Accelerating Standards Development

America Makes and ANSI Additive Manufacturing Standardization Collaborative (AMSC)

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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

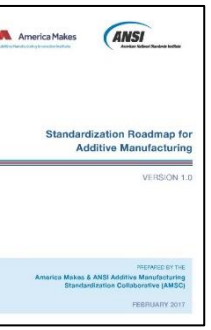
AMSC PURPOSE

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

March 2016

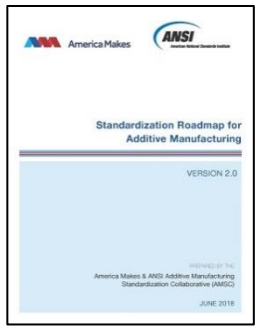
Additive Manufacturing Standards Collaborative (AMSC) formed



Feb 2017

Roadmap v1 Published

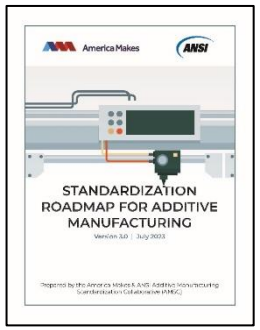
Heavy focus on metallic AM for aerospace, defense and medical industries



June 2018

Roadmap v2 Published

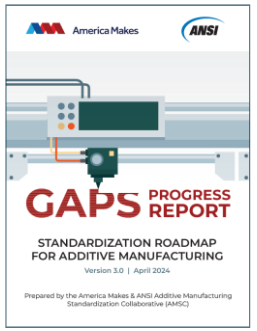
Added polymer content, electronic and electrical products industry



July 2023

Roadmap v3 Published

Added data WG, industry sectors, gaps metadata to augment filtering capabilities, current alternatives being used, R&D descriptions

