# NASA activities and perspectives on standardization in the AM certification process: NASA-STD-6030 and beyond

*Douglas Wells*
*NASA Marshall Spaceflight Center*
*Douglas.N.Wells@nasa.gov*

United States Nuclear Regulatory Commission
Public Meeting (Virtual)
Workshop on Advanced Manufacturing Technologies for Nuclear Applications
November 7-10, 2020

# Contents of Discussion

- Overview of selected standardization activities
  - Within Agency – NASA-STD-6030 development
    - Review of status
    - Key concepts
  - Supporting Standards Development Organizations (SDOs)
    - ASTM CoE R&D in LB-PBF Process Qualification

- Considerations for critical, but uninspectable AM hardware
  - Cooperative work with FAA on DARWIN code development for AM applications

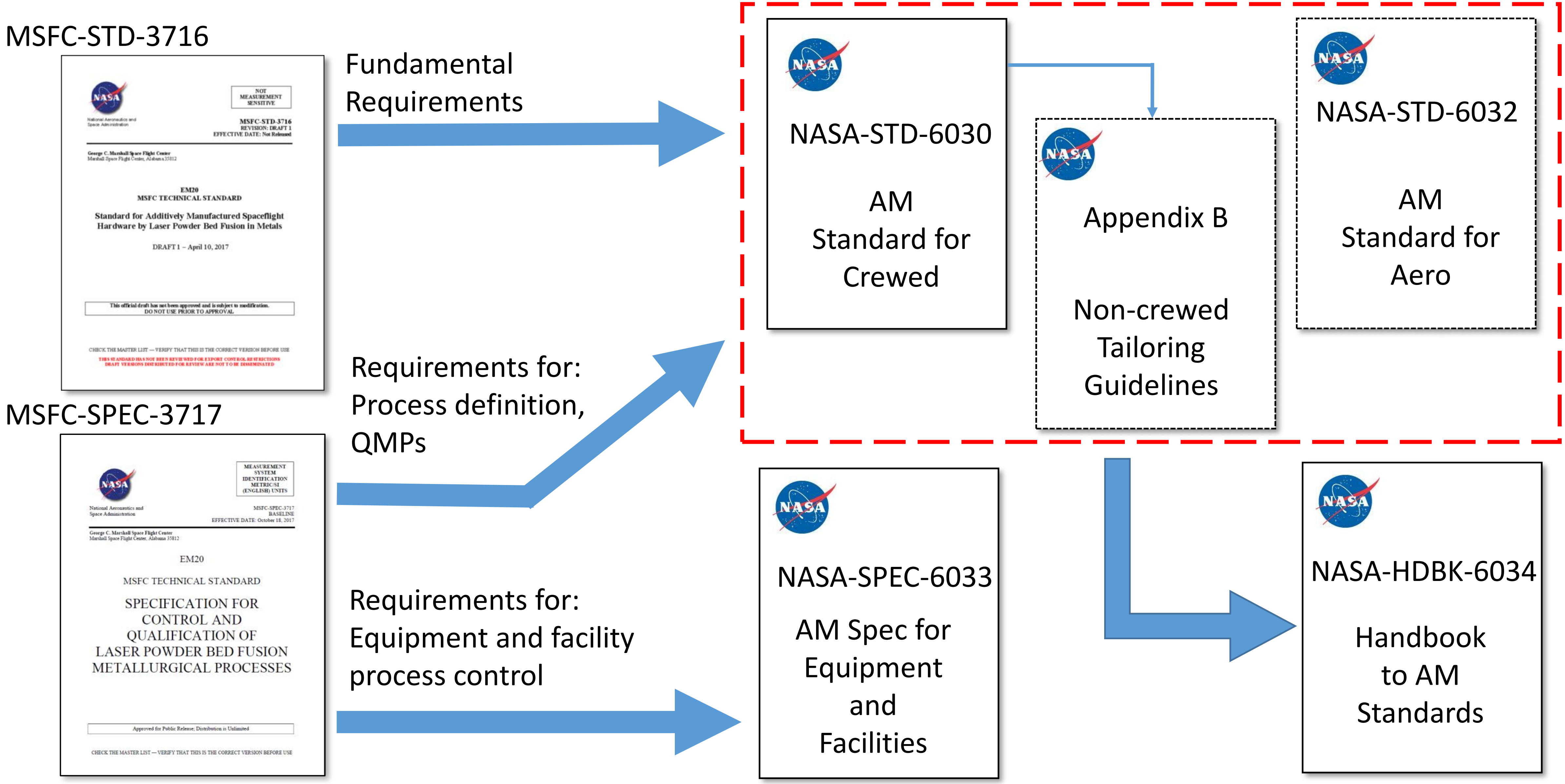
