Accelerating Standards Development

America Makes and ANSI Additive Manufacturing Standardization Collaborative (AMSC)

Last updated: February 2024

ANSI American National Standards Institute

America Makes

AM

American National Standards Institute

Standardization Collaboration

One way ANSI coordinates and supports the standardization system is through **standards collaboratives and workshops**, which:

- Bring together the public and private sector in a **neutral forum**
- Identify current and in-development standards, where gaps exists, and recommend solutions
- Identify organizations that can perform the needed work

ANSI does **NOT** write standards

Founded in 1918, ANSI is a private non-profit membership organization whose mission is to enhance U.S. global competitiveness and the American quality of life by promoting, facilitating, and safeguarding the integrity of the U.S. voluntary standardization system.

AMSC Mission and Goals

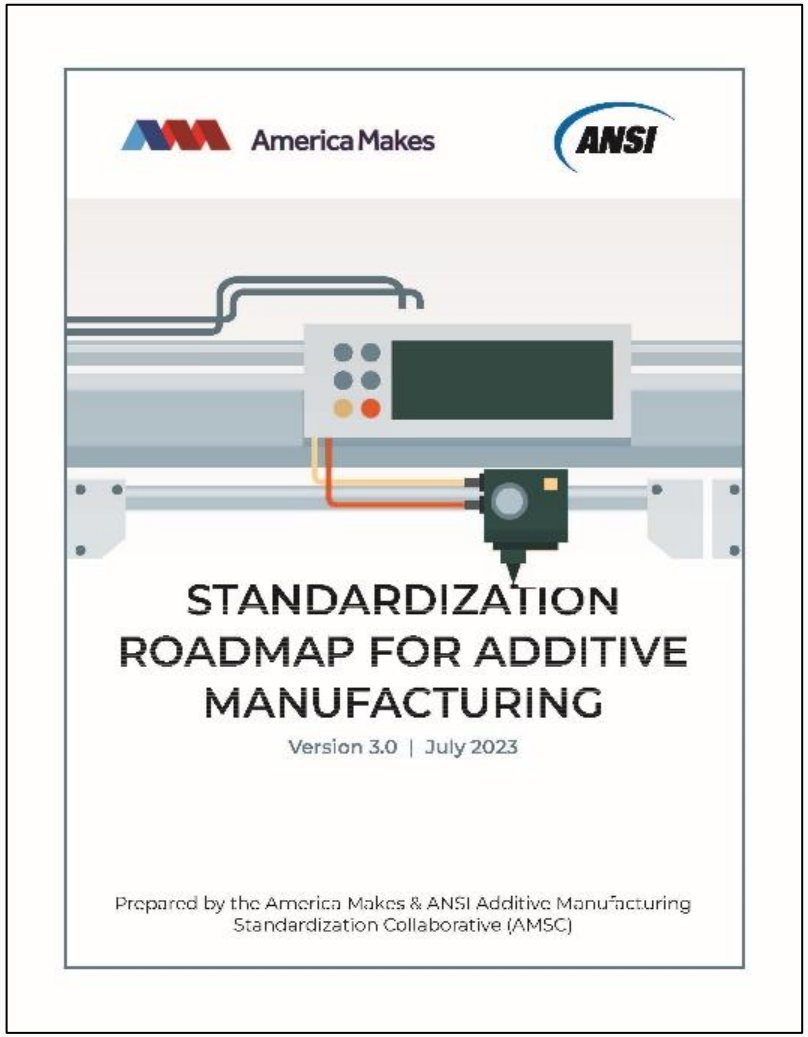
- Launched in March 2016
- Drive coordinated standards activity among AM Standards Developing Organizations (SDOs)
  - Avoid duplication of effort
  - Encourage liaisons between SDOs
  - Provide subject matter experts to help SDOs develop the standards
  - Better inform decision-making on resource allocation for standards participation and R&D needs
- Clarify the current and desired future standardization landscape
- Establish a common framework of AM standards and specs
- AMSC does not develop standards

ASMC PURPOSE

To coordinate and accelerate the development of industry-wide additive manufacturing (AM) standards and specifications, consistent with stakeholder needs, and thereby facilitate the growth of the additive manufacturing industry

Evolution of Roadmap

- **Feb 2017 (v1)** – heavy focus on metallic AM for aerospace, defense and medical industries
- **Jun 2018 (v2)** – added polymer content, electronic and electrical products industry
- **Jul 2023 (v3)** – added data WG, perspectives from additional industry sectors, more gaps metadata to enhance indexing/search capabilities, current alternatives being used until a standard is available, R&D expectations