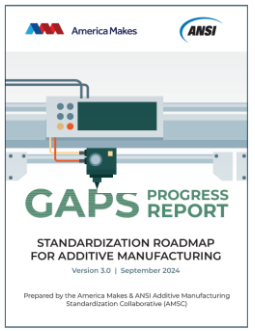


April 2024

Gaps Progress Report Published

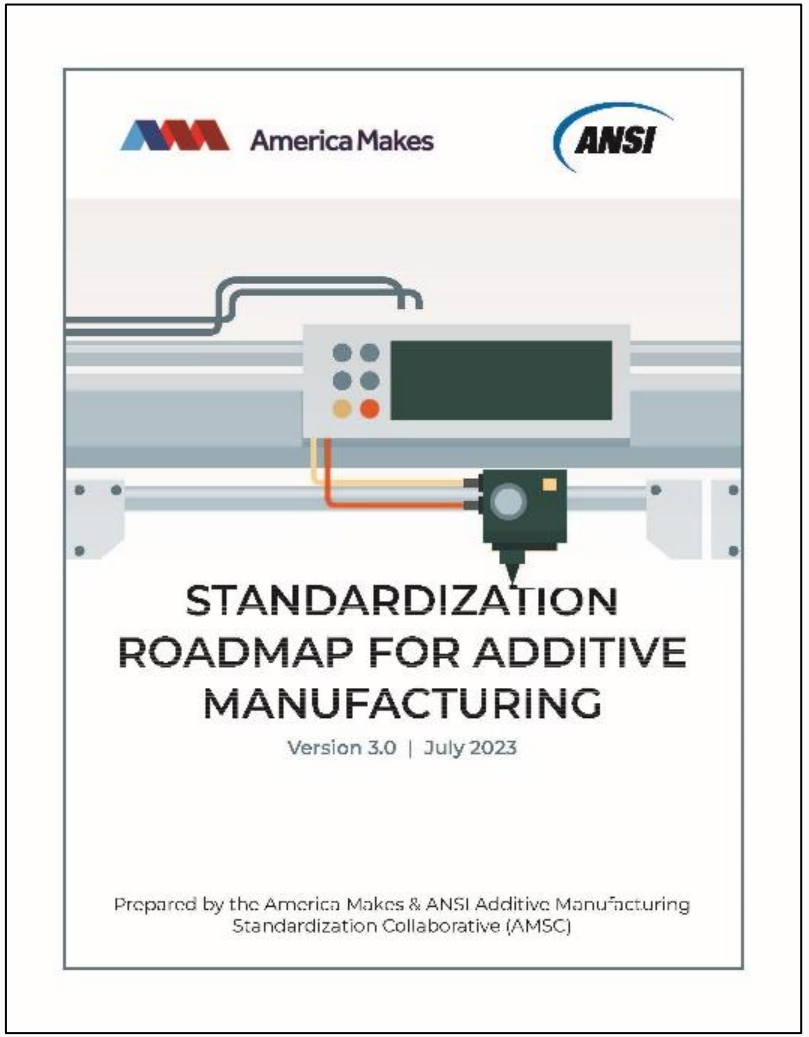
April & September 2025

Scheduled Future Gaps Progress Reports



Sept 2024

Gaps Progress Report Published



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

America Makes

ANSI
American National Standards Institute

America Makes & ANSI Additive Manufacturing Standardization Collaborative (AMSC)

Summary of Gaps and Recommendations Table in AMSC Roadmap v3

Standards tables last edited July 12, 2023

entified in the AMSC Roadmap version 3.0 published in July 2023. The
-development standards; and makes recommendations to address gaps
). This includes recommending pre-standardization research and
timeframes for when standardization work should occur and standards
lead such work. Additional metadata has been introduced in the new
ting/filtering by lifecycle area, industry sector, material type, AM
considers current alternatives being used until an AM standard or

orities, whether R&D is needed as well as by AM processes, lifecycle

ch results.
ts, etc.

K – AR) selections all offer an "agnostic" option. When AMSC members
Therefore, you can sort by gaps targeted towards a specific sector,
gnostic" would also include those specific selections.

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.

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*

Gaps Statistics v1 to v3

Version	# Gaps	# New Gaps	# Closed Gaps	# Withdrawn Gaps	# Gaps Require R&D
Roadmap v1.0 (2017)	89	89	n/a	n/a	58
Roadmap v2.0 (2018)	93	11	2	5	65
Roadmap v3.0 (2023)	141	60*	4	12	91

**22 of 60 new gaps were from a new chapter on Data, not previously addressed in v1 or v2*

Standards-Driven Public-Private Partnerships

2024 Project Objective:

- Inform the NIST implementation plan for the USG NSSCET (May 2023)
- Implementation Roadmap for USG National Standards Strategy for CET (July 2024)
- Supported through a cooperative agreement with NIST

ANSI Gathered Private-Sector Feedback:

- Identify existing and past public-private partnerships (PPPs)
- Learn approaches, best practices, different mechanisms for convening stakeholders
- Discuss what role PPPs can play to support CETs
- Determine if/where a PPP is appropriate during standards readiness phases

Brainstorming Sessions Summarized in Report:

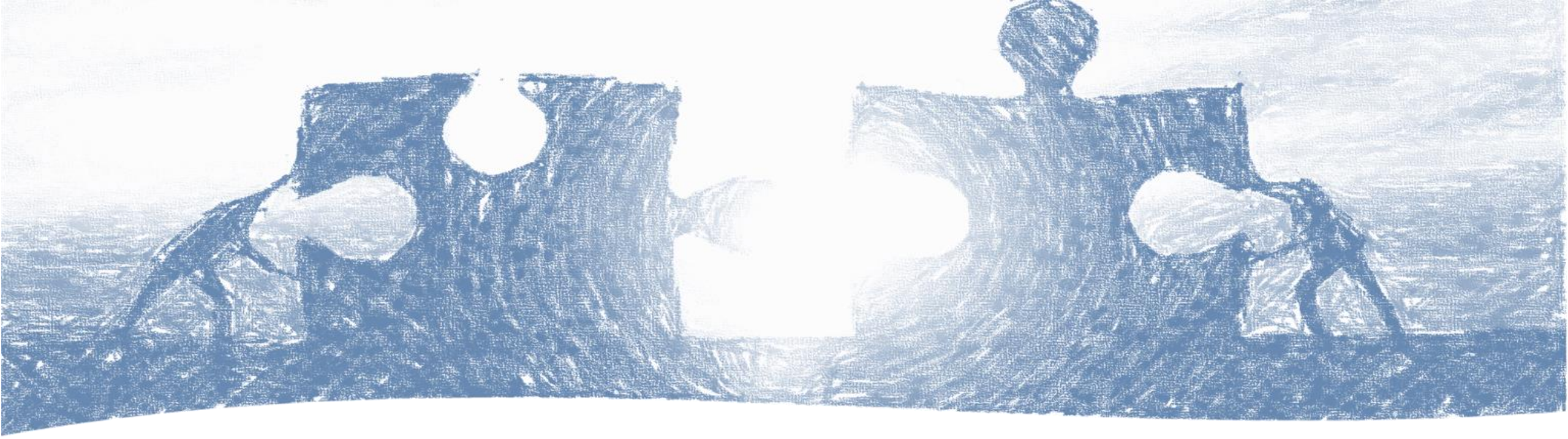
- Standards Readiness Phases & Standards-Driven Public-Private Partnerships (SD-PPPs)
- Common challenges and solutions in standards development
- Best practices for effective PPPs
- AI/ML in healthcare and manufacturing– July 17, 2024
- Automated and Connected ground vehicles & aircraft – July 30, 2024