# Motivations for Agency Standards

NASA has been motivated to develop internal standards for AM to provide for a complete and common foundation while industry standards (and standards of practice) evolve.

NASA AM standards have the following intent:

- To provide a consistent methodology for AM on NASA projects
- To define a complete and integrated approach to AM hardware implementation
- To ensure NASA visibility into the introduction of additively manufactured hardware
  - To allow for awareness and evaluation of risk with AM implementation

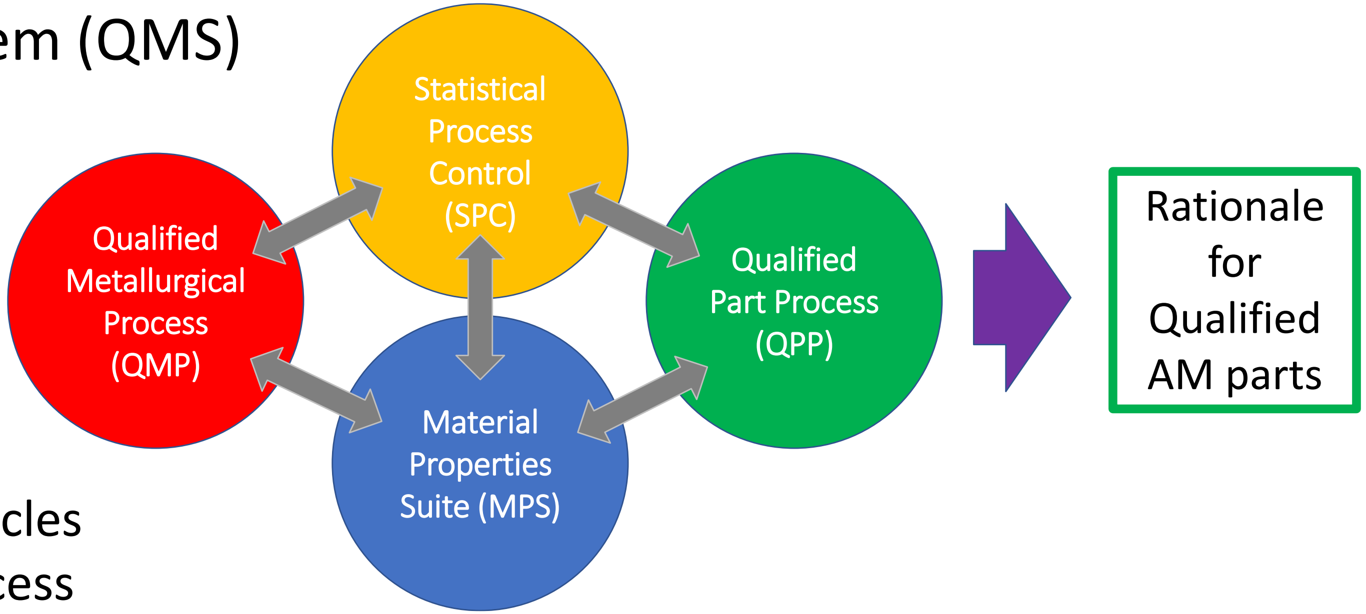
# New Agency Document Structure



# AM Certification: Governing Principles

- *Understanding* and *Appreciation* of the AM process
- *Integration* across disciplines and throughout the process
- *Discipline* to define and follow the plan

