



PennState

Applied Research Laboratory

Evaluating and Vetting AM Technology for Implementation

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Why AM?

- Out of production or long lead time
- Opportunity for improved Performance
- Reduce number of individual components

Things to Consider

- Performance Requirements
 - Material properties
 - Operating environment
- Form/Fit/Function Replacement
- Improved Performance Needed
- Redesign Required
- Accuracy
 - Net-shape
 - Near-net-shape
- Material Availability
 - Same material
 - Different material
 - Need to develop a new material
 - Post processing – HIPing, machining, heat treating



- Size
 - Equipment available
 - Post processing
- Cost
 - Material
 - Labor
 - Equipment
 - Number of components
 - Post processing
 - Development needed
 - Compare to existing process
- Schedule
 - Time required to produce components
 - Meet need-by date
- Summary of Evaluation
 - Cost
 - Performance
 - Schedule



ARL/PSU Approach

- Select Best Process from AM Tool Box
 - Powder Bed Fusion
 - Directed Energy Deposition (DED)
 - Laser Powder
 - Laser Wire
 - Hybrid Additive-Subtractive
 - Wire Arc Additive Manufacturing (WAAM)
 - Cold Spray – Hybrid Additive-Subtractive
 - SPEE3D – Cold Spray
 - ExOne – Binder Jet
 - Polymeric Systems
 - nScript – Plastic/Ceramic
- Post Processing
 - HIP
 - Machining
 - Heat Treating
 - Abrasive Flow Machining
- Inspection



<http://www.cimp-3d.org/>





- Implementation Path and Requirements
 - Typically differ by
 - Component
 - Process
 - Application
 - Service/Sponsor
- Goal is to have an acceptance specification/requirements
 - Branch of Service (NAVAIR, NAVSEA, Army Aviation, Army Ground Vehicles, Air Force, Marines and Coast Guard)
 - DoD
 - OSD Cold Spray Cross-Service Working Group
 - Understand how each service approves Cold Spray repairs
 - Working to get a uniform specification
 - Template for more universal approval of AM and other technologies



- Cost → Qualify the process from only a few parts
- Production time → Maintaining consistent processing conditions
- Lack of understanding on the important production variables
- Powder reuse
- Keeping track of all the processing steps from the design to the finished part
- Assuring consistent mechanical properties
 - Processing conditions
 - Raw material characteristics
- Defects
 - How can we find them?
 - Which ones are critical?
 - Do we need to conduct NDE (X-ray CT) on everything?
- Anisotropy → Correct or maintain consistently



Goal → Certified structural components

Certification of additive manufacturing (AM) of Ti-6Al-4V components for critical applications requires a protocol for ensuring process reliability

Ensuring process reliability → Concept for process qualification

- Captures requirements through the design, manufacturing, and quality assurance stages
- Reinforced by rapidly developing technologies
- May be supported by existing standards



Requirements for producing critical metallic components by AM

Design

Design that meets product requirements

- Designer awareness
- Design guidelines
- Design allowable properties
- Testing requirements

Manufacturing

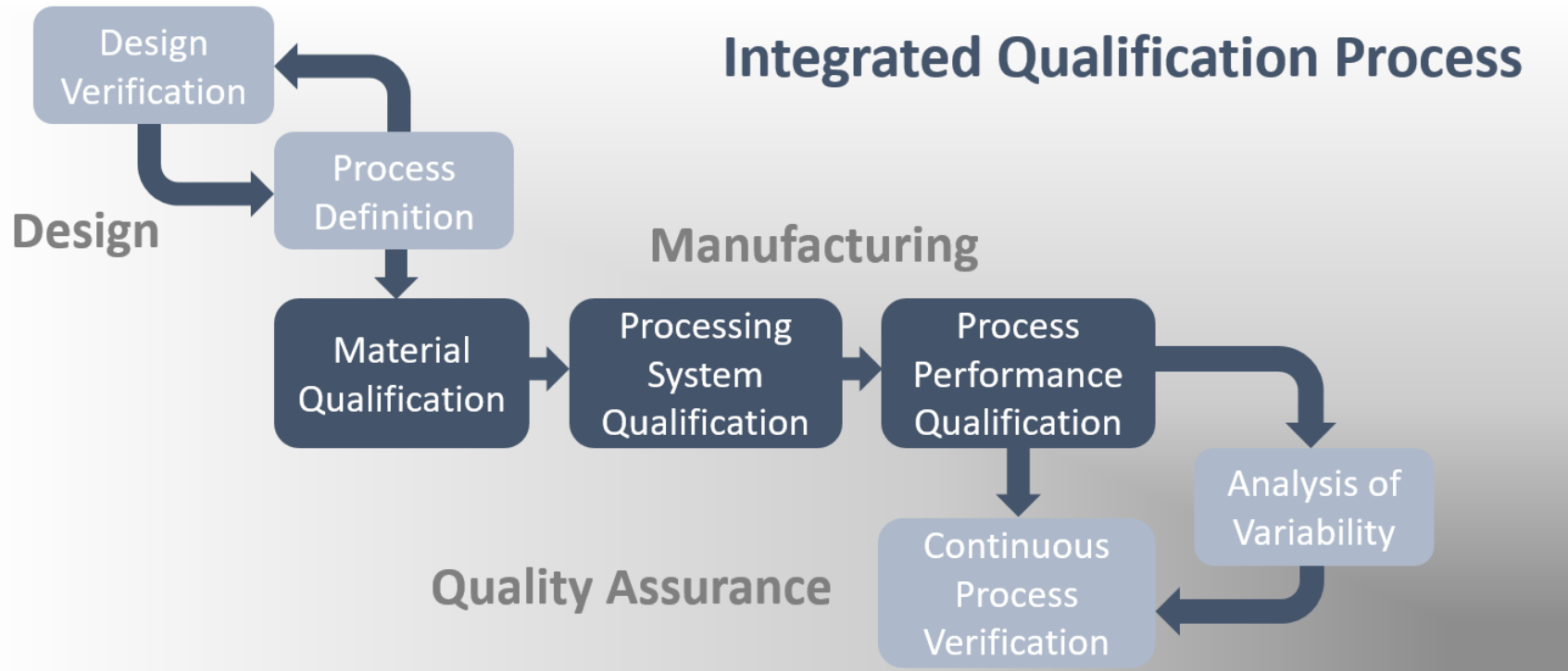
Define the manufacturing process that will meet design requirements

- Acceptance criteria
- Inspection requirements
- Continuous quality assessment
- Continuous process improvement

Quality

Assurance that the manufacturing process meets all requirements of the product design

- Material qualification
- Manufacturing process definition
- Manufacturing procedural qualification
- Manufacturing procedural specification
- Process monitoring
- Process documentation
- Testing plan





- Navy has instituted Uniform Industrial Process Instruction (UIPI) 6320-901: Cold Spray, Processes and Quality Control of
- UIPI provides inspection and test framework for Cold Spray repairs in depot operations for non-structural repairs
- Issued via Navy Technical Warrant Holder review/approval cycle
- Repair know-how captured in Qualified Spray Procedures (QSPs)
- ARL/PSU developed a NAVSEA approved training program to help qualify operators and educate engineers
- Working to expand process to Intermediate Maintenance Facilities (IMFs), Ship Repair Facilities (SRFs), Regional Maintenance Centers (RMCs) and Private Shipyards
- Model for other processes



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- Case-by-Case Basis
- DoD working toward a more uniform process
- Additional Work
- Material performance data
- Feed stock
- Inspection processes
- Process monitoring
- Select correct process for the application