ansi.org/pppforcets

AMSC: A Standards-Driven Public-Private Partnership

Standards-driven PPPs (SD-PPPs) are a type of PPP where resources invested are directly impacting consensus-based standards development.

- SD-PPPs may or may not involve contractual agreements, financial support, or formal relationships between public and private representatives.
- SD-PPPs may prove more effective when private-sector technology and innovation synergizes with public-sector priorities and incentives.
- Common work products of SD-PPPs are:
  - **Pre-standardization activities**: Roadmaps, gap analysis, research and development, workshops, etc.
  - **Standards development**: Support for the proposal and/or formation of new committees, identifying and convening technical experts, content development, outreach & education, etc.
  - **Implementation**: Increasing awareness, technical training, workforce development, conformity assessment, etc.



Five SD-PPP Models

Direct-Participation
Standards Acceleration
Funded Participation
Funded Standards Development
Policy and Conformance Driven

Common SD-PPP Work Products

SD-PPP Model	Common Work Products
Direct-Participation	- Pre-standardization: technical reports, strategic plans - Standardization: Standards development - Implementation: Increasing awareness, technical training, workforce development on standards
Standards Acceleration	- Pre-standardization: Technical workshops and symposia, standards road mapping (landscaping and gap analyses), and other research and technology reports
Funded Participation	- N/A, this supports increased participation to balance the representation of stakeholders in standards development
Funded Standards Development	- Pre-standardization: Research, research reports, databases, statistics - Pre-standardization: Formation of a new standards developing committee or SDO - Standards Development: Draft proposed test methods, design specification, best practices - Implementation: Increasing awareness, technical training, workforce development on standards
Policy and Conformance Driven	- Pre-standardization: Strategic plans and roadmaps - Standards Development: Standards (1 or more standards) - Implementation: Increasing awareness, technical training, workforce development on standards

SD-PPP Use Cases

Effort Resulted in 19 Use cases

- Various technologies/sectors
- Various work products (research, roadmaps, coordination, standards)
- Formal / Informal