- Have a plan
- Integrate a Quality Management System (QMS)
- Build a foundation
  - Equipment and Facility
  - Training
  - Process and machine qualification
  - Material Properties / SPC
- Plan each Part
  - Design, classification, Pre-production articles
  - Qualify and lock the part production process
- Produce to the plan – Stick to the plan



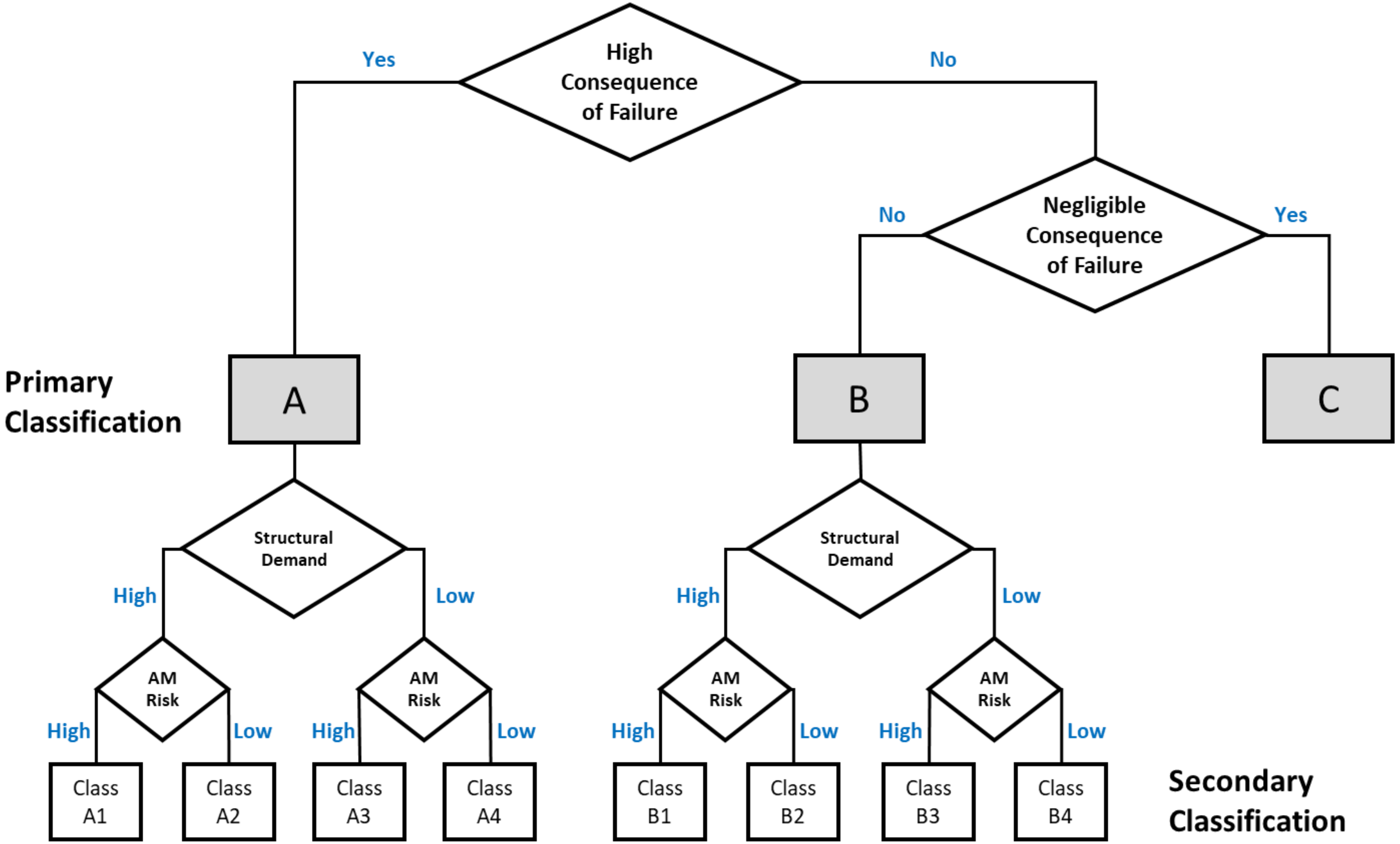
# Applicable Materials and Technologies in NASA-STD-6030

