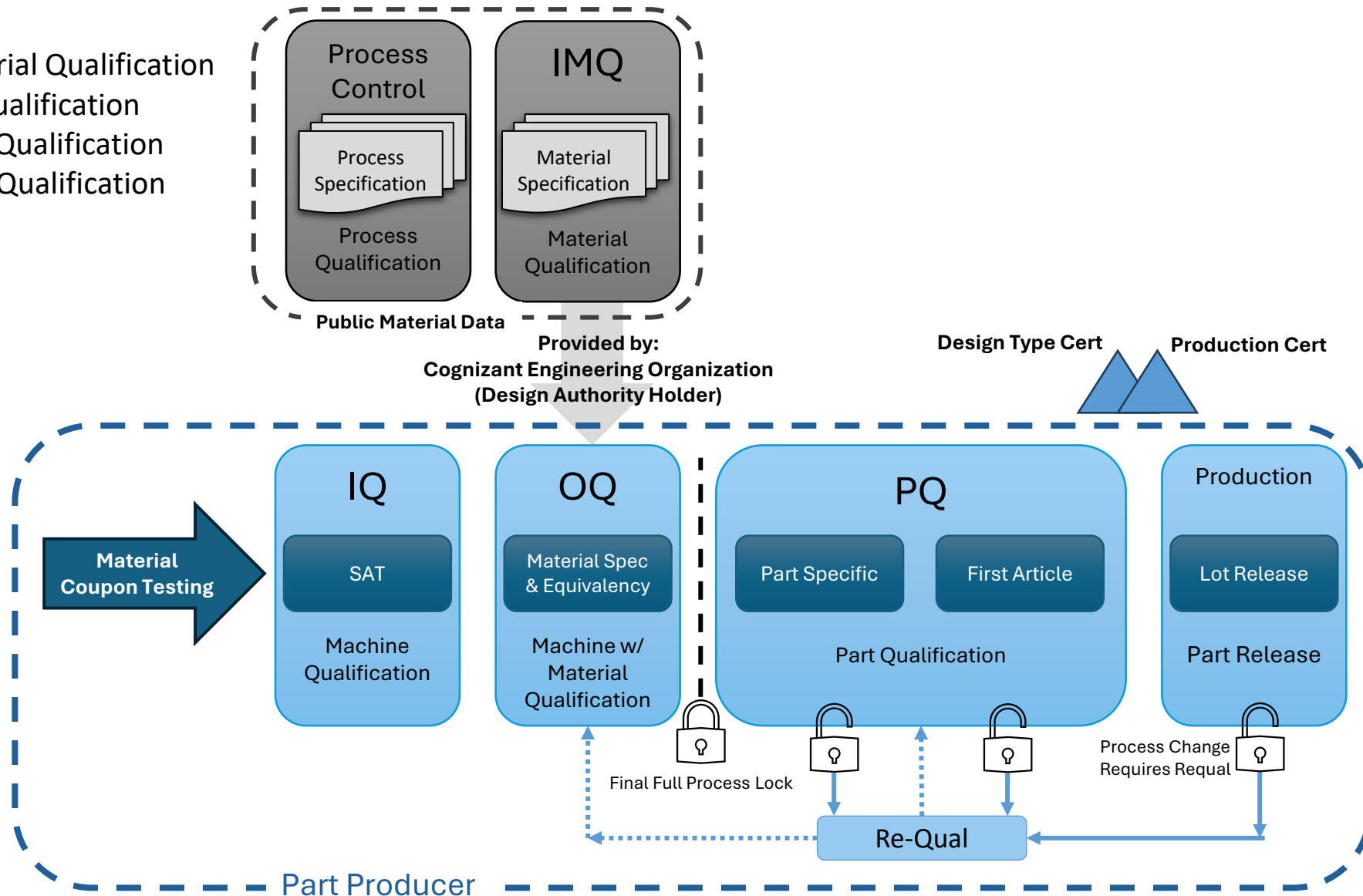
PRESCRIPTIVE-BASED

Qualification restricted to a single manufacturing solution (*relies on **input** control*)



What's with all the Q's?

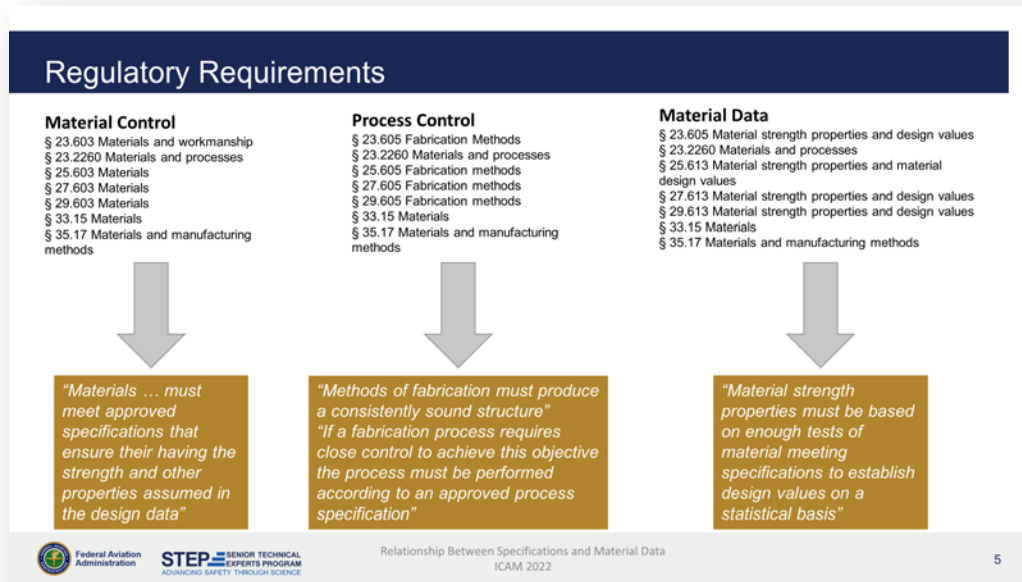
IMQ = Initial Material Qualification
IQ = Installation Qualification
OQ = Operational Qualification
PQ = Performance Qualification



§ 21.31 Type design.