ANSI SD-PPP Webpage

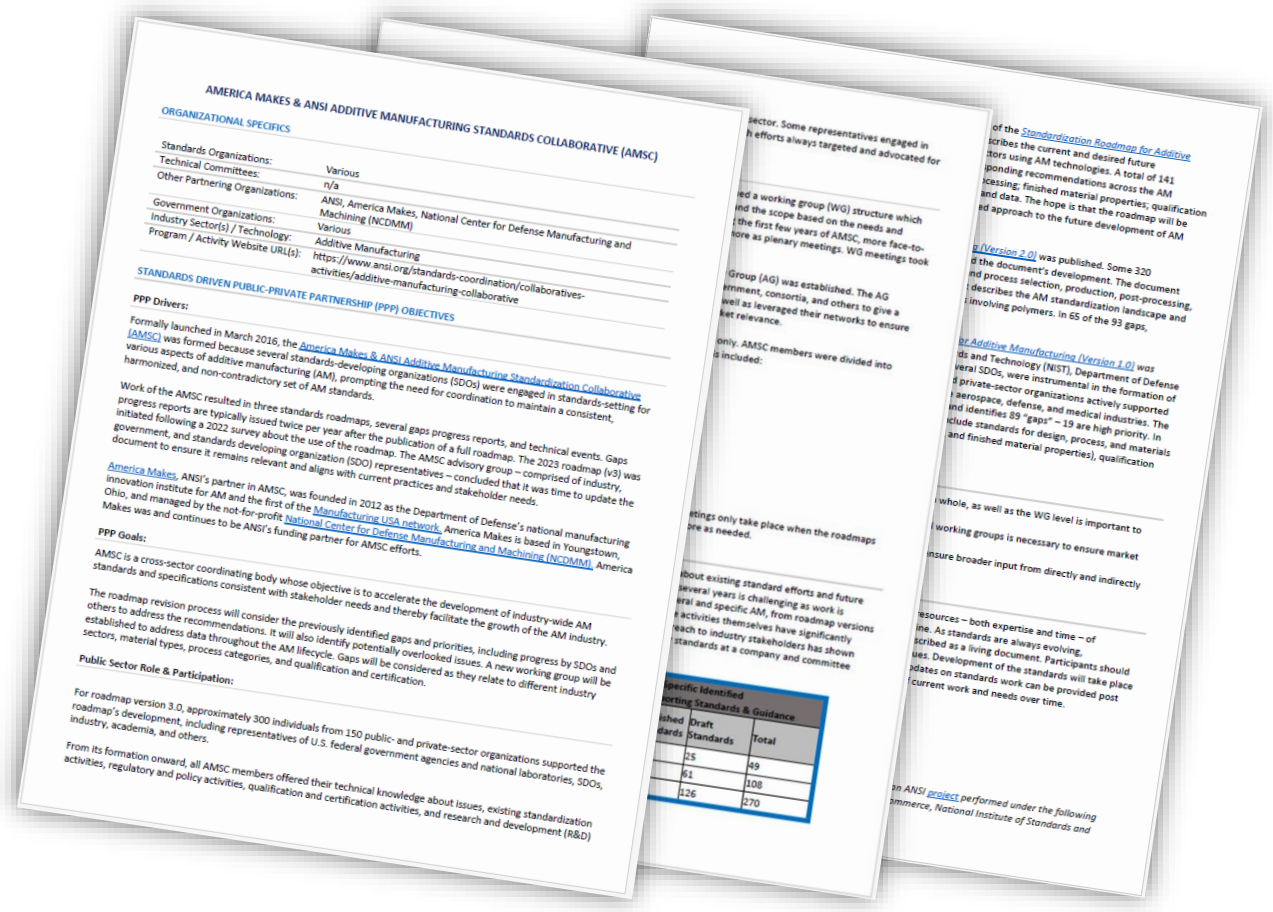
- Anticipated November 2024
- Additional Use Cases Underway
- Contact Christine Bernat to submit

Actual SD-PPP use cases often include the characteristics of more than one model. For example, a SD-PPP may be a “standards acceleration” and a “policy & conformance driven.”

Flexibility to meet industry’s needs is important.

America Makes and ANSI AMSC

Standards Acceleration SD-PPP


AMERICA MAKES & ANSI ADDITIVE MANUFACTURING STANDARDS COLLABORATIVE (AMSC)

ORGANIZATIONAL SPECIFICS

Standards Organizations:	Various
Technical Committees:	n/a
Other Partnering Organizations:	ANSI, America Makes, National Center for Defense Manufacturing and Machining (NCDMM)
Government Organizations:	Various
Industry Sector(s) / Technology:	Additive Manufacturing
Program / Activity Website URL(s):	https://www.ansi.org/standards-coordination/collaboratives-activities/additive-manufacturing-collaborative

STANDARDS DRIVEN PUBLIC-PRIVATE PARTNERSHIP (PPP) OBJECTIVES

PPP Drivers:

Formally launched in March 2016, the America Makes & ANSI Additive Manufacturing Standardization Collaborative (AMSC) was formed because several standards-developing organizations (SDOs) were engaged in standards-setting for various aspects of additive manufacturing (AM), prompting the need for coordination to maintain a consistent, harmonized, and non-contradictory set of AM standards.

Work of the AMSC resulted in three standards roadmaps, several gaps progress reports, and technical events. Gaps progress reports are typically issued twice per year after the publication of a full roadmap. The 2023 roadmap (v3) was initiated following a 2022 survey about the use of the roadmap. The AMSC advisory group – comprised of industry, government, and standards developing organization (SDO) representatives – concluded that it was time to update the document to ensure it remains relevant and aligns with current practices and stakeholder needs.

America Makes, ANSI’s partner in AMSC, was founded in 2012 as the Department of Defense’s national manufacturing innovation institute for AM and the first of the Manufacturing USA network. America Makes is based in Youngstown, Ohio, and managed by the not-for-profit National Center for Defense Manufacturing and Machining (NCDMM). America Makes was and continues to be ANSI’s funding partner for AMSC efforts.

PPP Goals:

AMSC is a cross-sector coordinating body whose objective is to accelerate the development of industry-wide AM standards and specifications consistent with stakeholder needs and thereby facilitate the growth of the AM industry.