AMSC Roadmap v.3

- **AM Lifecycle Areas:**
  - Design, Precursor Materials, Process Control, Post-processing, Finished Material Properties, Qualification & Certification (Q&C), Nondestructive Evaluation (NDE), Maintenance and Repair, Data
- **Background Information**: AM issues, standards, specifications, codes, regulations, etc. that are published or in development
- **141 Gaps:**
  - **Recommend**: New / revised standards, organizations that can do the work, and priority levels
  - **Identify:** Captures any pre-standardization research & development (R&D) needs
  - **Suggest:** Intended applicability to sectors, materials, lifecycle/Q&C areas, process categories
- **Participation**: Approximately 300 individuals / 150 organizations

Gaps and Recommendations Table

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Summary of Gaps and Recommendations Table in AMSC Roadmap v3

Standards tables last edited July 12, 2023

Row #	Section #	Section Title	Gap #, Title and Description	R&D Needed	R&D Expectations
5	2.1.2.4	Design Guides: Machine Customizable/ Adaptive Guides for AM	**Gap DE5: Support for Customizable Guidelines (WITHDRAWN).** Producing the same part on different machines from different manufacturers and often the same manufacturer will return different results. While process and application guidelines will provide meaningful insight, additional tailoring may be needed for specific instantiations. Methods that incorporate machine specific data into guidelines. For example, how to use in-situ monitoring to better inform internal guidelines.	Yes	Customizable guidelines require understanding process/machine/design characteristics and subsequent tradeoffs. New monitoring techniques and data being generated which support customizable design guidelines; applicable to various machines.
6	2.1.2.5	Design Guides: Design Guide for Post-processing	**Gap DE7: Design Guide for Post-processing.** There is a need for additional design guides for post-processing. Depending on the type of process used for post processing different practices may be used.	Yes	General research about post processing is needed, surface finishing and its correlation to fatigue and fatigue requirements.
7	2.1.2.6	Design Guides: Design of Lattice Structures	**Gap DE14: Designing to be Cleaned.** Currently there are no design guidelines for devices to assure cleanability post-production. When designing a device (including medical), cleanability must be evaluated at different stages for a number of reasons:	Yes	In terms of ways to determine what parts are likely to be cleanable before they are made, AM technology and material specific needs exist. Per #3 above, research on sterilization validation for where you place the soil is needed.

Significant Changes in Roadmap v3

2.2.1 Precursor Materials

- Addresses Use, Re-Use Mixing, Recycling Feedstock (previously under Process Control)

2.2.2 Process Control

- Revisions to Machine Qualification/Re-Qualification, Stratification, In-Process Monitoring
- Powder Blending and Powder Mixing Terminology (NEW)

2.2.3 Post-processing

- Added ceramics
- Environmental Health and Safety Hazards (NEW)

2.2.4 Finished Material Properties

- Terminology (NEW)
- Broke down Material Properties into Specification Content Requirements, Metals, Non-metals, and Test Methods
- Reworked Material Allowables section
- AM Defect Structures (NEW)

Significant Changes in Roadmap v3

2.3 Qualification & Certification

- Q&C Framework: Prescriptive vs Performance-based (NEW)
- Additional industry guidance documents
- Broke aerospace into spaceflight and aviation
- Added energy sectors
- Sector approaches content restructure (materials, processes, machines, parts, personnel, etc.)
- Conclusions (NEW)

Significant Changes in Roadmap v3

2.4 Nondestructive Evaluation (NDE)

- New subsections on Terminology and Equipment Standardization and Demonstration of NDE Capability under Common Defects Catalog
- New subsections under Test Methods/Best Practice Guides
- Added NDE of Ceramics and Composite Materials
- New section on Effect-of-Defect of Technologically Important AM Defects
- New section in In-Service NDE

New Chapter 2.6 on Data

Technical Areas

- 2.6.2 Data Formats and Representation
- 2.6.3 Data Registration, Fusion, and Visualization (managing data sets)
- 2.6.4 Data Management
- 2.6.5 Data Quality
- 2.6.6 AM Value Chain Data Usage and Management
- 2.6.7 AM Data Security & IP Protection
- 2.6.8 Data Architecture Integration and Interoperability
- 2.6.9 Sector Related Needs

Breakdown of Open Gaps

Section	High Priority (0-2 years)	Medium Priority (2-5 years)	Low Priority (5+ years)	Total
Design	8	11	2	21
Precursor Materials	2	9	8	19
Process Control	2	8	3	13
Post-processing	1	4	3	8
Finished Material Properties	9	0	1	10
Qualification & Certification	13	10	3	26
Nondestructive Evaluation	5	6	1	12
Maintenance & Repair	1	4	2	7
Data	13	12	0	25
Total	**54**	**64**	**23**	**141**

