

# America Makes & ANSI Additive Manufacturing Standardization Collaborative (AMSC)

Standardization Roadmap for Additive Manufacturing  
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# America Makes & ANSI Additive Manufacturing Standardization Collaborative (AMSC)



Nation's leading and collaborative partner in AM and 3D printing technology research, discovery, creation, and innovation



National coordinating body for voluntary standardization in the USA; serves as a neutral facilitator to identify standards needs

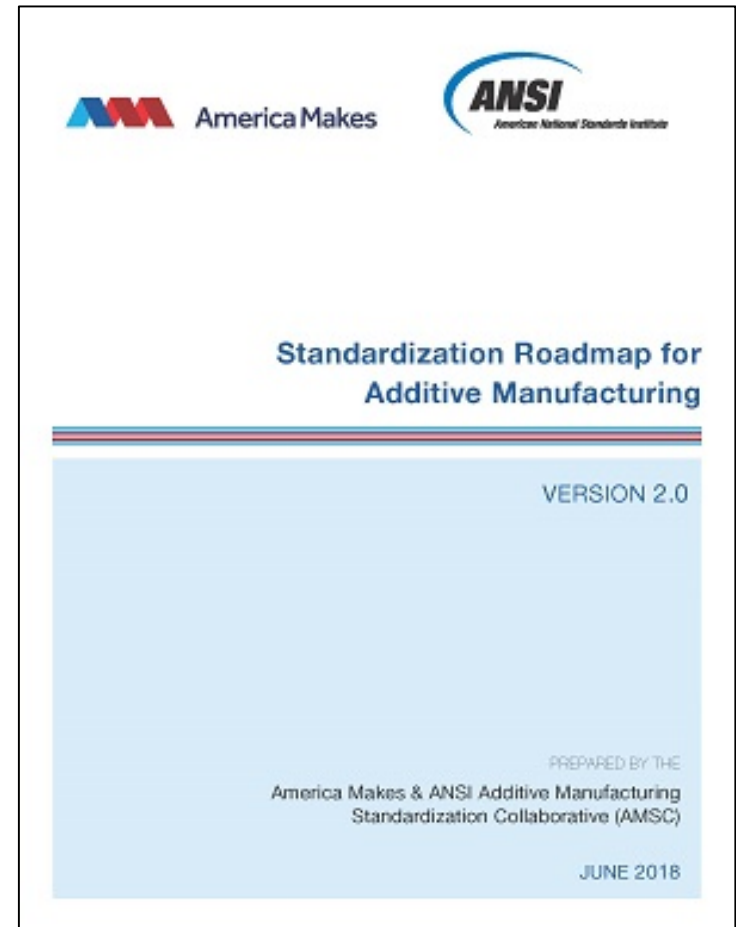
**AMSC Mission:** To coordinate and accelerate the development of industry-wide additive manufacturing standards and specifications, consistent with stakeholder needs, and thereby facilitate the growth of the additive manufacturing industry

# AMSC Objectives

- Facilitate the development of a common framework of standards and specs to help grow the AM industry
- Describe the current standards landscape
- Provide input to AM standards developing organizations (SDOs) on future standards needs
- Drive coordinated standards activity among SDOs and avoid duplication of effort
- Inform industry decision-making vis a vis resource allocation for standards participation
- Provide subject matter experts to work with SDOs
- AMSC itself is not developing standards

# AMSC Deliverables

- [Standardization Roadmap for Additive Manufacturing, Version 2.0 \(June 2018\)](#)
  - Identifies published and in-development standards and specifications, assesses gaps, makes recommendations for priority areas where there is a perceived need for additional standardization
- [Standards Landscape](#)
  - A list of standards directly or peripherally related to the issues described in the roadmap
- Both available as free downloads at: [www.ansi.org/amsc](http://www.ansi.org/amsc)



# AMSC Topical Areas & Working Groups

(“life cycle assessment of an AM part”)

- Design
- Process and Materials
  - Precursor Materials
  - Process Control
  - Post-processing
  - Finished Material Properties
- Qualification & Certification
- Nondestructive Evaluation
- Maintenance and Repair

## Horizontal WGs

**Medical WG** - evaluating medical content across document

**Polymers WG** - evaluating polymers content across document

# Specific Phase Two Goals & Outcomes

- Update gaps already identified
  - 42 gaps substantially revised
- Expand content on polymers
  - 234 references to polymers in v2; 98 in v1
  - 18 gaps mention polymers in v2; 9 in v1
  - 5 new gaps address polymers
  - Content cuts across all working groups
- Identify potentially overlooked gaps
  - 11 new gaps added
- Engage other industries (e.g., ground vehicles/heavy equipment, energy, industrial & commercial machinery, electronics)
  - Added new Q&C section on Electronics Industry
  - List of selected new participants on next slide