The roadmap revision process will consider the previously identified gaps and priorities, including progress by SDOs and others to address the recommendations. It will also identify potentially overlooked issues. A new working group will be established to address data throughout the AM lifecycle. Gaps will be considered as they relate to different industry sectors, material types, process categories, and qualification and certification.

Public Sector Role & Participation:

For roadmap version 3.0, approximately 300 individuals from 150 public- and private-sector organizations supported the roadmap’s development, including representatives of U.S. federal government agencies and national laboratories, SDOs, industry, academia, and others.

From its formation onward, all AMSC members offered their technical knowledge about issues, existing standardization activities, regulatory and policy activities, qualification and certification activities, and research and development (R&D)

Specific Identified Standards & Guidance		
	Draft Standards	Total
	25	49
	61	108
	126	270

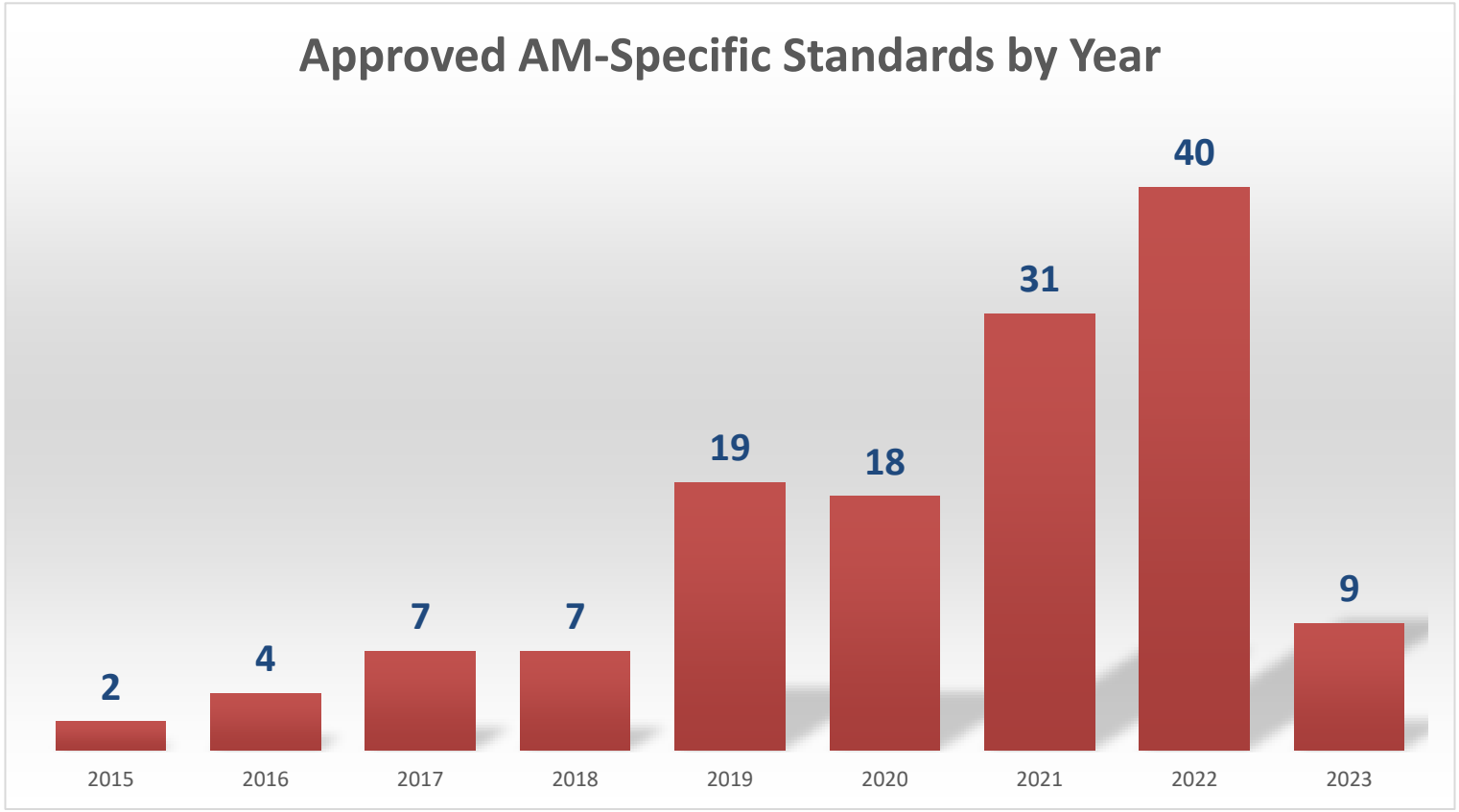
Standards Statistics v1 to v3

	All Identified Supporting Standards & Guidance			AM Specific Identified Supporting Standards & Guidance		
Roadmap	**Published Standards**	**Draft Standards**	**Total**	**Published Standards**	**Draft Standards**	**Total**
Roadmap v1.0 (2017)	242	39	281	24	25	49
Roadmap v2.0 (2018)	456	80	536	47	61	108
Roadmap v3.0 (2023)	513	155	668	144	126	270

