



NASA's Certification and Qualification Strategies for Additively Manufactured Hardware

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Rapid Qualification of AMT Components – Is it Rocket Science?
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Additive Manufacturing at NASA

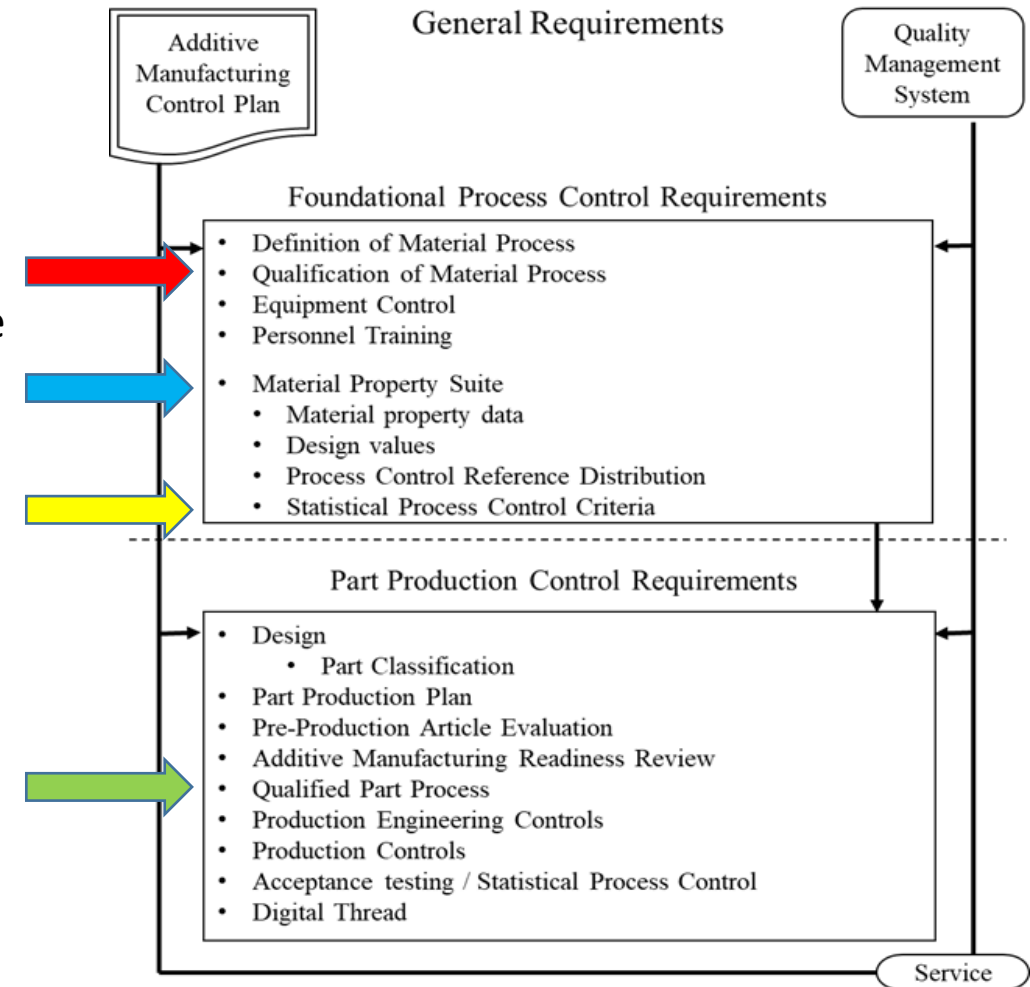
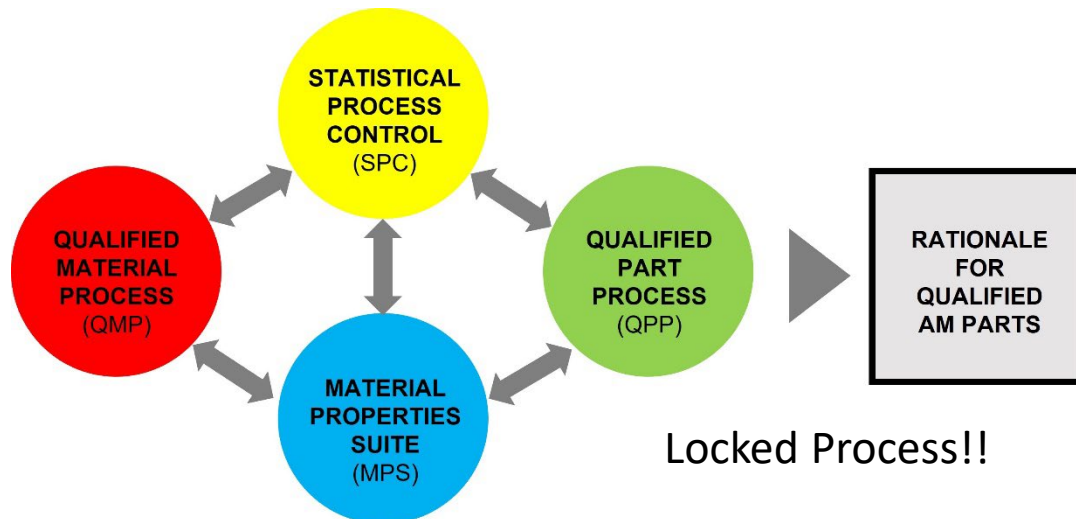
- Fully embraces advantages of AM
 - Cost/lead time/part count reduction, new design and performance opportunities, rapid design-fail-fix cycles
- While fully understanding the challenges
 - Especially in delivering high value, high performance AM hardware
- NASA has dual roles
 - Drive and foster AM technology research and development in support of broad industry adoption and industrialization
 - Develop protocols for spaceflight hardware certification for access to space that can safely meet mission objectives ← Today's focus