# New Phase 2 Participants Included . . .

- 3 Degrees
- 3D PDF Consortium
- 3M Company
- Addaero Manufacturing
- Align Technology
- American Bureau of Shipping
- ASSE
- Ampacet
- Arkema
- Assn for Manufacturing Technology
- B11 Standards Inc.
- Caterpillar
- DNV GL
- Drip Castles
- Dupont
- Eaton Corporation
- EWI
- Ford Motor Company
- Hanover Insurance
- Honeywell
- InfraTrac
- Jet Pulverizer
- Manufacturers Standardization Society
- Nat'l Ctr. for Mfg. Sciences
- NRC
- Philips Lighting
- Quintus Technologies
- Renishaw Inc.
- Siemens Energy
- SpaceX
- TechPlas Consulting
- Thermo Fisher Scientific
- Tosoh
- TUV Rheinland of NA

# New Gaps - V2.0

| New Gaps                                                                    | High | Med | Low |
|-----------------------------------------------------------------------------|------|-----|-----|
| D27: Standardized Design for Additive Manufacturing (DFAM) Process Chain    |      | 1   |     |
| D28: Specification of Surface Finish                                        |      | 1   |     |
| PM8: Use of Recycled Polymer Precursor Materials                            |      |     | 1   |
| PM9: Characterization of Material Extrusion Feedstock (Filaments & Pellets) |      |     | 1   |
| PM10: Sampling of Open Liquid Feedstock System                              |      |     | 1   |
| P7: Heat Treatment (HT)-Polymers                                            |      |     | 1   |
| QC16: Sterilization of Tissue Engineered Products                           |      | 1   |     |
| NDE6: NDE of Polymers and Other Non-Metallic Materials                      |      |     | 1   |
| NDE7: NDE of Counterfeit AM Parts                                           |      |     | 1   |
| NDE8: NDE Acceptance Criteria for Fracture Critical AM Parts                |      | 1   |     |
| M9: Laser Based Additive Repair                                             |      |     | 1   |
| Totals                                                                      | 0    | 4   | 7   |



# Withdrawn/Closed Gaps - V2.0

| Withdrawn Gaps                                                         | High | Med | Low |
|------------------------------------------------------------------------|------|-----|-----|
| Gap D25: Configuration Control of Digital Part Design                  |      | 1   |     |
| Gap PC17: Motion Control                                               |      |     | 1   |
| Gap FMP2: Coupon Testing                                               |      | 1   |     |
| Gap QC11: Process Validation for Pigments and Processing Aid Materials |      |     | 1   |
| Gap M2: Using AM to Print Tools                                        |      | 1   |     |
| Totals                                                                 | 0    | 3   | 2   |
| Closed Gaps                                                            | High | Med | Low |
| Gap D11: Design for 3D Printed Electronics                             |      | 1   |     |
| Gap D24: An Acquisition Specification                                  |      | 1   |     |
| Totals                                                                 | 0    | 2   | 0   |

- 42 Gaps Substantially Revised



# Open Gaps Breakdown - Version 2.0

| Priority                                                               | High |                                                                        | Medium |     | Low |     | Total |     |
|------------------------------------------------------------------------|------|------------------------------------------------------------------------|--------|-----|-----|-----|-------|-----|
| Section                                                                | V1H  | V2H                                                                    | V1M    | V2M | V1L | V2L | V1T   | V2T |
| Design                                                                 | 5    | 4                                                                      | 15     | 15  | 6   | 6   | 26    | 25  |
| Precursor Materials                                                    | 1    | 1                                                                      | 4      | 4   | 2   | 4   | 7     | 10  |
| Process Control                                                        | 4    | 4                                                                      | 8      | 8   | 5   | 4   | 17    | 16  |
| Post-processing                                                        | 0    | 0                                                                      | 4      | 4   | 2   | 3   | 6     | 7   |
| Finished Material Properties                                           | 2    | 3                                                                      | 3      | 1   | 0   | 0   | 5     | 4   |
| Q&C                                                                    | 5    | 4                                                                      | 6      | 8   | 4   | 3   | 15    | 15  |
| NDE                                                                    | 2    | 2                                                                      | 3      | 4   | 0   | 2   | 5     | 8   |
| Maintenance & Repair                                                   | 0    | 0                                                                      | 8      | 7   | 0   | 1   | 8     | 8   |
| Total                                                                  | 19   | 18                                                                     | 51     | 51  | 19  | 24  | 89    | 93  |
| <ul style="list-style-type: none"> <li>58 (v1) need R&amp;D</li> </ul> |      | <ul style="list-style-type: none"> <li>65 (v2) need R&amp;D</li> </ul> |        |     |     |     |       |     |

# 15 New Roadmap Sections/Subsections

- Section 1.5.10 MTConnect Institute
- Section 2.1.3 Design Tools: Standardized Design for Additive Manufacturing (AM) Process Chain
- Section 2.1.7 Design for Anti-counterfeiting
- Section 2.2.1.4 Characterization of Material Extrusion Feedstock (Filaments & Pellets)
- Section 2.2.1.5 Characterization of Liquid Feedstock
- Section 2.2.2.12 Anti-Counterfeiting
- Section 2.2.3.2 Heat Treatment: Polymers
- Section 2.3.2.3 Nadcap Program
- Section 2.3.2.9 Underwriters Laboratories
- Section 2.3.3.3 Medical Industry: Sterilization of Tissue Engineered Products
- Section 2.3.3.4 Electronic and Electrical Products Industry
- Section 2.4.6 NDE of Polymers and Other Non-Metallic Materials
- Section 2.4.7 NDE of Counterfeit AM Parts
- Section 2.4.8 NDE Acceptance Criteria for Fracture Critical AM Parts
- Section 2.5.2 Maintenance and Sustainment of Machines
- 36 Existing Sections/Subsections Substantially Revised; 8 Renamed/Repositioned;  
1 Withdrawn