+/- 5x

**Standards identified focus on the technical areas outlined in the AMSC Roadmaps. Additional related and specific standards may be available to additive manufacturing stakeholders.*

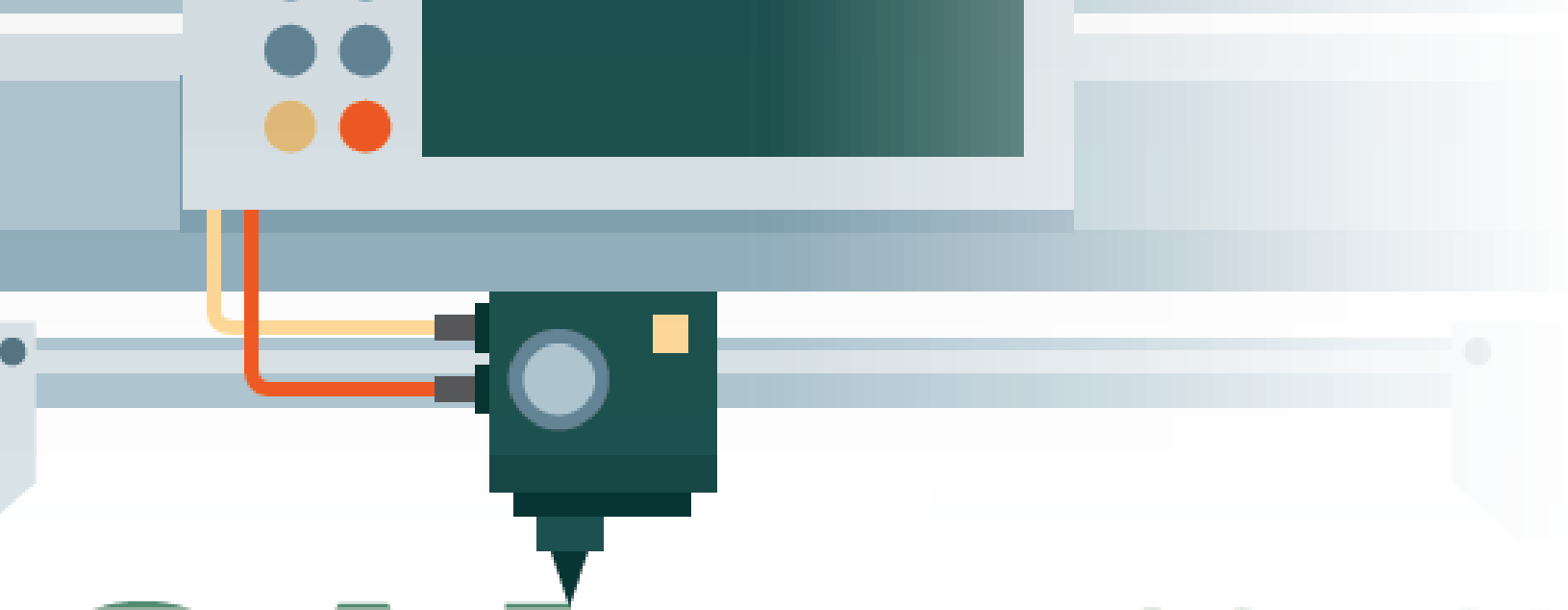
AM-Specific Standards Since AMSC Formed



**Statistics as of spring 2024, and only represent new standards reported against AMSC gaps, and does not include revisions to standards which may also fill industry needs in the same manner a new standard may.*

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
    - Roadmap (freely available / direct link)
    - September 2024 Gaps Progress Report
- Publish Gaps Progress Reports (2x per year)
- Collaborate to close gaps!



GAPS PROGRESS REPORT

STANDARDIZATION ROADMAP FOR ADDITIVE MANUFACTURING

Version 3.0 | September 2024

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