**Table 1—Applicable Technologies and Material Types**

| Category | Technology | Materials Form | Class A | Class B | Class C |
|---|---|---|---|---|---|
| **Metals** | Laser Powder Bed Fusion (L-PBF) | Metal Powder | X | X | X |
| | Directed Energy Deposition (DED) | Metal Wire | X | X | X |
| | DED | Metal Blown Powder | X | X | X |
| **Polymers** | L-PBF | Thermoplastic Powder | | X | X |
| | Vat Photopolymerization | Photopolymeric Thermoset Resin | | | X |
| | Material Extrusion | Thermoplastic filament | | | X |

<u>Adaptive technologies</u>—where process parameters change based on active feedback during the manufacturing process—are not allowed without a tailored, point-design methodology.

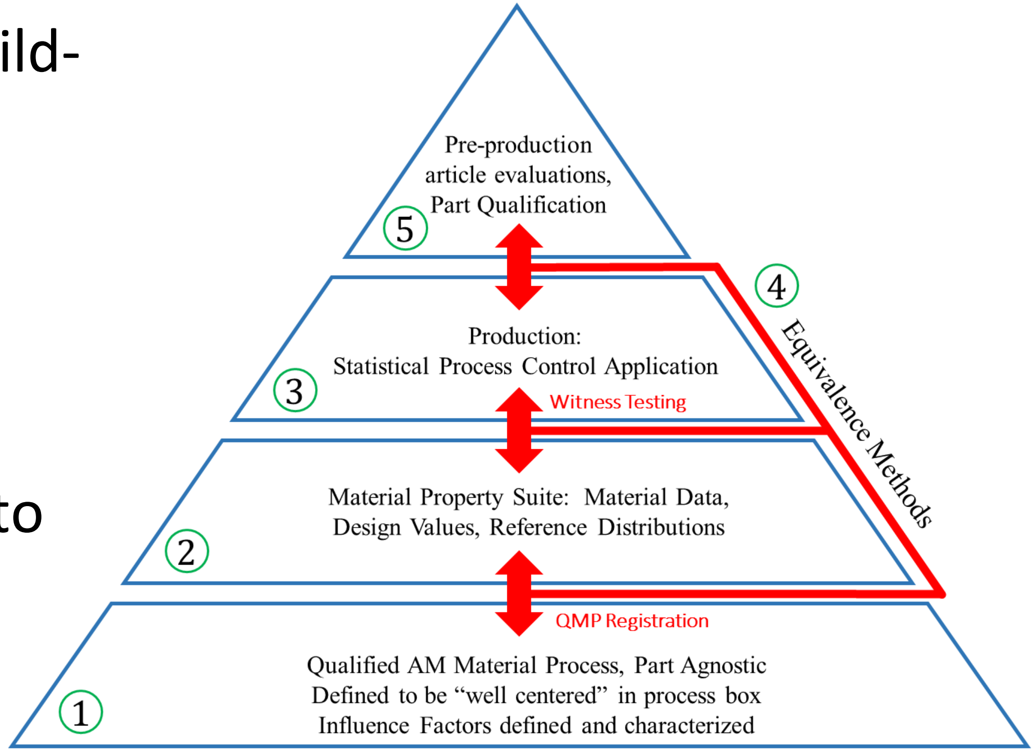
# NASA-STD-6030 AM Part Classification



# Material "Engineering Equivalence"

**Statistical process controls are important in sustaining certification rationale**

- *Statistical / Engineering **equivalency** evaluations* substantiate design values and process stability build-to-build
  a) Process qualification
  b) Witness testing
  c) Integration to existing material data sets
  d) Pre-production article evaluations
- Equivalency of material performance is an anchor to the structural integrity rationale for additively manufactured parts



# Standardizing AM Process Qualification

One example of NASA's involvement in the AM SDO landscape.

