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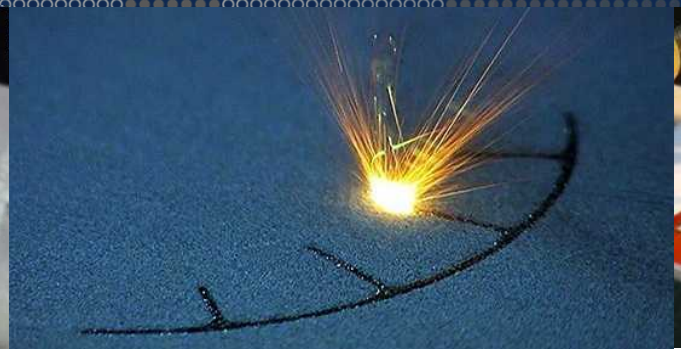

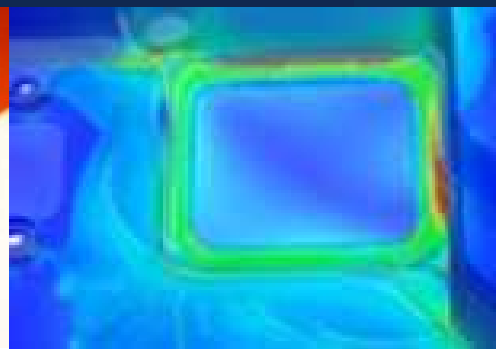

Qualification of Limited-Production, Additively Manufactured Parts for Use in Long-Life, High Consequence Applications

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Outline

- Qualification Approach
- Defining the Qualification Space
- Requirements Generation
- Qualification Strategy
- Summary

Qualification Approach

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Two approaches considered:

Holistic and design-agnostic approach

- Formed around RPP-103
  - Design
  - Manufacturing Processes
  - Acceptance Processes
  - Product/Material

Design-specific and requirements based approach

- Focused on functional performance of the AM design
- Qualification of design-critical AM characteristics

Which approach is correct?

Answer: They're Both Right!

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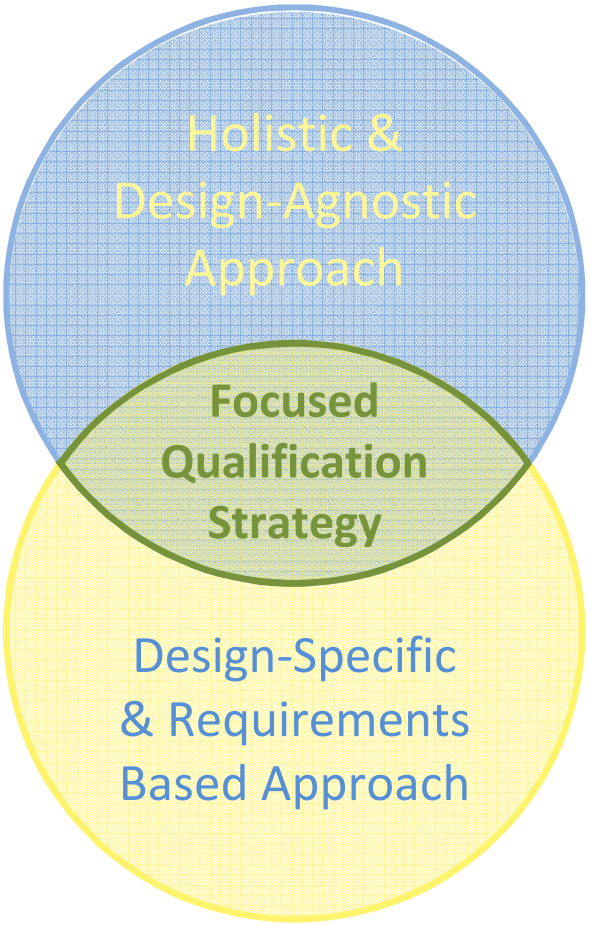
- Holistic and Design-Agnostic approach gives us "Big Picture" Qualification
- Design-Specific and Requirements Based approach gives us context
- Applying context to "Big Picture" qualification results in focused qualification strategy