91 Gaps Require R&D / 60 New Gaps

New Gaps in AMSC Roadmap v3

**High Priority*

Design (3)

- *DE29: Best Practices for Design for Anti-counterfeiting*
- *DE30: STEP Based 3D PDF*
- *DE31: Feature-based Support for STEP*

Precursor Materials (8)

- *PM11: Segregation of Powder*
- *PM12: Requirements for Large Storage and Transport Vessels of Powder Feedstock*
- *PM14: Test Method to Assess Hydrogen Content in Aluminum Powder Feedstocks*
- *PM15: Identification and Quantification of Impurities in Chemical Compositions*
- *PM16: Universal Reference Standard on Size Distribution*
- *PM17: Error Quantification of PSD Measurement Methods*
- *PM19: Terminology Related to Reuse of Feedstock Materials*
- *PM20: Recycling the Polymeric Structures to Fabricate Filaments*

New Gaps in AMSC Roadmap v3

**High Priority*

Process Control (1)

- *PC18: Powder Blending and Powder Mixing Terminology*

Post-Processing (1)

- *P8: EHS Hazards Related to Post-Processing Tasks.*
- *PM11: Segregation of Powder*

Finished Material Properties (6)

- *FMP6: Finished Material Properties Terminology*
- *FMP7: Material Properties: Specification Content Requirements*
- *FMP8: Material Properties (Non-Metals)*
- *FMP9: Material Properties: Test Methods (Metals and Non-Metals)*
- *FMP10: Catalogs of Process Specific Defect Types*
- *FMP11: Assessment of models linking defect structures and material performance*

New Q&C Gaps in AMSC Roadmap v3

**High Priority*

Civil & Defense Aviation Industry (5)

- *QC17: AM Part Material Development Timeline*
- *QC18: OQ/PQ Process Know-How*
- *QC19: Workforce Training*
- *QC20: Certifying agency KPV Checklist*
- *QC21: Detailed Requirements Integration Document*

Electronics and Electrical Products Industry (1)

- *QC22: Additively Manufactured Electronics (AME)*

Oil & Natural Gas Industry (1)

- *QC28: Susceptibility of AM Products to Corrosion and Environmental Cracking Mechanisms*

Nuclear Industry (5)

- *QC23: Production and Incorporation of AM Parts in Nuclear Applications and Facilities*
- *QC24: Nuclear AM Component In-service Performance*
- *QC25: Nuclear Industry Use of Artificial Intelligence (AI) and Machine/System Learning Technologies to Qualify AM Parts*
- *QC26: Nuclear Industry Use of Material and Production Data Combined with Digital Analysis and Diagnostic Informed Qualification of AM Components*
- *QC27: Use and Qualification of AM Non-metallic Advanced Materials in Support of New or Advanced Nuclear Fuel and High-temperature Reactor Applications*

New Gaps in AMSC Roadmap v3

**High Priority*

Nondestructive Evaluation (NDE) (5)

- *NDE9: Effect-of-Defect of AM Defects Detectable by NDE*
- *NDE10: In-service Inspection*
- *NDE11: Reliability of NDT*
- *NDE12: 3D Image Quality Indicator for determining the sensitivity of a CT system*
- *NDE13: Reference Radiographic Images and Standards for Additive Manufacturing Anomalies*

Maintenance and Repair (1)

- *M10: Best Practices on Repair using Additive Manufacturing*

New Data Gaps in AMSC Roadmap v3

**High Priority*

- *DA1: Standard Data Format for Material Characterization*
- *DA2: Process Specific Common Data Dictionary*
- *DA3: Digital Format for In Process Monitoring Data*
- *DA4: Data Capturing for Machine Logs During a Build*
- *DA5: Extended Design Specifications for Meta-Data Format Standardization*
- *DA6: Specifications and Representations for AM Big Data*
- *DA7: Additively Manufactured Electronics (AME) Data Transfer Format*
- *DA8: Customizable Standard AM Data Collection Templates*
- *DA9: Best Practices and/or Specifications for Registering and Fusing Data Sets During the AM Manufacturing and Inspection Process*
- *DA11: Best Practices for Anomaly Characterization and Localization for Part Defect Prediction Purpose*
- *DA12: Consistent Part Traceability and Provenance (Digital Twin)*