**Well-defined process qualification standards remain a clear gap in the AM standards framework**

- This gap impedes the diversification and responsiveness of AM part suppliers when qualification requirements are unique to each purchaser

Many fundamental concepts that define AM process qualification remain undetermined

- Terminology – What nomenclature is used to describe the process?
- Scope – What is within the scope of "process qualification"?
- Intent – What should the final outcome of a successful process qualification consist of?
- Rigor – How detailed and thorough should a process qualification be? Same for all parts?
- Application – How will a process qualification standard fit into the bigger picture of the AM standards framework?

# Standardizing AM Process Qualification

CENTER of EXCELLENCE Research to Standards ADDITIVE MANUFACTURING

**Core fundamentals of the project approach remain the same:**

1. Develop consensus within the ASTM CoE community regarding minimum requirements for the qualification of L-PBF machines and processes.
2. Establish a standard set of procedures, test methods, and evaluations used to establish L-PBF qualification based on fundamental objectives.
3. Establish quantitative and/or qualitative metrics applicable to each evaluation to define successful machine and process qualification.
4. Conduct development and round-robin-style trials of the qualification evaluations and associated metrics.
5. Establish a set of recommendations to appropriate F42 sub-committees for standards implementation.

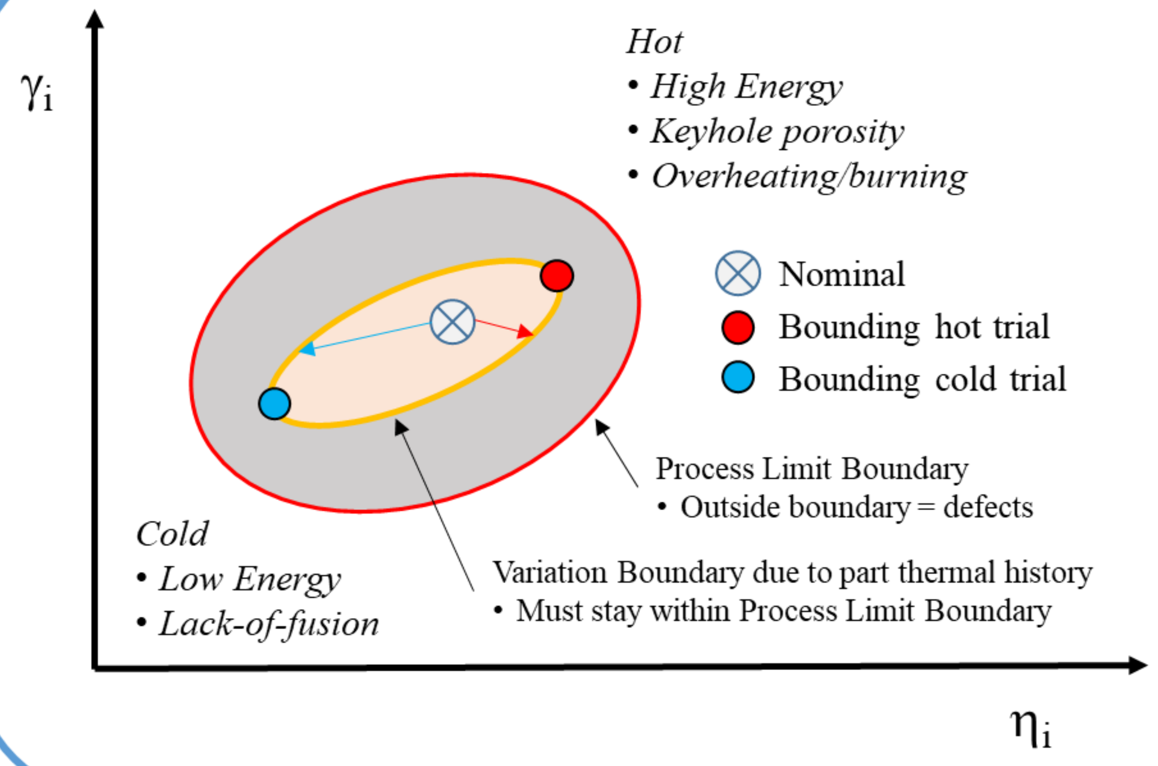
# Standardizing AM Process Qualification