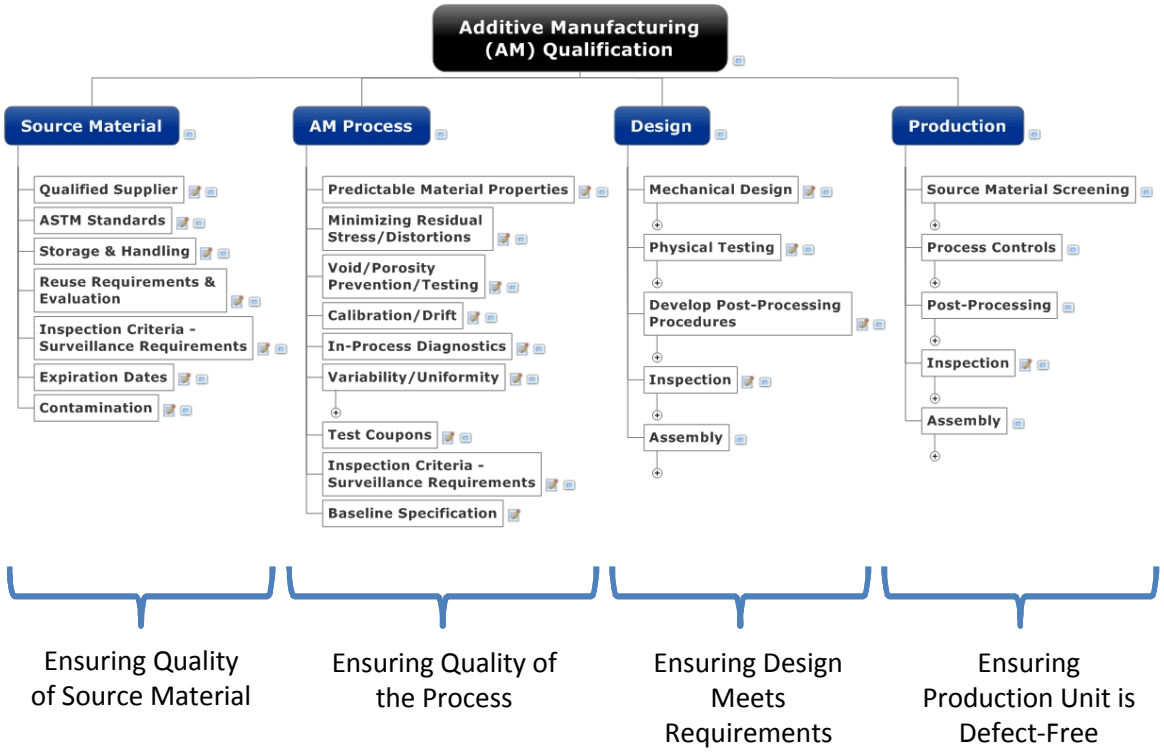


AM Qualification Outline

Qualification Strategy has four main tiers:

- Source Material
- Additive Process
- Housing Design
- Additive Production

- Each tier contains critical steps for qualification
  - Requires characterization of all aspects of design
- Parallel efforts due to time constraints
- Continually evolving process



Qualification Strategy is Focused on Defect Prevention at All Stages of Production Specifically Addressing Major Quality Concerns from an Industry Perspective

Defining the Qualification Space

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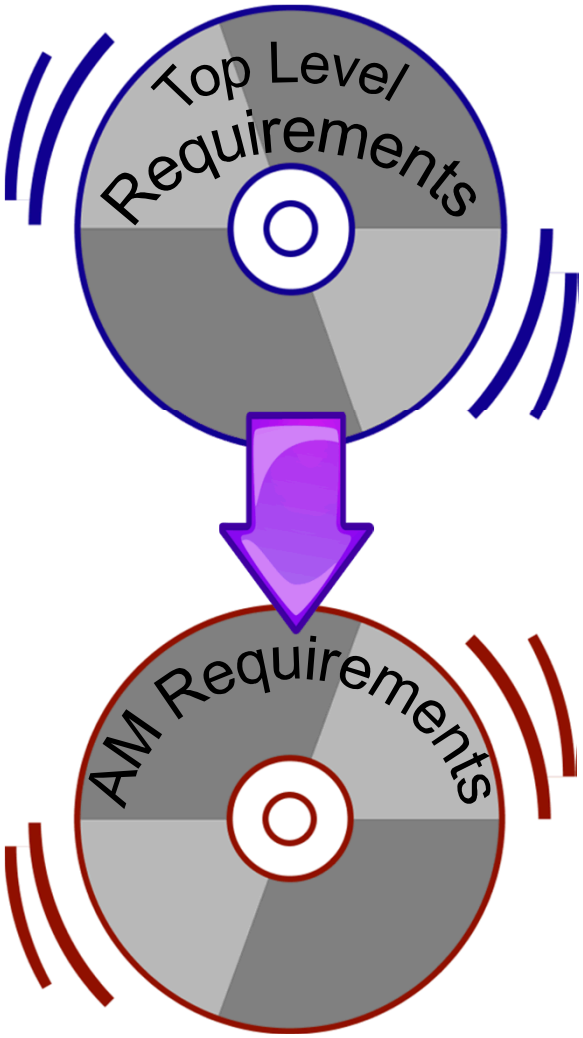
- Minimize Qualification Space
  - Controllable
    - Process Controls
    - Input Material
    - Design
    - Production Environment
  - Mitigate the uncontrollable
    - Destructive Testing
    - Proof Testing
    - Inspection
    - Post-Processing (heat treatment, machining, surface finish/coatings)

Additive Manufacturing Component Requirements

- AM requirements derived from top level assembly requirements
  - Functional, Geometric, etc.
- All qualification activities are requirement driven
- *Final qualification occurs with top level assembly*



Controllably Uncontrollable

- Design Space Controls
  - Testing of units
    - Proof Loading
    - Inspection of dimensions
    - Material Testing
      - Hardness, Tensile, Density, etc.
  - Post Printing Modifications
    - Machining tight tolerances
    - Heat treatment of units
    - Chromate coating
- AM part will be qualified separately prior to next level of assembly
  - Separate qualification documentation
    - New Technology
    - Critical Component
    - Medium amount of risk
- Inspection, processing, printing documented in detailed work instruction
  - Verifies housing meets necessary requirements

Six Month Look Ahead

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- Ongoing Material Studies
  - Vendor producing material coupons
  - Material coupons alongside housing builds
- Fabrication of Housing
  - Exercise housing machining and acceptance tests
- Computational Analysis
  - Quantify expected results through environmental testing
- Mechanical Assembly and Testing
  - Valid computational models
  - Demonstrate AM feasibility for surviving environments

Summary

- Qualify AlSi10Mg AM specifically for APBA housing ***ONLY***!
  - Same approach can be used to qualify AM for other applications
- Requirements Mapping:
  - Component-level requirements *carefully* derived to AM part
  - Detailed traceability from component to AM qualification test activities
- Minimization of Variability:
  - Material Specification – Define input material
  - Process Specification – Define print controls & CM config file
  - Specific Use Specification – Define build orientation, test coupons, build locations, post-machining, etc.
- Qualification Plan:
  - References Material, Process, and Specific Use Specifications
  - Defines qualification activities to ensure requirements can be verified

Goal is to verify material in the printed form-factor to ensure successful qualification at component level

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QUESTIONS?

Expanded Qualification Tree