NASA-STD-6030: Summary of Methodology



- General Requirements
 - Additive Manufacturing Control Plan (AMCP) and Quality Management System (QMS)
 - Backbone that defines and guides the engineering and production practices
- Foundational Process Control Requirements
 - Includes the requirements for AM processes that provide the basis for reliable part design and production
- Part Production Control Requirements
 - Includes design, assessment controls, plans (PPP), preproduction articles and AM production controls





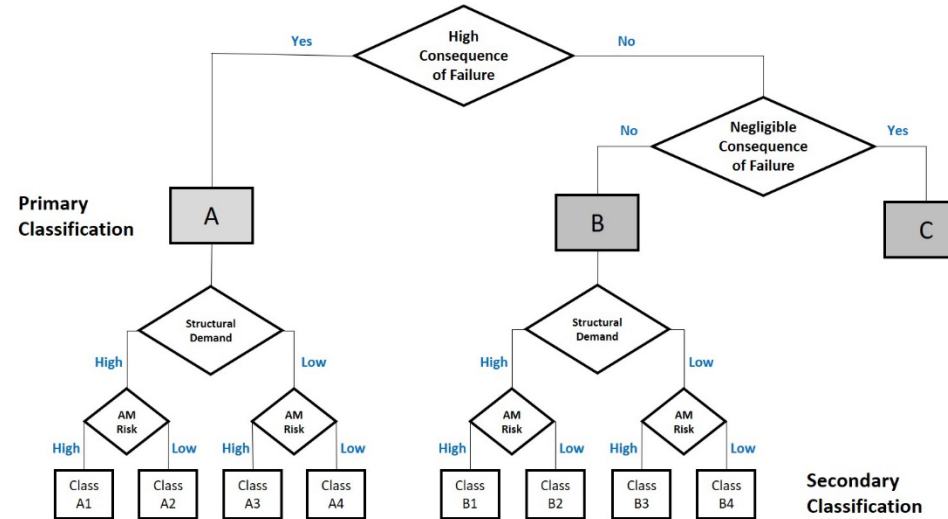
NASA-STD-6030: Key Elements



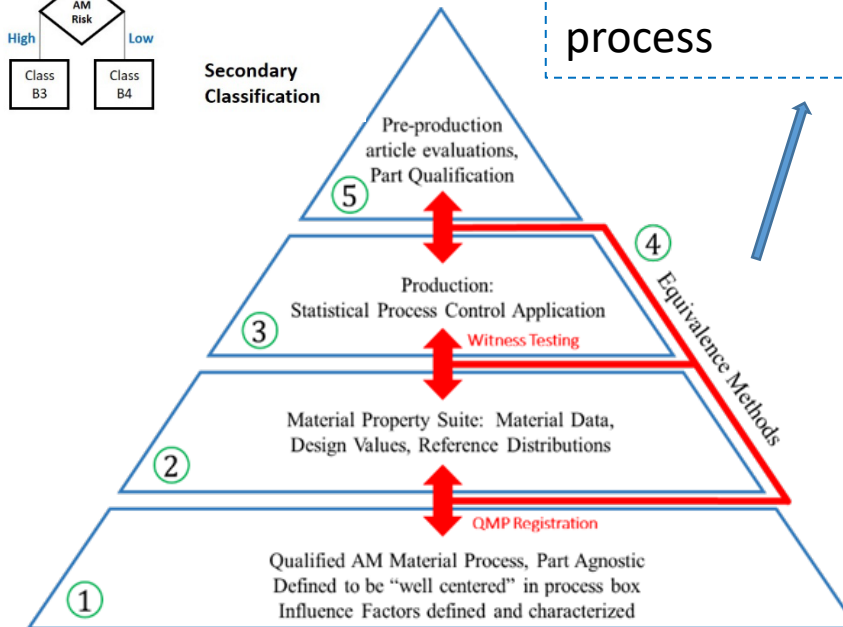
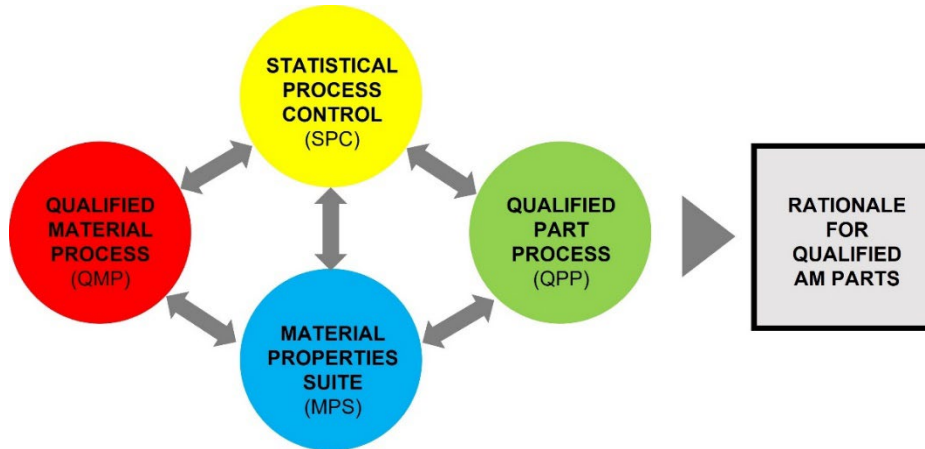
Applicable Technologies

Category	Technology	Materials Form
Metals	Laser Powder Bed Fusion (L-PBF)	Metal Powder
	Directed Energy Deposition (DED), Any Energy Source	Metal Wire
	DED, Any Energy Source	Metal Blown Powder
Polymers	L-PBF	Thermoplastic Powder
	Vat Photopolymerization	Photopolymeric Thermoset Resin
	Material Extrusion	Thermoplastic Filament

Classification System



Approach is heavily rooted in metallurgical understanding and respecting the evolving and meticulous metallic AM process





Equivalency

- One of this standards key strengths is its reliance on material engineering equivalence
 - Methodology for evaluating the quality of AM materials that acknowledges the broad range of characteristics that must be assured for an alloy to meet all of its expectations.