CENTER of EXCELLENCE
Research to Standards
ADDITIVE MANUFACTURING

**Thermal Challenge Build for Process Box Confirmation (Auburn University)**

Subset of Process Qualification Standardization

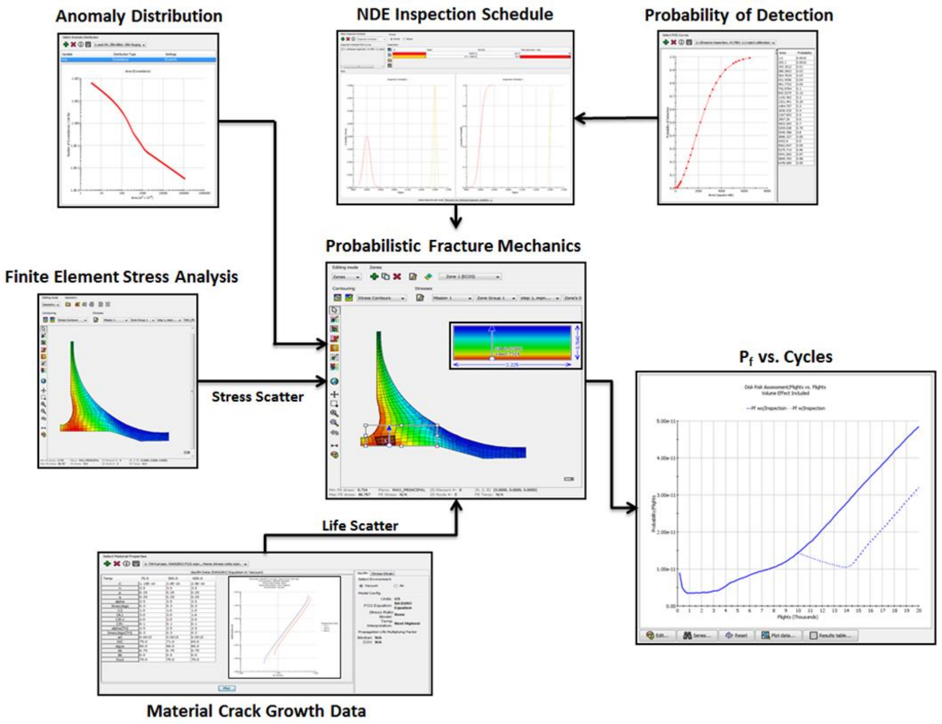
- Objective: confirm candidate parameter set is "well centered" in the process box.
- Develop standard parts or part design philosophy
- Challenge the AM process box through geometry, and potentially scan pattern
- Not used in defining process box during parameter development
- Needs to be able to work with fixed, "black box" parameter sets from OEMs



# Assessment of Non-inspectable Critical Parts

- **Risk level in AM parts for space applications continues to accelerate rapidly**
- **Need methodologies to assess damage tolerance (DT) in critical parts that, through mass or complexity, significantly limit or preclude traditional non-destructive inspection**

- **Challenges in work:**
  - Integration tools for deterministic or probabilistic DT assessment
  - DARWIN software through Southwest Research Institute
    - Projects complimentary to similar FAA efforts
    - Part zoning methodologies/considerations
    - AM defect characterization
      - Inherent
      - Rogue / process escapes
    - Leveraging NDI simulation to understand limits of coverage
    - Practical use of process data on a per-part basis
      - In situ monitoring data
  - Qualification of in situ monitoring systems



# Conclusions

1. NASA remains intently interested in standardization for AM
   - Working Agency (public) standards as well as with multiple SDOs
   - Standards for AM process qualification remains a focus
2. NASA has near-term challenges regarding risk management of high criticality parts with limited post-build structural integratory verification
   - Working on integrated methods to utilize all available data (traditional NDE, in-process data…) and assessment techniques (zoning, probabilistic assessments, …) to manage risk