The type design consists of—

(a) The drawings and **specifications**, and a listing of those drawings and specifications, necessary to define the configuration and the design features of the product shown to comply with the requirements of that part of this subchapter applicable to the product



"Process Control: If a fabrication process requires *close control* to achieve this objective the process must be performed according to an *approved specification*"

- From Cindy Ashforth Presentation, ICAM 2022

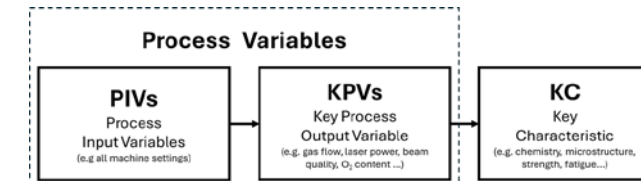
Process Specification

■ Purpose

- Establishes repeatable process controls for repeatable production
- Must contain sufficient detail to maintain "close control".

■ PCD: Process Control Documents

- PCD requirements are defined within a public Process Spec.
- PCD are typically detailed proprietary documents containing trade secrets controls by the part manufacturer
- LPBF PCDs
 - KPV Process windows
 - OQ and PQ Plan
 - Maintenance Plan
 - Contamination Control Plan
 - Software Control Plan
 - Feedstock Management Plan
 - Machine Configuration Plan
 - Calibration Plan
 - Process Interruptions Plan
 - Operating Condition Plan



FAA "approved specification" = Process Spec + PCDs



Creation of Public Material Data

- **Material Allowable** – A bulk (physical, static, or dynamic) material property.

Allowables are derived from the statistical reduction of data from a stable process.

- **Design Value** – A material or structural property that is established to represent the finished part property.

These numbers are typically based on material allowables and adjusted, using building block tests as necessary to account for the range of part geometric features (e.g., holes, notches, surface finish).

- **Material Specifications**

- Heat Treatment
- Powder Requirements (*usually in a separate spec*)
- Chemistry
- Microstructure / Grain Size
- Tensile: Ultimate, Yield, Elongation
- Porosity
- OQ Requirements



➤➤ OQ: Material Qualification

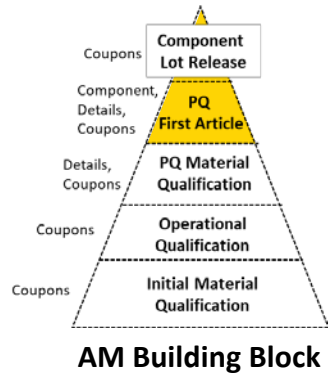
- **Machine & Material Combination**
– For each machine S/N
- **Material Coupons**
– Defined by Material Specification requirements
- **Material Specification Coupons**
– Also used for lot release
– At statistically relevant quantities.
 - Chemistry (min-max)
 - Microstructure / Grain Size (min-max)
 - Tensile: Ultimate, Yield, Elongation (min)
 - Porosity (max)
- **Operational Qualification Testing**
– At statistically relevant quantities.
 - Tensile Yield (equivalency)
 - As-printed surface LCF (statistical min)



➤➤ PQ: Material Qualification

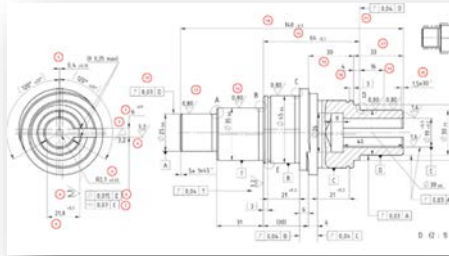
- **Machine & Part Combination**
– For each machine S/N
- **Part (or Part Family) Specific Coupons**
– Determined by Cognizant Engineering Organization (CEO)
- **Possible Part Specific PQ Testing:**
 - No additional coupons required
 - Part z-height coupons
 - Multi-laser stitch coupons
 - Special parameter coupons
 - Special fatigue coupons
 - Thin-wall coupons
 - Post-processed surface coupons
 - Part geometry coupons





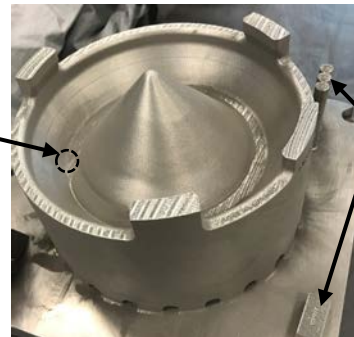
➤➤ PQ First Article

- **First Article Inspection (FAI)**
 - Production validation process which verifies that a new production process produces conforming parts
- **100% Characteristic Accountability**
 - Typically performed by “ballooning” drawing



- **Material Inspection Validates Lot Release**
 - Lot Release coupons are compared to Part Cut-Up material

Part Cut-Up



Lot Release Coupons



FAI could include part testing

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