Joint Defense Manufacturing Technology Panel's Perspectives of Needs for Standards and Discussion

Paul Huang, ONR ManTech

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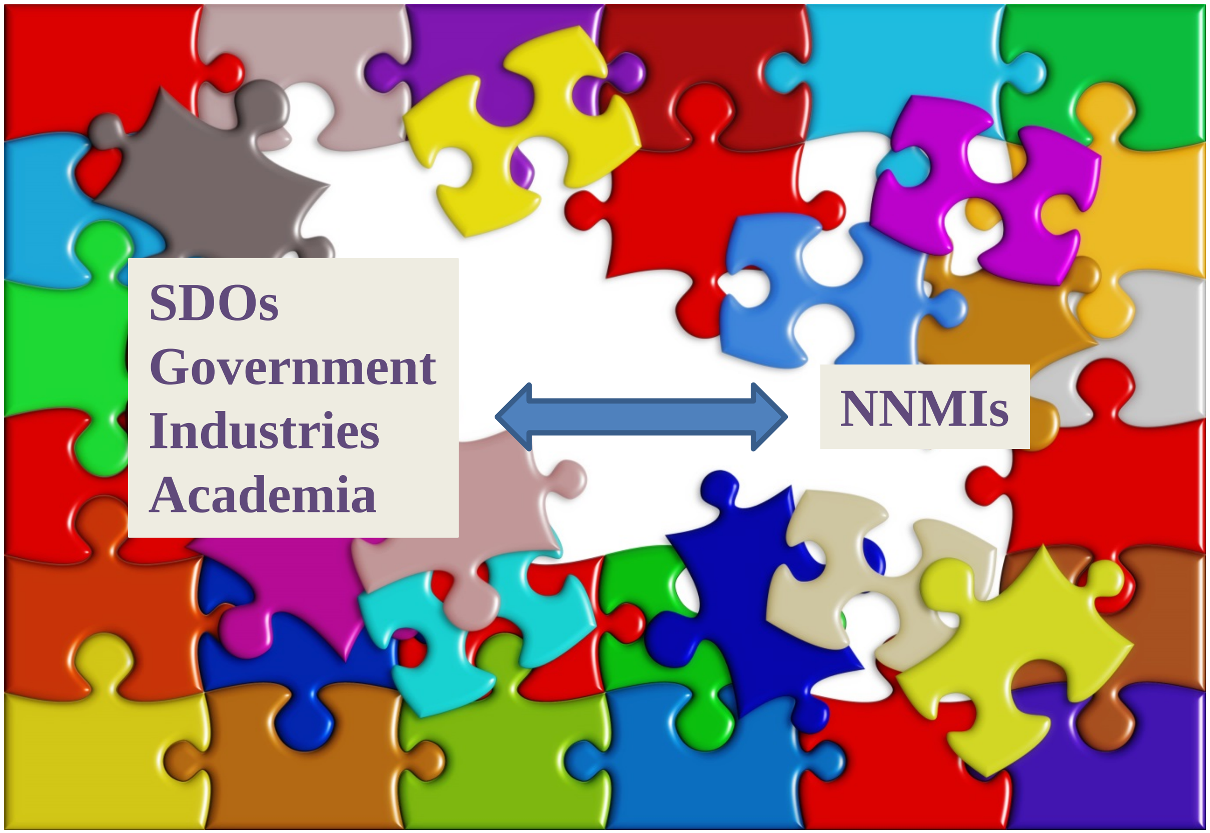
What is needed and where are we?

Digital Manufacturing Standards Landscape



Additive Manufacturing Standards Landscape

Air Force Perspectives

The AF recommends that SDOs stay within their historical areas of expertise. These are what the AF has come to rely on. For example, for aerospace structural metals:

- AMS feedstock materials standards
- AWS process standards
- ASTM testing standards

The AF approves for its use only those standards that meet its requirements, i.e., those published standards that do not meet AF requirements are not included in the AF standards database.

For AM structural components, because they are highly process sensitive, a handbook allowables approach is not preferred. A more appropriate approach to standards for AM is that used for welding, not materials.