 - The enabler that allows the AM material ecosystem to remain healthy and self-consistent in the face of sensitive processes with a multitude of known and unknown failure modes.
 - Requires reliable and diverse datasets, depth of knowledge in materials, good engineering judgement, and collaboration between engineering and quality assurance organizations.

Process → Structure → Property → Performance



Fracture Control Framework for AM Parts

- Fracture control is reliant on understanding the design, analysis, testing, inspection and tracking of hardware.
 - The adaptation of state-of-the-art AM technologies introduces new and unique challenges
 - e.g. Multiple lasers and adaptive technologies
 - For AM applications the application of conventional NDE techniques is questionable
 - There is a need to produce alternate approaches through the adaptation of a Probabilistic Damage Tolerance Approach (PDTA)
 - Computational modeling for AM
 - Understanding the “Effects of defects”
 - In-situ monitoring and inspection
- These items
MUST
Work
together not
separate



Rapid Qualification – Is there a path?

- Following NASA-STD-6030 the path to “rapid qualification” is a slippery slope
- Understanding the part classification is key
 - Consequence of failure followed by risk evaluation
- Maturity of data is a must have
 - Full understanding of existing data
 - Establishment of machine-to-machine equivalency
 - Material Equivalency
- Implementation of in-situ inspection, computational materials and machine learning is beginning – but there is a long road ahead of us
 - Attention to this subject is **high!!**