# Planned Next Steps

- Roadmap Promotion
  - America Makes MMX, Oct 30-31, 2018, Youngstown, OH
    - AMSC Roadmap presentation and SDO panel discussion
  - FormNext Conference, Nov 14, 2018 Standards Forum, Frankfurt, Germany
    - Panel 1: International Collaboration on AM Standards
    - Panel 2: Industry Discussion - Utilizing AM Technology and the Impact of Standards
- 2019 activity still under discussion but may include:
  - Ongoing roadmap promotion
  - Meetings with SDOs to track progress to address gaps
  - Providing an online table of progress on the gaps
  - Holding sector-specific workshops (energy could be one)

# Back-up Slides

# High Priority Gaps - Version 2.0

- D4: Design Guides for Specific Applications
- D17: Contents of a TDP
- D18: New Dimensioning and Tolerancing Requirements
- D19: Organization Schema Requirement and Design Configuration Control
- PM5: Metal Powder Feedstock Sampling
- PC2: Machine Calibration and Preventative Maintenance
- PC7: Recycle & Re-use of Materials
- PC9: Environmental Conditions: Effects on Materials
- PC14: Environmental Health and Safety: Protection of Machine Operators

# Design

- Design Guides
- Design Tools
- Design for Specific Applications
  - Design for As-built Assembly
  - Design for Printed Electronics
  - Design for Medical
- Design Documentation
- Design Verification and Validation
- **Design for Anti-counterfeiting**

# High Priority Gaps (contd.)

- FMP1: Material Properties (Metals, Polymers)
- FMP3: Cleanliness of Medical AM Parts
- FMP4: Design Allowables (Material Specifications)
- QC1: Harmonization of AM Q&C Terminology
- QC2: AM Part Classification System for Consistent Qualification Standards
- QC9: Personnel Training for Image Data Set Processing
- QC10: Verification of 3D Model
- NDE1: Terminology for the Identification of AM Flaws Detectable by NDE Methods
- NDE3: Standard Guide for the Application of NDE to Objects Produced by AM Processes



# Precursor Materials

- Storage, Handling and Transportation
- Characterization of Powders
- Characterization of Material Extrusion Feedstock (Filaments & Pellets)
- Characterization of Liquid Feedstock

# Process Control

- Digital Format and Digital System Control
- Machine Calibration and Preventative Maintenance
- Machine Qualification
- Parameter Control
- Adverse Machine Environmental Conditions: Effect on Component Quality
- Precursor Material Handling: Use, Re-use, Mixing, and Recycling Feedstock
- Precursor Material Flow Monitoring
- Environmental Health and Safety: Protection of Machine Operators
- Configuration Management: Cybersecurity
- In-Process Monitoring
- **Anti-counterfeiting**

# Post-processing

- Heat Treatment (metals, **polymers**)
- Hot Isostatic Pressing (HIP) (metals)
- Surface Finish (Surface Texture) (metals, polymers)
- Machining (metals, polymers)
- Post-curing Methods (polymers)

# Finished Material Properties

- Material Properties
- Component Testing
- Bio-compatibility & Cleanliness of Medical Devices
- Chemistry
- Design Allowables
- Microstructure

# Qualification & Certification

- Identified Guidance Documents
  - FDA Guidance on Technical Considerations for AM Devices
  - **Nadcap program**
  - Aerospace Corp Mission Assurance Information Workshop
  - CMH-17 & MMPDS Handbook
  - AWS D20
  - NASA MSFC Standard for AM Spaceflight Hardware by Laser Powder Bed Fusion in Metals
  - ASME Y14.46
  - **Underwriters Laboratories**
- User-Group/Industry Perspectives on Q&C
  - Aerospace, Defense, Medical, **Electronics** Industries

# Nondestructive Evaluation (NDE)

Scope: NDE of Finished Parts (NDE for In-Process Monitoring under Process Control WG)

- Common Defects Catalog Using a Common Language for AM Fabricated Parts
- Test Methods or Best Practice Guides for NDE of AM Parts
- Dimensional Metrology of Internal Features
- Data Fusion
- NDE of Polymers and Other Non-Metallic Materials
- NDE of Counterfeit AM Parts
- NDE Acceptance Criteria for Fracture Critical AM Parts

# Maintenance and Repair

- **Maintenance and Sustainment of Machines**
- Standard Repair Procedures
- Standard Technical Inspection Processes
- Model-Based Inspection
- Standards for Tracking Maintenance Operations
- Cybersecurity for Maintenance
- Surface Preparation for Additive Repair