The AF expects that the standards approach for polymer/composite structural materials will be similar to that for metals. More work, however, needs to be accomplished to understand the effects of defects, etc.

Army Perspectives

- Focused on repair with lasers.
- Roadmap developed for AM, but still work in progress
- Army is not using the military standard for laser repair (Mil-Std 3049), but they want to work it in to their practices.
- Specific AM Needs:
  - Additive for armor.
  - Printed Explosives.
  - Standards for repair parts – high demand for repair.
  - Need to know any unique loading or fatigue to specify for AM.
  - For repaired parts:
    - Army needs to define what tests are required for their repaired parts so that the AM can meet the requirements.
    - The PM doesn't really care if the design or material changes, as long as the part still works.

Navy Perspectives

Goals/Objectives:

- Ability to acquire AM parts using competitive sourcing from a Technical Data Package (TDP) enabled by common standards
  - Usable across machines, processes, and companies employing a neutral build file
  - High confidence that parts produced by AM using the TDP will meet performance and safety requirements

Impediments:

- Lack of sufficient AM standards and understanding in key areas:
  - Technical data package (TDP)
  - Neutral build file
  - Engineering design guidelines
  - Pedigreed materials properties
  - Process controls
  - Post-processing
  - Process Qualification & part certification
  - Machine qualification & calibration

Summary of Proposed Outline for Navy AM Standards

Category	Topics**
Technical Data Packages	• Part Build TDP • System Design TDP • Neutral Build Package Format
Design	• Design and CAD Model • Modeling and Simulation (i.e., FEA) • Materials properties (with dependencies on process type, process controls, post-processing) • Performance criticality
Materials and Processes	• Input Materials (Virgin and Re-cycled) Characterization/Certification • Machine Type/Model/Series (T/M/S) Calibration & Operation • Operator Qualification/Certification • Build Package
Manufacturing	• Manufacturing Plan • Quality Assurance (material, in-process, and post process inspection plans) • Statistical Process Controls (SPC) • Post-processing • Portability Validation (Equivalence across machine)
Parts Testing and Certification	• Parts Qualification/Certification • Testing, Inspection • Metrology • Non-Destructive Evaluation (NDE)
Support (Management and Sustainment)	• Digital Thread (Configuration and data management through the part life cycle) • Cybersecurity • Safety (Environmental, Human) • Education/Training

***Near-term priority topics (0-2 year need) are in red**

Defense Logistics Agency Perspective

DLA has agree to other services comments and has no additional comments

Common Threads

All the services have their own unique requirements, but there are some commonalities.

- **Materials**
- **Processes**
- **Inspection, Certification & Qualification Requirements**
- **Testing – both physical and virtual (M&S)**
- **Data library –**
- **Design guidelines**
- **Common Terminology**
- **Need to pool resources, and coordinate among all DoD efforts (i.e. NAMTII, Army COI AM, GO Additive, and DoD Additive Manufacturing Qualification and Certification Working)**
- **Strategic Plan(s) & Investment Strategy**
- **Others?**