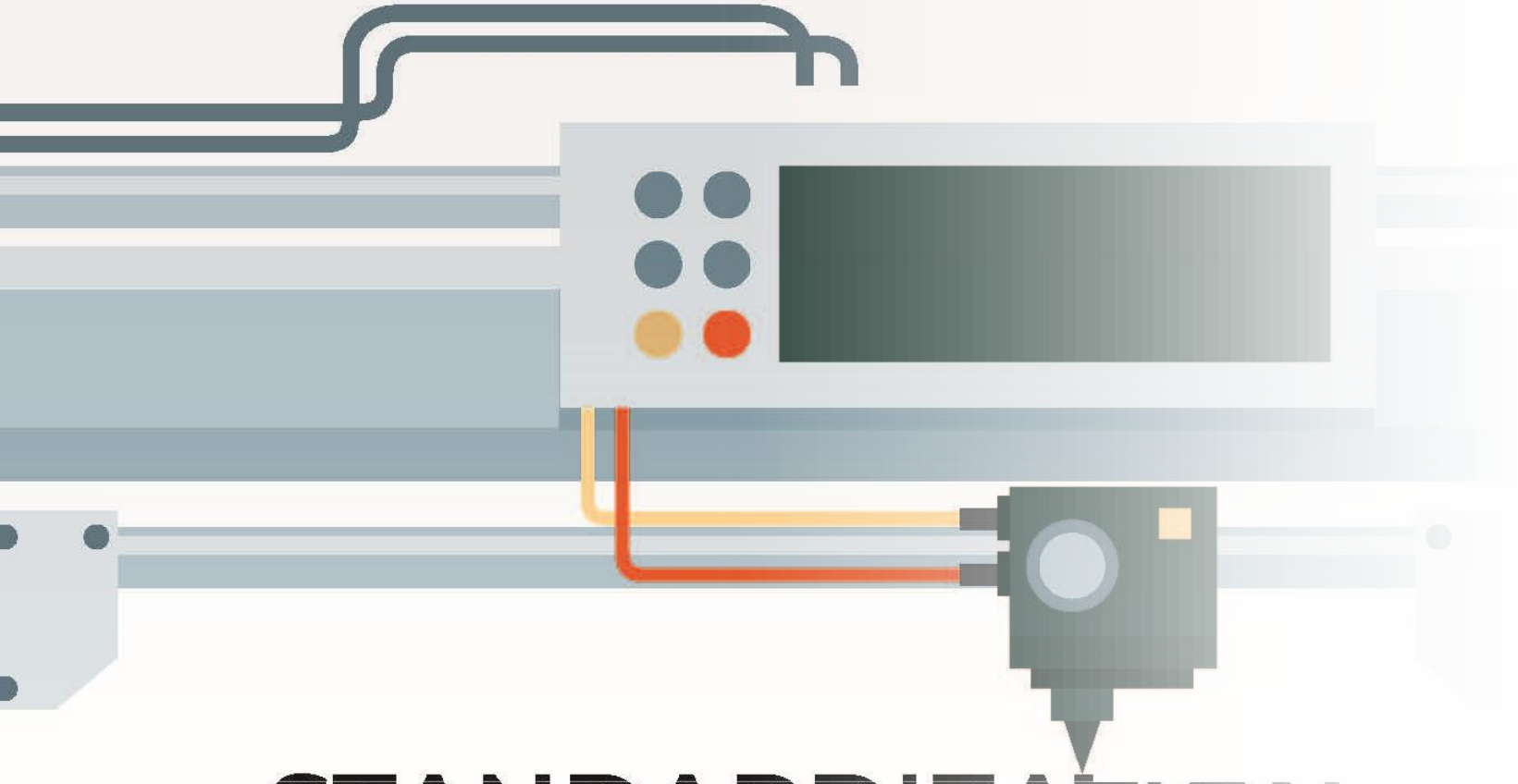
New Data Gaps in AMSC Roadmap v3

**High Priority*

- *DA13: Data Visualization*
- *DA14: Best Practices and Guidance for AM Data Collection*
- *DA15: Data Aggregation of Time Series and Object Data*
- *DA16: Data Retention Guidelines*
- *DA17: Assessment and Specifications of AM Data Quality*
- *DA18: Reference Workflow (Digital thread) for AM Part Fabrication*
- *DA19: Context and Scenario-specific Data Selection*
- *DA20: AM-Specific Security Guidance*
- *DA22: Technical and IP authentication and protection*
- *DA23: AM Machine Data Framework and Guideline for Automated AM Data Integration and Management*
- *DA24: Medical AM design file retention*
- *DA25: Quality Management of Medical AM Files*

Next Steps

- Increase awareness about roadmap availability and recommendations, especially to recommended organizations listed in the gaps
  - Add to agendas to Standards/Codes developing organizations technical committee meetings
  - Brief research organizations during project development phases
  - Outreach to AM stakeholders / individual organizations and related government bodies
  - Social media and other communication channels
    - Press Release
    - Roadmap (freely available / direct link)
- Collaborate to close gaps!



STANDARDIZATION ROADMAP FOR ADDITIVE MANUFACTURING

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