Significant Area of Mutual Interest: Qualification and Certification

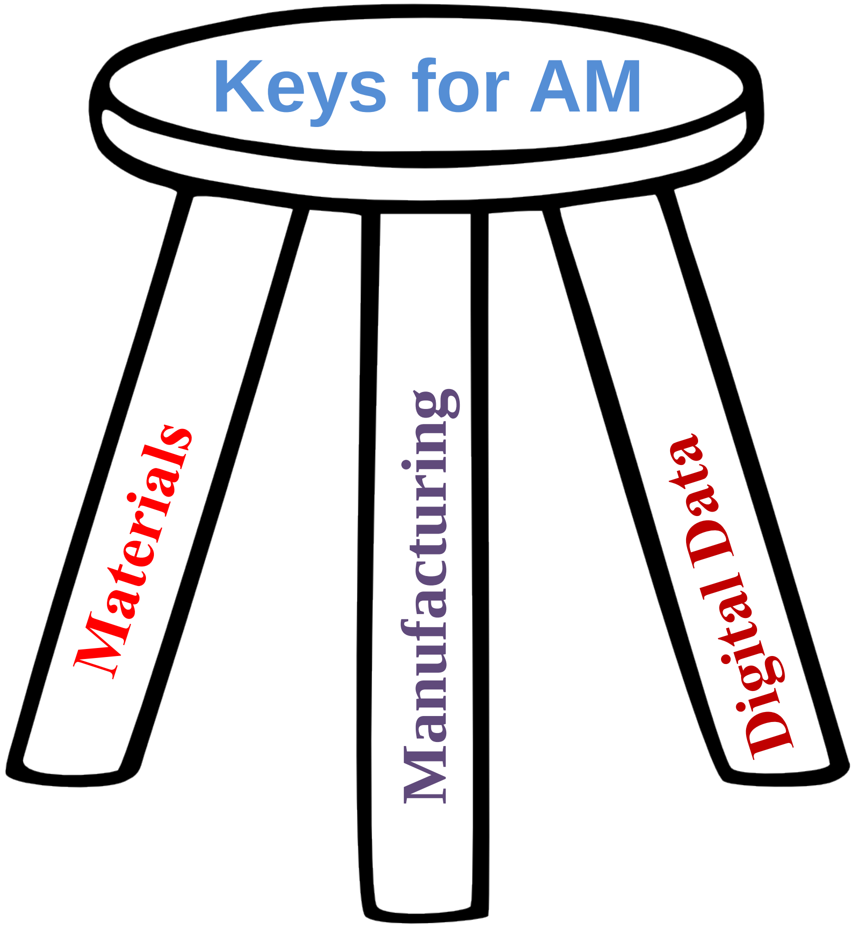
The Issue:

- How do we qualify materials, processes and certify products for a manufacturing method that can deliver a unique part, with nearly an infinite combination of material compositions and process variations under nontraditional processing conditions?

The solution:

- We must develop an approach for process qualification that is reliable, repeatable and credible for customers that are familiar with traditional materials and process specifications, but does not limit the potential and flexibility the process provides
- Traditional methods rely upon quantitative analysis through a combination of destructive and non-destructive evaluation (NDE)
- Advanced approaches include:
  - Materials and process modeling that provides pedigree and predicts performance
  - Less destructive evaluation and post-process evaluation through predictive modeling
  - Sharing of qualification property data between services and companies is important rather than continue to retain data as proprietary
  - Then follow up with application certification.

Issues and Concerns:



Competitive sensitive challenges

Materials:

- Raw stock & pedigree info
- Metals, Polymers, Ceramics, Hybrids
- Characterization
- Handling & Storage
- Testing, & others

Manufacturing:

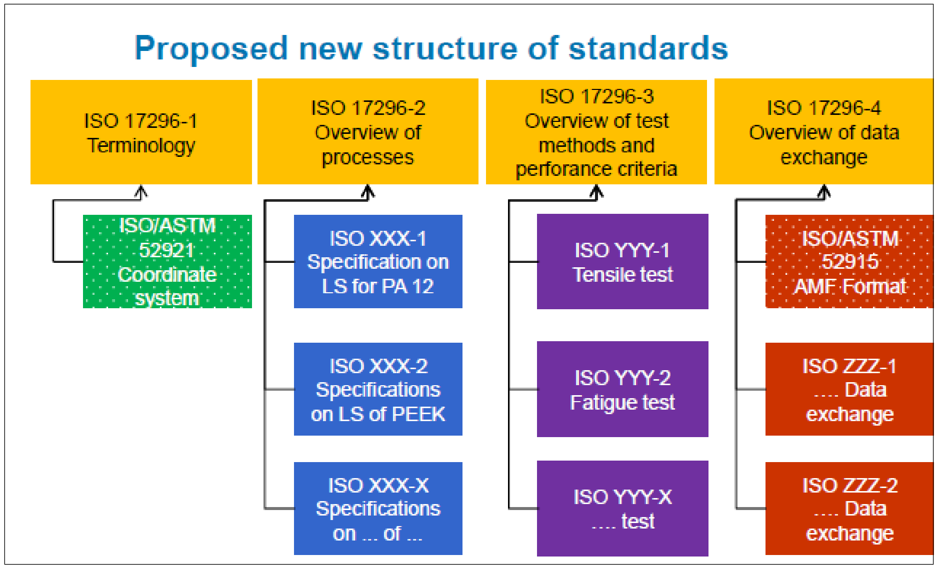
- Process parameter & controls
- Sensors, security
- Equipment pedigree info
- Producibility & Repeatability
- Inspection, & others

Digital Data:

- Model Quality, data formats
- IT infrastructure, Data Management
- Validation, Verification, Certification
- Integrated Computational Materials Engineering (ICME)
- Cyber Security, others

Where are the Expertise in Standard Developing Organizations (SDOs) and How do they interact?

ISO TC 261/ASTM F42



AWS D20 committee on AM

D20A/TG1 on General Requirements

D20B/TG2 on Material Characteristics

D20C/TG3 on Prequalification

D20E/TG5 on Fabrication

D20F/TG6 on Inspection

ASME: 14.46, 14.41.1

SAE's: AMS & AS standards

Others: SME, ASNT, IEEE, ASM, DoD MIL STD & DTLs, NAVSEA Tech Pubs, Industries (Primes) etc..

Some Print Formats:

AMF, STL, 3MF, STEP(ISO-10303)

What about Safety/ Regulations Stds?

Summary

- AM is already being used in the DoD for process enabling, intermediate, and finals parts.
- For final parts, AM is being approved on a case by case basis across the services.
- For intermediate and process enabling parts where AM is used to enable the final part build and design, such as tools, dies, and consumables, AM parts are used as a drop-in substitute for the current process.
- The majority of AM parts are for repair items where the original supply chain no longer exists.
- For new parts, the business case for using AM revolves around long lead time items and parts with increased complexity.

Future Steps

What's Next?

- Gap Analysis
- Coordinate who will participate and how
- Prioritize the development of the various standards
- Reach agreement who will lead and maintain the standards
- Periodic Meetings

Needs:

- Better coordination among all players i.e SDOs, Government (DoD, NASA, DoC, DoE, DoT, FAA), Industries (Aerospace, Defense, Auto, Energy, etc), Academia, and NNMIs
- Funding!!

Backups

Navy Perspectives

· As we look at the list of standards we need to develop our requirements to enable DOD/Industry to increase our use of AM and reduce the "proprietary" standards for qualification and certification, we need to focus the standards committees on our priority applications of AM.

· We talked about a prioritized list of top level DOD needs to focus the standards:

- o AM for metal aerospace components - including safety critical items
- o New materials standards to address fire/smoke/toxicity for expeditionary/shipboard use of AM (metal and polymer)
- o Maintenance plan for AM standards across multiple standards organizations (ASTM, ASME, DWG)
- o Data/analysis repository to accelerate and support standards development

Navy has some unique requirements for AM based on the various platforms in construction and in sustainment which may require MIL SPECS or STD.

ONR Additive Manufacturing S&T

- **Vision**

  Exploit the flexibility and opportunities afforded by Additive Manufacturing (AM) to provide the warfighter with high-performance systems that could not otherwise be produced, and technologies that enhance operational fleet readiness, improve energy efficiency, and reduce total ownership cost

- **Approach**

  Make strategic S&T investments that enable full exploitation of AM:

  Push the limits of AM length scales, material selection and complexity of material and design

  Develop the understanding and tools to rapidly and confidently certify lots of one

  Actively assess and leverage partner services, agencies, industry and academia activities (e.g. DARPA Open Manufacturing, America Makes, Oak Ridge National Laboratory, etc.)

- **Examples**
  - Direct Digital Manufacturing (DDM) Accelerated Certification Technology – develops in a heuristic technique for rapid qualification/certification
  - Disruptive Technologies in Direct Digital Manufacturing – demonstrates the repair of single crystal turbine blades, closed-loop process control and micro/nano DDM
  - Cyber-enabled Manufacturing Systems – improves closed-loop feedback control for real-time shape compensation
  - Advanced Integrated Computational Materials Engineering (ICME) and Additive Manufacturing (AM) Methods for Improved Performance, Reduced Cost Heat Exchanger – provides opportunity for material design, processing and rapid prototyping with tailored microstructural topology- Including FY17 FNC “Quality Made”